THE FIRST BOOK OF GALEN ON THE USEFULNESS OF THE PARTS [I, 1][a]

[The Hand]

1. Just as every animal is said to be one because, having a certain individual circumscription, it is manifestly not joined to other animals at any point, so also its parts, the eye, nose, tongue, or encephalon,[1] are said each to be one, because each clearly has a circumscription of its own. But if it were not joined to the neighboring parts at some point, but were altogether separate, then it would not be a part at all, but simply one. Therefore, all bodies that do not have their own circumscription at every point and are not everywhere joined to others are called parts. And if this is true, animals will have many parts, some large, some small, and some also not divisible at all into another form.[2]

2. The usefulness of all of them is related to the soul. For the body is the instrument[3] of the soul,[4] and consequently animals differ

[a] The bracketed figures in the margin refer to the pages of Helmreich's edition of *De usu partium*.

[1] For the reason why I have preferred to use the term encephalon rather than brain throughout the translation, see chapter 4 of Book VIII.

[2] In other words, parts may be not only heterogeneous, like the eye, which can be divided into many different elements, but also homogeneous, like blood, bone, or flesh, which cannot. For the ancient conception of homogeneous and heterogeneous parts, see Aristotle, *De part. an.*, II, 1, 646a8–647a8.

[3] *τὸ ὄργανον*. The primary meaning is instrument, implement, or tool; one of the secondary ones, organ (of the body). Since Galen frequently applies the word to parts now not ordinarily spoken of as organs, I shall use "instrument," as the general, more inclusive term. Galen's own definition of *ὄργανον* is found in his *Methodus medendi*, I, 6 (Kühn, X, 47), where he says: "I call *ὄργανον* a part of the animal that is the cause of a complete action, as the eye is of vision, the tongue of speech, and

greatly in respect to their parts because their souls also differ. For some animals are brave and others timid; some are wild and others tame; and some are, so to speak, members of a state and work together for it, whereas others are, as it were, unsocial. In every case
[I, 2] the body is adapted to the character and faculties of the soul. The horse is provided with strong hoofs and adorned with a name, for truly it is a swift, proud animal and not faint-hearted. The strength of the brave, fierce lion, however, lies in its teeth and claws. So, too, with the bull and boar; the one has horns as its natural weapons, and the other tusks. On the other hand, since the deer and hare are timid animals, their bodies are fleet, but entirely unarmed and defenseless; for swiftness, I think, befits the timid and weapons are for the brave, and so Nature[5] did not arm the one at all or strip naked the other. Now to man—for he is an intelligent animal and, alone of all creatures on earth, godlike[6]—in place of any and every defensive weapon, she gave hands,[7] instruments necessary for every art and useful in peace no less than in war. Hence he did not need horns as a natural endowment, since, whenever he desired, he could grasp in his hand a weapon better than a horn; for certainly swords and spears are larger weapons than horns and better suited for inflicting wounds. Neither did he need hoofs, for clubs and rocks can crush more forcibly than any hoof. Furthermore, nothing can be accomplished with either horns or hoofs without coming to close quarters, but a man's weapons are effective at a distance as well as near by, javelins and darts excelling horns, and rocks and clubs excelling hoofs. But, you say, a lion is swifter than a man. Well, what then? With his skillful hands man tamed the horse, an animal swifter than a lion, and, using a horse, he both escapes and pursues the lion, from his
[I, 3] lofty seat striking down at him below. Surely then, man is not

---

the legs of walking; so too arteries, veins, and nerves are both *ὄργανα* and parts of animals." And *vide infra*, chapter 12 of Book IV, *ad init.*

[4] Galen follows Aristotle (*De anima*, II, 4, 415b7–20), who holds that the soul is the efficient, formal, and final causes of the body, which reciprocally serves the soul as instrument.

[5] For Galen's concept of Nature, see my Introduction, pp. 10–12.

[6] Cf. Aristotle, *De part. an.*, II, 10, 656a7–8: "For of all living creatures known to us, man is the only one to have a share of the divine, or at least he has it to a greater degree than all the rest."

[7] As is well known, Galen in this famous passage in praise of the hand leans heavily on Aristotle (*De part. an.*, IV, 10, 687a5 ff.) and elaborates his thought.

naked, easily wounded, defenseless, or unshod, but, whenever he wishes, may have a corslet of iron (an instrument harder to damage than any kind of skin), and sandals, weapons, and vestments of all sorts are at his disposal. In fact, the corslet is not his only protection, since he also has houses, towers, and city walls. If he were born with a horn or some other defensive weapon of the kind growing upon his hands, he could not use them at all to build a house or tower, or to make a spear or corslet or other similar things. With these hands of his, a man weaves himself a cloak and fashions hunting-nets, fish-nets and traps, and fine-meshed bird-nets, so that he is lord not only of animals upon the earth, but of those in the sea and the air also. Such is the hand of man as an instrument of defense. But, being also a peaceful and social [8] animal, with his hands he writes laws for himself, raises altars and statues to the gods, builds ships, makes flutes, lyres, knives, fire-tongs, and all the other instruments of the arts, and in his writings leaves behind him commentaries on the theories of them. Even now, thanks to writings set down by the hand, it is yet possible for you to hold converse with Plato, Aristotle, Hippocrates, and the other Ancients.

3. Thus man is the most intelligent of the animals and so, also, [I, 4] hands are the instruments most suitable for an intelligent animal. For it is not because he has hands that he is the most intelligent, as Anaxagoras says, but because he is the most intelligent that he has hands, as Aristotle [9] says, judging most correctly. Indeed, not by his hands, but by his reason has man been instructed in the arts. Hands

[8] Reading πολιτικόν with Helmreich for the πολεμικόν of Kühn's text, where, however, the Latin version has *politicum*.

[9] *De part. an.*, IV, 10, 687a7–18. For Anaxagoras, see Sarton (1927, I, *86*) and the literature there cited.

Hofmann (1625, *6*) calls attention to the fact that when Galen in the ensuing argument mentions the calf, butting before its horns have sprouted, he is using a common poetical figure. For example, Lucretius (*De rerum natura*, V, 1033–1035), though with a point of view diametrically opposed to Galen's, writes:

> Sentit enim vis quisque suas quoad possit abuti.
> Cornua nata prius vitulo quam frontibus extent,
> Illis iratus petit atque infestus inurget.

And Ovid (*Halieuticon*, 2–3) also writes:

> Vitulus sic namque minatur,
> Qui nondum gerit in tenera iam cornua fronte.

Galen refers again to newborn animals striving to use their powers in *De foetuum formatione*, cap. 6 (Kühn, IV, *692*).

are an instrument, as the lyre is the instrument of the musician, and tongs of the smith. Hence just as the lyre does not teach the musician or tongs the smith but each of them is a craftsman by virtue of the reason there is in him although he is unable to work at his trade without the aid of his instruments, so every soul has through its very essence certain faculties, but without the aid of instruments is helpless to accomplish what it is by Nature disposed to accomplish. In observing newborn animals striving to exert themselves before their parts are perfected, we can see clearly that it is not the bodily parts that lead the soul to be timid or brave or wise. Now I have often seen a young calf butting before its horns have sprouted, a colt kicking with hoofs still soft, a shote, quite small, trying to defend itself with jaws innocent of tusks, and a newborn puppy attempting to bite with its teeth still tender. For every animal has, untaught, a perception of the faculties of its own soul and the virtues resident in its parts. Or why else, when it is possible for the small
[I, 5] boar to bite with his little teeth, does he not use them for battle instead of longing to use those which he does not yet have? How, then, is it possible to say that animals learn the usefulness of their parts from the parts themselves, when they obviously know their usefulness even before they have them? Now if you like, take three eggs, an eagle's, a duck's, and a serpent's; warm them, and in due season hatch them out; and you will see two of the animals that have been formed making trial of their wings even before they are able to fly, and the other, though still soft and weak, wriggling and struggling to crawl. And if you raise them to maturity under one and the same roof and then take them out in the open and let them go, the eagle will fly up high in the air, the duck will fly down onto some marshy lake, and the serpent will creep away into the earth. Afterwards, without having learned, the eagle, I think, will hunt its prey, the duck will swim, and the serpent lurk in its den. "For," says Hippocrates,[10] "the instincts of animals are untaught." So it seems to

[10] *De aliménto*, cap. 39 (Littré, IX, *112*, *113*). Galen writes, Φύσιες γὰρ ζῴων ἀδίδακτοι; the text as given by Littré reads, Φύσιες πάντων ἀδίδακτοι, but he notes that in one manuscript the ζῴων which is the last word in the preceding sentence has been shifted to become the first word of this one. Cf. Hippocrates, *De morbis vulgaribus*, VI, 5 (Littré, V, *314*, *315*), "Nature, though without instruction or understanding, does what is necessary"; and see also Galen's long exposition (Kühn, XVII, pt. 2, *233* ff.) of this passage, in which he develops

me that the other animals acquire their skills by instinct rather than by reason, bees, for example, molding [their wax],[11] ants working at their treasuries and labyrinths, and spiders spinning and weaving. I judge from the fact that they are untaught.

4. Now just as man's body is bare of weapons, so is his soul destitute of skills. Therefore, to compensate for the nakedness of his body, he received hands, and for his soul's lack of skill, reason, by means of which he arms and guards his body in every way and [I, 6] equips his soul with all the arts. For if he had been born with a natural weapon, he would have that one alone for all time, and just so, if he had one natural skill, he would lack the others. But since it was better for him to make use of all weapons and all the arts, he was endowed with no one of them at birth. Indeed, Aristotle[12] was right when he said that the hand is, as it were, an instrument for instruments, and we might rightly say in imitation of him that reason is, as it were, an art for arts. For though the hand is no one particular instrument, it is the instrument for all instruments because it is formed by Nature to receive them all, and similarly, although reason is no one of the arts in particular, it would be an art for the arts because it is naturally disposed to take them all unto itself. Hence man, the only one of all the animals having an art for arts in his soul, should logically have an instrument for instruments in his body.

---

the same thought. It is, in fact, one of his favorite themes, being stated, for instance, in *De nat. fac.*, I, 13 (Kühn, II, *38;* Galen [1928, *61*]); *De semine*, II, 6 (Kühn, IV, *643*); and *De foetuum formatione*, cap. 6 (Kühn, IV, *692–693*). See Daremberg (in Galen [1854, I, *115–116*]) for other examples and further comments.

[11] Helmreich omits *τὰ σίμβλα* of the Kühn edition.

[12] In *De part. an.*, IV, 10, 687a20–21, where the Greek text reads *ὄργανόν τι πρὸ ὀργάνων*. The sense seems to be that the hand is an instrument enabling man to make use of many instruments, and Ogle (1911) so understands it, for he translates the Aristotelian phrase, "An instrument for further instruments." Earlier translators of Galen, however, have treated it variously: "La main estre instrument qui surpasse tous instruments" (Dalechamps in Galen [1608, *17*]); "Est enim manus instrumentum omnium primum seu perfectissimum" (Hofmann [1625, *8*]); "Pulchre igitur Aristoteles manum velut organum quoddam ante organa esse dixit" (Kühn, III, *8*); "An instrument in place of all other instruments" (Bellott and Jordan in Galen [1850, *9*]); "Das Organ der Organe" (Nöldeke in Galen [1805, *12*]); "Un certain instrument qui tient lieu d'instruments" (Daremberg in Galen [1854, I, *117*]).

5. Come now, let us investigate this very important part of man's body, examining it to determine not simply whether it is useful or whether it is suitable for an intelligent animal, but whether it is in every respect so constituted that it would not have been better had it been made differently.[13] One and indeed the chief characteristic of a prehensile instrument constructed in the best manner is the ability to grasp readily anything of whatever size or shape that man would naturally want to move. For this purpose, then, which was better—for the hand to be cleft into many divisions or to remain
[I, 7] wholly undivided? Or does this need any discussion other than the statement that if the hand remained undivided, it would lay hold only on the things in contact with it that were of the same size as it happened to be itself, whereas, being subdivided into many members, it could easily grasp masses much larger than itself, and fasten accurately upon the smallest objects? For larger masses, the hand is extended, grasping them with the fingers spread apart, but the hand as a whole does not try to grasp the smallest objects, for they would escape if it did; the tips of two fingers are enough to use for them. Thus the hand is most excellently constituted for a firm grasp of things both larger and smaller than itself. Furthermore, if it was to be able to lay hold on objects of many different shapes, it was best for it to be divided into many differing members, as it now is, and for this purpose the hand is obviously adapted best of all prehensile instruments. Indeed, it can curve itself around a spherical body, laying hold of and encircling it from all sides; it surrounds firmly objects with straight or concave sides; and if this be true, then it will also clasp objects of all shapes, for they are all made up of three kinds of lines, convex, concave, and straight. Since, however, there are many bodies whose mass is too great for one hand alone to grasp, Nature made each the ally of the other so that both together, grasping such a body on opposite sides, are in no way inferior to one very large hand. For this reason, then, they face toward one another, since each was made for the sake of the other, and they have been
[I, 8] formed equal to one another in every respect, a provision suitable for instruments which are to share the same action. Now when you have considered the largest objects that man can handle with both hands, such as a log or rock, then give heed, pray, to the smallest,

[13] This is Galen's first statement of his thesis. It will recur again and again.

such as a millet seed, a very slender thorn, or a hair, and then, when you have considered besides how very many bodies there are that range in size from the largest to the smallest, think of all this and you will find that man handles them all as well as if his hands had been made for the sake of each one of them alone. He takes hold of very small objects with the tips of two fingers, the thumb and forefinger, and slightly larger objects with the same two fingers, but not with just the tips; those still larger he grasps with three fingers, the thumb, forefinger, and middle finger, and if there are any larger yet, with four, and next, with five. After that the whole hand is used, and for still larger objects the other hand is brought up. The hand could act in none of these ways if it were not divided into fingers differently formed; for it was not enough in itself for the hand merely to be divided. What if there had been no finger opposing the four, as there is now, but all five of them had been produced side by side in one straight line? [14] Is it not very clear that mere number would be useless, since an object to be held firmly must be either encircled from all sides or at least laid hold of from two opposite points? The ability to hold an object firmly would be destroyed if all the fingers had been produced side by side in one straight line, but as it is, with one finger set opposite the rest, this ability is nicely preserved; for this one finger has such a position and motion that by turning very slightly it acts with each of the four set opposite to it. Hence it was better for the hands to act as they do now, and Nature therefore gave them a structure suited to such actions. [I, 9]

6. Now it was necessary not only that the tips of two opposed fingers should act in fastening upon small objects, but that the tips should also be such as they now are, soft, round, and provided with nails. Thus if the ends of the fingers were composed not of flesh but of bone, it would be impossible for them ever to lay hold of small articles such as thorns or hairs, nor would this be possible if, though they were fleshy, the flesh were too soft and moist. For it is necessary for the object grasped to be surrounded as completely as possible by the prehensor so that there may be firm support. No hard or bony substance can enfold anything, whereas substances moderately soft and therefore sufficiently yielding are able to do so. But of course excessively soft and almost fluid substances yield to hard objects more than is necessary and easily flow away from them.

[14] Cf. Aristotle, *De part. an.*, IV, 10, 687b11–17.

[I, 10] Consequently, the best instruments for grasping firmly would be those which, like the ends of the fingers, have a nature midway between hardness and extreme softness.

7. But since the objects themselves that are to be grasped also differ in consistency, some being harder or softer than others, Nature gave the finger tips a structure suited to laying hold of all kinds of them. This is the reason why the finger tips were not composed of either nail or flesh alone, but of both together, having the best mutual arrangement. Thus the flesh was located in the parts that face each other, by the extremities of which they were to seize on objects, and the nails were placed on the outside as a foundation for the flesh. The finger tips, then, lay hold on soft bodies with their fleshy parts alone, but are unable to pick up without the aid of the nails bodies that are hard and hence press and bear hard against the flesh; for then the flesh is turned back and needs a foundation. Furthermore, hard objects could not be grasped by the nails alone, because the nails, being hard, would readily slip off from them. Therefore, since the fleshy substance of the finger tips compensates for the slipperiness of the nails, and the nails offer support to the easily deformed flesh, the finger has been fashioned into an instrument capable of laying hold of all small, hard objects. You will
[I, 11] understand more clearly what I mean when you consider nails that are out of proportion. Those that are excessively long and so strike against each other cannot pick up a little thorn or hair or anything else of the kind, and those that are too short to reach to the ends of the fingers deprive the flesh of its support and make it incapable of laying hold on anything. Only nails that come even with the ends of the fingers will best provide the service for the sake of which they were made. It is for this reason that Hippocrates [15] too has said, "The nails neither to project beyond, nor to fall short of, the finger tips." Thus, it is when they have a duly proportioned size that they best fulfill the uses for which they were made. Of course, they are also useful for many other purposes; for example, when it is necessary to scrape, scratch, skin, or tear something apart. In fact, in nearly all the circumstances of life and in all the arts, especially those requiring precise manual skill, we need some instrument of the sort,

[15] *De officina medici*, cap. 4 (Littré, III, *284–287*). Kühn extends the quotation to include the following sentence, but this is not correct.

but it is as a prehensile instrument for seizing small, hard objects that the hand most needs the fingernails.

8. Now why, pray, did Plato, although he was a follower of Hippocrates if ever anyone was and took the greatest of his opinions from him, speak so slightingly of the usefulness of the fingernails? And why did Aristotle, who was very clever at explaining the workmanship of Nature and so forth, overlook so much of their usefulness? Plato [16] says that like certain bad workmen the gods who [I, 12] fashioned man made nails grow on his finger tips, as if they were practising in advance the formation of the claws that would be necessary in other animals. But Aristotle [17] says that nails were formed for protection, though he does not say from what they were to give protection, whether cold, heat, wounds, or bruises. In fact, it is impossible to entertain the notion that they were formed for the sake of protection against these or any other things.

I have mentioned Aristotle and Plato not because I wished to confute what they have said wrongly, but in order to point out why I have felt impelled to begin a discussion of these matters.[18] For since there was much difference of opinion among the physicians and philosophers of old concerning the usefulness of the parts (the former believed that our bodies are not formed for the sake of anything or with any skill at all,[19] and the latter, that they are formed for some purpose and skillfully, one philosopher claiming one use for each of the parts, and another, another), I sought first to discover a standard for judging this difference of opinion and then

[16] *Timaeus*, 76 (Plato [1920, II, *54*]). For a very full discussion of this passage and for the further views of Hippocrates, Aristotle, and Galen on the nature of finger nails, see Daremberg (in Galen [1854, I, *122–124*]).

[17] *De part. an.*, IV, 10, 687b22–25.

[18] In other words, his reasons for undertaking to write *De usu partium*. Cf. chapter 2 of Book XVII.

[19] The first cut at Galen's particular detestation, the Epicureans. For convenient accounts of the medical sects of his time and their philosophical backgrounds, see Sarton (1954, *30–38*) and particularly Brock (1929, *12–13, 15–20, 130–153*), who translates here one of Galen's own essays on the medical sects, *De sectis ad eos qui introducuntur* (Kühn, I, *64–105*). See also Galen, *De nat. fac.*, I, 12, 13 (Kühn, II, *27–30;* Galen [1928, *42–49*]).

to devise some one universal method which will enable us to find the usefulness of each part and its attributes. Accordingly, since Hippocrates [20] says, "Taken as a whole, all the parts in sympathy, but taken severally, the parts in each part cooperate for its effect," it seemed
[I, 13] proper to me to test the saying first in those parts whose actions we know with certainty, for then we should be able to pass to the others also. And now I shall tell how I made the test, after I have first explained this saying of Hippocrates, which is too obscure for most people because it is written in the archaic style and with his customary conciseness. This is the way it should be interpreted: All the parts of the body are in sympathy with one another, that is to say, all cooperate in producing one effect. The large parts, main divisions of the whole animal, such as the hands, feet, eyes, and tongue, were formed for the sake of the actions of the animal as a whole and all cooperate in performing them. But the smaller parts, the components of the parts I have mentioned, have reference to the work of the whole instrument. The eye, for example, is the instrument of sight, composed of many parts which all cooperate in one work, vision; it has some parts by means of which we see, others without which sight would be impossible, others for the sake of better vision, and still others to protect all these. This, moreover, is also true of all the other parts, the stomach, mouth, tongue, and feet, and true of the hands too, concerning which I now propose to speak. Now everyone knows what the work of the hands is (for it is very clear that they were formed for the sake of grasping), but everyone does not yet perceive that all parts of the hand are of such a nature and size that they cooperate in the one work performed by the whole
[I, 14] instrument. Hippocrates, however, perceived it, and I am now about to demonstrate this same proposition. In fact, this proposition is the basis of the method for discovering usefulness and for confuting the errors of those who hold opinions foreign to the truth. Now if the work accomplished by the thorax, lung, heart, and other parts was as abundantly evident to everyone as that of the eyes, hands, and feet, our discourses on the usefulness of the parts would not disagree at so many points, but as it is, since the work accomplished by most of the parts is not clearly known and yet without a good knowledge of this

[20] *De alimento*, cap. 23 (Littré, IX, *106*, *107*). The text as given by Littré omits *συμπαθέα*, included by both Kühn and Helmreich.

it is impossible to discover the usefulness of any one of them in particular, obviously those who mistake the actions of the instruments also miss entirely the usefulness of the parts. Therefore, since neither Aristotle nor any of the Ancients mention all the actions of the instruments, we cannot approve [21] their writings on the usefulness of the parts. Furthermore, there are also some authors who in most cases assign the correct actions to the parts, but who, being untrained in the method of discovering usefulness, frequently go astray in particular instances, just as I have shown a little above in speaking of the fingernails. In fact, the best philosophers are plainly ignorant of their usefulness, nor, as I was saying, do they understand the writings of Hippocrates. Now if, knowing the action of the hand, we nevertheless still need some method for discovering the usefulness [of its parts], how, then, shall we readily find the utility of each of the parts of the encephalon, the heart, and almost all the other viscera? [22] Some say that the governance of the soul resides in the heart, others say in the meninges, and still others say in the encephalon, so that some claim one utility and others another for the parts of these instruments. But of course we shall examine these questions later on. I have mentioned them here, however, only to show why I have undertaken this treatise on the usefulness of the parts when Aristotle has written so fully and so well on this subject, and no small number of other physicians and philosophers, among whom, certainly, is Herophilus of Chalcedon,[23] have also expressed themselves well, though perhaps more briefly than Aristotle. Nor are the writings of Hippocrates adequate, since he treats some subjects obscurely and omits others altogether, though in my estimation, at any rate, he has written nothing that is incorrect. For all these reasons, then, I have felt moved to write a complete account of the usefulness of each of the parts, and I shall accordingly interpret [I, 15]

[21] Reading *ἀποδέξασθαι* with the manuscripts for Helmreich's *ἀποδείξασθαι* and Kühn's *ὑποδέξασθαι*.

[22] Whose actions are not agreed upon. In the next sentence it is Aristotle who places the governance of the soul in the heart, and Erasistratus who places it in the meninges. See *De plac. Hipp. et Plat.*, I, *passim;* VIII, 3 (Kühn, V, *181–210, 602* ff.).

[23] Helmreich properly emends *Καρχηδονίῳ* to *Χαλκηδονίῳ*. For Herophilus of Chalcedon, "the greatest anatomist of antiquity," see my Introduction, pp. 24–26.

those observations of Hippocrates which are too obscure and add others of my own, arrived at by the method he has handed down to us.

9. Let us therefore begin again where we left off in our discourse and review in detail the whole structure of the hand; indeed, if we train ourselves thoroughly by discussing this part, whose action is
[I, 16] perfectly clear, we shall the more easily learn the method to be used in discussing other parts later on. Then let us make our fresh start with Hippocrates' statement as if it were the voice of God. For in the same treatise in which he points out the usefulness of the fingernails and in the course of it teaches us how long they ought to be, Hippocrates likewise points out the usefulness of dividing the hand into fingers and setting the thumb opposite the other four. He writes as follows: "A good shape for the fingers, a wide space between, and the thumb opposite the forefinger." [24] In fact, the division took place for the sake of enabling the fingers to spread apart to the greatest extent, often a very useful position. And so he properly says that it is particularly when the fingers have that [ability] for the sake of which they were formed that their construction is most advantageous. For surely, to this construction is due also the opposition of the thumb to the other fingers, since if the hand were merely divided into fingers and the thumb were not set farthest from the others, it would not be opposable to them. Verily, here too Hippocrates teaches many things in but few words to those, at least, able to understand what he says. Hence, when I have once called attention to the method of exposition found in all his writings, it will perhaps be proper for me to imitate not only the other virtues of the man but also this very trait in him of teaching much in few words and to abstain from going over all his sayings in detail. Except in passing, therefore, I do not propose [in every instance] to state that Hippoc-
[I, 17] rates had an excellent understanding of such matters; my purpose is rather to discuss in detail the usefulness of all the parts.

First, however, I shall explain further just this one point of all those set forth by him in the passage cited, a thing most necessary for a physician to learn, but impossible to discover without careful reflection on the usefulness of the parts. And what is this thing? It is the recognition of what is the best construction for the body. Now

[24] *De officina medici*, cap. 4 (Littré, III, *286*, *287*). Again Kühn erroneously extends the quotation to include the following sentence.

clearly the best construction is that in which all the parts [of the instruments] contribute services sufficient for the actions of the instruments as a whole. Thus Hippocrates says, "A good shape for the fingers, a wide space between, and the thumb opposite the forefinger," and if you ask again why this is so, the answer he has written is at hand: "Taken as a whole, all the parts in sympathy, but taken severally, the parts in each part cooperate for its work." What, then, is the work of the hand, the part we are now considering? Obviously, it is grasping. But how will all the fingers cooperate for this effect? They will cooperate, if the spaces between them are wide, and the thumb is opposed to the forefinger, for then every action the fingers perform will be well done. And so, if you are seeking to discover the proper form for the eye or nose, you will find it by correlating structure and action. In fact, this is your standard, measure, and criterion of proper form and true beauty, since true beauty is nothing but excellence of construction, and in [I, 18] obedience to Hippocrates you will judge that excellence from actions, not from whiteness, softness, or other such qualities, which are indications of a beauty meretricious and false, not natural and true. Hence the qualities a slave dealer would value in a body are not the same ones that Hippocrates would commend. Perhaps you think that in Xenophon's [25] story Socrates is jesting when he is arguing over beauty with those who were supposedly the most handsome men of their time. Now if he were speaking simply of beauty without reference to action and without using action as the one measure of beauty, then perhaps he would be only joking, but since in the whole discussion Socrates relates the beauty of construction of the parts to the excellence of their action, we must no longer believe that he is only joking, but that he is also very much in earnest. Of course it is characteristic of the Socratic muse constantly to mingle grave and gay. Well, what I have said thus far is amply sufficient to show the usefulness of my proposed task and to explain how the thoughts and sayings of the Ancients should be understood.

So let us treat of the whole structure of the hand in regular order, leaving nothing unexamined so far as that is possible. However, in

[25] *Symposium*, V (Xenophon [1922, *445–449*]). Galen discusses beauty again in *De plac. Hipp. et Plat.*, V, 3 (Kühn V, *448* ff.), where the emphasis is placed on symmetry of both bodily parts and actions. See also chapter 13 of Book XI *infra*.

order that the discourse may proceed systematically, let us enumerate all the inherent attributes of bodies. The first and most important of these is temperament (the mixtures),[26] since it is temperament that is responsible for the characteristic essence of the parts. For the
[I, 19] nature of the body is determined by the commingling in a certain way of the hot, the cold, the dry, and the wet. For example, flesh has the nature of flesh, and a nerve that of nerves, and each of the other parts is such as it is because of the mingling in a definite way of the four qualities I have mentioned. The parts, then, possess these qualities by virtue of their essence, and their odors, flavors, colors, hardness, and softness follow of necessity. There are necessarily other contingent attributes also, namely, position, size, contexture, and conformation. Accordingly, whenever one wishes to examine carefully the usefulness of everything appertaining to an instrument, let him first inquire to what its action is due, and he will find that in most cases the action is derived from the characteristic substance but sometimes from one of the secondary attributes, such as color in the case of the eyes.[27] Next let him investigate the usefulness of each of the other parts [of the instrument] to see whether it is serviceable because of its action or because of some attribute resulting from temperament, as bone is serviceable on account of its hardness. After this, he should examine each contingent attribute both of the whole instrument and of its parts. These attributes, as I said a little earlier, are position, size, contexture, and form. But if anyone thinks that he has properly examined the usefulness of a part before he has applied all these tests, to see whether he is right or has at some point gone astray, he is sadly mistaken.

10. Let us not ourselves wittingly fall into this error, but let us

[26] For other statements of the Greek doctrine of crasis or temperament, see Adelmann (in Fabricius [1942, *693–694*]), and see also my Introduction, pp. 44–45.

[27] Galen must mean here not the color of the iris, but the transparency of the crystalline lens, which he thinks of as "clear, radiant, gleaming, and pure," and which he calls the principal instrument of vision. See Chapter 1 of Book X. This list of attributes to be examined and other similar lists given later on are not original with Galen. Celsus (1935, I, *14, 15*) in the proemium of *De medicina* also gives a similar one in reporting the opinions of writers on rational medicine before his time. Perhaps there was an ultimate, obscure connection with the ten categories of Aristotle.

make the test in all its steps, as I have shown above, for the hand first, since we have undertaken to speak first of this part, and then also for each of the other parts in order, keeping action as the point [I, 20] of departure for our investigation and at the same time the criterion for what we discover. Accordingly, since the work performed by the hand is grasping, and it would never be able to grasp anything if it were without motion (for then it would not differ at all from a dead hand or one made of stone), it is clear that the part of it most important for its action will be that which is found to be the cause of its motion. Since, indeed, I have shown [28] that all voluntary motions (those of the hand are of course voluntary) are performed by muscles, the muscles of the hand would be the most important instrument of its motion. All the other parts, however, were made some for the sake of performing the action better, others because the action would be impossible without them, and still others for the protection of the whole. We have seen [29] that the fingernails were made for the sake of bettering the action of the hands, because, although even without their aid the hands would certainly be able to grasp, they could not handle objects of all sizes or grasp as well as they can now. For I have pointed out that small, hard objects would readily escape them if some hard substance capable of supporting the flesh did not underlie the tips of the fingers. Thus far I have discussed the usefulness of the position and hardness of the fingernails.

11. I have not yet told why they were made just so hard and no harder or why they are rounded on all sides, but it is now the proper [I, 21] time to do so. If they had been made still harder than they are now, like bone, for one thing they would be less suited for grasping, because they could not bend even a little, and in particular they would be easily broken like all brittle substances. Accordingly, in providing for their safety Nature made them moderately hard so as not to detract in any way from the usefulness for which they were made and also to keep them from being easily harmed. But let the construction of all similar parts indicate to you how provident Nature was when she made them softer than bone to the extent that they yield a little to anything falling violently upon them from

[28] In many passages; see, for example, *De motu musculorum*, I, 1 (Kühn, IV, *367–373*).

[29] See chapter 7 of this Book.

without and deaden the force of the blow. For Nature fashioned all exposed, unprotected parts of animals from some substance that would not be easily bruised because of its softness or easily broken because of its dryness. Hoofs are such a part, whether solid or cloven, and also the spurs of the cock, and horns. It would have been expedient for these parts, as defensive weapons, to be harder than they are now, so as to be able to crush and cut with greater force, yet for their own safety it was better for them not to be so hard as to be easily broken. For the same reason we say that the best dagger is not one made of brittle iron such as is found especially in India,
[I, 22] although this may cut very rapidly, but one hard enough to cut readily and yet not be easily broken. Hence prominent and exposed parts of the body that are strong and analogous to defensive weapons are harder than mere coverings but not hard enough to be broken. Now those parts of the body that were not formed to serve as weapons at all, but are simply parts of the body necessarily exposed, like the ear, nose, elbow, and knee have a still softer substance, so that they are more yielding and consequently withstand better the impact of whatever impinges upon them from without. Human fingernails are such parts and for this reason they were made much softer and more delicate than the claws of wolves, lions, or leopards. For they are not the defensive weapons of a wild beast, but parts belonging to a civilized, social animal and adapted for grasping objects accurately. But why are they rounded on all sides? Is not this also for the sake of safety? For a circular shape is the only one nicely adapted for firm resistance, since it has no exposed angle to be broken off. Since, however, the ends of the nails tend to be worn off by scraping or by any other use we make of them, they are the only animal parts constructed by Nature that are capable of growth even when the body as a whole has already stopped growing. They do not grow in length, breadth, and thickness, as the other parts do, but
[I, 23] only in length, like hair, the new nails growing up from below and pushing forward the old; and Nature did this purposely, in order to substitute material for what is continually wearing off at the tips. Thus everything about the fingernails shows the utmost foresight on the part of Nature.

12. That bones too were made in the fingers for sake of bettering the action you may learn from the following discussion. I suppose that the fingers could move in many different ways even without the

aid of bones, just as the arms of the octopus can, but no work we do would ever have firm support if we did not have a part that was hard and resistant. Now bone is such a part in the animal body, and this is the reason why bones were formed in the fingers, arms, and legs, and in many other places in the body. What support the bones contribute to the other instruments perhaps my discourse will show as it proceeds, but it is possible now for us to see that this support is serviceable to much of the work accomplished by the fingers, if we reflect that without the aid of the bones we could not write, cut, or do anything of the sort any better than we could if the fingers trembled. In fact, the condition [now] produced by disease would always be the natural one for all of us, for the fingers would bend and, as it were, be distorted because they were so soft. As a defense against this, however, the Creator gave us bone with the qualities it [I, 24] naturally possesses in order to support the fingers in each of the positions they assume. Moreover, this very ability to assume so many positions is most useful and results from the fact that each finger is composed of several bones. They would lack this faculty if each were fashioned from a single one, for then they could perform well only those acts requiring the fingers to be extended. Surely here too we must needs admire the skill of Nature in giving the fingers a construction suited to all actions. For if they were made without bones, they would do well only the work in which we need to curve them around the object to be grasped, and if they had just one bone, they would be of real use only in work where we need them extended. Since, however, they are not made without bones or with only one, but each finger has three of them articulating with one another, they therefore readily assume the positions necessary for all actions. When all the joints are flexed, we use the fingers as if they had been made without any bones, and when all are extended, it is as if each finger were made with only a single one. Often, however, we do not need the joints all extended or all flexed, for sometimes we extend or flex only the first, second, or third, and sometimes the first and the second, or the second and third, or the first and third, thus making six different positions. Because of the greater or lesser extension in each of these cases, it is impossible to say but easy to [I, 25] comprehend how great is the total number of intermediate positions. Of course, complete flexion and likewise complete extension are indivisible into the more or the less, but it is inconceivable how great

a number of intermediate positions the motion of the joints may produce when they are flexed or extended sometimes more and sometimes less. Hence, because the fingers are constructed as they are, they may assume not merely six different positions, but more correctly six general types of position, whereas the number of particular positions is infinite. Of the two other constructions [I have mentioned], the one without bones would permit the fingers to assume only a rounded shape, and the one with a single bone only a straight one; as it is, however, they are not prevented from taking these shapes, and besides these they have gained the six general types and a host of particular positions. They can, of course, be absolutely straight only when the bones of which they are composed lie in a straight line, and the perfectly circular shape is impossible.

13. This difficulty is certainly the reason why Nature contrived to form flesh [on the fingers]. She did not need to maintain any on the upper sides of the bones, for there it would be an excessive burden, but she did cause it to grow on the under sides of them all so that whenever it is necessary to encircle an object with the fingers, the flesh, being soft, may yield gently to what it encounters and correct the straightness of the bones. For the same reason she also made it least abundant right at the joints and very plentiful between
[I, 26] them. For, being naturally disposed to bend, the joints did not need the same sort of aid as the bones, and the flesh, besides contributing nothing useful to them, would also be a hindrance to their motion, weighing them down excessively and occupying the free space on their inner sides. These, then, are the reasons why Nature formed no flesh at all on the outer sides of the fingers, but on their inner sides placed a great deal in the intervals between joints and very little at the joints themselves. Moreover, she also made enough flesh grow on the sides of the fingers to fill up the empty spaces between them in order that the hand may be able to act both as an instrument cleft into many parts and as one quite undivided. In fact, when the fingers are held close against one another, the spaces between them are entirely eliminated by the flesh, so that if you wish to hold a liquid in the hollow of your hand, it will not run out. These are the many great benefits the flesh confers on the hand, and besides these it can also soften and polish anything that requires a moderately soft instrument for this purpose; and there are many such things in all the arts. These are the particular uses of the flesh on the hand. The uses

of flesh in general (and of course the hand no less enjoys the benefits of these) I shall give in the very words of the author who has best described them. Plato [80] says in *Timaeus:* "Flesh is a protection from the burning heat of the sun and a defense against the winter's cold and also against falls, yielding softly and easily, like articles made of [I, 27] felt, to the objects it encounters. It has within it a warm moisture which in summer exudes and makes the surface damp, thus imparting a natural coolness to the whole body. And again in winter, by aid of this internal warmth, the flesh affords moderate protection from the cold which envelops and attacks it from without." Now, that the flesh is, as it were, a sort of defense, very like something made of felt, needs no discussion. In like manner it is apparent too that it contains warm moisture derived from the blood. But most people do not also agree that all moisture moderately warm, as of course that of the flesh is, wards off equally well the extremes both of cold and of heat. Nevertheless, if I should first remind them of the virtues of the bath and then also explain the nature of the phenomenon itself, perhaps they would be won over. Certainly you would find nothing better than a bath for cooling properly anyone overcome by excessive heat, or for warming easily anyone exhausted by severe cold. For a bath, being by nature both wet and moderately warm, relieves with its moisture the dryness resulting from the heat and counteracts with its warmth the chill resulting from the cold. But I have now said enough about the flesh.

14. I am again returning to the point where earlier I digressed from my discussion of the nature of the bones in the fingers. Now it has been amply demonstrated that we need these bones as a firm [I, 28] support for the actions and that we need more than one in each finger to make possible a greater variety of positions. However, I have said nothing about how many bones there ought to be, or the proper size for each one, and nothing about their shape or method of articulation. Well, then, let us say at once that there ought to be three bones, neither more nor less, in each finger. If there were more than three, none of the actions would be at all improved (for I have adequately demonstrated that all of them are perfectly performed with just the three bones), and in addition, perfect extension of the fingers would perchance be somewhat impaired, being less rigid than it is now, since the more parts there are composing a body, the more

[80] *Timaeus,* 74 (Plato [1920, II, 52]).

easily it bends. But if there were less than three bones, the fingers would not enjoy such a great diversity of particular positions. Hence three are enough to enable them to move in many different ways without being too flexible.[21] Now as regards size, it is very clear to everyone that the first bone in the series ought to be larger than the one that comes after it, for one sustains and the other is sustained, and the one that lifts should be larger than what it lifts. Moreover, it has also been shown before [22] that the fingers should end in tips that are very small and round; this could not be accomplished in any way other than by a gradual decrease in size of the bones, and hence it is necessary for the second bone always to be smaller than the first. As
[I, 29] for their shape, it has the same utilities as those I have mentioned in connection with size, inasmuch as the bones taper from a broad base above to a narrower end below. But I must give resistance to injury as the reason why they are also round; for of all shapes, that is the hardest to damage, since it has no projection liable to be broken off

[21] If Galen could be asked why, in view of all this, the thumb has only two phalanges, he would reply that what is now regarded as the first metacarpal bone is in reality the first phalanx of the thumb. See pp. 135–136, 170–171. In *De ossibus ad tirones*, cap. 19 (Kühn, II, 771–772), he gives his reason for thinking so: "The interval between the carpus and the fingers is called the metacarpus. It articulates with the carpus by synarthrosis, and with the first phalanges of the fingers by diarthrosis. . . . Only in the thumb does the first phalanx articulate obliquely by diarthrosis with the metacarpus [*sic*] itself. Thus each finger has three bones, the more proximal phalanx always entering the concavity at the beginning of the phalanx coming next after it. For it is reasonable to say that there are three bones in the thumb too and not to assign its first phalanx to the metacarpus, since it articulates by diarthrosis at both ends, as the first phalanges of the fingers do, whereas the bones of the metacarpus do not. Hence one might say with good reason that there are four bones in the metacarpus and fifteen in the five fingers. On the other hand, those who assign the third bone of the thumb to the metacarpus say that there are fourteen bones in the fingers and five in the metacarpus." See Daremberg (in Galen [1854, I, *136–137*]) for the debate on this point; and for a review of Galen's treatment and a comparison of it with those of his predecessors and successors, especially with that of Vesalius, see Michler (1964). Dr. Charles Goss has called it to my attention that "Galen has a good point. The pattern of ossification of the first metacarpal is more like that of a phalanx than that of the other metacarpals."

[22] *Vide supra*, pp. 73–74.

by anything striking against it from without. Now why is each bone nicely arched on its outer side, but not so much on the inner surface or at the sides? Is not this too for the betterment of the action? Indeed, it is with their inner parts that the fingers rub, soften, or grasp all objects, and these are actions which would be poorly performed if the bones were arched in these regions. With their outer parts, however, they do not perform these or any other actions, and these were therefore carefully constructed solely to resist injury. Furthermore, at the sides they are not liable to injury because they protect one another, and when approximated, they must leave no space between them; hence it was necessary for them not to be arched in these regions. Sufficient proof of what I have said is found in the construction of the thumb and little finger: the former has a nicely arched surface above, and the latter below. For on these sides, they are not protected by anything nor are they associated with another finger. Surely, Nature's skill in constructing the bones is marvelous.

15. The way in which they articulate is no less marvelous; for the three bones in each finger were not produced in any simple, accidental fashion, but their joints, like door hinges, have processes which fit [I, 30] into concavities. Perhaps you will consider even this not so very marvelous, but if you will examine the connections of all the bones throughout the entire body and find processes always corresponding to concavities that receive them, then, I know full well, it will seem to you the greatest of marvels. Now if the concavity were broader than necessary, the joint would be loose and unsteady; on the other hand, if it were too narrow, the motion of the joint would be difficult because there would be no room for rotation and there would be considerable danger of breaking off the straitened processes of the bones. We do not, however, find either of these conditions, and a sort of raised rim surrounds all of the concavities of the joints, providing for them a great safeguard against ever being dislocated except by some extraordinary force. Yet since there would still be danger that such a safe construction would make movement too difficult and that the bony processes would be worn off, Nature has again searched out a double remedy, first covering each member of the joint with cartilage and then pouring over the cartilages themselves a sort of oily substance, a greasy, glutinous fluid, which gives every joint an easy movement and protection against

wear. Nature's contrivance of ridges around the concavities was in
[I, 31] itself sufficient to prevent dislocation of the joints, but she did not entrust their safety to this alone, because she perceived that an animal would frequently have to make many forcible and violent movements. In order, then, that every joint might be guarded carefully on all sides, she caused certain ligaments to grow out from each bone and stretched them from one to the other. Some of these ligaments are round and thick, like nerves, and others are like membranes, long and thin; they are always so formed with a view to the usefulness of the joints, the largest and thickest of them guarding the largest, most important joints, whereas the others are attached to smaller, less important ones. All these contrivances are common to all the joints, even to those in the fingers, where they are particularly suitable. For these articulations are small, but nicely hollowed out, surrounded on all sides by delicate rims, coated with thin cartilage, and bound together by membranous ligaments. Moreover, it is surely one of Nature's cleverest devices in the construction of the fingers not to make the rims on the bones at all uniform in size, but much larger on the outer sides of the fingers and smaller on the inner sides. For if they were smaller on the outer side, they would allow the joints to bend back even beyond their farthest extension, and if they were larger on the inner side, flexion would be greatly curtailed, so that in both cases the result would be harmful; both
[I, 32] firmness of extension and variety in flexion would be lost. But since the converse is true, the rims on the bones, far from being a detriment, have been of the greatest assistance to the movements of the fingers. Now why are the finger bones hard and solid, without marrow? [88] Is it not because they are exposed on all sides and hence

[88] Cf. *Hippocratis de fracturis liber et Galeni in eum commentarius*, II, 8 (Kühn, XVIII, pt. 2, *432*), where Galen remarks, "He [Hippocrates] says that both parts [the hand and foot] are composed of many small bones; of many small, *hard* bones, I add, for they have no medulla and no cavities at all, being not unlike little stones." This error was picked up by Vesalius (*1555, 3*), who included the phalanges among the hollow bones, "however much it seemed otherwise to that prince of professors of anatomy, Galen, who decided that the bones of the fingers are solid" (*quantumvis secus Galeno Anatomes professorum praecipuo visum sit, ossa digitorum solida constituenti*). Jacobus Sylvius (Jacques Dubois) rushed to Galen's defense, claiming that in his day the bones of the fingers *were* solid, because those parts were so much stronger then. See Sylvius (*1555, 86*), and for his general statement of the mutability of the human body, see Sylvius (*1555a*, f. 1–4 verso).

easily injured? This special construction gives them a firmness and resistance that are a splendid remedy for the vulnerability resulting from the thinness of their outer coverings.

16. Such are the characteristics of the bones in the fingers. Next I shall discuss the properties of their other parts, that is,[84] when I have first reminded you that, as I have shown, it is impossible to determine correctly the usefulness of a part before its action is known. It is evident, and we all agree without needing to demonstrate it, that the action of the hand is grasping, but there is no agreement at all on the actions of the veins, arteries, nerves, muscles, and tendons; the actions of these parts are not self-evident and hence do need further discussion. This, however, is not the proper time to inquire into them, for I propose to speak not of actions, but of usefulness. Accordingly, for the success of my discourse it will be necessary both now and in all the rest of this work to use as fundamental principles the conclusions I have reached through proofs set forth in my other writings. For I have shown in my book *On the Teachings of Hippocrates and Plato* that the encephalon and the spinal medulla are the source of all the nerves (the encephalon being in its turn the source of the spinal medulla itself), that the heart is the source of all the arteries and the liver of the veins, and that the nerves receive the psychic faculty from the encephalon, the arteries the faculty of [I, 33] pulsation from the heart, and the veins the natural faculty from the liver.[85] The usefulness of the nerves, then, would lie in conveying the faculty of sensation and motion from its source to the several parts; that of the arteries is to maintain the natural heat and nourish the psychic pneuma; and the veins were formed to produce the blood and also to convey it to all the parts. Furthermore, I have told in my book *On the Movement of the Muscles* how tendons, nerves, and ligaments differ from one another,[86] and, as one would expect,

[84] Πρότερον γ' ὑπομνήσας, Helmreich; πρότερον ὑπομνήσας, Kühn.

[85] All these principles are set forth at great length in Galen's *De plac. Hipp. et Plat.*, VI, (Kühn, V, *505–585*).

[86] *De motu musculorum*, I, 1–2 (Kühn, IV, *368–376*), and see both the discussion immediately ensuing here and chapter 3 of Book XII. Cf. also *Methodus medendi*, VI, 4 (Kühn, X, *408–409*), and *De anat. admin.*, XIV (Galen [1906, II, *169–170;* 1962, *185–186*]). In consulting the last-named treatise, it is necessary to bear in mind that only the first eight books and part of the ninth are extant in the original Greek and are included in Kühn's edition. The remainder of Book IX and Books X–XV were recovered about 1844 in an Arabic version, which was

the nature of muscle has been discussed in the same work, which also states that muscles are the instruments of voluntary motion, and that their aponeuroses are called tendons.[87]

17. For the present discussion and for all the rest of this work, I shall use these principles as the bases for my demonstrations and tell the benefits derived from them in each of the instruments, beginning once more with the fingers. Since Nature had given the bones of the fingers the construction best suited to a prehensile instrument but found it impossible to give the bones themselves, being so earthy and rocklike, a share in voluntary motion, she devised a way to move them by means of other parts. She therefore caused tendons to grow out from the muscles of the forearm and extended them straight to the fingers; for what the Ancients [88] called nerves, the structures that
[I, 34] are plainly visible from the outside and that move the fingers, are the tendons. They take origin from the nerves and ligaments which are distributed through the muscles and come together again, and their usefulness is determined by the nature of their components. They have sensation and voluntary motion, and they also bind the muscles to the bones; the first of these uses, sensation and motion, they obviously derive from the nerves, and from the ligaments comes

---

translated into German as *Sieben Bücher, Anatomie des Galen* by Simon and published in 1906 along with the Arabic text. This German translation was in turn translated into English by Duckworth, whose work was carried forward and carefully checked with the Arabic after his death by his editors, Lyons and Towers. It was published in 1962. References to the first part will therefore be to Kühn and to Singer's (1956) English translation, whereas for the second part references are given to Simon's and Duckworth's versions. See Anonymous (1844); Simon (in Galen [1906, I, *ix–xvii*]); and the introduction to Duckworth's version. See also note 12 of Book II of this work.

[87] "Aponeurosis" for Galen does not have its modern meaning, but denotes either the place at which the muscle proper ceases and the tendon begins (see, for example, pp. 96 and 97 *infra*) or, as here and in *De motu musculorum*, I, 1 (Kühn, IV, *368–369*), the tendon itself. See also *De anat. admin.*, I, 3 (Kühn, II, *233;* Galen [1956, *8*]); *Methodus medendi*, VI, 4 (Kühn, X, *411–412*); and Hyrtl (1880, *41–42*).

[88] See, for example, Hippocrates, *De locis in homine*, cap. 4 (Littré, VI, *282–285*); Plato, *Timaeus*, 74 (1920, II, *52–53*); Aristotle, *Hist. an.*, III, 5, 515a27–515b26; *De part. an.*, III, 4, 666b13–17; and Ogle's (1911) note on the last-named passage.

their usefulness in attaching the muscles to the bones. Now ligaments are like nerves, white, bloodless, and without a lumen, and for this reason many of the more ignorant imagine them to be nerves. However, they do not arise from the encephalon and spinal cord but extend from one bone to another, and hence they are much harder than nerves, quite without sensation, and incapable of moving anything.

Nature therefore extended all the tendons we find at the wrist from the muscles of the forearm to the fingers and fastened them to each of the joints, not, of course, into the actual junction of the bones (for what would be the use of that?) and not to the end of the first bone of the articulation, since that would be of no benefit at all, but to the head of the second bone, the one that is to be moved. This is the device, I think, that is used in moving puppets [39] with cords; for, passing over their articulations, the cords are fastened to the [I, 35] beginning of the parts beyond, so that the puppets [40] readily obey the force of the upward pull when the cords are tightened. If you have ever seen what I am describing, you have clearly perceived already how each joint in the fingers is moved by its tendons. Thus the distal member of each articulation, moving around the proximal member, which remains motionless, is extended when the outer tendon pulls on it and flexed by the inner one. Now why, pray, did Nature ever produce such long tendons instead of making the muscles grow out from the wrist? The answer is that it was better for the hand to be light and thin, and not to be burdened with a mass of flesh making it heavy and thick, since if it were, it would do more slowly and poorly many of the things which it now does readily and well. But because it was necessary to lead the tendons up over a long distance, and because there was danger that if they were unprotected in a place devoid of flesh they would be easily pinched and severed or heated and chilled, Nature protected them by devising tough membranes [41] with which she clothed them on all sides. In this way they suffer no pain when they come in contact with things striking against them from the outside and also with the bones themselves. Moreover, for the whole distance from the muscles to

[39] *τὰ εἰδωλα*, literally, images. Daremberg (in Galen [1854, I, *143*]) translates *les marionettes.*

[40] *τὸ εἰδωλον*, Helmreich; *τὸ κῶλον*, Kühn.

[41] The fibrous and synovial tendon sheaths.

the joints the tendons are carefully rounded to make them less vulnerable, but where each is attached to the phalanx which it is to
[I, 36] move, it is flattened; for if it exerts traction on more than one point, it will move the bone more easily.

Now since it is possible for each finger to have four motions,[42] flexion, extension, and two lateral movements, it was reasonable, I think, for tendons to be attached to each joint on its four sides. In fact, if any one of the four were without a tendon, the part would to that extent be crippled. And the tendons obviously are attached on the four sides of the fingers. Some of them arise from the muscles of the forearm—those which flex the fingers from the muscles on its inner side [*flexores digitorum, superficialis* and *profundus*]; those which extend them, from the outer muscles [*extensor digitorum communis*]; and those which turn them in the direction of the little finger, from muscles producing lateral movements [*extensores digitorum proprii*].[43] But other tendons arise from the small muscles of the hand [*lumbricales*], and these are the ones which perform the other lateral motion, that, namely, in the direction of the thumb. Thus Nature has overlooked no movement of any of the fingers nor any one of the tendons controlling these movements. And we must not neglect to mention other provisions much more important than these, although these alone would suffice to demonstrate very great skill on her part. For Nature, being just in all her dealings, not only bestowed every possible motion upon the fingers; she also caused the size of the tendons to correspond exactly to the usefulness of the motions. The largest finger, also called the antihand [the thumb], has a slender tendon [of *flexor digitorum profundus*] [44] on its inner

[42] τὰς πλείστας, added by Kühn after κινήσεις, is omitted by Helmreich.

[43] Here is the first indication that Galen is describing conditions in the ape and not in man, as he says he is. In man only the second and fifth fingers are provided with an extensor proprius, whereas in the ape there is also one each for the other two fingers. See Howell and Straus (1933, *139–140*) and compare Galen's more detailed description in *De anat. admin.*, I, 6 (Kühn, II, *254–255;* Galen [1956, *18*]), where he is admittedly giving directions for the dissection of the ape. See also *De musc. diss.* (Kühn, XVIII, pt. 2, *979;* Galen [1963, *488*]).

[44] One thinks at once of flexor pollicis longus, but in the ape this is lacking and flexor digitorum profundus ends in five tendons, one of which goes to the thumb. See Howell and Straus (1933, *136*), and compare the parallel passages in *De anat. admin.*, I, 5 (Kühn, II, *248–251;*

side and two rather stout ones [of *extensor pollicis longus* and *abductor pollicis longus*] on the outer side. Laterally it has a thin, [I, 37] small muscle [*adductor pollicis*] on the side next the forefinger, but a much larger one [*abductor pollicis brevis*] on the other side in the thenar of the hand. Each of the other four fingers has two large tendons [of *flexores digitorum, superficialis* and *profundus*] on its inner side and on its outer side one [of *extensor digitorum communis*] which is as large as the smaller one of the two on its inner side; but the tendon [of *extensor proprius*] proceeding to the outer [ulnar] side of the finger is thinner than this, and the remaining one [of *lumbricalis*] which leads to the inner [radial] side is thinnest of all.

All these tendons have been so arranged with good reason, as I have said. For example, since we perform most actions, and the most vigorous ones too, with the four fingers flexed, we needed to have not only large but also double tendons on the inner side of the hand. In fact, whenever we hold anything with one hand or both together, or whenever something is to be stretched, crushed, compressed, or softened, we do these things with the four fingers flexed. The contrary is true of the thumb, however. For except when we must place it on top of the other fingers after they have already been flexed, we do not need to flex it to perform any action; moreover, the first joint of the thumb, which articulates with the wrist, is entirely idle in a motion of this kind, since its flexion would not assist any action whatever. The other two joints act usefully only when we lay the thumb upon the other fingers, flexed within it, as if compressing and binding them tightly. Hence, no tendon is inserted [I, 38] into the inner side of the first joint of the thumb; a small one [of *flexor digitorum profundus*] reaches the inner side of the second and third joints, and the remaining one [of *adductor pollicis*] which proceeds to the side, is weakest of all. Again, the tendons [of *extensor digitorum communis*] which extend the other fingers are much smaller than those which flex them, but considerably larger than those [of *extensores proprii* and *lumbricales*] reaching to the sides. Of course, if the tendons that oppose the very strong and thick ones on the inner side had been made extremely weak and

---

Galen [1956, *15–16*]), and *De musc. diss.* (Kühn, XVIII, pt. 2, *985–986;* Galen [1963, *490*]).

thin, they could not hold the fingers firmly in all positions from complete flexion to complete extension. In fact, I have shown in my book *On the Movement of the Muscles*[45] that in everything we do using the intermediate positions, we need the simultaneous action of two muscles opposing one another. In the thumb, however, there is no tendon set exactly opposite to the one that flexes it, for if there were, it would lie directly in the middle of the outer side; instead, two tendons [of *extensor pollicis longus* and *abductor pollicis longus*] appear there, one inserted on each side of the center, and if both are tensed at once, they extend the finger perfectly, but when they act singly, each one draws the thumb toward its own side. The action of the tendon [of *extensor pollicis longus*] which draws the thumb toward the forefinger is taken up by the small muscle [*adductor pollicis*] situated in that region, and the opposite action is taken up by the large one [*abductor pollicis brevis*] in the thenar of the hand. For it was reasonable for the thumb to be drawn farther away from the forefinger and for its movement to this posi-
[I, 39] tion to be more vigorous, like the opposite motion of the other four fingers, which would thus be kept as far as possible from the thumb. I have told earlier,[46] however, what a great advantage this separation is for the work of the hand. For the same reason, of the tendons that extend to the sides of the fingers those [of *extensores proprii*] that move them away from the thumb are much larger than those [of *lumbricales*] that move them toward it.

Hence Nature has done all these things with skill, and she was skillful too when she arranged that the thumb alone should have four sources of lateral motion, whereas each of the other fingers has only two; for it is only the thumb whose chief action is to approach and withdraw from the other fingers. So, in order that it might move as far as possible in both these directions, Nature established at each side of it a double control for lateral motion—for motion toward the forefinger, the tendon [of *extensor pollicis longus*] and the muscle on that side [*adductor pollicis*], and for the opposite motion, the other tendon [of *abductor pollicis longus*] on the outer side and

[45] *De motu musculorum, passim.* See in particular I, 4–6 (Kühn, IV, *384–396*). This treatise contains Galen's physiology of muscular motion. For summaries of it, see Meyer-Steineg (1911) and Nardi (1938).

[46] *Vide supra,* pp. 73, 78–79.

the muscle [*abductor pollicis brevis*] in the thenar. For one of the tendons was formed to draw the thumb toward the forefinger, and the other, to draw it away, and one of the muscles that take up the action of the tendons was formed to make it approach as near as possible and the other to make it withdraw as far as possible.

I have now described the size, number, and location of the tendons and muscles moving the fingers, and if I have omitted any minor point such as a description of the tendons on the inner side of the hand and particularly of the one [of *flexor digitorum profundus*] on the inner side of the thumb, I will now proceed to discuss it. Indeed, I have already said that the latter must be single and more slender than the others, and that it must be inserted on the second joint of [I, 40] the thumb, but I have not yet stated that although every tendon has been formed to draw toward its own head the part it is to move, and although the head of this tendon has been placed precisely in the middle of the joint at the wrist, anything rather than flexion would be the result if the thumb were drawn toward this point. And yet, here too is something marvelous, a device of Nature's which you will admire as it deserves, if you will only reflect that the head of the tendon charged with bending the thumb ought to be centrally located in the hollow of the hand. If this had been done, however, it would be necessary for the muscle set at the tendon's head and of course lying along the line of it to extend to the little finger, assuming a position that is for numerous reasons absurd and unnatural; first, because the hollow of the hand, so useful in many ways, would be spoiled; secondly, because the lightness of the hand would be destroyed; in the third place, because the four fingers would be prevented from bending; and in the fourth place, because the beginning of the muscle would be located at the little finger, a result the most absurd and impossible of all. In such a position, moreover, it would be difficult, or rather impossible, for the nerve coming down from above to be inserted into the head of the muscle, since the [other] end, or at all events certainly the middle of it, would be encountered first. Hence, since it was impossible to fix in this location the tendon charged with bending the thumb, and since on the [I, 41] other hand the tendon would be unable to produce any flexion when placed elsewhere, providing flexion for the thumb came near being wholly impracticable and impossible. How, then, did Nature resolve

so great a difficulty? She made the tendon grow from the aponeurosis[47] at the wrist. Indeed, what else could she do? But she did not extend it straight to the thumb, nor did she make it originate from parts in the vicinity of the thumb. On the contrary, this tendon begins at the same place as the one leading to the middle finger [part of the *flexor digitorum profundus*]; it is carried on top of it for some distance and is bound up with it in strong membranes. When these tendons reach the hollow of the hand, the one for the thumb, passing out through the membranes, diverges from the other one, just as the reins for a pair of horses run along the yoke and are separated by passing through certain rings. For the reins bend and form an angle, so to speak, at the rings and, when they are pulled, draw the yoked animals in the direction of the rings; in like manner, when this tendon is tensed by the muscle pulling on it, the finger is drawn along with it, not toward the location of the muscle, but in the direction of the place where the tendon is bent in passing out through the membranes. These are the reasons, certainly, why this tendon begins at the same head that is common to the other tendons and follows the path I have described. But why is it carried on top of the other tendons? Is it not clearly because this tendon is the instrument of a relatively unimportant motion? Nature always places the more important parts deep within the body, and unimportant ones near the surface. Indeed, it is through this same providence that the
[I, 42] tendons on the outer side of the hand which belong to the other fingers are superficial, and the tendons of the thumb lie underneath them.

So too with the tendons on the inner side that lead to the four fingers; the ones [of *flexor digitorum profundus*] passing through deep below the surface of the hand are much larger than those [of *flexor digitorum superficialis*] that lie above them. The former divide to flex the first and third joints, and the latter flex only the second. Now the insertion of these tendons into the bones and their relations to one another are marvelous and mysterious, and there are no words capable of explaining perfectly things that we learn through the senses alone. Nevertheless, we must try to tell how they have been arranged, for it is not possible to admire the skill of Nature before explaining the structure [of the parts]. Two aponeu-

[47] Here used to mean the place at which the muscle proper ceases and the tendon begins. See note 37 of this Book.

roses of muscles appear at the bend of the wrist, where they lie one above the other, the larger deep below the surface along the bones, the smaller superficial. The larger, deep-lying aponeurosis divides into five tendons,[48] and the smaller one lying above it into four, for the thumb does not receive any branch from this one. All the tendons are led straight to the fingers with the smaller ones carried on top of the larger, and each of the four pairs is protected with strong membranes[49] for the whole distance. When they reach the first joints of the fingers, each deep-lying tendon broadens out and, by means of the membranous ligament surrounding it, bends the head of the first phalanx.[50] Thereafter both members in each pair are [I, 43] carried forward in a continuation of their original path straight toward the tip of the finger, the same tendon lying underneath, and the whole still protected by membranes. When they reach the second joint, the superficial tendon in turn divides into two branches, each of which broadens out, passes around the deep tendon, and is inserted into the inner side of the head of the second phalanx. The deep tendon, however, henceforth advances alone to the third articulation, where it is inserted into the head of the third and final bone of the finger. Now the joints are flexed by the tendons inserted as I have described, but they are extended by the tendons [of *extensor digitorum communis*] on the outer side of the wrist. Although these are much smaller than the tendons on the inner

[48] See note 37 of this Book. And, as noted above (see note 44), flexor pollicis longus as a distinct muscle is lacking in the ape, its place being taken by a fifth tendon from flexor digitorum profundus.

[49] The fibrous and synovial tendon sheaths.

[50] This error, also found in Galen's *De musc. diss.* (Kühn, XVIII, pt. 2, *953–954;* Galen [1963, *491*]), is corrected in *De anat. admin.*, I, 3 (Kühn, II, *234–235;* translation by Singer [1956, *8–9*]: "For then [when writing an earlier version of my anatomy] I knew nothing of the fine muscles at the extremities of the limbs which flex the first joint of each finger and toe [*lumbricales*]. I thought that this action was performed solely by the membrane which encloses on the outside the tendon running down to the end of their internode." The error did not escape Vesalius (1555, *366, 368–269*).

It should be noted, however, that the "fine muscles" flexing the first joint of each finger, identified as lumbricales by Singer, are rather the interossei. The lumbricales according to Galen (*vide supra*) are responsible for lateral movement of the fingers in the direction of the thumb. For the interossei, see pp. 117, 182.

side, we plainly distinguish them, even before dissection, because they are prominent and unprotected, covered only by membranes and thin skin, whereas the tendons on the inner side are concealed by plenty of flesh, formed for the sake of the benefits I have mentioned earlier. But the deep-lying flexor tendons [of *flexor digitorum profundus*] on the inner side of the hand move the first and third joints of each of the four fingers, both because these joints are more important for the actions of the fingers than the middle one, and because the tendons are large enough to serve two articulations. For similar reasons, the small tendons [of *flexor digitorum superficialis*] are inserted only into the middle joints because the
[I, 44] [small] mass of them cannot be divided between two articulations. Furthermore, when the motions on each side of it are intact, the middle joint of the finger somehow moves together with the joints at the ends, and hence may be said to be less important than they are. For whereas we can flex the middle joint alone and independently of those on each side, when the latter are flexed it is impossible to avoid flexing the middle joint too. Consequently, if at any time the tendon moving the middle joint is injured and the other tendon remains unharmed, the middle joint will retain some part of its motion. But if the other tendon is injured, the motion of both the first and third joints will be completely destroyed,[61] even though the tendon moving the second joint is intact. From this discussion it is evident that this group of the smaller tendons has with good reason been placed superficially, since they are the less important. Thus, it was for the sake of improving the action that the number, size, position, division, and insertion of the tendons were made as they are.

18. Since sensation is not inherent in flesh and it would have been absurd for a prehensile instrument to be covered with a part lacking sensation, Nature implanted in the flesh itself a goodly portion of all the nerves coming down into the whole hand. But when this was done, the flesh straightway became muscle, that is, if it is true that muscle originates from the distribution of nerves through flesh. And certainly Nature has put these muscles to good use; for she caused
[I, 45] tendons [of *lumbricales*] to grow from them, which she inserted into the lateral parts of each finger, on the left side of the fingers in the right hand, and the right side in the left hand. The other tendons

[61] Here Galen is forgetting the interossei, which in his system would presumably still be able to flex the metacarpophalangeal joint.

[of *extensores proprii*] inserted into the lateral parts of the fingers she formed from the muscles of the forearm, and not unreasonably, as my discourse will proceed to show if first we return again to the point from which earlier we digressed. Since it is not when we grasp a large, bulky body, but when we hold a small article or a liquid that we most need to flex all four fingers at the same time, it was very useful for them to fit together so accurately when flexed as to leave no space between them. Indeed, this is obviously the case, but it would not be if the fingers themselves did not have fleshy sides or if all the tendons moving them had not sprung from one origin. This origin, located at the bend of the wrist about in the middle of the space there and drawing on all of the tendons together and each one severally, forces the ends of the fingers to bend toward it. Hence, when only the first and second joints are flexed while the third is extended, the tips of the fingers remain in contact, although they are much more slender than the other parts of the fingers and so ought to stand apart from one another. Because they all incline toward a single origin, however, namely the head of the tendons, they are [I, 46] fitted accurately together. For the tendons all begin at this one point and pass to the fingers along straight lines making equal angles at the head. There is accordingly every necessity that a finger drawn by its tendon toward the head, should approach its own tendon and incline in the direction of the head, and so, even if you deliberately use force, you cannot bend the fingers and keep them spread apart. In fact, Nature's workmanship makes impossible from the very beginning anything that would be of no use to us.

Again, since the fingers must be extended and spread apart as widely as possible when we grasp a large, bulky body with both hands or with only one, Nature has not neglected to provide for this action also. For she worked out lateral movements for the fingers, and in this way made it possible for us to spread them apart as much as we wish. But even if the fingers did not have lateral movements, they would clearly tend to separate from one another when they are extended, because the tendons [of *extensor digitorum communis*] that extend them are formed like those that flex them, originating from a single head, and branching from it at equal angles. Of course, all tendons having such an origin and traveling in straight lines must constantly diverge more and more, the farther they go from their origin. Indeed, this is obviously true of the tendons in the [I, 47]

fingers; for if you do not employ the lateral movements at all, but only extend and flex the fingers, they will separate when extended and come together when flexed. Hence Nature did not create the lateral movements simply to separate the fingers, but to make the separation as wide as possible. When once they had this advantage, however, they also gained something else not unprofitable; for by tensing the left tendon in the sides of the fingers on the right side of the hand, and the right tendon of the fingers on the left, we can bring the fingers together when they are exended. Again, when we spread the fingers very widely apart, we tense the right tendon in the fingers on the right side of the hand, and the left tendon in the fingers on the left. If we use neither of the lateral tendons, but only those on the back of the hand, the fingers will take a position midway between the two I have described, and in persons with thin hands, all the tendons are visible in this position, extending from their common origin out to the ends of the fingers in straight lines. The tendons on the inner side of the hand, like those on the back, extend in straight lines in all movements not employing the lateral tendons, but cease to be straight and become somewhat oblique when the lateral tendons act. Consider, then, in this instance also the marvelous wisdom displayed by the Creator. For since it is better, when the fingers are flexed, not to employ the lateral movements, which were not meant to be of assistance then, but to employ them in extension, because then they will often be useful, Nature gave the
[I, 48] tendons [of *lumbricales* and *extensores proprii*] controlling these movements a construction prompt to serve the betterment of the action and incapable of impairing it. In the first place, since she caused some of the lateral tendons to grow off from the small muscles [*lumbricales*] within the hand itself, and the others from large muscles [*extensores proprii*] in the forearm outside the hand, the former are of necessity small and weak in comparison with the latter, which are larger and stronger. She arranged their attachments with the idea that it was better for both a weaker and a stronger tendon to be fastened to each finger; in the right hand the weaker tendons are attached to the left sides of the fingers and the stronger to the right, whereas in the left hand, the weaker ones are attached to the right sides and the stronger to the left. Then, too, she conducted neither of them to the precise center of the sides of the fingers, but placed the ones on the outer [ulnar] sides of the fingers

higher up [more dorsally] nearer the extensors and farther from the flexors. With these arrangements, first the lateral movement to the outside [toward the little finger] would be the stronger, and secondly it would not occur at all when the fingers are flexed. I have told why it is useful for this movement not to occur [when the fingers are flexed] and shall now tell why it is useful for it to be the stronger.

19. We need the ability to move the fingers laterally in order to separate them as widely as possible from one another, and, accordingly, these movements would be quite unnecessary if such a separation was never to be of any use to us. But when [Nature] placed the thumb in opposition to the other fingers, she realized that the lateral movements of the fingers in the direction of the thumb would be very advantageous. And if we must spread them apart as far as possible when attempting to handle a very large body, it is useful for the four fingers to move toward the outside [in the direction of the little finger] and the thumb toward the inside [extension]. For this reason she gave the thumb a rather large tendon [of *extensor pollicis longus*] to control its motion toward the inside, but she limited the size of the other tendons [of *lumbricales*] not only because an intelligent workman properly makes nothing superfluous but also because she would have weakened the opposing motion [toward the little finger] [52] if she had balanced it with another of equal force. Moreover, weakness [of tendons of *lumbricales*] is not unserviceable in suppressing entirely motion [toward the thumb] when we flex our fingers. [I, 49]

However, in order to make this discussion demonstrative and yet not too long, we need to assume certain propositions which have been demonstrated in my book *On the Movement of the Muscles.*[53] These propositions are as follows: In every joint, as I have shown, there is one position, the middle one, that is free from pain; all the others on either side are painful. Those positions near the middle are less so than those farther away, and the farthest ones, those beyond which no flexion or extension is possible, are very painful indeed; for these farthest positions are assumed when the muscles producing [I, 50]

[52] Daremberg (in Galen [1854, I, *155–156*]) says that this opposing motion is flexion, but it seems unlikely that Galen would have thought of two movements at right angles as opposites.

[53] *De motu musculorum*, I, 10–II, 1 (Kühn, IV, *418–426*).

them are under extreme tension, and we naturally feel the most pain when there is maximal contraction of the muscle controlling the motion and complete extension of its antagonist. In positions on either side of the middle, both muscles are active or one of them acts alone, and in the middle position it is sometimes possible for neither to act.

These statements hold true for the fingers also. When the arm hangs wholly idle and relaxed, as in great fatigue, there is no muscle acting on the fingers and they assume the middle position. If we then try to move them in either direction, we must tense the tendons and muscles, on the outer side when we extend the fingers and on the inner side when we flex them. If we wish to extend and move them laterally at the same time, it is clear that we shall use the tendons and muscles formed to extend them and also those formed to move them laterally. Similarly, if we attempt to flex and move them laterally at the same time, we shall use the tendons and muscles capable of flexing, and also those capable of moving them laterally. But although there are two lateral movements, the location of the insertion of the tendons [of *extensores proprii*] suppresses the outward one [in the direction of the little finger] when the fingers are flexed; for the tendons are inserted not exactly in the middle of the side but higher up, near the extensor tendons. Indeed, I have also demon-
[I, 51] strated in my treatise *On the Movement of the Muscles*[84] that two opposing motions cannot occur at the same time. The occurrence of the other lateral movement, however, [in the direction of the thumb] is prevented not by the position of the tendons [of *lumbricales*], whose insertion on the inner side, where the flexor tendons are, does not obstruct the movement, but by the weakness of the tendon, as I have said before. Now although the extensor tendons situated on the outer side of the hand are larger than those that produce lateral movement, they are nevertheless not so much larger as to destroy the lateral action completely. On the other hand, it is not easy to describe the difference in size between the lateral and flexor tendons on the inner side, for we ought to see rather than to be taught through words that those inserted at the side are indistinct and hard to make out, because they are so small, whereas the others are not only the largest in the hand but double as well. Necessarily,

[84] *De motu musculorum* I, 4–5 (Kühn, IV, *382–391*).

therefore, when the fingers are flexed by the large tendons,[55] the small tendons are carried along by the force of the movement. For in general, whenever a body is subjected to two principles of motion acting at an angle to one another, if one of them is much the stronger, the other is inevitably nullified, but if the difference between them is slight or they are of equal strength, the resultant motion of the body is compounded of both of them.

Countless examples of this are seen practically every day. For instance, if a boat is being rowed and has the wind on its beam, and if the forces of the wind and the rowers are equally matched, the result is necessarily a compound motion, and the boat moves not [I, 52] directly forward, or straight to the side, but on a course midway between the two. Now if the force of the rowers is the greater, the boat moves forward more than to the side, and if on the other hand the wind is the stronger, the boat then moves more to the side than forward. If the discrepancy between the forces is so great that one of them prevails completely over the other, the boat is carried sideways when the force of the rowers is eliminated and forward when that of the wind fails. Well! If the breeze was very gentle, and the ship long and light, with many oarsmen, could the motion due to the wind ever be distinguished? But neither could the rowing have any perceptible effect if the wind was very strong, and the ship very large and heavy, with only two or three oarsmen. Hence, since the motion of the small tendons is so weak that they move the fingers laterally only a little even when the large tendons are not in motion, it could never be distinguished when the large ones are acting. But since most people are unaware of this very fact, that the motion of the small tendons even when acting alone is feeble, they have naturally been unable to reach the conclusion which follows, namely, that this motion would have to be obliterated when it was joined with a very strong one. The cause of their ignorance is that the lateral movement of the fingers to the outside [in the direction of the little finger] is very great, and they believe that the whole distance from one extreme position to the other is the measure of the [I, 53] lateral movement to the inside [in the direction of the thumb]. But the magnitude of both the lateral movements ought to be measured

[55] For Helmreich's *καμπτόντων τοὺς μεγάλους τῶν δακτύλων*, I suggest reading *καμπτόντων τῶν μεγάλων τοὺς δακτύλους*. This was probably intended to be the reading in Kühn's text, where *τοὶς* is an obvious misprint.

not from one extreme position to the other, but from the middle position, and the middle position is that in which the tendons extending the fingers look exactly straight. In fact, even if the lateral tendons are cut through, extension and flexion of the fingers are not impaired at all; on the contrary, the fingers obey in order all the tendons that are left undamaged.[56] The correct measure, then, of the magnitude of a movement is the distance from any lateral position to the one in which the tendons are kept straight. And if you use this rule to judge the extent of the lateral movement toward the inside, it will be apparent to you how slight it is.

20. I have given a sufficient explanation of the lateral movements. I have said that the movement toward the inside [in the direction of the thumb] must be the weaker, and that both lateral movements occur when the fingers are extended, but cease when they are flexed. It is clear that in all these statements I have been speaking of the four fingers. Now the thumb, being opposed to them, is endowed not only with a special position, but also with actions and with insertions for its tendons that are different from those of the other fingers. For the weakest of the thumb's movements is the inner one [flexion], the very one that is strongest in the other fingers, and the lateral movements, weakest in the fingers, are strongest in the thumb. Likewise, the thinnest tendon [from *flexor digitorum profundus*] is the one on the inner side, and the lateral tendons [of *extensor pollicis longus* and *abductor pollicis longus*] [57] are the thickest, the opposite of the
[I, 54] arrangement in the fingers. Similarly, just as flexion is the most powerful action of the fingers and needs two tendons, so in the thumb the lateral movement toward the outside is the more powerful of the two and is accomplished both by the muscle situated on that side [*abductor pollicis brevis*] and by the tendon [of *abductor pollicis longus*] attached to the first phalanx. I shall, however, tell from what muscle this tendon arises and what course it follows to the base of the thumb when I treat of all the other tendons inserted into the fingers.[58]

21. At this point it is proper for us not to pass over the statements

[56] Πείσονται δ' ἑκάτερον ἐν μέρει τῶν κινούντων αὐτοὺς τενόντων ἀδιαστρόφων μεινάντων follows βεβλάψονται in Helmreich's text but is omitted by Kühn.

[57] Daremberg (in Galen [1854, I, *158*]) identifies these muscles as adductor pollicis and abductor pollicis brevis, but see pp. 92–95 *supra*.

[58] *Vide infra*, pp. 119–121.

of certain men who embrace the doctrines of Epicurus, the philosopher, and Asclepiades,[59] the physician, and who disagree with me on these matters; we should rather examine their teachings carefully and show wherein they are mistaken. These men do not believe that it is because tendons are thick that their actions are powerful, or because they are slender that their actions are weak, but think that actions are what they are as the necessary result of their usefulness in life, and that the size of the tendons depends on how much they are moved; that is, tendons that are exercised in all likelihood thrive and grow thick, whereas those that lie idle get no nourishment and waste away. Hence they say that Nature did not form the tendons as they are because it was better for the tendons of powerful actions to be strong and thick and those of more feeble actions to be thin and weak—for if so, apes would not have fingers like ours[60]—but, as I [I, 55] have said before, they claim that parts which are exercised necessarily become thick because they are well nourished, and parts that lie idle are poorly nourished and become thin. But here is my answer, O admirable gentlemen: Since you had taught that neither skill nor the lack of it has had anything to do with the size of the tendons, you found it necessary first to say the same sort of thing about their number, position, and insertions, then to offer some reflections on the differences in them due to age, and to make, though without much confidence, additional statements which you did not in the least know to be true about the apes. Now for one thing, you will find that the tendons controlling powerful actions are not only large, but double, and again, as regards the influence of age, we find that age makes no difference in the number of the tendons. On the contrary, alike in the infant and the adult and even in the child in the womb, although[61] it performs as yet no action with its tendons, we find that the double tendons are still double and the large ones still large. But perhaps you think that in individuals who take exercise, parts somehow become double, and that in those who are lazy, parts are

[59] For Asclepiades, see among many possible sources Hirsch (1884, I, *211–212*); Sarton (1927, I, *214–215*); and particularly Allbutt (1921, *177–191*).

[60] Presumably because they perform different actions; see Daremberg (in Galen [1854, I, *159*]).

[61] Reading *καίτοι* with Helmreich for the *καὶ τοῖς* of Kühn's text. Probably a case of dittography.

diminished by half. If this is so, then hard workers will doubtless have four feet and four hands, and those who take their ease will have only one leg and one hand! Or is not all this the arrant nonsense
[I, 56] of men loath to search out the truth and anxious to wrap up and hide away even some beautiful discovery? How do you account for the fact that with thirty joints in the fingers of both hands and tendons applied to each joint and inserted on the four sides of it, as I have said before, the first joint of the thumb is the only one of them all to have tendons inserted laterally and on the outer side, but none at all on the inner side? If you compute the total number of insertions in the ten fingers, you will find one hundred twenty of them, obtaining this result because there are thirty joints and four insertions into each. But since there is one lacking in each of the thumbs, the total remaining will be one hundred eighteen. Now by the gods! When you can find no fault in these many attachments, in either the mass of the tendons, or their location, or the manner of their insertion, and when on the contrary [in each finger] you see a marvelous correspondence in the insertion of the tendons, with only one lacking in the same way in each thumb (and this was not omitted without reason, but because we had no need of it), do you maintain that such things have all been done at random and without skill? Certainly, if we flexed this joint [of the thumb] in the same way as the others, I know that you would then criticize harshly and vehemently the uselessness of Nature's labor in creating an unserviceable
[I, 57] motion and a tendon that was superfluous. Do you not admire her for equipping completely the one hundred eighteen places where the insertion of tendons was necessary, and for passing over with good reason the one place in each of two fingers where no tendon was necessary? Truly, it would be much better if you were readier to praise success than to censure failure, unless you can tell us of some vast usefulness of a marked bending of the first joint of the thumb. For you could criticize Nature as unskillful only if she had manifestly omitted a useful motion; but you have no such example to cite. In fact, as I have also shown before, in all actions, when the four fingers are completely flexed, we need two movements of the thumb; one movement when it becomes a cover, so to speak, for the open space at the forefinger, and the other when it is laid down upon the fingers, binding them together and compressing them within it. But the first of these movements is controlled by one of the tendons

[of *extensor pollicis longus*] which move the thumb laterally, and the second by the tendon [from *flexor digitorum profundus*] governing the flexion of its second joint; this is the tendon which I have said arises from the common head of the tendons flexing the fingers and is inserted into the inner side of the second bone in the thumb. The creation of this and of all the other tendons as well has already been described in part and will be further explained later on.

22. Now, however, let us call to mind the works performed by [I, 58] the thumb. These I have mentioned before when I pointed out that the usefulness of the thumb is as great as that provided by all four of the opposed fingers together. It is with this in mind, so it seems to me, that men call this finger the antihand, since in their opinion it is itself the equivalent of a whole hand. For they see that the actions of the hand are destroyed to an equal degree by cutting off either the four fingers or only the thumb.[62] Thus, if half the thumb is somehow destroyed, the hand suffers a loss of usefulness for the work it does and a disfigurement equal to what it would suffer if all the other fingers should be injured in the same way. Tell me, O noble sophists and clever accusers of Nature, have you ever seen in the ape this finger that is commonly called the antihand and that Hippocrates [63] calls the great finger? And if you have not seen the ape's thumb, will you have the effrontery to say that it is just like the human thumb? If you have indeed seen one, I suppose you saw that it is short, slender, distorted, and altogether ridiculous, just as the ape's whole body is. "Verily, a little ape is always beautiful to children," says one of the Ancients [64] and so reminds us that this animal is a laughable toy for children at play, for it attempts to mimic all human actions but fails most ridiculously. Have you not seen an ape trying to play the flute, dance, write, and do all the other things that man does [I, 59] well? Now what do you think? Does the ape manage all these things as well as we do, or does he perform them in a laughable way?

[62] Aristotle (*De part. an.*, IV, 10, 687b20–22) says "the reason why [the thumb] is called the great finger, even though it is small, is that without it the other fingers would be practically useless." Daremberg (in Galen [1854, I, *162*] calls attention at this point to the learned disquisition of Hofmann (*1625, 22–23*), who cites many examples of the practice of cutting off the thumb either as drastic punishment or as a way of making a captive enemy less dangerous.

[63] *De officina medici*, cap. 4 (Littré, III, *286, 287*).

[64] Pindar, *Pythian Odes*, II, 72–73 (Pindar [1915, *178, 179*]).

Perhaps you would be ashamed to say that they are not ridiculous performances. Nevertheless, O most learned accuser, Nature would say to you that an animal with a ridiculous soul should be given a body with a ridiculous structure. Accordingly, as my discourse proceeds, it will show how the ape's whole body is a caricature of the human body. You will see how true this is of the hands when you reflect with me that if an artist or sculptor intended to produce a caricature of the human hand, the result would be exactly like what we see in the ape. For we are most inclined to laugh at those imitations which carefully preserve the likeness in most of their parts but go entirely astray in the most important ones. Then what advantage is there in having four fingers well formed if the thumb is so poorly arranged that it cannot even be called the great finger? Surely this is its condition in the ape, where it is separated only slightly from the forefinger, and is utterly ridiculous besides. And so, in this instance also, Nature is just, as Hippocrates [65] often used to call her, because she has bestowed a ridiculous body on an animal with a ridiculous soul. So too, Aristotle is right when he maintains that all animals have been fitly equipped with the best possible bodies, and he attempts to point out the skill employed in the construction of each one.[66] But they are wrong who fail to perceive the order manifest in the construction of other animals or of the
[I, 60] animal constructed most excellently of all; they fight a great fight for fear that they will somehow be shown to have a soul more intelligent than animals created without reason and a body with a construction suitable for an intelligent animal. Well, let us leave these people alone.

23. I shall speak of what remains to complete this first book, namely, the usefulness of the number and inequality of the fingers, and then I shall stop. When we judge by the benefits we enjoy from the fingers as they are, it is not at all difficult to discover that they would accomplish most of their work less efficiently if there were fewer of them and that, on the other hand, there is no action for which we need a greater number than we have. Now when you consider the fingers logically, one by one, you will easily determine

[65] For example, twice in *De fracturis*, cap. 1 (Littré, III, *412–415*).

[66] This is, of course, the theme of the whole of Aristotle's *De partibus animalium*.

that if there were fewer of them, many of their actions would be impaired. Certainly, in losing the use of the thumb we should lose the effectiveness of all the fingers, for without the thumb none of them can do anything successfully. Of the remaining fingers, the forefinger and middle finger not only stand next to the thumb in position but are also second to it in usefulness. For always when we grasp small objects, nearly always when our work involves skill, and even when we must use force, we obviously need them. Although the one next to the middle finger and the little finger are less serviceable than the others, their usefulness clearly lies in work where we need to surround the thing we grasp on all sides. Now if this is a small object or a liquid, the fingers must curve around and hold it in on all sides; in this action the thumb is most useful as a [I, 61] cover for the other fingers, and the second finger comes next to it in value. A large, hard object, however, must be grasped with the fingers spread apart as far as possible, and in this case the greater number of fingers will grasp the object better because they will make contact at a greater number of points. I believe I have said before [67] that in these actions the lateral movements of the fingers are very effective, when the thumb is drawn inward and all the other fingers outward, with the result that the mass is encircled on all sides. And if it is [thus] encircled, a greater number of fingers would clearly be superfluous, for just the five are sufficient to do it and Nature does nothing superfluous. In fact, she is equally careful to make nothing insufficient and nothing in excess.[68] For a deficiency in construction renders the work to be accomplished defective, and a superfluity, by imposing an extra burden, hinders parts that are strong enough in themselves to function and thus causes injury. Finally, the abnormal formation of a sixth finger confirms my reasoning.[69]

[67] *Vide supra*, p. 101.

[68] Cf. *De nat. fac.*, I, 6 (Kühn, II, *15*; translation by Brock [1928, *24–27*]), where Galen says, "This [formative] faculty [of Nature] we also state to be *artistic*—nay, the best and highest art—doing everything for some purpose, so that there is nothing ineffective or superfluous, or capable of being better disposed. This, however, I shall demonstrate in my work 'On the Use of Parts.'"

[69] Cf. Galen, *De morborum differentiis*, cap. 8 (Kühn, VI, *862*), and also p. 728 *infra*.

24. Why were all the fingers made unequal, with the middle one the longest? [70] Was it not because it is better for their tips to fall in the same line when they grasp large bodies or try to hold small
[I, 62] objects or liquids? Indeed yes, for a well-balanced grasp of large objects is of great assistance in holding them firmly and throwing them vigorously. Obviously, in such actions as these the five fingers reach out to the circumference of a circle, particularly when they enclose bodies that are exactly spherical. From these spherical bodies one may perceive very clearly what it is that really happens in the case of other bodies also, though in the latter it is not so plainly evident that it is the evenly balanced opposition of the finger tips to one another all around an object that makes them grasp more firmly and throw more vigorously. The same thing is to be seen, I think, in triremes,[71] where the ends of the oars reach to the same line although

[70] Cf. Aristotle, *De part. an.*, IV, 10, 687b17–20.

[71] This comparison may well have stemmed from the similar one of Aristotles' referred to in note 70, where he says, "The finger that stands at the other end of the row is small, while the central one of all is long, like a centre oar in a ship. This is rightly so, for it is mainly by the central part of the encircling grasp that a tool must be held when put to use" (translation by Ogle [1911]). With this passage of Aristotles' one should compare another statement of his (*Mechanica*, cap. 4, 850b10–13); here he asks why the "middle rowers" in a ship have the greatest effect and concludes that it is because their leverage is greater, since on account of the curvature of the ship's side they are seated farther inboard than the rowers nearer the bow and stern.

It should be noted, however, that Aristotle is not speaking specifically of the trireme, as Galen is, and that triremes, so far as can be determined, had straight sides which tapered sharply to the narrow bow only forward of the rowers' benches. Moreover, in the trireme the "middle rowers," the *mesoneoi* or zygites, are not those in the waist of the ship, but those handling the middle bank of oars and sitting above the thalamites in the first or lowest bank and below the thranites in the third or highest bank. It would seem on the face of it that the thranites, being highest above the water, must have had the longest oars, but there is evidence to indicate that in order to decrease the vertical space occupied by the three banks of rowers, the thranites sat directly above the thalamites, leaving the latter no more than necessary headroom, and that although the zygites did sit higher than the first bank and lower than the third, they did not sit in the same vertical plane with the others, their benches being located farther inboard toward the longitudinal axis of the ship and midway between two adjacent tiers of the

the oars themselves are of different lengths, for in this case too, the middle ones are made longest for the same reason. I believe that earlier in my discourse, when I said that the thumb in closing down upon the forefinger is like a cover for the empty space there, I showed that the inequality of the fingers has an obvious usefulness when we try to close the hand, whenever, in fact, we wish to hold carefully small bodies or liquids, but I hope by the addition of a few words at this point to complete the demonstration of the whole matter. Now if in these actions you should imagine that the little finger, lying below the others, had become longer, or one of the middle fingers shorter, or that the thumb in opposition to them had a different position or size, you would realize perfectly that the present construction is by far the best and that the greatest injury to their actions would result if even the least detail in the arrangement of the fingers was altered. For we could not properly handle large or small objects, or attempt to hold a liquid with any success if the size of any one of the fingers was changed. Hence it is evident how very precise is the construction they have been given. [I, 63]

25. It is now time for me to bring this first book to a close. In the second I shall treat of the remaining parts of the arm, that is, the wrist, forearm, and upper arm. Next, in the third book I shall point out Nature's skill as displayed in the construction of the legs. Thereafter, in the fourth and fifth, I shall speak about the instruments of nutrition, and in the two following, about the instruments of the pneuma.[72] Then in the next two, I shall speak of the parts of

---

thalamites and thranites. With some such arrangement their oars would necessarily be the longest and Galen's comparison would be just.

The problem of the disposition of the rowers in a trireme, however, is a knotty one, and although much has been written on the subject, it is regarded as still unsolved. The interested reader may consult Cartault (1881), Kopecky (1890), and Alexanderson (1913) for reviews of all the evidence and for full and clear discussions of the factors involved.

[72] Galen uses the word pneuma in two senses, as Brock (in Galen [1928, *xxxiv–xxxv*]) points out. It may mean for him either the inspired air or one of the three kinds of spirit: *natural*, produced in the liver and carried by the blood in the veins; *vital*, produced in the heart from the air and blood and carried in the arteries; and *psychic*, produced in the brain from arterial blood and carried by the nerves. By the instruments of the pneuma he means those concerned in respiration and the transformation of the inspired air into vital pneuma. See my Introduction, pp. 46–49.

the head. The tenth book will be entirely taken up with my explanation of the construction of the eyes. The following section will contain a description of the parts of the face, and the twelfth book will describe the parts of the spine. The thirteenth will finish whatever is left to say about the spine and add the complete explanation of the shoulder blades. In the two following books I shall treat of the parts that have to do with generation and all those related to the
[I, 64] ischium. The sixteenth book will discuss the instruments common to the whole animal, namely, arteries, veins, and nerves. Finally, the seventeenth will be like an epode [73] to all the others, showing the arrangement and proper size of all the parts, and explaining the usefulness of the whole work.

[73] For the reason why Galen chose this term for his epilogue, see chapter 3 of Book XVII.

THE SECOND BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Wrist and Arm]

1. Having undertaken to write about the usefulness of the parts of the human body, I first made clear in the preceding book the method by which anyone can find the useful purpose for which Nature has created each one of them, and I began with the exposition of the hand because that is the most characteristic of mankind. Then, since I proposed to treat of all the parts of the hand so as not to leave anything, even the least detail, uninvestigated, I first discussed the fingers and showed that all their parts exhibit a most marvelous workmanship. Indeed, the number, size, and shape of the fingers and [I, 65] their organization in other respects[1] all show that they have been constructed so advantageously for the action of the hand as a whole that no better construction could possibly be imagined.[2] The first book ended with the movements of the fingers; first the usefulness of each finger had been discussed and then the tendons controlling them, which grow out some from the muscles surrounding the ulna and radius and others from the small muscles of the hand. It would therefore be logical to begin this second book with a discussion of the muscles. Now Nature has so ordered the muscles in establishing them in their proper places, in making their origins very secure, in bringing their terminations to the points where there is need of them, and in assigning to them the proper size, degree of safety, and number, that no one could possibly contrive a better construction. In the first place, then, to begin with their number (and it will be right to discuss their usefulness only after I have told how many of

[1] Reading ἄλληλα with Helmreich for the ἀλλήλους of Kühn's text.

[2] Daremberg (in Galen [1854, I, *168*]) adds, "As has been said," but there is no such clause in the Greek.

them there are, where they are located, and what movement has been entrusted to each one), there are in all twenty-three muscles of the forearm and hand, seven small ones in the hand,[3] the same number of large ones occupying the whole space on the inner side of the forearm, and the remaining nine on the outer side.

[I, 66] 2. The small muscles of the hand [*lumbricales*] control one of the lateral movements. Two of the muscles on the inner side of the forearm, and those the largest, flex the fingers [*flexores digitorum, superficialis* and *profundus*]. The next largest, also two in number, flex the whole wrist [*flexores carpi, radialis* and *ulnaris*]. The two oblique muscles [*pronatores, teres* and *quadratus*] turn the radius and with it the whole arm to the prone position. The seventh one [*palmaris longus*], the last and smallest of those extending the length of the forearm, in the opinion of anatomists before my time also flexes the five fingers, but actually no movement of the fingers is entrusted to it and it has been formed for a certain marvelous purpose which I shall explain later in this book.[4] Of the nine muscles on the outer side of the forearm, one [*extensor digitorum communis*] extends all the fingers except the thumb; two others [*extensores digitorum proprii*] [5] move the same four fingers laterally. A fourth muscle [*extensor pollicis longus*] moves only the thumb, giving it the more oblique of its two external movements, the other being furnished by another muscle [*abductor pollicis longus*] which also moderately extends the whole wrist; [6] the vigorous extension of the

[3] *Vide infra,* chapter 3 of this book, *ad init.*, for Galen's enumeration of these seven, a number he reaches by ignoring the interossei and failing to distinguish some of the muscles producing the thenar and hypothenar eminences.

[4] *Vide infra,* chapter 6.

[5] In the ape extensor digiti secundi proprius and extensor digiti tertii proprius have a common origin, and so do extensor digiti quarti proprius and extensor digiti quinti proprius. See Howell and Straus (1933, *139, 140*).

[6] In the ape the long abductor of the thumb is inserted both into the base of the first metacarpal bone (the first phalanx of the thumb according to Galen) and into a radial sesamoid. See Howell and Straus (1933, *139–140*), who add that in some cases it may split into two distinct portions in the lower forearm; in fact, in *De musc. diss.*, (Kühn, XVIII, pt. 2, *980–981*) Galen treats it at first as two muscles, saying, however, that the two are "adnate" and may be said to be one. See, however, Goss's different interpretation (in Galen [1963, *489*]).

wrist, however, is performed by two other muscles [*extensor carpi ulnaris* and *extensores carpi radiales, longus* and *brevis*].[7] The remaining two [*brachioradialis* and *supinator*] supinate the radius and carry the whole arm with it to the same position.

All this is revealed by dissection. I should now proceed to tell why the muscles were so formed, but first, for the sake of clearness, I shall define briefly the terms to be used in the discussion. The upper extremity consists of three main divisions, the upper arm [I, 67] (βραχίων), the forearm (πῆχυς), and the hand (ἀκρόχειρον).[8] For the purposes of the present discussion we need not concern ourselves with the upper arm. The term forearm (πῆχυς) is applied to all that part of the limb that lies between the diarthroses at the wrist and elbow (ἀγκών). Now the ἀγκών, according to Hippocrates,[9] is the part on which we lean, but what is called ἀγκών by Hippocrates and olecranon (ὠλέκρανον) in Attic Greek is in fact a part of the larger one of the bones of the forearm; indeed, I suppose it is this bone which is more properly called πῆχυς (the ulna). If you hold your arm in a position midway between prone and supine, this bone will be below, and the other one, the radius, will be above. And it is with reference to this position that we speak of the inner or outer side of the arm, or its top or bottom. The convex processes (ἀποφύσεις, outgrowths) of the radius and ulna which articulate with one another at the wrist are called by this same name, apophyses, which indeed they really are, but they are also sometimes called heads and condyles. Now that we have agreed on these terms, you will understand the discussion that follows.

3. The number of muscles in the hand is easily determined. Each

[7] Extensor carpi radialis longus and extensor carpi radialis brevis are considered by Galen to be a single muscle with two tendons of insertion, one of which is inserted into the base of the second metacarpal bone and the other into the base of the third metacarpal. See pp. 119, 121, 122, 124, 130, 139–140, and cf. Galen's *De anat. admin.*, I, 6 (Kühn, II, *256;* Galen [1956, *19*]).

[8] Literally, "end of the arm." Galen's use of χείρ is very loose and it must be decided from the context in each case whether he means by it arm or hand. See *De anat. admin.*, III, 2 (Kühn, II, *346–347;* Galen [1956, *63*]), for his own distinction; unfortunately he does not abide by his expressed intention of reserving χείρ for the arm and using only ἀκρόχειρον (ἄκρα χείρ) for the hand.

[9] *De fracturis*, cap. 3 (Littré, III, *426, 427*).

finger has one small muscle of its own [*lumbricalis*], as I have said
[I, 68] before, and there are in addition two others [*abductor pollicis brevis* and *abductor digiti minimi* with perhaps *flexor digiti minimi brevis*], the largest in this region, which form the so-called thenars, making the fleshly parts of the hand elevated and the middle hollow. They also serve to spread the thumb and little finger wide apart from the others. Nature has used these muscles to good advantage; she made them so that the thenars might be fleshy and elevated above the middle part of the hand, but once having made them, she did not suffer them to remain as merely idle and motionless flesh, but used them to provide certain movements for the adjacent fingers. Certainly the muscle between the thumb and forefinger [*adductor pollicis*] was also formed to make that part of the hand fleshy, but Nature has made additional use of it to produce the movement which brings the thumb toward the forefinger. Knowing, however, that the thumb needed its lateral movements to be more vigorous, she did not entrust them only to the muscles I have mentioned [*abductor pollicis brevis* and *adductor pollicis*], but brought down stronger tendons from the muscles of the forearm [*extensor pollicis longus* and *abductor pollicis longus*] and attached them to the thumb. Similarly, in dealing with the little finger she did not entrust the lateral movement in which it is drawn away from the other fingers only to the muscle I have already mentioned [*abductor digiti minimi* with perhaps *flexor digiti minimi brevis*],[10] but she did entrust the movement in which the little finger is drawn toward the others to a single muscle situated beside it [*lumbricalis IV*]. Since the corresponding movements of the other three fingers did not need to be at all vigorous, as I have shown in the preceding book, she assigned them only to the muscles of the hand [the remaining *lumbricales*]. Consequently, since there are four of these muscles,
[I, 69] two at the thumb, and one more at the little finger, it was reasonable for all seven to be located in the hand and for each of them to be provided with a single tendon. For, being so small, they could not be separated into more than one tendon, and even if they were larger, they would not have a position or usefulness such that the origins of several movements could be focused at one point.

[10] In this case, the other muscle to which the movement of the little finger away from the others was entrusted is extensor digiti minimi proprius. See pp. 92, 94, 100.

In the preceding book I have shown that this [separation into more than one tendon] is both possible and useful in the case of the muscles extending and flexing the fingers and likewise for the muscles that draw the fingers away from the thumb [*extensor digitorum communis*, *flexores digitorum*, *superficialis* and *profundus*, and *extensores digitorum proprii*]. It has also been shown there that one tendon to each finger is enough for extension, whereas for flexion each finger needs one to move the first and third joints and another for the second; hence a single muscle was formed on the outer side [of the arm] to extend all the fingers, but no one muscle is entirely responsible for flexion. On the contrary, just as two tendons have been formed, so also there are two muscles at their heads, and very large ones too, because the tendons are very large, but the muscle on the outer side [of the arm] is much smaller because its tendons are smaller. In the first book I demonstrated the usefulness of the tendons. It is reasonable, then, that of the two muscles on the inner side, the one whose tendons move the first and third joints [*flexor digitorum profundus*] should be much larger than the other whose tendons move the second [*flexor digitorum superficialis*], the size of the muscles in this case too being proportional to the mass of the tendons. Moreover, the muscle from which the larger tendons controlling the double movement arise lies underneath with the other one on top of it, for Nature always keep in greater safety the [I, 70] parts that subserve more numerous or more useful actions. These two muscles occupy exactly the middle of the available space because it was better, as I have shown before,[11] for the heads of the tendons flexing the fingers also to arrive at a central point. On each side of them lies a muscle which flexes the wrist [*flexores carpi*, *radialis* and *ulnaris*], and I shall speak of the usefulness of them when I explain the movements of the wrist. The fifth and last muscle [*palmaris longus*] extending longitudinally on the inner side of the forearm is superficial and the thinnest of all the muscles I have been describing. All anatomists before my time have erred in thinking that the fingers are flexed by this muscle, and this was not the only mistake they made; they were also completely ignorant, as I was myself for a long time, of the small muscles [*interossei*] that flex the first joints of the fingers. These muscles have been fully discussed in

[11] *Vide supra*, p. 99.

my books *On the Dissection of the Muscles* and *Manual of Dissection.*[12]

I should prefer to finish this present treatise without mentioning the mistakes of others, and so I intended from the beginning,[13] but during my discussion of this subject it has occurred to me that when I disagree with the earlier anatomists, my future readers may suspect that I am the one who is wrong and not they. For it is reasonable, I suppose, to believe that one man alone is in error rather than every-
[I, 71] one else. Moreover, this notion will be even more likely to occur to those who are not familiar with my other anatomical works in which I have shown the mistakes my predecessors made in dissecting and have listed the causes of those mistakes, causes which will even now lead anyone undertaking dissection into errors like theirs if he is not on his guard. Anyone who sees what I have seen when I dissect will be amazed that these anatomists were ignorant of the tendons and their movements, and that they overlooked whole muscles, and he will call anyone blind who makes such monumental errors. Well then, to omit everything else they missed in the anatomy of the hand, who is there that has eyes and yet fails to see that each finger has lateral movements in addition to its flexion and extension? Nev-

[12] *De musc. diss.* (Kühn, XVIII, pt. 2, *953–954;* Galen [1963, *491*]); *De anat. admin.*, I, 9 (Kühn, II, *266;* Galen [1956, *24*]); and see also chapter 10 of this Book and chapter 10 of Book III. Singer (1956) has translated the second of these two titles, *On Anatomical Procedures;* another possibility would be *Anatomical Exercises.* It should be noted that in *De usu partium* Galen's references to his *Manual of Dissection* were made to an earlier, much shorter work, which was burned and which the extant *De anatomicis administrationibus* was written to replace *after* he had completed *De usu partium.* See *De anat. admin.*, I, 1 (Kühn, II, *215–217;* Galen [1956, *1*]; *De libris propriis*, cap. 2 (Kühn, XIX, *20*); chapter 10 of Book XVI *infra;* and Simon (in Galen [1906, I, *ix*]). For the convenience of the reader, however, I have supplied the parallel references in the extant work. See also note 36 of Book I.

[13] At this point Daremberg (in Galen [1854, I, *173*]) aptly remarks, "Galen was too jealous of his reputation and too inclined to criticize his compeers, dead or living, to keep such a resolution. We should even congratulate ourselves that he has followed his natural bent; that vanity of his has served well the history of science and in particular the history of anatomy. We owe to him at many points our knowledge of the opinions of the medical predecessors and contemporaries of the Pergamite and our knowledge of his own discoveries."

ertheless, when these anatomists mention the tendons moving the fingers, they speak of those that extend and flex them, without taking into consideration that there must also be some sources for the lateral movements. Then are you still surprised or incredulous that they are ignorant of some of the more obscure facts of anatomy, when they do not even know what is to be seen without dissection? Now let me once for all make this general statement to apply to my whole treatise so as not to be forced to say the same thing repeatedly: I am now explaining the structures actually to be seen in [I, 72] dissection, and no one before me has done this with any accuracy. Hence, if anyone wishes to observe the works of Nature, he should put his trust not in books on anatomy but in his own eyes and either come to me, or consult one of my associates, or alone by himself industriously practise exercises in dissection; but so long as he only reads, he will be more likely to believe all the earlier anatomists because there are many of them.[14]

4. But to take up my subject at the point where I disgressed, let us speak of the superficial muscle [*palmaris longus*] which appears on the inner side of the forearm directly under the skin and which has been misunderstood by anatomists. [As the palmar aponeurosis] it underlies all the smooth and hairless part of the inner surface of the hand and grows there for the sake of important utilities of which I shall speak a little later when I have finished my exposition of the muscles that move the fingers.

On the inner side of the forearm there are only two of these muscles [*flexores digitorum, superficialis* and *profundus*], as I have said, and four on the outer side. Of the latter, the muscle extending the four fingers [*extensor digitorum communis*] properly occupies a central position, as I have shown before, and there are two other muscles, one on each side of it [*extensor carpi ulnaris* and *extensores carpi radialis, longus* and *brevis*]. Lying below it is a muscle which controls the lateral movement of the two smallest fingers [*extensores digiti minimi* and *digiti quarti proprii*] and which has close to it two other muscles grown together to a certain extent and hence considered by anatomists to be one [*extensor pollicis longus* and *extensores digiti secundi* and *digiti tertii proprii*]. From one of these

[14] Literally, "he will be the more likely to believe all the earlier anatomists, the more numerous they are."

[*extensores proprii*] two tendons issue, each leading to one finger,
[I, 73] the first to the finger that is longest and occupies the middle position, the second to the forefinger. From the other muscle [*extensor pollicis longus*] one tendon issues and is inserted into the largest finger which is also called the antihand [the thumb]. All these muscles move the fingers laterally, and they have very logical locations in the forearm. For just as the muscle controlling the straight extension of the four fingers occupies a central position, so for the same reason those producing lateral movement are located in the parts toward which they are to draw the fingers, and this, I think, is very strong proof of precise skill, since Nature did not, like a lazy workman, place the sources of the lateral movement of the fingers in parts close to them, but in parts which, though farther away, are most suitable for the action. Now the thumb begins so close to the radius that they almost touch, but the muscle moving the thumb [*extensor pollicis longus*] nevertheless takes its rise from the ulna. The same is true of the muscle [*extensores digiti secundi* and *digiti tertii proprii*] moving the next two fingers laterally in contrast to the one that turns back the whole wrist [*extensor carpi radialis, longus* and *brevis*]. For the latter has its origin at the radius and is inserted by a bifurcate [15] tendon into the region proximal to the fore and middle fingers; in fact, you can see that these muscles are placed in such a way that they form something like a letter Chi (X), because each one has acquired from its origin a position suitable to
[I, 74] the movement it is intended to perform. You will have still greater confidence in the truth of what I am saying when you observe all

[15] Emending μικρῷ to διχρῷ on the strength of Galen's other descriptions of this muscle; see pp. 121, 122, 124. Daremberg (in Galen [1854, I, *176*]) identifies it as the carpal component of abductor pollicis longus, but this is incorrect for two principal reasons: (1) the description gives only the radius as the origin, whereas the long abductor also arises from the ulna; the radial extensors, of course, arise from the humerus, but on the radial side, and have no part of their origin from the ulna; (2) the extensors are inserted, as Galen always says this muscle is, "into the region proximal to the fore and middle fingers," whereas the two components of the long abductor are inserted into the thumb and the radial sesamoid bone, "the part of the wrist proximal to the thumb," as Galen says. See Howell and Straus (1933, *138–140*) and cf. *De anat. admin.*, I, 6 (Kühn, II, *255–256;* Galen [1956, *18–19*], and *De musc. diss.* (Kühn, XVIII, pt. 2, *979–980, 981–982;* Galen [1963, *488, 489*]).

the muscles that move the wrist; these I shall describe after I have explained the remaining tendon of the thumb [*abductor pollicis longus*] so that none of those attached to the fingers may be omitted. I have said before [16] that it was better for the thumb not to have its exactly straight extension performed by a single tendon, but to have it originate from two oblique tendons, and I have just now been describing the tendon and muscle [*extensor pollicis longus*] which turn the thumb toward the forefinger. The other tendon [metacarpal component of *abductor pollicis longus*], however, that draws the thumb away from the forefinger has a common head with the one [carpal component of *abductor pollicis longus*] that supinates the whole wrist. It is round and grows out along the whole finger like a cord, extending as far as the last phalanx.[17] The tendon [carpal component] that shares its origin, however, flattens out, is inserted into the part of the wrist proximal to the thumb, and supinates the hand.

There are four movements of the wrist—extension, flexion, pronation, and supination. Two muscles and their tendons control flexion and two others extension. These same muscles also control the lateral movements, and there is a fifth muscle [*extensor carpi radialis, longus* and *brevis*] assisting to some extent in pronation; this is located on the outer side of the forearm and ends in a double tendon about at the center of the metacarpus. One of the tendons [*flexor* [I, 75]
carpi ulnaris] flexing the wrist, which are found, of course, on the inner side of the forearm, is inserted into the region proximal to the little finger, and the other [*flexor carpi radialis*] into the region proximal to the thumb. In like manner the tendons extending the wrist, situated of course on the outer side of the forearm, are inserted, one proximal to the little finger [*extensor carpi ulnaris*], and the other proximal to the thumb [carpal component of *abductor*

[16] *Vide supra*, p. 94.

[17] As Daremberg (in Galen [1854, I, *176*]) properly points out, this sentence has obviously been misplaced. It cannot apply to the metacarpal component of abductor pollicis longus, which Galen himself (*vide supra*, p. 104) knew to be inserted on the thumb's metacarpal (the first phalanx according to Galen). It must have strayed from a description either of extensor pollicis longus or of the tendon from flexor digitorum profundus, which in the ape takes the place of the human flexor pollicis longus.

pollicis longus]. If both members of a pair act at the same time, the hand is flexed by those on the inner side and extended by those on the outer side. If only one tendon is tensed, either the one on the inner side at the thumb [*flexor carpi radialis*] or the one on the outer side at the little finger [*extensor carpi ulnaris*], it weakly pronates the hand, whereas the tendon [*flexor carpi ulnaris*] on the inner side at the little finger or on the outer side at the thumb [carpal component of *abductor pollicis longus*] supinates it. If, however, the tendons on the inner side at the thumb [*flexor carpi radialis*] and the outer side at the little finger [*extensor carpi ulnaris*] both act together, the resulting pronation of the hand is no longer weak, but is performed to the greatest possible extent. In the same way, when it is the tendons on the inner side at the little finger [*flexor carpi ulnaris*] and the outer side at the thumb [carpal component of *abductor pollicis longus*] that act together, the hand is completely supinated. Since pronation combined with extension of the wrist is by far the most useful position in all the ordinary actions of life and therefore merited greater consideration than supination, Nature added a fifth tendon, a double one, to control the wrist's rotation to this position. It originates from the muscle [*extensor carpi radialis, longus* and *brevis*] at the radius and is inserted into the region of the metacarpus proximal to the fore and middle fingers. Why, then (for I think our present discussion has thus far neglected this point), has Nature not entrusted the extension and flexion of the hand each to a
[I, 76] single muscle and tendon? In the first place, if there were only one muscle and tendon, it would make the flexion of the whole joint loose and unsteady, not firm and accurate, while as the hand is now constructed, flexion is perfectly firm and strong. Then, too, in the center of the wrist where one single tendon would have to be attached, there would be no room for it, because the space there is already occupied, on the inner side by the tendons flexing the fingers and on the outer side by the extensors. Thirdly, in addition to these reasons, there would be need of other tendons to perform the lateral movements. As it is, however, with two tendons each for flexion and extension, we are at once enabled to perform with them the other movements of the hand as well; we are not in want of a suitable place for the muscles performing these movements; and we act with much greater firmness and strength than we could under the other arrangement. All these are essential advantages.

Here it becomes necessary to pay strict attention as we go on and to distinguish the movements of the wrist from those of the whole forearm, because the latter also has four movements corresponding to those of the wrist, and I shall have more to say about them later on.[18] But for the present we should at least recognize that even if the hand is kept absolutely still, we may clearly observe four movements of the forearm perfectly accomplished by its articulation with the upper arm; for we see the whole member extended, flexed, pronated, [I, 77] and supinated while the hand remains quiet. Extension and flexion are performed by the articulation of the ulna with the central portion of the [end of the] humerus; the lateral movements of rotation are performed by the articulation of the radius [with the humerus] on the outer side of the head of the latter [that is, at the capitulum].[19] The description of the muscles attached to both these articulations and their number and size will be given later at the proper place in my discourse.[20] For the present, it is enough to know that the muscles extending and flexing the forearm are located in the upper arm, but those that rotate it are in the forearm itself; the latter are oblique because the movement they produce is oblique, and they extend to the radius because this movement results from the articulation of the radius with the humerus. I shall also discuss these muscles later on. I have mentioned them here, however, because I now propose to enumerate all the muscles of the forearm. There are nine of them that have very properly been formed on the outer side and seven on the inner side, including in each case a pair of the muscles of which I have just been speaking. Consequently, there remain on the outer side of the forearm seven muscles that were formed for the sake of the hand, and five on the inner side. In order to make the discussion of their usefulness easy to comprehend, it will be well for me to review in a brief summary what we know of them.

5. The largest one of them all [*flexor digitorum profundus*], [I, 78] which flexes the first and third joints in each of the four fingers, stretches the whole length of the forearm and occupies all the center

[18] *Vide infra*, chapters 15 and 16 of this Book.

[19] Daremberg (in Galen [1854, I, *178*]) says, "by the articulation of the radius with the outer side of the head of the ulna." This interpretation strains the Greek and is not consistent with what Galen says in what follows almost at once and also in chapter 13 of this Book.

[20] *Vide infra*, pp. 126–128 and chapter 16 of this Book.

of its inner side. The second muscle [*flexor digitorum superficialis*], lying upon the first and united with it,[21] gives off to the four fingers the tendons which I have said are inserted on the second joints. Lying above these two is a third muscle [*palmaris longus*] which, like them, extends the whole length of the forearm; it is situated directly under the skin and spreads out [as the palmar aponeurosis] to cover the palm of the hand completely. These three occupy the central part [of the forearm], and the remaining two [*flexores carpi, ulnaris* and *radialis*] are small muscles, one on each side; they flex the wrist and are inserted into it, one on the same side as the little finger and the other on the same side as the thumb. Turning now to the outer side of the forearm, we find that the muscle [*extensor digitorum communis*] extending the four fingers is superficial and located directly beneath the skin, and that it occupies the whole of the central region of the member. Three others lie obliquely, diverging from the center; two of these [*extensor pollicis longus* and *extensores digiti secundi* and *digiti tertii proprii*] send their prolongations to the three largest fingers, the third [*extensores digiti quarti* and *digiti minimi propii*] to the two smaller fingers. Of the three remaining muscles, I have said that one [*extensor carpi ulnaris*] on the ulnar side extends the wrist with a single tendon; the other two are on the radial side, and one of them, passing obliquely beyond the condyle of the radius and dividing into two branches, extends the wrist [carpal component of *abductor pollicis longus*] and at the same time draws the thumb away from the other fingers [metacarpal component of *abductor pollicis longus*]. The other one [*extensores carpi*
[I, 79] *radialis, longus* and *brevis*], lying beside it on the outer side, reaches the part of the metacarpus proximal to the fore and middle fingers, as I have said; it rotates the hand to the prone position and extends the wrist.

6. It remains for me to explain the tendon [palmar aponeurosis] situated under the skin on the palm of the hand; it takes its origin

[21] In the ape flexor digitorum superficialis gives off near its main origin a deeper head which joins flexor digitorum profundus, and it is perhaps this junction to which Galen is referring when he says here that these two muscles are united. See Howell and Straus (1933, *135–136*) and cf. *De anat. admin.*, I, 4 (Kühn, II, *241–242;* Galen [1956, *12*]), where he says that they were commonly thought to be completely one for the entire length of the forearm.

from the straight muscle [*palmaris longus*] in the center of the forearm, which is smaller than the other four muscles because it does not move any articulation and which is located immediately beneath the skin in the central region of the member. The tendon issues from this muscle before it reaches the articulation at the wrist where it first begins to spread out. It resembles a sort of white and bloodless second skin, underlying the skin of the whole hand including the fingers. The real skin that covers the entire body can be stripped off (δέρεσθαι), and this is the reason, I suppose, why it is called δέρμα, but this second skin, of which I am now speaking and which we find in the palm of the hand and likewise in the sole of the foot, the forehead, almost all the face, and various other parts of the animal body, cannot be so removed because tendons or muscles are inserted into it. The description of these insertions and their usefulness I shall give in my discussions of the individual parts. [I, 80] In general, however, we should recognize in this connection that certain tendons are inserted into the skin in order to give it keener sensation and voluntary motion, or to make it tight, hard, and hairless. It is fitting, I think, for the hands as prehensile instruments to have a tight skin for several reasons, but particularly so that they may grasp small objects firmly and accurately. Moreover, the skin here should also be more sensitive than that of any other part, for it was not necessary that there should be one instrument for prehension and another for touch, or that the instrument which holds and lifts external objects and moves and handles them in every way should be separate from the one which then distinguishes in them warmth, coldness, hardness, softness, and the other different qualities perceptible to the touch. On the contrary, it was better that as we grasp an object, we should at the same time determine its nature. Furthermore, it was not easy or suitable to make distinctions of quality with any instrument of the body other than the hand, or with all parts of the hand at that, but only with those on its inner side by virtue of which it is a prehensile instrument. If, then, it was proper for the hand to be an instrument of touch because it was also a prehensile instrument, it was logical that the same parts that make it prehensile should also make it an instrument of touch. Then, too, the hairlessness of this part of the skin, resulting from the broad [I, 81] tendon spread beneath its surface, contributes no little to the power to discern accurately all the qualities perceptible to touch.

For just as the skin, if it were thickly covered with hair, would not come in contact at all with objects close to it because the hair would encounter them first, so in its present completely hairless state, it does not permit any part of these objects to escape its touch, but apprehends them fully because it comes directly in contact with all their parts. It is evident to everyone that the growth of the tendon beneath the surface of the skin in this region makes it hard and that this is a very useful provision for much of the work we do. These are the reasons why tendons cling closely to the skin on the palms of the hands.

7. It is now time to take up whatever remains to complete the description of the ulna and radius, for though I have already dealt with nearly everything concerning them, there are still left for me to discuss certain other points (though only a very few) that have to do with the explanation of the oblique muscles of the forearm that move the radius. Now why are there two muscles to pronate the radius [*pronatores*, *teres* and *quadratus*], and two to supinate it [*supinator* and *brachioradialis*], and why do they have no tendons? [22] Just as it has been shown [23] that in the case of the muscles extending and flexing the wrist it was better to have two of them inserted into the extremities of the bones they are to move, so we find the same arrangement for the muscles moving the radius. For in this instance too it was better not to entrust the whole movement to
[I, 82] one muscle fixed at the mid-point of the radius when it was possible to have two, one inserted at the upper end near the humerus and the other below near the wrist. Both of them, however, lie along the bone for some distance and are not merely attached to its extremities, inasmuch as insertion takes place by means of the fleshy parts without the aid of terminal tendons. Now since fleshy parts do not have a strong hold on bone, they need more points of contact so that the same firmness that is provided by the strength of tendons attached at only one point may be conferred on the weak fleshy parts by insertions at many points. If you remember what I have said

[22] Brachioradialis, of course, has a tendon of insertion and Galen was aware of it; for he speaks of it presently, before finishing the discussion of these muscles. Daremberg (in Galen [1854, I, *182*]) is too kind to him here, translating, "And why do three of these muscles have no tendons?," a rendering unsupported by the Greek.

[23] *Vide supra*, p. 122.

before,[24] you already know why it was neither desirable nor possible for tendons to grow out from these muscles, but in case you do not, I will recall it to you briefly. If a bone does not receive muscular insertions, the reason is either that it is hard or small, or that it was better for the member to be kept fleshless and light. Neither of these considerations applies to the radius; for it is neither hard nor small, and there is no reason why it should be light rather than fleshy. Moreover, since the radius and ulna lie so close together, a muscle originating at the ulna could not form a tendon for insertion into the radius; for a tendon arises from the gradual reuniting of the nerves and ligaments which have been scattered throughout the flesh of the muscle. But this gradualness makes necessary a longer path, especially if it is from a large muscle that the fibers are collected. The [I, 83] truth of what I say is attested by the muscle [*brachioradialis*] which lies along the radius on its upper side. Of the four muscles I am now discussing, this is the only one giving rise at its end to a membranous tendon, and this tendon is implanted [25] on the inner side of the radius near the wrist; indeed, it is also the only muscle moving this bone with very few points of attachment, and it is the longest not only of the muscles that move the radius but also of all the other muscles of the forearm. These are the reasons, then, why four of these muscles have been made, why they are oblique, and why they are all entirely fleshy with the exception of this fourth one of which I have just been speaking; for this one, as I have said, gives rise to a very short, membranous tendon.

Nature has placed each of them in the most suitable location; those that pronate the member [*pronatores*, *teres* and *quadratus*] are situated on its inner side, deeper than all the others for the sake of safety, since, as I have shown earlier,[26] the hand performs most of its actions, and those the strongest and most necessary, in this position. Then it was, of course, necessary to place the supinating muscles [*supinator*, *brachioradialis*] on the outer side, but it was not possible to give them both positions at the ends of the radius corresponding to the muscles on the inner side; for the end near the wrist could not accommodate two oblique muscles, because it must be

[24] *Vide supra*, p. 91.
[25] Reading ἐμφυόμενος with Helmreich for Kühn's ἐκφυόμενος.
[26] *Vide supra*, p. 122.

[I, 84] light and nearly fleshless and it was already reserved for the heads of all the tendons that move the hand. Accordingly, Nature made one of the two [*supinator*] entirely of flesh and hid it away in the space between the ulna and radius, giving it an origin from the ulna and an insertion into the radius. She could not, however, locate the other one [*brachioradialis*] in a place [near the distal ends of the ulna and radius] which could scarcely accommodate even a single muscle, and since she had no other space available, she placed it on the upper side of the radius itself, making it longer than all the other muscles that clothe this member. The upper end of the muscle extends up the outer side of the humerus and is in part suspended from the muscles there, becoming very slender as it descends among them. This end of it is like a head, so to speak, but the lower end, by which it moves the radius, ends in a membranous tendon inserted on the inner side of the radius near its articulation with the wrist. Anatomists before my time have erred greatly in their explanation of this muscle for many reasons which I give in my *Manual of Dissection.*[27] I think, however, this present discourse has demonstrated sufficiently what precise skill Nature used in dealing with these muscles when she concealed those on the inner side of the arm deep below the surface to protect them and treated only one of the external muscles so, because it was impossible to locate both of them there and the actions of the hand are not greatly impaired even if the muscle lying along the radius on its upper side is injured. But if the muscle [*pronator quadratus*] on the inner side is injured, the most important
[I, 85] actions of the whole arm are destroyed as a result; indeed, no harm from external causes, at least, could come to this muscle unless the bones in its vicinity should first be completely severed or crushed. Nature always makes such provision for the safety of the more important parts. It is the same with the tendons I discussed a little while ago which move the fingers and the wrist; the less important ones are superficial and the others are deep below the surface. Since, as I have said, Nature was compelled to place the less important muscle along the upper side of the radius, it was reasonable for her to extend it up the outer side of the humerus, for only thus would it

[27] *De anat. admin.*, II, 1–3 (Kühn, II, *280–291;* Galen [1956, *31–36*]). But Galen speaks here of their errors in general, not of their treatment of brachioradialis, which I cannot find him attacking specifically in that work. See note 29 of this Book.

be rendered oblique, a necessary provision if it was to control an oblique movement.

It is now clear to anyone who has followed this discussion with any attention at all that Nature has had good reason to make as many muscles as there are and to give each one the size, situation, and number of tendons it now has. If, however, there is anything I have failed to explain in my discourse, anything analogous to what I have said, or similarly related to what I shall say later on, we shall not find it difficult to discover since we already have so much to help us. For in all our efforts we will keep in mind just one thing—something which I said at the very beginning of this treatise and which will be a shining light leading us[28] whither we must go and guiding us surely to the discoveries we are seeking. And what is this thing? It is [I, 86] the necessity of understanding exactly the action and before that, of course, the entire construction of each part by observing carefully, each man for himself, what is to be seen in dissection. For now the books of those who call themselves anatomists are full of countless errors which I discuss in another work,[29] not merely pointing out the individual mistakes, but also explaining their causes. In truth, being taught by Nature herself, you would have no difficulty in discovering the usefulness of the parts if only you would look carefully at their construction.

Let us cite an example: only by dissection can you see how

[28] Reading ἡμᾶς with Helmreich for Kühn's ὑμᾶς.

[29] Cf. chapter 3 of this Book. Daremberg (in Galen [1854, I, *185*]) says that this other work is without doubt the *Manual of Dissection*, that is, *De anatomicis administrationibus*, but the fact is that Galen does not list the particular errors and the cause of each one in that work, as may be seen, for example, from note 27 above. It may be that Kühn (I, *cxciii*, where, however, the reference to *De usu partium* is not given correctly) is right in thinking that Galen is referring here to a lost treatise, to which Kühn assigns the title Περὶ σφαλμάτων ἀνατομικῶν καὶ τῶν ἐκείνων αἰτίων ("On the Errors of Anatomists and Their Causes"). There is one passage in Book XV (p. 675), however, in which Galen makes a similar statement about his "anatomical exercises," which are ordinarily assumed to mean the earlier *Manual of Dissection*. See note 12 of this Book. Perhaps the earlier, lost *Manual* did contain such a list, but it is more likely that Galen had in mind his *De musculorum dissectione* (Kühn, XVIII, pt. 2, *926–1026*; Galen [1963]), where he does indeed constantly correct the errors of his predecessors, especially Lycus the Macedonian.

Nature has provided for the safety of the tendons that lie upon the ends of the ulna and radius at the wrist, where they are fleshless, bare, and exposed to danger because of their convexity. For nobody is such a blockhead as to inquire further or doubt or question whether Nature provides for the safety of the parts when he sees carved out of the bone a groove corresponding to the tendon which must pass through at that point. If a person was slow and utterly thick-witted, he might still be puzzled, seeing this same thing in only one, two, or even three bones, but when he sees that in all parts of the body whenever a nerve or tendon must traverse a large, bony protuberance, one of these three things happens, either the part is hollowed out, or it is pierced through, or the nerve makes a detour
[I, 87] around the base of it but never extends bare and defenseless over the convexity, surely then it will dawn on him what skill Nature exhibits in providing for the safety of every part. Moreover, if he sees that strong membranes clothe and are spread over and beneath not only nerves and tendons but also all vessels lying in bony grooves, I suppose he will understand still more clearly that Nature has made all such devices to render the parts invulnerable. These devices are found in every part of the body and especially in the prominences of the bones of the wrist. Indeed, the epiphyses of the radius and ulna are hollowed out to receive the tendons of the three muscles on the outer side of the arm that move the wrist [carpal branch of the *abductor pollicis longus*, *extensores carpi radialis*, *longus* and *brevis*, and *extensor carpi ulnaris*]. All the tendons here are also immediately surrounded by hard, strong, broad ligaments growing out from the very bones on which the tendons lie, so that they are not readily injured by objects striking against them from without, nor do they suffer from the hardness of the bones. Now just as it is only by careful observation of what is to be seen in dissection that we realize how Nature has provided for the safety of the parts, so we learn in the same way that she has given each muscle and tendon a size corresponding to the importance of its actions, as I have shown in the first book; that is, she entrusted the weaker actions to small muscles and tendons, but made those charged with the more vigor-
[I, 88] ous actions not only large but double. Furthermore, I have already shown that Nature has employed consummate skill in determining the number and position of all the muscles and tendons, and there is nothing yet remaining for me to tell about them.

8. It is now time to proceed to the discussion of the bones, beginning with those in the hand, since the bones there are very numerous. I have pointed out earlier [30] that three bones having the shape, size, and position that they actually do have are necessary for each finger, but nothing has been said as yet to explain why Nature made the carpus of eight bones [31] and the metacarpus of four,[32] why these bones have many different shapes, and why the carpal bones are fitted together in two rows and the metacarpal in one. Moreover, their shapes, hardness, and positions have not yet been discussed. We should begin now with an explanation of their number, for it would seem absurd for our Creator to have made only one bone each in the thigh and upper arm, which are the largest of the members, but eight of them in such a small member as the carpus and four in the metacarpus. In the fingers the diversity of the positions they assume indicates the usefulness of the number of their bones, but in the carpus and metacarpus there is no such obvious reason. Certainly (for one must make one's defense [33] with an opposing discussion, as Hippocrates says somewhere) these bones are fitted together so skillfully as to leave nothing wanting for accuracy and perfection. In the first place, although no one of the eight carpal bones greatly [I, 89] resembles any other in shape or size, they nevertheless achieve such close union in their articulations that it is hard to tell how many of them there are. In fact, unless you carefully scrape away the ligaments and strip off the protecting membranes, you will think they are all one bone.

How can it fail to indicate marvelous skill and foresight that the carpus, though composed of so many bones of so many different

[30] *Vide supra*, chapters 12 and 14 of Book I.

[31] Galen's treatment of the carpal bones is a curious mixture. The carpus of the ape is composed of nine bones, the eight present in man and a ninth central, intermediate bone. He ignores this ninth bone and thus leads us to hope that here he will have described conditions in man, but he then proceeds to speak of articulations of the pisiform and triquetrum with the ulnar styloid process and of a radial sesamoid, all characteristic of only the ape's carpus. *Vide infra*, and see Sullivan (1933, *69–71*).

[32] See note 31 of Book I.

[33] Accepting on the basis of the Hippocratic text (*De ratione victus in morbis acutis*, cap. 11 [Littré, II, *302, 303*]) Helmreich's emendation, *τιμωρητέον*, for the *ἀντιτιμωρητέον* of the manuscripts and Kühn's text.

shapes, is concave on its inner side as much as is suitable for the hand and convex on its outer side to the extent that this too is advantageous? Does not the additional fact that its upper end next to the forearm is arched into such a shape and degree of convexity that it is very well adapted for articulation with the bones situated above it also indicate perfect skill and foreknowledge of what is best? And surely you will not admire the construction of this part of the carpus alone but look also at the lower end, for there you will see four small concavities in a row which articulate with the bones of the metacarpus. These junctions together with all the articular surfaces within the carpus itself are coated with cartilage and bound together on the outside by strong membranes which serve as ligaments at the joints and at the same time as sheaths for all the bones. The four bones of the metacarpus run side by side as far as the fingers, but they are separate from one another, not closely united as the bones of the carpus are, because the metacarpals must articulate with the fingers, instruments that separate as widely as possible from one another, whereas the upper carpals must articulate with the ends of the ulna and radius, which are joined together. Moreover, the metacarpals are slightly convex on their outer sides and rather concave on the inner sides, because it was necessary for them to have a shape like that of the carpals which they follow. Indeed, the shapes of the carpals and metacarpals are so much alike that their junction presents two smooth surfaces, a concave on the inner side and a convex on the outer side. [I, 90]

Whenever we must extend the hand completely, all the fingers are extended by the tendons on the outer side as if they would bend them back, and at the same time the joint at the carpus is also extended. The carpus and metacarpus, compressed by both these [actions] and, as it were, pried up forcibly with a lever, are compelled to abandon their former positions; although they cannot move to the outside because of the tension of the tendons located there, it is still possible for them to be displaced inward, and being hard pressed on all sides, they would retire as far as possible in that direction if their ligaments were slack and thin. As it is, however, the strength of the ligaments comes to their aid and keeps them from being entirely dislocated. Nevertheless, because each joint yields a little, the sum of all these yieldings gives an appreciable movement of some magnitude. It is the tendons on the outer side that furnish

most of the energy for this movement, for they bear against the convex sides of the bones and press them all inward. Hence, these [I, 91] two results of extension are to be noted: the hollow previously existing on the inner side of the hand is eliminated by the bones moving in to occupy it, and the former convexity of the outer part disappears. And so it happens that the instruments at the carpus and metacarpus extend the hand both by filling up its cavity and by flattening its convexity. Whenever we wish to hollow the hand with precision, we do everything the opposite way, that is, we relax the tendons on the outer side, tense those on the inner side, and flex the fingers. As a result of all these [actions], every bone readily withdraws again to its outer position. But neither of these movements would occur if the bones were quite unable to yield, and they would not yield if they were all one uncompounded bone. Hence, because there are many bones, they have acquired the ability to change their position and so make the hand both as hollow as possible and then straight again, as we need first one and then the other of these two movements; but if there were not many bones, one or the other of the positions would be lost to us. Such a construction as this not only helps the action of the hand, but also contributes to its safety. For if there were only one bone extending from the fingers to the forearm, concave on its inner side, convex on its outer side, and as bare of flesh as these parts ought to be (the preceding book [34] has shown this to be true), it would be easily broken by every hard object that [I, 92] struck against it, and when it was broken, the whole structure would be disrupted because it was only one bone. But as it is, since there are twelve of them, only one twelfth of the entire system is destroyed if one bone is injured. Moreover, to protect the system completely, it was better for it to consist of many bones, and further, of bones just as hard as they are; for by yielding at the joints to objects striking against them, they break the force of the blows. It is in just this way that a dart or spear or any other weapon of the sort pierces a stretched hide more easily than one not under tension, because the one offers resistance and the other by yielding a little deadens the force of the blows falling upon it. Thus the combining of these bones results in two advantages: there is the resistance to injury they all enjoy in common, and also that of each individual bone, the first

[34] *Vide supra*, p. 91.

depending on their number, the second on their hardness. Likewise, the diversity of their shapes contributes enormously to the invulnerability they have in common; for they yield in many different ways to blows falling upon them from all directions, whereas if this were a combination of bones that were all the same shape, they would not be so well protected, because they would not be able to yield in every direction. These are the reasons, then, why [the carpus and metacarpus are composed of] many bones combined in this fashion.

9. Next I shall explain why we have eight bones in the carpus and four in the metacarpus [35] and why it would not have been better to have either more or less. These questions I shall answer by reminding you first of one of the points I made near the close of the first book, and by giving now the demonstration of another. The first book explains [36] why it was better for us to have neither more nor less than five fingers, and something has also been said earlier of the reason why they were arranged not all in line like the toes, but with the thumb placed opposite the others.[37] I shall now add what remains to complete that discussion. The foot is an instrument of locomotion and the hand is an instrument of prehension; the former, then, would properly have firmness for support and the latter diversity of shape for grasping. Now for firm support the digits should be arranged all in one line, whereas the ability to grasp readily all sorts of objects requires the great digit to be opposed to the others. But if it were placed exactly opposite all the others and occupied the middle of the space on the inner side of the wrist, many of the hand's activities would be impaired, especially those involving the palm, whether one hand alone was used or both together. For this reason, then, the thumb had to be placed beside the other fingers, but well separated from them. Although there were two possibilities for a lateral position, either beside the little finger or beside the forefinger, there was good reason for placing the thumb beside the forefinger, for in this position the hands must face toward one another, while in the other they would have to turn away. Moreover, when the fingers are completely flexed, there is no space left open at the little finger, but at the forefinger there is a considerable space which evidently needs the thumb as a sort of lid. Since, then, it was most needful for the

[I, 93]

[35] See note 31 of Book I. [36] In chapter 23.
[37] See chapter 5 of Book I, *ad fin.*

thumb to be located in this place, Nature gave its first phalanx an articulation with the nearest bone of the carpus; for if it had been connected with one of the metacarpals, it would be separated by only a small interval from the forefinger, and if this were so, its action with the forefinger would be impaired, in like manner its action with each of the others fingers, and still more its action when an object is encircled. In all these cases the usefulness of the thumb plainly depends on its wide separation from the other fingers, and it was on this account, surely, that Nature separated it as far as possible from the others. [I, 94]

10. In the region between the forearm and the four fingers, Nature has placed the carpus and metacarpus, which are composed of many bones for the reasons I have already mentioned. But I now propose to tell why the former has eight bones and the latter four.[38] Obviously, since there are five fingers and the thumb articulates with the carpus, the metacarpus has four bones, because each of the other fingers articulates with it. I must first point out why there are eight bones in the carpus and show that its bones must be arranged in two rows. The metacarpal bones are separated from one another because they are proximal to the finger bones, which are widely separated, and because Nature was preparing a space for the [interosseous] muscles which she constructed so very reasonably, as I have shown before.[39] The bones of the carpus are all joined together, those next the forearm more closely than those adjoining the metacarpus. It [I, 95] was necessary for the former to be almost like one bone, since they must act as one in articulating with the forearm and in taking part in many vigorous movements; for all the energetic actions of the hand involve movement of the joint at the wrist. But it was not necessary for the other carpals to act as one bone in their association with the metacarpals, which are separate from one another, and these carpals are not obliged to take part in any violent movements. In fact, it was much more advantageous for them to be joined together loosely for better resistance to injury, because in this way they can better break the force of the blows that fall upon them. Therefore, since it was better that the carpus should be composed of many bones and that the ends of those next the forearm should be joined together differently from the ends of those adjoining the metacarpus, Nature arranged them in two rows. Now since there are necessarily four

[38] See note 31 of Book I. [39] *Vide supra*, pp. 117–118.

bones in the metacarpus and the first bone of the thumb lies beside them in the same row (this bone is assigned for this very reason to the metacarpus by some), the lower end of the carpus with which this whole row articulates must be composed of four bones, and the other end, articulating with the forearm, of three. Since the carpus must be very narrow where it articulates with the forearm and the part where the fingers are produced is very broad, the narrowness or breadth of every part of the intervening portion depends upon its
[I, 96] distance from the ends. Now there are three rows of bones between the forearm and the division of the hand into fingers, and consequently, the first row next to the forearm consists of three bones, the second of four, and the one articulating with the second has five bones, of which one belongs to the thumb and the other four to the metacarpus. From this description, then, it would seem that the carpus is composed of seven bones in all, but if you will wait to hear the special discussion of the elongate bone [*os pisiforme*] lying on the inner side of the carpus where it articulates with the slender apophysis [styloid process] of the ulna, and if you will consider the uses for which Nature has formed it, you will be thoroughly persuaded that it was better for the carpus to be composed of eight bones, neither more nor less. This is enough to say about them; the following discussion will be concerned with the epiphyses and apophyses to be found in all the members, not merely those in the wrist alone.

11. Wherever bones must articulate with one another, particularly if the bones are large, one bone necessarily receives the other, which enters it, and the one that receives needs a concavity, and the one that enters, a convexity; at such points Nature has accordingly constructed certain apophyses or epiphyses for both [members of the joint]. These are convex and rounded on all sides in the bones that enter the joint, whereas in those that receive they are hollowed out on the inside, but convex exteriorly. Thus the ends of the ulna
[I, 97] and radius, since the carpus must articulate with them, properly have each an epiphysis that is convex and rounded exteriorly and concave within. Now the epiphysis of the radius has a rim all around it which clasps exactly the end of the carpus adjoining it, but the epiphysis of the ulna is not constructed in quite the same way. The inner side of it next to the radius does have this type of construction, but the extremity of it that lies directly in the line of the long axis of the

member ends in a rounded head [styloid process] which by means of a glenoid concavity encircles the adjacent bone of the carpus [*os triquetrum*].[40] Thus the wrist joint is a double one, the first part involving the ends of the carpus itself which enter the concavity between the apophyses[41] of the radius and ulna, and the other, smaller part involving the bone [*os triquetrum*] which clasps the small apophysis [styloid process] of the ulna. This second part was made for rotating the hand to the prone and supine positions, but the other, larger part extends and flexes the carpal joint. These, then, are the actions for which the convexities at the ends of the ulna and radius were made, but Nature also makes use of them to secure another advantage, just as she is accustomed frequently to make something that was created for a certain purpose serve other uses as well.[42] For she has located the heads of the tendons moving the fingers in the concavity between these eminences, thus establishing as if with a wall or tower a safe refuge for the tendons. [I, 98]

12. Because of the small apophysis [styloid process] situated low down on the outer side of the ulna and clasped by one of the bones of the carpus [*os triquetrum*], as I have said, the end of the ulna is considerably elevated on that side, and the parts of it on the inner side are depressed; here, accordingly, Nature has placed an elongate bone [*os pisiforme*] like a sort of rampart, directed straight inward, to protect the other parts in that region, especially the nerve [*ramus palmaris manus nervi ulnaris*] coming from the spinal cord and distributed through the inner parts of the hand. This is the eighth bone of the carpus, and in all that I have said up to this point I have been putting off the discussion of the right reason displayed in its formation. Since all the bones of the carpus were fitted together so nicely that Nature was in want of a place in which to establish this bone in safety, she has cleverly invented many admirable devices. In the first place, she carefully made the lower end of it slender, for

[40] Not in man, but in the ape; see Sullivan (1933, 70).

[41] Reading ἀποφύσεων with Helmreich for the ἐπιφύσεων of Kühn's text.

[42] Galen makes this point many times (see the Index). It was undoubtedly suggested to him in the first place by Aristotle, who also says repeatedly that Nature uses one structure for more than one purpose. See *De part. an.*, II, 16, 659a19–23 and 659b34–660a2; III, 1, 662a18–24; IV, 10, 688a19–25 and 689b34–690a4.

only so could she hope to find some suitable place in which to settle it. Next, she prolonged it upward considerably, and in that region she made it loose-textured and cartilaginous, thus preparing a suitable place for the insertion of the tendon [of *flexor carpi ulnaris*] flexing the wrist on that side; for this tendon is too large to be safely attached by just a little cartilage to any of the carpal bones themselves, and so Nature attached it to this one [*os pisiforme*]. The
[I, 99] slender lower end [of the pisiform] she directed downward between the bone [*os triquetrum*] which clasps the small apophysis of the ulna [styloid process] and the large head itself, which is also called a condyle; from the outer and lower part of this head there arises the little neck that ends in a small head [styloid process] articulating with one of the carpal bones [*os triquetrum*],[43] as I have said. This cartilaginous bone [*os pisiforme*], lying in a very shallow concavity, would necessarily be vulnerable and easily displaced in any direction, but Nature has bound it to the adjacent bones with strong membranes which pull on it equally in all directions, though even so it is scarcely able to maintain its proper position, lying at the outer edge of the bone [*os triquetrum*] that clasps the small apophysis of the ulna [styloid process]. Since the large tendon [of *flexor carpi ulnaris*] is attached to the head of this bone[44] [*os pisiforme*] and would be likely to displace it and pull it loose, Nature placed another stress in opposition to that of the tendon by causing the opposite side of the bone to give rise to a ligament which terminates at the metacarpus [pisometacarpal ligament]. Thus, because the cartilaginous bone is drawn upon with equal force on all sides it does not fall away in any direction. This is the way in which the parts of the wrist on the side where the little finger lies are arranged.

Since on the side where the thumb lies it was likewise necessary to give some protection to the other nerve [*ramus superficialis nervi radialis*] coming down from above, part of which passes through to the outer parts of the hand, and since it was also necessary to find a place for the insertion of the other tendon [of *flexor carpi radialis*]
[I, 100] flexing the hand and there was no room to affix another such bone as

[43] This description is obscure at best. Daremberg (in Galen [1854, I, *196*]) thinks that the carpal bone with which "the small head" articulates is the lunate, but this seems impossible. See Sullivan (1933, 70) and cf. Galen, *De ossibus ad tirones*, cap. 18 (Kühn, II, 770–771).

[44] Reading αὐτοῦ with Helmreich for the αὐτῆς of Kühn's text.

the one [*os pisiforme*] on the side of the wrist where the little finger lies—for all these reasons Nature made for the first bone [*os scaphoideum manus*] of the carpus an elongate, loose-textured, cartilaginous apophysis [tubercle of the scaphoid] extending toward the inner side of the hand, and on it she inserted the tendon [of *flexor carpi radialis*] flexing the hand. She certainly did not, however, entrust its whole insertion to this attachment alone, but prolonged the tendon as far as the metacarpus, making it bifurcate for the sake of safety and inserting it on the bases of the metacarpal bones proximal to the middle and index fingers. Now she did here the same thing she had done for the tendons [of *flexor digitorum profundus*] that lie on the inner side of the hand and move the first and third joints of the fingers, and for the same reason. For since those tendons were supposed not to end merely at the first joints but to go forward as far as the third, she attached them to the bones [of the first joint] by ligaments, and in the same way she inserted this tendon of which we are now speaking not into the apophysis itself, but into the ligament surrounding it, so that the tendon could proceed farther, for a tendon inserted into a bone necessarily comes to an end at that point. Furthermore, Nature has also fashioned another apophysis [45] on a smaller cartilaginous bone [46] fastened by strong ligaments to the carpal bone [*os scaphoideum manus*] of which I have just been speaking and also to the adjacent bone [*os trapezium*], which articulates with the first phalanx of the thumb. Her purpose in this was to [I, 101] attach there one part of the tendon which, as I have said, moves both the thumb and the wrist [carpal component of *abductor pollicis longus*]. This bone may be considered a ninth bone of the carpus, but it is not so reckoned by anatomists any more than the other so-called sesamoid bones which Nature for good measure has conferred on many of the joints of the hands and feet to protect them. The other two tendons moving the wrist [of *extensores carpi radiales, longus* and *brevis*, and *extensor carpi ulnaris*] flatten out and, as I have also said before,[47] are attached to the metacarpus, one of them

[45] Reading ἀπόφυσιν with Helmreich for the ἐπίφυσιν of Kühn's text.

[46] In the ape there is a sesamoid bone which is associated with the greater multangular and recives the insertion of the carpal component of abductor pollicis longus. See Howell and Straus (1933, *139–140*) and *vide supra*, p. 114.

[47] *Vide supra*, pp. 121–122 and chapter 5 of this Book.

to the bones proximal to the second and third fingers and the other to the bone proximal to the little finger. Moreover, no apophysis, epiphysis, or any extra bone needed to be formed in addition for either of these tendons on the outer side, and it was sufficient for them to be joined to the bones only with cartilage since they were themselves smaller and were also charged with weaker movements.

I have discussed nearly everything about the hand that is at all important, but if I have omitted any detail, it can readily be discovered, as I have said, just by observing the construction of the part itself. Such a detail is the fact that of the four tendons extending and flexing the wrist, those on the outer side are clearly observed to be oblique and are attached, one to the outer parts of the bone proximal to the little finger and the other to the inner parts of the bone proximal to the thumb [tendons of *extensor carpi ulnaris* and carpal component[48] of *abductor pollicis longus*]. Also, a careful observer will see that the tendons on the inner side are even more oblique and
[I, 102] that this obliquity has been arranged for a purpose, in order that these tendons may not only extend and flex the hand but also control its lateral movements. My discussion of this subject is now complete.

13. Next in order I must speak of the position and form of the radius, and I shall likewise include in the same discussion my treatment of the ulna. It was reasonable for the radius to be placed obliquely, just as the ulna is properly straight, for the position of each bone had to accord with the nature of its motion. Now when a member is extended and flexed, the motion takes place on its long axis, whereas pronation and supination are lateral movements, and this is the reason why the radius is oblique and the ulna straight; for the ulna is of use in extending and flexing the arm and the radius in moving it laterally. For the same reason their articulations with the humerus are not alike, but I shall deal with this subject a little farther on. I have already said that the position of the radius is oblique, and now, since there are in all two possible positions for an oblique bone, which must either begin at the inner and end at the outer side of the member or, conversely, begin at the outer and end at the inner side, I shall explain why Nature chose the second of these possibilities for the radius. In speaking of the lateral movements of the arm, I have

[48] Daremberg (in Galen [1854, I, *198*]) slipped here by identifying this tendon as the *metacarpal* component.

also said before [49] that supination is useful for only a few actions and pronation for many more, which are more important as well. For this reason, then, Nature gave the radius the position in which it would obey the movements of pronation more readily, and she did this by placing its upper end at the outer side of the head [capitulum] of the humerus and extending the lower end toward the thumb. If she had used the opposite arrangement, the radius would be moved more easily to the supine position than to the prone, for the prone position is nearer to the actual situation of the radius, and the supine to the opposite arrangement. Of course, when any member is moved, the change is made with comparative ease and readiness to a position nearby, but it is more difficult if the position is farther away. These are the reasons why the radius was placed obliquely and why it was slanted in this particular direction. But why does it rest upon the ulna? The reason is that the ulna is longer than the radius and furnishes most of the articulation with the humerus; and it is reasonable for a shorter [50] bone to be supported on a longer one. And why are both bones slender in their middle portions and thicker at the elbow and wrist? The reason is that the middle portions must make room for the muscles and the ends must expand to form epiphyses, which, as I have said before,[51] are useful for articulation. Why too are the ulna and radius thicker at one end than the other, the ulna thicker at the elbow and the radius at the wrist? Is it not because the articulation at the wrist is common to both bones, whereas in the articulation with the humerus the ulna's share must exceed that of the radius to the same extent that the ulnar articulation is the more important for the action of the arm? [52] [I, 103]

14. Now that I have said enough about the position and form of both the radius and ulna, there still remains the discussion of their articulation with the humerus. At this end of the ulna there are two apophyses, convex on the outside and hollowed out within; one of these [olecranon], the larger of the two, [arises] from the posterior and lower side of the bone, and the other [coronoid process], which [I, 104]

[49] *Vide supra*, p. 122.

[50] Reading *βραχύτερον* with Helmreich for the *βραχύτατον* of Kühn's text.

[51] *Vide supra*, p. 136.

[52] Accepting Helmreich's emendation, *ὅλης* for the *ὅλαις* of the manuscripts and Kühn's text.

is much smaller, from the anterior and upper side. Since the cavities in the apophyses face toward one another, they combine to form one large cavity [*incisura trochlearis*] resembling the letter Sigma.[53] We call both these apophyses κορώνας and κορωνά (coronas), a name given them because they are rounded; in particular, the posterior, larger one is called ὠλέκρανον (olecranon) by the Athenians and ἀγκών (elbow) by Hippocrates, as I have said before.[54] This is the form of the upper end of the ulna.

15. I shall now describe the [lower] end of the humerus. There is an epiphysis on each side of its head, one on the outer, the other on the inner side [lateral and medial epicondyles]; between them lies a smooth, round concavity [trochlea] resembling the grooves of [the device] called a pulley, and around this concavity the coronas of the ulna are moved. At each end of the concavity is a βαθμίς (socket)—for βαθμίς is the name Hippocrates[55] has used for the concavities of the humerus—into which the coronas of the ulna are introduced when the arm is extended and flexed, and these sockets [olecranon and coronoid fossae] determine the limits of complete extension and flexion. This is the reason Nature has given them their form, size, and especially their position at this end of
[I, 105] the humerus. When the anterior corona leads the way in the motion, the whole ulna turns in that direction and the arm is flexed, for the inward motion of the ulna is the cause of flexion; if the ulna turns in the other direction—and this happens when its posterior corona leads the way—then the arm is extended. Thus, as long as the coronas of the ulna move freely around the convexities of the humerus, the anterior corona flexes the whole articulation and the posterior extends it. When they reach the sockets, however, and settle into them, their progress is checked, and this is the limit of their motion in each direction. Now if there were no sockets at all, or if they were larger or smaller than they actually are, many actions of the arm would be impaired. For if there were none at all, extension and flexion would be quite impossible because the convexities of the humerus would strike against the coronas of the ulna; if the sockets were smaller than they are, extension and flexion would be incom-

[53] Not, of course, like Σ, the present conventional form of Sigma, but like C, one of the earlier forms of the letter.

[54] See chapter 2 of this Book.

[55] *De fracturis*, cap 2 (Littré, III, *420, 421*).

plete, and the more prematurely the sockets encountered the coronas, the more severely would these actions be curtailed; and it is clear to everyone that if the sockets were larger than they are, or if the bone of the upper arm were pierced all the way through, the ulna would be bent back beyond the point of complete extension. If this happened, we could not perform with any force the strong [I, 106] and vigorous acts for which we need the arm accurately extended; for the posterior corona, being so unstable and so extremely loose, would easily slip out of the concavity of the humerus and the strength of the action would be impaired more and more as the extent of the dislocation increased. But with the sockets as large as they actually are, extension and flexion of the arm are so exact that neither movement suffers from excess or defect.

Anyone who cares to look may see that the shape of the sockets was devised to fit perfectly that of the coronas entering them because it was better so; certainly it was better than the prominences should be clasped firmly and accurately by the concavities at every point so as to leave no empty space between them. For this purpose there could not possibly be a happier arrangement than the present one in which each socket begins with a rather broad lip above and ends lower down [56] in a very blunt point. Moreover, it is, of course, proof of no small providence that the sockets grow gradually narrower to correspond with the coronas entering them so that no part of the latter is constricted and no part is too loose or unsupported. Likewise, I suppose it is evident to everyone that the location of the concavities just where the coronas of the ulna must fall during complete extension and flexion of the forearm is another indication of the skill with which they were placed. In fact, when we cannot [I, 107] find concavities in any other part of the humerus [57] and when both the concavities we find [here] are obviously not placed idly or at random but in a most suitable position, how can anyone deny that they have been made because it is better so? And not only their position but their size too, their shape, and their whole nature are so serviceable and so nicely adapted to the actions of the arm that if

[56] That is, in the fundus.

[57] As Daremberg (in Galen [1854, I, *202*]) points out, all the manuscripts read τοῦ πήχεως (the ulna) here, but the sense clearly calls for τοῦ βραχίονος (the humerus) and I have accordingly accepted his emendation.

even the least detail were altered, the member would be to that extent disabled.

You will best realize that the coronas of the ulna are also most beautifully constructed when you consider how seriously the actions of the arm would necessarily be impaired if the coronas were shorter or longer, more oblique or straighter, narrower or broader, or altered in any way whatever. For example, if we suppose the coronas to be longer than they are, it is clear to everyone that in falling too soon upon the humerus they would hinder considerably the complete extension and flexion of the arm. On the other hand, if they were smaller than they are, for one thing the ulna would be bent back and flexed toward the rear, and for another the safety of the whole articulation would be endangered, so that the humerus would be easily dislocated from the ulna, riding up over the posterior apophysis [olecranon] in flexion, and the anterior [coronoid
[I, 108] process] in extension. If the coronas were more rounded or straighter than they are, the rounded concavity [trochlea] between the condyles of the humerus would necessarily be made too loose at many points and would no longer fit the coronas everywhere closely and evenly as it does now. In like manner, if the coronas were any narrower, they in their turn would fit loosely into the broader space in the middle of the humerus around which they move, and as they swam about, so to speak, they would frequently be displaced laterally so that the rectilinear motion of the whole forearm would be deranged and the unsupported, unsteady actions of the arm would be weakened. Similarly, if the coronas were broader than the space in the middle of the humerus, they could not enter it and thus would hang precariously on the rims of the heads of the humerus. As it is, however, with their width exactly equal to the space like a pulley [trochlea] in the humerus, both of them are held securely on both sides by the condyles; the coronas cannot incline sideways in either direction, and the articulation thus becomes safe and useful to the actions [of the arm].

The smaller head of the humerus that lies on the outer side [lateral epicondyle with capitulum] was made for articulation with the radius, and the larger one on the inner side [medial epicondyle] has no bone adjoining it. It therefore projects toward the inner side of the arm and seems bare and fleshless to anyone observing and touch-
[I, 109] ing it. But the discussion of this head belongs rather to my exposition

of the vessels of the whole body, not of the arteries and veins only, but of the nerves as well; for I have determined to discuss them in detail all together in a separate section farther on in my discourse,[58] and so I shall also speak of the inner head of the humerus at that time because it was made to protect the vessels. In this instance too, Nature makes a structure provide an additional advantage, for she fastened to this head the upper ends of the muscles lying straight along the inner side of the forearm. I should, however, speak of the head on the outer side of the humerus [lateral epicondyle with capitulum] in this present discussion, because the radius embraces it by means of a shallow concavity, and thus controls the rotation of the forearm. Likewise, certain strong, membranous ligaments grow out from the region of the epiphyses. These encircle the whole joint, bind it together, and hold it fast in such a way that the head of the humerus [capitulum] does not easily escape from the subjacent concavity (though this is superficial and without much depth) and yet the actions of the joint are not at all impeded, since the substance of the ligaments is such that they stretch greatly when pulled and thus do not hamper any movement. Those that surround all the other articulations also have the same nature and serve the same purpose. In fact, there is no joint wholly deprived of ligaments, but all have their share, whether many and strong or few and weak, and Nature does not assign ligaments at random, but makes their number [I, 110] and strength correspond to the need of each joint for firm protection and freedom of motion. For she is not wont to make anything defective, superfluous, or worthless. Hence she has surrounded all the joints and in particular this one at the radius of which I am now speaking with adequate ligaments, making their number and thickness correspond to the usefulness of the joint. In the same way, although the articulation of the ulna with the humerus is very secure, she has wrapped it too in strong ligaments because she was mindful of the violence of its movements, and the ligaments with which she has bound together the radius and ulna at both ends are also strong. But this is enough to say about the elbow joint; I must now proceed to speak of the remaining parts of the arm.

16. These remaining parts are the four muscles and one bone of the upper arm; its nerves, arteries, and veins will also be described

[58] In Book XVI; this subject is discussed in chapter 8.

when I discuss all the vessels of the whole body.[59] It is reasonable that the bone of the upper arm should be rather convex on its outer side and rather concave on the inner, for it was better, as I said at the very beginning,[60] for the hands to turn toward one another, and if
[I, 111] so, then the concave sides of the bone should face in toward one another and the convex sides be turned away and face outward. For one thing, this feature of their construction renders the humeri more suitable for embracing rounded bodies and, in addition, it makes room for the vessels entering the arm. It is also clear, I suppose, that it was better to cover the bone of the upper arm with the muscles moving the forearm, because it needs to be clothed and protected from heat and cold as well as from hard bodies with which it comes in contact, and the skin alone without flesh is not sufficient protection against any of these ills. Now nearly all anatomists have allowed that flesh is a part of muscle, as I myself have also stated in my book, *On the Movement of the Muscles*.[61] But no one has accurately described the way in which the flesh is interwoven with nerves and ligaments, and no one has explained its usefulness. I shall, however, consider these matters farther on in my discourse;[62] for present purposes this point which is granted and which also is evident in dissection is sufficient, namely, that flesh forms a part of the substance of muscle. And so, because the humerus needs to be protected on all sides by flesh, and because it must also have lying along it the muscles moving the forearm, it was not provided with idle flesh and with muscles separately, but in receiving the muscles it also gained the flesh.

Now as the two movements of the forearm are extension and
[I, 112] flexion, the muscle controlling flexion had to be located on the inner side of the humerus and the muscle controlling extension on the outer side. But such an arrangement would leave completely exposed all the intermediate parts of the humerus, by which I mean the upper and lower sides, where no muscle had been applied to it. Hence it was necessary either to allow these parts to go entirely unprotected from injury because they were without covering, or to cause useless flesh which would not be a part of any muscle to clothe the member. Either expedient, however, would be negligent on Nature's part and

[59] In Book XVI. [60] *Vide supra*, p. 72.

[61] *De motu musculorum*, I, 1–2 (Kühn, IV, *367–376*).

[62] See chapter 3 of Book XII.

not according to her custom. Consequently, to avoid forming useless flesh or leaving a part of the member bare and unprotected, she doubled the number of muscles, thus at the same time making the movements stronger and more secure. It is at once clear that four muscles produce stronger movements than two, and it needs no long discussion to show that their action is also safer; for when in each position there are two muscles instead of one, if one muscle is ever injured, the other can still move the member. If, however, Nature had simply doubled each muscle and superimposed one of each pair on its fellow, she would have thus provided strength and safety for the movements, but would have left the intermediate parts of the humerus still uncovered. But when she placed the muscles obliquely on the member so that they cross like the letter Chi (X), she gained, in addition to the uses [63] I have mentioned, a covering for all sides of the humerus. Now of course if these muscles were supposed to provide the member with rectilinear movements in extending and flexing the elbow joint, their oblique position would [I, 113] be of no advantage to them; it would, indeed, produce precisely the opposite effect. But is it not the most admirable feature of the construction of these muscles that, like the tendons moving the wrist, they accomplish one rectilinear movement by means of two that are oblique? One of the muscles flexing the forearm [*biceps brachii*] begins on the inner side of the shoulder region and extends thence to the front of the humerus; [64] the other one, the smaller of the two [*brachialis*],[65] grows out from the outer side of the humerus and thence crosses gradually over to the inner side. Thus their position manifestly resembles the letter Chi, and it is also manifest that their motion is oblique. When the larger muscle acts, the hand touches a point on the inner [medial] side of the shoulder joint, and when the smaller one acts, the hand touches the corresponding point on the outer side of the joint. You can verify this description first in

[63] Reading χρείαις with Helmreich for the χώραις of Kühn's text.

[64] Galen knew that biceps brachii has two heads, though nothing is said about it here. See *De anat. admin.*, I, 4, 11 (Kühn, II, *238, 274–275;* Galen [1956, *10, 28–29*]). See also note 68 of this Book and Temkin and Straus (1946, *171–176*).

[65] In the ape the lateral origin of brachialis "may extend far up the humerus, in extreme cases approaching the surgical neck of the bone" (Howell and Straus [1933, *132*]).

the ape by stripping the skin from the upper arm and pulling on the tendons near their insertions, as I have explained in my *Manual of Dissection*,[66] and then you can also test it in yourself without dissection. For if you hold motionless all the joints of the whole arm excepting only the articulation of the ulna with the humerus, you can never move the hand to any point beyond the limits I have mentioned.

You will find a similar arrangement of the posterior muscles of the
[I, 114] humerus [*triceps brachii*], for each of them is placed so that it opposes one of the muscles on the inner side. They are both inserted into the elbow, but most of one of them into its inner side and most of the other into its outer side. The first of these muscles is attached at its upper end to the inner side of the humerus [medial head?], and the other to the back of it [lateral head?].

As I said at the very beginning of this whole work,[67] the usefulness of a part cannot be determined correctly unless its action is known. Now since the common run of physicians do not know the actions of most of the parts and some are even ignorant of construction, it is not to be expected that they will have sound opinions on usefulness. For they think it is enough simply to know that there are two flexor muscles for the forearm and two extensors, and they say it is taking needless trouble to inquire where they begin and end. Once, when one of these physicians and I were examining a young man who could touch the inner [medial] side of his shoulder with his hand but not the outer [lateral] side when he flexed his forearm, this doctor could not recognize in which muscle the trouble lay; he was even completely ignorant that the larger muscle [*biceps brachii*] is inserted into the radius and the smaller [*brachialis*] into the ulna, but supposed instead that both muscles reached the space between the two bones. How, then, could such a man determine the usefulness of the position of these muscles when he did not know how they were placed? And certainly, not knowing their position, neither could he know their action.

[I, 115] When these two muscles act together, they flex the forearm exactly in a straight line; when one acts without the other, the forearm is inclined slightly to one side or the other, as I have said. We need

[66] *De anat. admin.*, I, 11 (Kühn, II, *272–273;* Galen [1956, *27*]), and *passim*. See also Temkin and Straus (1946, *171–176*).

[67] *Vide supra*, pp. 96–97.

not be surprised that although each muscle pulls on only one bone (one of them on the ulna and the other on the radius), the other bone is also drawn along at the same time, because the two bones are bound together on all sides with numerous strong ligaments. For it is possible by means of the muscles of the forearm to rotate the radius independently only because the movement is a very slight one and because the pull is exerted at many points. In regard to the muscle [*biceps brachii*] which is brought down in a straight line along the humerus,[68] which acts through only one tendon, and which causes so great a movement of the whole limb as to make the fingers approach the shoulder, it is not impossible or particularly surprising that the second bone moves together with the one moved [by the muscle], especially because one part of its tendon [*aponeurosis m. bicipitis brachii* (*lacertus fibrosus*)] is inserted on the ligaments common to both bones. Now Nature was skillful when she arranged things in this way, and there was also good reason for making one of the two muscles larger than the other. For I have already said frequently that for the arm the inward movements are predominant. Since, then, these muscles cause the forearm to deviate in opposite directions from perfectly straight flexion, it was logical to make the muscle that moves it inward [*biceps brachii*] stronger than the one that moves it outward [*brachialis*]. It was also logical to make the oppos- [I, 116]
ing muscles [*triceps*] correspond, each to its fellow, because if Nature had set the smaller outer muscle opposite to the larger inner muscle, and the larger outer muscle opposite to the smaller inner one, she could justly be called unskillful. But obviously she has done no such thing either here or in any other part.

If ever a workman has shown great foresight in the matter of proportion and proper relations, it is Nature in her formation of the animal body, and it is for this reason that Hippocrates[69] was very right to call her just. Surely the arrangements I have described are just, and it is also right for the muscles of the upper arm to be larger

[68] This is a confusing statement in view of Galen's previous contention that the larger muscle flexing the arm is oblique and crosses the other (brachialis) to form an X. One might think that he was speaking then of the short head and now of the long head if it were not for his assertion that there are (only?) two flexor muscles. See note 64 of this Book.

[69] *De fracturis*, cap. 1 (Littré, III, *412–415*).

than those of the forearm, because the former move the forearm and the latter the wrist and fingers, so that the muscles moving the parts differ in size as much as the parts they are to move. The size of the bones must also correspond to the size of the muscles beneath which they lie; hence the humerus is larger than the ulna, and for the same reason the femur is larger than the tibia. Now if the bones, besides being large, were also hard and very dense, without cavities or marrow, the weight of the members would be enormous. For this reason the large bones were made more porous, with looser texture and larger hollows than all the smaller ones. And in this instance, too, Nature has cleverly made additional use of the cavities, for she stores there the proper nourishment of the bones which we call marrow. But I shall speak of marrow later on.[70]

[I, 117] 17. It would be logical to tell next why the upper arm was made with one bone and the lower arm with two, but first there should be a discussion of articulations in general. I have said earlier that Nature has given the parts of the instruments forms well suited to the actions for which the instruments were made and that she has also taken equal care to make them proof against injury;[71] I shall now show how true this is for the articulations of the body. Where the motion of a joint must serve many vigorous actions and there is reason to fear that their violence may cause dislocation, the joint is bound and held together on all sides. On the outside it is surrounded with many stout ligaments, both membranous and rounded, cartilaginous ones. Its prominences that enter concavities fit them exactly, so that there is no looseness there, and they are also perfectly supported by certain rims like brows [on the edges of the concavities]. On the other hand, where the articulation serves only a few weak actions, Nature, having now nothing to fear, makes the ligaments thin and membranous, and the whole union of the bones a very loose one. As I proceed to treat of each individual part, I shall remind you that all the joints of the body follow this same rule in
[I, 118] their construction, and we can see here that it is true of those in the arm, which is the part now under discussion.

There are very many vigorous actions that we perform by moving the articulations at the wrist and elbow; for this reason these joints are made secure first by the very way in which the bones are

[70] *Vide infra*, pp. 541–543. [71] *Vide supra*, pp. 75 ff., 129–130.

fitted together and then by the ligaments that bind them together on the outside and that have been made everywhere thick and hard. But because the shoulder joint is seldom used for energetic actions, being motionless in most cases or moving without much force, the bones themselves are loosely fitted together and the membranes surrounding them are even more lax. For Nature did not make these membranes cartilaginous, thick, or hard at all, but exceedingly thin, soft, and capable of stretching readily to a marked degree. Now at the wrist and elbow certain ligaments have been formed that are both thick and hard; these hold the bones of the articulations together on all sides and prevent them from separating or drawing very far apart. Hence, although the wrist and elbow are often forced to act with violence, they are less subject to dislocation than the shoulder joint. For bones cannot slip past one another unless they draw well apart, and this maximum separation is caused by weakness and laxity of the ligaments and by the [loose] way in which the bones are fitted [I, 119] together when the edges of their concavities are flat and not everywhere surrounded by rims. Indeed, even when the concavities are surrounded by rims, the edges of the rims are frequently broken in violent motion and so allow the joints not only to be dislocated then, but also to suffer repeated dislocations from that time forth. Hence it is clear that the precise shaping of the articulation plays no small part in preventing dislocation.

Then why has Nature not constructed all the joints so as to be safe from this danger? The reason is that there is a necessary anatagonism between diversity of movement and safety of construction, and a single structure cannot enjoy both advantages, for the one depends on the looseness of the joint, and the other on a tight, close union. Where diversity of movement involves no risk, inventing devices for safety would be vain and superfluous, but where it is risky and perilous, Nature has chosen rather to protect the joint from injury. Since in the elbow and wrist she had provided for safety rather than diversity, incurring the danger of practically crippling the members by restricting them to one sort of movement, she placed an additional articulation beside each of these joints to furnish lateral movements. Now at the shoulder joint the humerus can be not only extended and flexed but also moved circularly in any [I, 120] direction; for its head is rounded, the ligaments are lax, and the concavity of the neck of the scapula is shallow and everywhere

regular in shape, like the head of the humerus. The joints at the wrist and elbow, however, being bound tightly on all sides, cannot vary their motion or move in a circle,[72] and so, since they cannot, and since diversity of movement must not be entirely disregarded, Nature made the articulation at both places a double one so that in each case the additional [73] articulation might supply the deficiencies of the first. Thus circular and lateral movements are provided for these members at the upper joint by the articulation of the radius with the humerus, and at the lower by the articulation of the carpus with the slender apophysis of the ulna [styloid process].[74] Now the finger joints, like the shoulder, are provided with lateral movements, but not with such free circular movements, although the ligaments surrounding them are thin and membranous; for the bones are shaped differently from those at the shoulder. Their heads are not everywhere regular in shape, because they are not perfectly round, and the edges of the concavities receiving them are produced to form delicate rims which clasp the heads firmly on all sides; the concavities also receive the epiphyses of the so-called sesamoid bones, and
[I, 121] thus the finger joints have, so to speak, an average construction, by which I mean that just as the wrist and elbow joints are more secure than they are, so by an equal amount they themselves are more secure than the shoulder joint. Nature had good reason for making them so, for although they are best used for grasping small objects when they act alone, they nevertheless act well together with the wrist and elbow joints when larger objects are grasped. Moreover, being useful for many more actions than the other articulations, they are bare on all sides, not swathed like the shoulder joint in large muscles, which, however, are no hindrance to its movements and contribute greatly to its safety. And so, of the two conditions on which the safety of a joint depends, namely, strength of the ligaments and precision in fitting the bones together, both are found at the wrist and elbow, only one in the fingers, and neither to any

[72] At this point Daremberg's translation (Galen [1854, I, *213*]) adds the clause, "ce qui rendait superflu tout soin de la variété des mouvements." Neither Kühn's text nor Helmreich's has any such clause, and Helmreich's critical apparatus gives no indication that it occurs in any of the manuscripts.

[73] Accepting Helmreich's emendation, προσιούσης, for the προιούσης of the manuscripts and Kühn's text.

[74] *Vide supra*, pp. 136–138.

marked degree at the shoulder. Nature, then, was well advised to add the radius to the ulna, making a double articulation, since joints with a safe, tight construction cannot have diversity of movement.

18. We now need no long discussion to understand why the oblique movements [of the forearm] at the wrist are very small, whereas those up near the humerus are very great. For the bones of the wrist itself and the radius are so exactly joined to the ulna at its [I, 122] lower end that many physicians have thought that these bones do not have each a movement of its own, but that they behave as if they had been united to form one bone and had only one movement common to them all. Up near the humerus, however, the upper ends of the radius and ulna are separated far enough to allow the radius to move freely alone without the ulna, a movement impossible at its lower end. Furthermore, the articulation between the slender apophysis of the ulna called styloid and the bone [*os triquetrum*] of the carpus on the side where the little finger lies is a very small one because the bone of the wrist is necessarily small; and this articulation has very little movement both because of its small size and because in that same region the ulna is attached to the radius, and the little bone to all the other bones of the carpus. It is only because these bones are sufficiently separated from one another that the movement is large enough to be noteworthy.

19. I have discussed nearly all the parts of the arm. The arteries, veins, and nerves, however, are instruments common to the whole body, and for this reason, as I have said before, I shall treat of them [75] when I have finished the exposition of all the other parts. Moreover, at the end of the work [76] I shall also discuss the size and position both of the arm and of all the other members as well; for we must compare the members with one another if we wish to show that [I, 123] they are properly proportioned and well arranged. So at this point I shall stop talking about the arm and turn to a discussion of the leg because of the similarity in construction. The exposition of the muscles that move the shoulder joint, together with the rest of the discussion of the shoulder and shoulder blade, I shall include in the thirteenth book of these commentaries.

[75] In Book XVI. [76] In Book XVII.

THE THIRD BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Foot and Leg]

1. Man is the only one of all the animals to have been provided with hands, instruments suitable for an intelligent animal; likewise, of animals that go afoot he alone was made biped and erect, for the reason that he had hands. The vital parts of the body are all contained in the thorax and abdomen and need the limbs for locomotion; in the deer, dog, horse, and similar animals, the fore limbs were made legs like the hind limbs, and this conduces to swiftness. In man, however, the fore limbs became hands; for one who was to tame the horse with his skillful hands had no need to be swift himself, and in place of speed it was far better for him to be provided with instruments necessary for all the arts.

But why, then, was he not given four legs and hands as well, like
[I, 124] the centaur? The reason is that, in the first place, a commingling of such widely different bodies was impossible for Nature. For it was not merely their shapes and colors that she would have had to combine, as sculptors and painters do; she would also have been obliged to blend their very substances, which are absolute and will not mingle. Indeed, if man and horse should ever mate, the uterus would not bring the seed to perfection. If Pindar as a poet accepts the myth of the centaurs, we should be indulgent, but if he speaks as an intelligent man, pretending to understand what is beyond the grasp of ordinary mortals, we must censure his claims to wisdom when he dares to write:

. . . [Centaurus,]
Who lay with the Magnesian mares at the foot of Pelion.

Thence was born a wondrous race, like to both who gave them birth.
The mother gave their lower parts, the sire the parts above.[1]

Now a horse and ass can mate; the female of either species can receive, preserve, and perfect the semen of the male of the other species, and the result is a hybrid animal. Similarly, a female wolf can mate with a dog and a female dog not only with a wolf but also with a fox, just as a female fox can mate with a dog.[2] But a mare could probably not even receive human semen into the hollow of the uterus because a longer male member would be necessary, and if the semen ever were introduced, it would be destroyed either immediately or very shortly. However, knowing that the muse of poetry [I, 125] needs the marvelous more than all her other ornaments, we concede you, O Pindar, the right to sing and recount legends; for you [3] wish not to teach, I suppose, but to astonish, charm, and enchant your hearers. But we who are concerned with truth rather than legends know well that the substance of a man is utterly unable to mingle with that of a horse. And even if we should grant that this animal, so strange and monstrous, could be conceived and perfected, nothing could be found to nourish the creature. Would the lower, horselike parts be nourished with grass and raw barley, and the upper parts on cooked barley [4] and food fit for men? In that case the animal should have been given two mouths, one human and the other that of a horse, and if we must judge from the presence of two breasts, it seems likely that it would also have two hearts.

Even if we should be willing to pass over all these absurdities,

[1] Pindar, *Pythian Odes*, II, 44–48 (Pindar [1915, *174–175*]). Galen was not the first who felt it incumbent upon him to protest that it would be impossible to produce a centaur; see Lucretius, *De rerum natura*, V, 878–891. Vesalius (*1555*, *176*) deplores this long passage on the centaur and says that Galen was "in Pindaro irridendo magis, quam spectandis ossibus occupatus"—busier making fun of Pindar than in inspecting the bones.

For a similar protest of Galen's against accepting the literal existence of the monsters and preternatural phenomena of mythology, see his *De plac. Hipp. et Plat.*, III, 8 (Kühn, V, *356–359*).

[2] Perhaps an echo of Aristotle, *Hist. an.*, VIII, 28, 607a1–8; cf. *De gen. an.*, II, 7, 746a29–35.

[3] Reading *βούλεσθε* with Helmreich for the *βούλεσθαι* of Kühn's text.

[4] Reading *ἐφθαῖς* with Helmreich for the *ἐφθοῖς* of Kühn's text.

however, and grant that this man with the legs of a horse could be engendered and support life, he would gain nothing from such a structure except swiftness, and this would not be advantageous at all times and places, but only on smooth, level plains. If ever he had to run uphill or down, or over sloping or irregular country, it would be far better for him to have legs constructed as a man's actually are. Thus a man is better able than that monstrosity, the centaur, to leap
[I, 126] over an obstacle, to climb sharp, precipitous rocks, and, in short, to traverse all sorts of difficult country. I should like to see a centaur build a house or ship, scramble up the mast to the yardarm, or perform any of a sailor's tasks. How terribly awkward he would be at all of them, and how perfectly impossible many of them would be for him! If he was building a house, how would he climb long, slender ladders to the tops of high walls? Or how would he climb to the yardarm of a ship? [5] Would he be able to row when he could not possibly sit down properly? And even if he could, the presence of his front legs would hinder the action of his hands. But though he was of no use as a sailor, perhaps he would make a good farmer. Here too, however, he would be even more useless, especially if his task was climbing trees and picking fruit. Do not think that these are the only situations where he would be absurd, but review all the other arts and imagine him working as a blacksmith, or cobbling, weaving, mending, or writing books. How would he seat himself? What sort of a lap would he have on which to rest his book,[6] and how would he handle all the other tools? For in addition to all the other special advantages man enjoys, he is the only one of all the
[I, 127] animals who can conveniently sit down on his hip bones. This fact has indeed escaped most people; they believe that man alone stands erect but do not perceive that he is also the only animal that can sit. That centaur of the poets, at any rate, whom you would properly call not a man but rather a sort of horse-man, could not support himself securely on his hip bones, and even if he could, he would be clumsy in using his hands because in everything he did his forelegs would get in his way, just as we too would be hindered by two long wooden sticks fastened to our breasts. And if while so equipped we

[5] I suggest that this sentence is a repetition of the clause a few lines above and should be rejected.

[6] See Daremberg's note (in Galen [1854, I, *219–220*]) on the Ancients' way of writing.

were made to recline on a couch, surely we should present a queerly mixed appearance, that would be queerer still if we were sleepy. Indeed, here is another strange thing about this centaur, namely, that he could not make any use at all of a couch, and he would be quite unable to lie down to rest on the earth. For in the centaur the construction of one part of his body requires one method of repose, and the remainder another; the human part needs a couch, the equine needs the earth. But perhaps it would be better for us to have four legs if they were human legs and not those of a horse. Such an arrangement, however, would be of no help to us in any action, and we should lose our natural swiftness as well. If we cannot use four legs to advantage when they are those of a horse or a man, certainly we cannot when they are those of any other animal, for some animals have legs more like those of a horse and others like those of a man. Moreover, when we should find four legs to be two too many, it would clearly be still more foolish for us to be provided with six [I, 128] or more. For, generally speaking, if an animal is meant to make proper use of hands, it should not have an impediment either natural or artificial projecting from its breast.

2. Now because the horse, beef, dog, lion, and other similar animals were not meant to practise any art, it would be as idle for them to be biped as it would be for them to have hands. What advantage, indeed, would they gain from standing erect on two feet if they had no hands? It seems to me that if they were so constructed, not only would they gain nothing, but they would also be deprived of the advantages that normally are theirs; these are, first, convenience in feeding, second, protection for the anterior [ventral] parts of the body, and third, swiftness. Now having no hands, some animals are obliged to bring food to their mouths with their fore legs, and others to get it by stooping. Carnivorous animals have feet divided into toes; herbivora have hoofs, either solid or cloven. The carnivora are always very brave, and for this reason their feet are not only divided into toes but also provided with strong, curved claws; for so they are enabled to hunt their prey more quickly and hold it more easily. The herbivora are none of them as brave as the carnivora. The horse and bull, however, frequently display considerable [I, 129] courage, and hence one of them has solid hoofs and the other horns. But the herbivora that are entirely without courage have neither solid hoofs nor horns to defend themselves, but only cloven hoofs.

Now the herbivora bend their heads to graze, but carnivora use their front feet in place of hands to hold fast the prey they have caught and to convey food to their mouths.[7] If their feet were strengthened with solid hoofs, as we might expect from the tension and vigor of their whole bodies, they would, to be sure, become much swifter than they are now, but they would sacrifice these other more essential uses of their legs.

Since bloodless animals have a colder temperament and are therefore much weaker and more sluggish in their movements, they have been provided with many small legs, small because these animals are not strong enough to lift and move large ones, and numerous because they are small. For since swiftness of locomotion results from either the number or large size of the legs, animals that cannot have large members can still enjoy this advantage by having a large number of them. For this same reason the whole bodies of some animals, such as the *iulus*[8] and centipede, have been greatly elongated, for Nature was providing space for the growth of many legs, but she did not need to make a large number of legs for animals like
[I, 130] the grasshopper and cricket to which she could give legs that are long and slender, though not large. But Aristotle has a long and excellent discussion of the difference[s] of the bloodless animals.[9]

All red-blooded animals that go afoot and resemble man most closely have four feet to provide swiftness and protection, and brave animals have them to serve sometimes instead of hands into the bargain. I have said enough about the value of four feet to animals in making them swift and helping brave ones to hunt and eat. But you will realize that it is also safer for them to go on all fours than to stand erect on two feet, if you consider how much more vulnerable the parts in the abdomen and thorax are than those at the back. Because animals walk as they do [on four feet], the vulnerable parts are concealed and protected by the parts above, and it is the parts not easily injured that are prominent and exposed. In the erect posture, on the other hand, the parts in the abdomen would be uncovered and unsheltered, bare, altogether unprotected, and so

[7] See Aristotle, *Hist. an.*, II, 1, 497b18–21; *De part. an.*, II, 16, 659a19–24, and especially IV, 10, 687b25–688a4.

[8] Millepedes. For the *iulus* and centipede, see Aristotle, *Hist. an.*, *IV*, 1, 523b17–18, and *De part. an.*, IV, 6, 682a35.

[9] In *Hist. an.*, IV, 1–7, 523a31–532b26.

extremely liable to be injured. For since animlas do not have hands and cannot reason as man does, they must interpose something else to protect the abdomen and thorax, and compensate for the natural weakness of the parts contained there. Hence it was better for all animals supplied with blood, other than man, to be quadrupeds and for the bloodless animals to have many feet. Conversely, it was better for man to be biped, because unlike the other animals he does not need the advantages resulting from a larger number of legs and [I, 131] would be handicapped in many ways if he were not biped. You may object that birds too are biped. Man, however, is the only one of all the animals that is erect; for in him alone the spine lies in a straight line with the legs, and if this is true of the spine, of course it also applies to all the vital parts of the body. For the spine is a keel,[10] so to speak, for the whole body, and in birds, just as in quadrupeds, the legs make a right angle with the spine; only in man do they extend in a straight line with it. In fact, when quadrupeds and winged animals are walking, the legs have the same position in relation to the spine that they have in man when he is seated, and this is the reason why I said just now that no one of them ever stands erect.

3. Why, then, cannot animals sit down supported by their hip bones as man does (for it seems this point still remains to be discussed)? The reason is that the members attached to the hip bones must bend backward at the articulation of the femur with the tibia. In the sitting position, the spine itself makes a right angle with the femur, and if the femur in turn does not make another right angle with the tibia, the latter will not be placed upright on the ground, and thus the position will be rendered unstable. If, then, the sitting position is assumed by bending [back] at the knee the members attached to the hip bones, it is clear that four-footed animals cannot sit, because in all of them the hind legs bend forward.[11] The fore [I, 132]

[10] This and other passages (*vide infra*, pp. 570, 573, 594, 669–670) where Galen compares the spine to a keel are of particular interest because of the later use of *carina*, the Latin word for keel, by embryologists to denote the axial and paraxial structures in the embryo. See Adelmann (1966, III, *1087–1091*). For Galen's use of terms having to do with the sea and ships, see Gerlach (1936) and note 71 of Book I.

[11] Cf. Aristotle, *Hist. an.*, II, 1, 498a3–31, and *De incessu animalium*, cap. 12, 711a8–712a22. Note that both Aristotle and Galen have confused the articulation of the femur and tibia with that of the leg bones and the tarsus in quadrupeds.

limbs are attached to the shoulder blades, just as in man, and the hind limbs to the hip bones; in both cases, however, flexion is in the opposite direction to the flexion of the corresponding member in man, that is, the front legs bend back and the hind legs forward, because in quadrupeds it was better for the flexures to turn toward one another, whereas in man the members attached to the shoulder blades are arms, and it was advantageous for them to bend forward at the elbow. For I have shown in one of the preceding books [12] that it is better for the hands to be turned toward one another. Likewise, the legs are with good reason flexed toward the rear, for only thus, as I explained just now, is it possible to sit successfully. Hence an animal can assume three different positions when its spine extends in a straight line with its legs: it can be perfectly supine or prone when it lies on its back or its stomach, or it can be perfectly erect when it is supported firmly on its feet. If the legs form an angle with the spine, however, it is clear that in none of these positions will the animal be perfectly straight, so that I was right when I said earlier that only man stands erect. All the other animals are more or less prone and move very much as a baby creeps on its hands. The gecko, the lizard, and all such short-legged animals are completely prone, for their abdomens are always in contact with the ground,
[I, 133] and this condition is even more marked in the snake. The horse, dog, beef, lion, and all other quadrupeds hold a position midway between the perfectly prone and wholly erect animals. The birds too belong to this class even though they are bipeds, for they do not have their instruments of locomotion in a straight line with the spine.

Thus man is the only one of all the animals to stand erect, and I have shown that he is also the only one to sit. All the actions which the hands perform in the exercise of the arts require these two positions; for some we perform standing and some sitting, but nobody does anything lying supine or prone. It was right for Nature not to give any other animal a structure enabling it to stand erect or to sit, since the other animals were not meant to make use of hands. To think that man has an erect posture for the sake of looking readily up to heaven and being able to say,

I reflect Olympian light from my undaunted countenance,[13]

[12] *Vide supra*, p. 72.

[13] A fragment from the writings of Empedocles; see Diels (1956, I, 330).

is to be expected of men who have never seen the fish called *uranoscopus* (heaven-gazer),[14] which looks perpetually up to heaven whether it wants to or not, whereas man would never see the heavens if he did not bend his neck back. Moreover, this ability to bend the neck is not, of course, characteristic of the human animal alone, but is found to an equal degree in the ass as well, not to mention long-necked birds that can look up easily when they [I, 134] wish and can also readily turn their eyes in every direction. It is a mark of gross carelessness if a person fails to listen to Plato[15] when he says, "Looking up does not mean lying on one's back and yawning, but in my opinion means using one's reason to meditate on the nature of things." But, as I said in the beginning, few of my predecessors have had a correct understanding of the usefulness of the parts. For this very reason I should press on more earnestly and strive to complete the whole work, neglecting no property at all of any of the parts, as I have also said before, neither position nor size, contexture, shape or other form, softness, hardness or other qualities depending on temperament, the relations parts have with one another, whether symphysis (σύμφυσις, a growing together) attachment, or juxtaposition, nor, finally, the means taken to secure protection.

4. Let us, then, begin again with the discussion of the legs and show that each part of them has been made so skillfully that no better construction could possibly be conceived. Here, too, my approach to the discussion and my discovery and demonstration of the various problems will be according to the method laid down in the beginning. Now since the legs are instruments of locomotion, just as the hands are prehensile instruments, and since the legs are not simply instruments of locomotion, but of locomotion that is spe- [I, 135] cially suitable for an intelligent animal (it was with this in view that I explained in the discussion just concluded what the proper number of legs is), it would be logical to show that all their parts are so constructed as to be most suitable for a reasoning, two-footed animal. Would it be better for him to have feet round and hard like those of the horse, or elongate, broad, soft, and divided into many

[14] Probably the Stargazer, *Uranoscopus scaber*, L; see Thompson (1947, *98–99*).

[15] *Republic*, VII, 529 (Plato [1920, I, *788–789*]). Galen does not quote exactly, but paraphrases.

toes, as they actually are? The first construction would, perhaps, be likely to make them swift and hard to injure, advantages not inherent in the second, which, however, is evidently suitable for walking over rough ground and even for climbing high walls, trees, or cliffs. Now if neither type of construction can confer both sets of advantages and it is absolutely necessary to choose between them, the first is clearly preferable for the horse and the second for man. For because the horse is a quadruped, he can go safely upon his four feet, although they are rounded; for a biped, however, such a construction would be extremely dangerous, unless you assume that his hoofs would be very large and broad as well as round. But such feet would be a useless burden and anything but instruments of swiftness; surely if feet are made round in order to be swift, they must also be small,
[I, 136] as in the horse. Similarly, the hardness [of foot] that is suitable to the horse for protection would be of no use to man, who can make himself sandals, and frequently it would even be a disadvantage. As it is, if anything is the matter with an old sandal, it is easy for a man to put on a new one in its place, but if his feet had natural sandals, like the solid hoofs of the horse or the cloven ones of the beef, he would have to go lame as soon as anything was wrong with them. Since these animals have no hands and no skills it was better for them to have feet protected in some way against injury, but since a man can find sandals for every situation and at times even needs to go barefoot, it was better for his feet to be entirely without covering.

5. I have said enough to show that it was better for the feet to be elongate and soft. Next I must show why they are as long and wide as they are, why they are slightly concave on the lower surface and convex above, and why they are divided into toes. Now, as I have said, the human leg is an instrument, not of simple locomotion, but of the kind of locomotion suitable for an intelligent animal, and we shall therefore keep our concept of the leg not absolutely simple, but complex. Hence I ought to tell first how locomotion takes place and
[I, 137] then how it is modified to make it suitable for man. Locomotion takes place when one leg is moved around the other which is supported on the ground.[16] Support is furnished by the foot, but the motion is the work of the whole leg, and so locomotion is accom-

[16] See Aristotle, *De incessu animalium*, cap. 12, 711a20–27, and pp. 675–676 *infra*.

plished by support and motion, and the foot is the instrument of one element and the whole leg of the other. This becomes very evident when we stand still without moving, for then the feet none the less furnish the support for which they were made, and even when we are walking and running, one foot is firmly placed on the ground while the other along with the whole leg is carried past it. Our ability to move from place to place depends on the leg that is being moved, for it is this leg that accomplishes change of position, but it is the foot supported on the ground that keeps us from falling. Indeed, how could it move an animal forward if it did not itself receive motion?

Two recent occurrences will sufficiently reinforce my argument: I am referring to a disease of the feet which has afflicted many persons,[17] and to the acts of a cruel pirate near Coracesium in Pamphylia. The disease caused putrefaction of the feet and the pirate chopped them off, so that in both cases the sufferers could not walk without canes, which did not, of course, help them move their legs, but clearly furnished the support hitherto received from their feet. [I, 138] They could indeed stand, supported by their two mutilated feet, but they could not walk, since they would have to entrust the whole weight of the body to one mutilated member. I have seen certain other cases in which only the toes were lost as a result of frostbite, and these persons could stand, walk, and run, at least on smooth, level ground, as well as those whose feet were whole. If, however, they had to traverse rough ground, particularly if it was precipitous, they not only fell behind, but were entirely helpless and unable to compete. Those who have lost by putrefaction not only their toes

[17] Daremberg (in Galen [1854, I, *231*]), relying on Haeser (1839, I, *62–83*), suggests that this disease was the Antonine plague or plague of Galen, which raged throughout the Roman Empire between the years 165 and 180. Galen himself makes several references to it in his works, but nowhere includes gangrene of the feet among the symptoms he describes. He says once (*De simplicium medicamentorum temperamentis ac facultatibrus*, IX, 1 [Kühn, XII, *191*]), however, that it closely resembled the Athenian plague described by Thucydides, and Thucydides in Book II, section 50, of his history of the Peloponnesian War (Thucydides [1951, *111*]) says that many who survived lost their toes. But this seems evidence much too slender for identification. For an excellent presentation and review of all that is known of the Antonine plague, including the citations from Galen, see Gilliam (1961).

but also that part of the foot proximal to the toes, called the *pedion* [metatarsus],[18] find it difficult to walk not only on rough ground but also on a level plain. If the part called the tarsus, proximal to the *pedion*, is destroyed, to walk with safety and even to stand firmly will be equally impossible. From all these examples it is clear that feet must be broad and elongate to give steady support, and that this is the reason why such feet have been provided for man who, more than quadrupeds, needs stability in locomotion.

This provision was made for him only because he is biped, not at all, of course, because he is intelligent; it is on account of his intelligence, however, that he has been given the versatility of support proper for those who must walk in difficult places. This he could not
[I, 139] do if the joints in his feet were not of many different shapes. For just as I have shown earlier that the hands can clasp conveniently objects of every shape because of the variety of their articulations and the concavity of their inner surfaces,[19] so also the feet can stand firmly in every sort of place because, in an imitation as close as possible of the hands, they have articulations of many different shapes and are concave in those parts which must fit over the convexities of the ground. Here indeed is that extra feature in the construction of the human leg, the feature I was anxious to find earlier, when I said that

[18] I have transliterated and kept Galen's name (*πεδίον*, primary meaning, a plain) for this part of the foot, since there is no Greek word *μετατάρσιον* to correspond to *μετακάρπιον*, a term which Galen has used freely for the metacarpus. In another treatise, *Hippocratis de articulis liber et Galeni in eum commentarii*, III, 92 (Kühn, XVIII, pt. 1, *613*, *615*), he equates *πεδίον* with *στῆθος*, meaning breast, breastbone, heel of the hand, or ball of the foot.

For a discussion of the metaphorical and etymological meaning of *πεδίον*, see Michler (1961), who points out that when Galen defines it, as he does a few pages farther on, as the part of the foot in contact with the flat ground, he is probably fabricating a false etymology. In Michler's opinion, *πεδίον* may have been applied to this part of the foot because it means a furrowed field (the furrows being the troughs between the tendons of the metatarsus), or because it has been confused with *πέδιον*, the diminutive of *πέδη* or *πέζα*, the latter being the Hippocratic term for foot.

[19] *Vide supra*, pp. 72–73, 131–133. For the concavity of the foot, of which much will be heard in the next few pages, see also Galen, *Hippocratis de articulis liber et Galeni in eum commentarii*, III, 92 (Kühn, XVIII, pt. 1, *613*).

Nature has given man feet suitable not only for an animal that walks, but also for one that reasons. One might define this feature in one brief sentence by saying that it is the division of the feet into toes, together with the concavity of the middle part [of the soles]. There would be no better way for you to learn how effective this concavity is in providing stability on convex surfaces than to watch a man going up a long, slender ladder; for he fits the hollow of his foot over the convexity of the rungs of the ladder and then bends down his toes and heel on either side, curving the entire sole as much as possible, and making it grasp the object beneath it like a hand. I seem now to have established by another line of reasoning the same thing I demonstrated at the beginning; for I showed a little earlier that the [I, 140] feet were made to give firm support, and that for this purpose long, soft, broad feet would be best. The present discussion, in demonstrating that the human foot can give adequate support in all sorts of places and adding that this follows necessarily from its construction, is not establishing a different point but rather the same one I made at first.

Then what is there left to say? [I must still show] that there is one unifying principle to account for the construction of the feet, which from the present discussion seems to consist of two elements. I have said that there was good reason for dividing man's foot [into toes] and forming a hollow in the middle parts, to enable him to walk in all sorts of places by fitting the concavity over the convexities beneath his feet, as I have said just now, and, I should add, by using the toes particularly in places that are precipitous, oblique, or sloping. Of all these arrangements, what, then, is the cause that should be expressed as one unifying principle? Compelled by the nature of the case, I mentioned it a little earlier in my discourse when I said that the human foot imitates the hand as closely as possible. Certainly if this is true and the hand is an instrument of prehension, the foot must somehow be prehensile too, though in a different way. It is not true of the horse's foot, however, which had been entirely deprived of any ability to grasp; for the horse's foot was not made to provide the diversity of movement necessary for a reasoning animal, but to give him nimble swiftness and agility. The feet of the lion, wolf, and [I, 141] dog have a structure midway between the two extremes, being neither solidly in one piece like those of the horse, nor jointed in many different ways like the human foot. They use them like hands

for hunting and feeding, but find them quite useless for the many other actions that man performs.

6. Here again my discourse is compelled by the facts themselves to compare feet divided [into toes] to hands. Let us, moreover, accept as a starting point and elementary principle, so to speak, of all that I am to say next that it is absolutely necessary for the human foot to be made not merely for simple support like the foot of the horse, but for prehension also, and that it is impossible for both purposes to be fully realized in the same structure; for then the feet would become either hands or the feet of a horse. Now if they were hands, the great toe would have to be set opposite the other digits, as I have shown in the preceding book, and if it were, the ability to serve as a support would be entirely lost. But if human feet had been made very small, hard, round, and agile, like those of a horse, they would be completely ruined for prehension. Accordingly, since it was only possible to choose the advantages conferred by one arrangement and avoid its objectionable features, Nature has divided human feet into digits and given them many joints like hands, but
[I, 142] instead of setting the great toe opposite the others, she placed them all in one row.

Is this, then, the only difference in construction between the feet and hands? Or is there also something else, more remarkable, in the structure of the feet, which they possess because they are instruments of locomotion? There is indeed a feature, neither unimportant nor fortuitous, which is common to all feet with the exception of the feet of the horse,[20] because horses' feet are not made like hands in any respect. It is present to a different degree in different animals but is very prominent in those whose feet have a decided resemblance in structure to the hand.[21] In man the resemblance is complete in every particular: there is a part called the tarsus corresponding to the carpus, and to the metacarpus, a part called the *pedion* [metatarsus] by modern physicians; there is also considerable similarity between the fingers themselves and the toes. These three parts of the foot, then, the digits, *pedion*, and tarsus, are the ones that correspond to similar parts in the hand, and none of them is found in the horse.

[20] Reading *οὐ γενόμενον* with Helmreich for the *γενόμενον μόνον* of Kühn's text.

[21] Accepting Helmreich's emendation, *πάντως*, for the *πάντων* of Kühn's text.

The part of the foot directly underneath the shank of the leg, the part in a straight line with the whole limb resting upon it, is present in all feet, but does not have a single name, as the tarsus and *pedion* have. It is composed of three bones, each of which is named: the ankle bone [*astragalus, os tali*] and heel [*calcaneus, os calcis*] (these are names used by laymen) and the navicular [*os naviculare pedis*], a name used by physicians skilled in anatomy. These bones alone have no corresponding parts in the hand and are simply instruments made for support alone.[22] All the other parts are instruments of support and prehension as well. Indeed, the tarsus and *pedion* are neither of them one simple part, but, like the carpus and metacarpus, they are each composed of several small, hard bones. [I, 143]

7. Now let us do for the foot the same thing we have done for the hand, namely, describe each simple part of it, telling its size, shape, and something of its position; let us tell also how many parts there are and how they are placed in relation to one another. Likewise we should discuss their softness or hardness, their looseness or density of texture, and any other of the qualities inherent in bodies that they may have, explaining the usefulness in every instance and showing that no other construction could possibly be better. This makes as long a treatise as the discussion of the hand, but the similarity of their structure has shortened it; for the parts of the foot which it has because it is a prehensile instrument and which are formed like the hand should be referred to what I have said about the hand, but the parts it has as an instrument of locomotion must be explained here in detail.

It is characteristic of the foot as a prehensile instrument that it is composed of many bones of different shapes, articulating with one another by means of various joints and held together by membranous ligaments. For the same reason it also has five digits and the same number of joints in each one as the hand, but the position of the digits all in one row has a different explanation, being character- [I, 144]

[22] The tarsus in the modern view of course includes the calcaneus, talus, and navicular, and not merely the cuboid and cuneiforms, as in Galen's scheme. One may suspect that he too might have included the three larger bones if he had not felt it necessary to find in the foot because of its double function (support as well as prehension) some part not corresponding to a similar part in the hand with its single function of prehension.

istic of the foot as an instrument of support. Similarly, this use of the foot also explains why the toes are shorter than the fingers. For the larger size of the fingers is suitable to an instrument that is purely prehensile, but since the foot is prehensile only in order that it may be an instrument of locomotion in every sort of place, the toes are long enough as they are. Now the inner [medial] side of the foot is arched and the outer [lateral] flat to enable it to act at one and the same time as a prehensile instrument in clasping and fitting itself over the convexities of the ground and as an instrument of support. Since in walking one leg is in motion and the other presses against the ground and supports the whole weight of the body, there is a good reason for Nature to have made the support on the inner side more elevated. For if one side of the foot were exactly like the other, first, the foot itself most markedly and then the whole leg with it would bend over toward the foot that was off the ground, and it is clear that if this happened we should be likely to fall when we walk. Hence it is to provide stability that the inner side of the foot has been arched. Certainly those who lack this elevation are easily thrown when they wrestle and [fall when they] run, sometimes even when they walk, in uneven places. You will feel still greater confidence in this reasoning as you read further in this book, but for
[I, 145] the present what I have said is sufficient. Indeed, it is obvious that there was good reason for the foot to be raised and arched on the inner side to give both steady support and exact prehension.

You will not, then, inquire further either why the anterior part of the calcaneus is comparatively thin and narrow or why it seems to withdraw somewhat toward the little toe's side of the foot.[23] For if it were thick and broad as it is at the back and remained uniformly so as it extended forward, how could a hollow be formed on the inner side of the foot? Hence Nature has acted with good reason here in removing much of its thickness and breadth from the inner side of the bone, and on this account it appears to be prolonged on the little toe's side. And again, for the same reason, the talus seems to turn more toward the inner side although at the rear it rests on the middle of the calcaneus. But because the latter grows increasingly narrow toward its anterior end and it seems to withdraw from the inner toward the outer side of the foot, the talus with reason appears to be

[23] To form the concavity of the medial surface of the calcaneus.

placed on the inner side of it and to overhang it, so to speak. And how better could a concavity be formed on the inner side of the foot than by making the bone beneath grow smaller and narrower on the inner side while the bone lying above it maintains its original size? Indeed, the calcaneus must always be firmly planted on the ground since it bears the weight of the whole member, whereas the bone lying above it must be raised off the ground. For the same reason the bones adjoining the calcaneus and talus are similarly arranged. [I, 146] The one called the cuboid, which is adjacent to the calcaneus, lies on the outer side of the foot and is in firm contact with the ground, and the bone called the navicular, adjacent to the talus and lying on the inner side of the foot, is elevated like the talus itself and lifted free of the ground. So too the three bones of the tarsus [*ossa cuneiformia, mediale, intermedium,* and *laterale*] that are adjacent to the navicular also appear elevated in the same way and lie on the inner side of the foot. For beside these, on the outer side of the foot and low down in contact with the ground, lies the cuboid bone, which I have said articulates with the calcaneus itself. Thus the usefulness of the first seven bones of the foot is already evident.

8. There are good reasons why the calcaneus is very large, smooth on its lower surface, rounded above and at the rear, and elongated on the outer side of the foot. It is very large because it directly underlies the whole member; its lower surface is smooth to give firm support; its other parts are rounded to protect it from injury; and it is elongated on its outer side (that is, on the little toe's side of the foot) and becomes gradually thinner in order to form the concavity on the inner side of the foot. For the same reason the talus does not become thinner; it also remains elevated, off the ground, and is jointed to the elevated navicular to form a vaultlike figure in that region. Next in order after these come the bones of the tarsus, three of them [*ossa cuneiformia*] attached to the navicular and the fourth [*os cuboideum*] to the calcaneus. This fourth one is solidly in [I, 147] contact with the ground on the outer side of the foot, as I have said; the other three become gradually more elevated; and this bone [24] is

[24] There is nothing to indicate whether Galen means by "this bone" the first cuneiform, as seems likely. Daremberg (in Galen [1854, I, *239*]) interprets it as the navicular, but from the following clause it seems that the bone in question should be one of the four making up the tarsus according to Galen.

the highest of all so that this part [25] called the tarsus may have bones to support it and that at the same time the inner side of the foot may be raised off the ground. Next after the talus, the navicular, and the three bones attached to the navicular [26] come the bones of the *pedion,* which are in contact with the ground (and this is the reason why anatomists have named this part of the foot *pedion*).

Then come the toes. The one on the inner side of the foot is the largest, though not composed of three phalanges like the others but of two; for since the inner side of the foot must be elevated and concave like a vault, it was reasonable that at both ends it should have the firm support of the largest bones. At the hinder end there was already the calcaneus, but if the great toe at the front end had not been made much larger than the others and if it had not been composed of only two phalanges, there would have been no security for the bones that are elevated. In the first place, therefore, the difference in size between the great toe and the other toes in the foot is not the same as that between the thumb and the other fingers in the hand but much larger, and in the second place, the great toe is not composed of three bones like the thumb and all the other digits, but of two. For inasmuch as Nature, I suppose, needed larger bones in that situation, she avoided dividing the great toe into many small
[I, 148] parts. Moreover, this same part of the *pedion* which is proximal to the great toe is seen to be reinforced by two bones [*ossa sesamoidea*] like certain props or foundations, which serve to bind the first bone of the great toe to this part of the *pedion,* already firmly supported on the ground; for, as I believe, Nature has provided safety in every way for this part of the foot because it must be under especially great strain on account of the concavity or vault, so to speak, of the bones lying proximal to it.

This would be the right place to tell how [27] the *pedion* is analogous to the metacarpus and whether they differ in any respect. It seems to me that they do not [28] correspond in every particular. Obviously in both parts there is a bone proximal to the first phalanx

[25] Helmreich: στηρίζοιτο τοῦτο τὸ μέρος. Kühn: ἰσχυρίζοιτο τὸ μέλος.

[26] One would expect the cuboid to have been included in the list.

[27] Reading πῇ with Helmreich for the ἓἰ of Kühn's text.

[28] Helmreich omits μή, inadvertently, I think, since his critical apparatus does not indicate any manuscript support for the omission and the sense requires a negative.

of each digit, but since in the foot all the digits lie in one row, the number of them properly equals the number of bones in the *pedion*, whereas in the hand the metacarpus is properly composed of four bones because the thumb has been provided with a special position, being separated as much as possible from the other fingers and being led off near the carpal joint. Now when Eudemus,[29] thinking it necessary to preserve an exact correspondence, said that the *pedion* and metacarpus are both similarly composed of five bones and that the great toe in the foot and the thumb in the hand have each two phalanges, he was ignoring the facts; for in the hand the thumb is clearly composed of three bones, as their articulations and move- [I, 149] ments make manifest. And yet the correspondence of these parts as they are constructed is clear without the necessity of our falling into error as Eudemus has done.

Certainly it is not hard to see the resemblance in construction between the carpus and tarsus. The tarsus is composed of four bones and the carpus of double that number, since it is arranged in two rows; for it is characteristic of prehensile instruments to be made up of a large number of small parts, whereas instruments of locomotion have larger parts and fewer of them. The parts toward the front of the foot are exactly like prehensile instruments, and so they have the same number of bones as the corresponding parts of the hand, since the one bone that is subtracted from the great toe is added to the *pedion* and the total number is thus kept the same. But because the parts at the back of the foot are instruments of locomotion only, there are no parts in the hand corresponding to them. The tarsus, the remaining part of the foot, midway between the ends, is neither exactly like nor entirely unlike [either kind of instrument], for it has been constructed in the only way suitable for a part lying between two extremes and partaking in due measure of the nature of both. The bone called the cuboid, situated on the outer side of the tarsus, articulates with the concavity at the end of the calcaneus. The other three bones [*ossa cuneiformia*] are fitted to three facets[30] on the navicular, and the navicular itself clasps in its turn the head of the

[29] For Eudemus of Alexandria, a younger contemporary of Herophilus and Erasistratus, see Sarton (1927, I, *160*) and my Introduction, pp. 28–29.

[30] Facets = κύβοις meaning cubes, dice, spots on the dice, hollows above the hips of cattle, etc.

talus. The talus, again, lies between the epiphyses of the tibia and
[I, 150] fibula and is clasped by them above, at the sides, and at the back too; it rests upon the calcaneus and is firmly settled there by means of two protuberances which fit into two concavities on the calcaneus.

The work of extending and flexing the foot is accomplished by the articulation which I have said the upper part of the talus makes with the epiphyses of the tibia and fibula, but the articulation of the talus with the navicular is the source of the lateral movements. The other juxtapositions of the bones in the foot, like the many small articulations in the hand, give some slight assistance to the joints I have mentioned [talus with the tibia and fibula, talus with the navicular] but independently have no perceptible effects. Hence from these considerations the talus seems to be the most important of the bones concerned with moving the foot and the calcaneus to be the most important of those that furnish support. Consequently, it is fitting that the former should be bounded by round surfaces and the latter should be smooth underneath, as nearly motionless as possible, and firm and steady to support the bones in its vicinity. Moreover, the calcaneus ought to be much larger than the other bones, larger even than the talus itself. And yet the talus too is a large bone because it articulates with the very large bones above it and forms an ample apophysis at its anterior end where it adjoins the navicular, but the calcaneus is nevertheless much larger, for it projects to the rear not only beyond the talus but also beyond the tibia itself, and it
[I, 151] extends far forward. Its breadth is proportional to its length, and its thickness to both the other dimensions. It lies directly below the axis of the leg and carries nearly all the weight of it alone; through the leg it supports the thigh and, through the thigh, the body above, especially when we have occasion to leap or take a long stride forward. It is for these reasons, then, that the calcaneus must be of considerable size, for otherwise Nature could not properly have entrusted such heavy burdens to it.

For the same reason it was better to locate [31] it in such a way that it would be steady and not uncertain and likely to slip. Now if it articulated with the tibia and fibula without the intervention of the talus, it would be extremely loose and unsteady; for at the point where the member proximal to the foot comes to an end and the

[31] Reading *θέσιν* with Helmreich for the *ἔνθεσιν* of Kühn's text.

foot [itself] begins, there must necessarily be the most important of all the articulations in the foot and the freest motion. This is the reason why the talus has been placed between the tibia and the calcaneus.[22] The calcaneus, however, must be closely connected with the talus, and Nature was also careful not to allow the stability of its situation to be in any way impaired because of the rather vigorous motion it enjoys by reason of its nearness to the talus. She therefore first inserted the two apophyses of the talus firmly into the concavities of the calcaneus, as I have already said, and then with numerous hard, cartilaginous ligaments, some broad and some round, she bound the calcaneus not only to the talus but also to all the other bones in its vicinity, to the best of her ability arranging the ligaments to preserve a suitable stability. Moreover, knowing as she did that [I, 152] the calcaneus has much work to do in every situation, Nature made its characteristic substance extremely hard and stretched beneath it hard skin very well suited to soften and deaden all the blows of hard bodies striking against it.

Since, as I have said, the parts on the outer side of the foot must be flat on the ground and the parts on the inner side elevated, and since there was danger of making the foot too heavy if the elevation was secured through many large bones, Nature formed the concavity at the middle of the inner side, and in constructing it so she provided another advantage for the foot as a prehensile instrument, an advantage I have previously mentioned as contributing greatly to firmness of support on the convexities of the ground. This concavity, then, was obviously formed to gain three ends: first, to make the elevation on the inner side of the foot; second, for prehension; and third, to lighten the foot. The first of the three gives firmness of support, the second, versatility in walking, and the third, swiftness of movement.

Let us refer here once more to the foot of the ape. Now the ape's hand presents a laughable copy of the human hand because only the thumb is distorted, but its foot does not differ from the human foot by being defective in the construction of any one part; on the contrary, there are a great many points of difference. The toes are very widely separated from one another and are much larger than [I, 153] the fingers of the hand. The toe that we should expect to be the largest of all is the smallest, and there is nothing that supports the

[22] Reading *πτέρνης* with Kühn for the *περόνης* of Helmreich's text.

pedion in the parts proximal to this toe. Indeed, the *pedion* is not at all firmly supported but has instead a hollow like the hollow of the hand. The legs do not lie exactly in line with the spine as they do in man, and the bend at the knee too is different. The ape also lacks entirely the flesh at the back of the hips which in man covers and conceals the passage for the discharge of excrement and which is formed as an excellent protection against the objects beneath him when he sits supported by his hips. As a result, the ape can neither sit properly, nor stand erect, nor even run. Like the mouse, he climbs with great rapidity up smooth, perpendicular places, because his feet are hollowed and his toes are widely separated. For such a construction, enabling the foot easily to wrap itself around all convex bodies and grasp them firmly on all sides, is very suitable for an animal formed by Nature for climbing to high places.[33]

9. I have said enough about the bones in the foot and I will speak a little later about the tendons and muscles. First, however, I intend to discuss the remaining bones in the whole leg, because they too
[I, 154] contribute to the work I have already been discussing. There is a single bone in the thigh (*μηρός*, femur, thigh), just as there is in the upper arm, and two in the leg analogous to those in the forearm. The larger of the two [the tibia] is called by the same name as the whole member (*κνήμη*) and the smaller one is the fibula (*περόνη*). The femur has with good reason been made the largest of all the bones in the body, for it is fitted directly into the acetabulum and is the first bone to sustain the whole weight of the body above it.

Nature has prepared an excellent support for the head of the femur in the cavity [the acetabulum] of the bone called the hip bone, but it obviously does not extend straight out from this cavity, and if one gives it only a hasty examination, it seems actually malformed, since its front and outer sides are convex and the other sides are concave. Hippocrates[34] too knew this form and advises that

[33] Cf. Galen, *De anat. admin.*, II, 8 (Kühn, II, *322–323;* Galen [1956, *51*]). Galen is forced here to abandon one of two ideas, both of which he has cherished, namely, that the ape has a ridiculous body because it has a ridiculous soul and that Nature has formed every animal in the best possible way in view of the actions it must perform. He has wisely chosen to abide by the second, since it is the central theme of his work.

[34] *De fracturis,* cap. 20 (Littré, III, *484–487*); cf. Galen, *Hippocratis de fracturis liber et Galeni in eum commentarius,* II, 69 (Kühn, XVIII, pt. 2, *517–519*), and see Daremberg (in Galen [1854, I, *244*]).

when a fracture of the femur is reduced, its shape should be preserved and the bone should not be straightened. Persons whose femurs are naturally straighter than they should be are decidedly knock-kneed.[35] Hippocrates also tells somewhere [36] how very inconvenient this condition is not only for running but even for walking and standing firmly, but I suppose this is daily self-evident to all who happen to get a good look at such a person. Now if the neck of the femur close to the acetabulum were not directed obliquely outward as it emerges, it would be too near the neck of the other femur, and [I, 155] if so, what space would be left for the muscles on the inner side of the thigh, muscles which must necessarily be very large? What space would there be for the nerves from the spinal cord that are distributed to the whole leg, or for the veins and arteries, or for the glands that fill up the places where the vessels divide? [37] For certainly we should not say that these vessels ought to go down the outer side of the thigh where they would be exposed and easily injured by every blow falling upon them. Probably even we ourselves, not to mention Nature, would have been conscious of error here if we had located in a place where they were liable to be injured veins so large that when one of them is damaged, the animal can scarcely survive. If it is one of the important arteries in this region that is damaged, the animal's life can by no means be saved. Hence, if space must be provided there for many large nerves, veins, arteries, glands, and muscles, the femur had to be inclined toward the outside as it leaves the acetabulum. It is indeed so directed, and its outer parts obviously project beyond the general line of the side of the body. If the neck joining the femur to its head [38] is directed less sharply to the side in certain individuals, the parts at the groin are narrowed and compressed, and as a result the whole thigh and the knee too are forced to bend outward.

Why, then, did Nature not place the acetabulum farther to the side where the convexity [tuberosity] of the femur is now? For if she had done so, she would have placed the neck of the femur below

[35] Literally, "crooked at the knee." Daremberg (in Galen [1854, I, *244*]) translated freely, "ont les genoux tout à fait en dehors." The distortion, however, would be inward, not outward.

[36] *De articulis*, cap. 53 (Littré, IV, *232–235*).

[37] Reading *σχίσεις* with Helmreich for the *χώρας* of Kühn's text.

[38] Literally, "the neck of the head of the femur."

[I, 156] the acetabulum in a straight line with its head and made the femur straight. The reason is that the weight of the body must fall in a vertical, straight line through the acetabulum and the head of the femur, especially when in walking and running we raise one foot and move it past the other which is supported on the ground. This result is best obtained by supporting at its center the member that carries the weight, and if such a position of the leg is safest for us when we walk, it is clear that the other position would be very dangerous. For these reasons it would not be safe to move the acetabulum and with it the head of the femur to the outer part of the ischium; the present arrangement is best. And again, if the space for the parts thus became too narrow, there remained one remedy, namely, not to extend the femur in a straight line with its head, but to make it slant toward the outside, as it actually does. If, however, this inclination toward the outside were continued unchanged as far as the knee and there were no turn back toward the inside, another sort of distortion of the leg would be the result.[39] And so there is good reason why first the neck turns most sharply toward the outside as it leaves the head; why the upper half of the whole femur is then also inclined outward; and why its lower portion turns back to the inside toward the knee.[40] This makes the shape of the femur as a whole convex on its outer side and concave on the inner side. It is likewise concave posteriorly and convex anteriorly, a shape that
[I, 157] makes it easy for us to sit down and do whatever work we perform seated, such as writing with the book spread out on our laps. So too all other objects are spread out on the convexity of the thighs more conveniently than they would be if the femur had a different shape. Furthermore, when we support the weight of the body on one leg—and we know that this position is frequently useful in our daily life and in the practice of the arts—it is better for the femur to be bent than straight. For if the members that support a body were as

[39] That is, the person would be bowlegged.

[40] Vesalius (*1555, 164*) describes the femur without any such simian bend and is taken to task for it by Jacobus Sylvius (*1555*), who ascribes the greater straightness of the bone in their day to the use of swaddling clothes and the weaker condition of the human body. Otherwise, according to him, the femur would have exactly the shape described by Galen.

wide as the parts of the body they support, the position of the body when it rested on either of the supporting members would be very firm and hard to upset, since each part of the body above would have something directly underneath to support it; in the same way, because the femur is curved, with some of its parts located at the outer side of the body, others more toward the center, and still others midway between the two, there is no part in the body above that lacks direct support. It was, therefore, to gain this advantage that Nature made not only the femur but also the tibia more convex on its outer side. The best proof of what I have said lies in the fact that individuals whose legs are bowed too much (formed so in some cases before birth and in others as a result of early training) support themselves on both feet or on either one alone much more firmly and with less danger of falling than those whose legs are straight. But Nature was not aiming solely at firm support when she made the legs, but was just as anxious that we should be able to run swiftly when the need arose. Hence, whereas she was careful not to bend [I, 158] the legs too much, she did curve them sufficiently to give firm support without impairing the ability to run swiftly. Since it was reasonable, as I have shown above, that the upper part of the tibia immediately below the knee should curve slightly outward and the lower part near the ankle should turn inward again, it was also proper for the same reason to elevate the parts on the inner side of the foot, in order, of course, to balance the inward curvature of the tibia in that region. When a little while ago I was explaining the usefulness of the parts on the inner side of the foot, this was the point I kept for discussion later on. There is, then, nothing still left to account for in the bones of the leg; their size, whether large or small, their position, shape, and arrangement, their varying degrees of hardness, and the rounded and circular ligaments binding them together—all bear most convincing witness to the providence and skill of Nature. I have yet, however, to speak of the muscles and tendons. The arteries, veins, and nerves[41] I have said that I will explain near the end of the whole work,[42] because they are instruments common to the entire body and because a common usefulness

[41] Kühn's text omits *νεύρων*, but the Latin translation has *nervorum* in italics.

[42] In Book XVI.

has been entrusted to them; for of course it is useful to cool and nourish all the members, and to provide them with the psychic faculty.

10. I must now speak of the movements of the legs, describing the
[I, 159] many different kinds they obviously have, and showing that it was better for these movements to be neither more nor less numerous and no differently ordered than they are. At the same time I should remind you of the movements of the arms and mention that Nature had two aims in constructing our legs, that is, she did not create them only to be swift, as she did for the horse, but to furnish firm support as well, and so she made them somewhat prehensile, like the arms. Thus, my discussion of this whole matter will come more quickly to a successful conclusion if I merely indicate the features that are common to both legs and arms and, passing over these lightly, dwell rather on what is peculiar to the legs. So too, the skill of Nature will appear more clearly if I examine carefully every analogy in the construction of the two members and show that there is nothing lacking or in excess in either of them. And yet I have fully explained the upper limbs in the preceding book, and whoever has not marveled at Nature's skill is witless or has some private interest at stake. (This would be a good place to quote that saying of Thucydides.)[42] Certainly he is a witless person who does not understand the actions which it was best to assign to the hands, or who supposes that they would be better performed if the hands were constructed differently; and a person has some private interest at stake if he is quick to adopt worthless doctrines which prevent him from agreeing that Nature has done everything with skill. But we
[I, 160] should pity those so unfortunate as to have had from the beginning a wrong understanding of these most important matters and should teach those who are intelligent and love the truth.

First I shall remind them of what I have demonstrated in the construction of the hands, namely, that each finger must have four

[42] In Book III, section 42, of his history of the Peloponnesian War. Diodotus is speaking: "As for the argument that speech ought not to be the exponent of action, the man who uses it must be either senseless or interested: senseless if he believes it possible to treat of the uncertain future through any other medium; interested if wishing to carry a disgraceful measure and doubting his ability to speak well in a bad cause, he thinks to frighten opponents and hearers by well-aimed calumny" (translation by Crawley [1951, *168*]).

movements, being flexed by two very large tendons [of *flexores digitorum, superficialis* and *profundus*], extended by a single one [of *extensor digitorum communis*] smaller than the flexors, moved outward in the direction of the little finger by a still smaller one [of *extensor digiti proprius*], and finally turned inward in the direction of the thumb by the smallest tendon of all which I have said arises from one of the small muscles of the hand [*lumbricalis*]. Then I shall point out that in the feet, as we might expect, each toe has these same four movements, being flexed by the largest tendons, turned inward [toward the great toe] by the smallest, and extended and turned outward [toward the little toe] by tendons intermediate in size.

But the flexor tendons are not so large as the flexors in the hand because it was not necessary for the foot to be made an instrument of prehension to the same degree, and so I shall show how Nature for reasons which I made clear when I was discussing the hand kept the insertions of the tendons the same, but limited their size. For although the feet are larger than the hands, there is not the same difference in the size of their respective tendons; those of the feet are much smaller, because the fingers are used far more and must perform more vigorous actions more frequently [than the toes]. Hence [I, 161] it is reasonable that in the feet and the hands the size of the digits and also of the tendons should be in inverse proportion [to the size of the members], that is, the whole foot exceeds the whole hand in size by as much as the fingers and the tendons of the hand exceed those of the foot. In the hands the principal actions are performed by the fingers because they are prehensile instruments, but since the feet were constructed not entirely for prehension but for firm support as well and since they must sustain the weight of the whole animal, it was better for them to be much larger than the hands, but to have small digits. Consequently, it was also better for the tendons of the feet to be much smaller than those of the hands, inasmuch as they were to move smaller instruments, constructed to control fewer and weaker actions. Hence there was no good reason why all four kinds of the tendons moving the toes should arise from muscles in the leg, as those in the hand arise from muscles in the forearm;[44] only two

[44] Here Galen ignores the lumbricales and interossei of the hand, only to mention them specifically later, the lumbricales almost at once and the interossei a little farther on.

kinds originate there, the one by which the toes are extended [*extensor digitorum longus* and *extensor hallucis longus*] and the one by which the first and third joints of the four [lesser] toes are flexed [*flexor digitorum longus* and *flexor hallucis longus*].[45]

We should especially admire the skill of Nature in her dealings with the hands and feet, for since she found in them both likeness and unlikeness, she arranged the likenesses analogously, but the
[I, 162] unlikenesses in ways that are not analogous. Now when the articulations of the digits must each have four movements and when inward motion [flexion] must always be the greatest and therefore have two sources, in this respect there is similarity between the foot and hand. But when all the tendons for the toes must be smaller and when the parts of the foot are larger and more numerous, this constitutes a certain dissimilarity in the members. I must indeed tell how justly Nature has arranged these matters. She has given each articulation four movements and provided five tendons to control them, just as she did in the hand, but these tendons do not all originate from analogous places. For in the hand, as I have shown, the tendons controlling lateral movement inward [toward the thumb] are the only ones derived from small muscles [*lumbricales*] in the hand itself; all the others come down from the forearm. But this is not so in the foot, where three tendons [of *flexor digitorum brevis*, *extensor digitorum brevis*, and *lumbricales*] originate in the foot itself and two [of *extensor digitorum longus* and *flexor digitorum longus*] come down from the leg. In the hand there was no space available [for more than one set of tendons], but since the foot is elongate, Nature established the muscles [*lumbricales*] controlling the lateral movement inward [toward the great toe] in the region of the *pedion*, and in all the remainder of the foot, extending as far back as

[45] In the ape flexor hallucis longus is inserted not only into the great toe but also into the third and fourth toes, and flexor digitorum longus, which supplies the second and fifth toes, also sends off tendons to join those of flexor hallucis longus. Galen was aware of this and gives a good description in *De anat. admin.*, II, 7 (Kühn, II, *317–320*; Galen [1956, *48–50*]), but his treatment here in *De usu partium* suffers from his attempt to prove analogy with the hand and his desire to shorten his exposition of the foot and leg. In this particular passage he fails to include the flexing of the great toe in the movements originating up in the leg, but very soon he will make clear that he knew the distribution of the tendons of the two long flexors.

the calcaneus, she placed the muscles [*flexor digitorum brevis*] flexing the second joint of the four [lesser] toes. In the same way she placed on the upper side of the foot other muscles [*extensor digitorum brevis*] controlling the lateral movement outward [toward the little toe]. Now because in the hand the muscles analogous to these had to be larger, while the member itself was smaller, two sets of them could not be placed there, and only the first ones I mentioned are found. Hence there are in all seven muscles in the hand; besides the five that control the lateral movement inward [in the direction of the thumb] [the four *lumbricales* and *abductor pollicis brevis*], there are two additional muscles, the one on the outer side of the hand at the little finger [*abductor digiti minimi*] and the one that moves the thumb toward the forefinger [*adductor pollicis*]. But in the foot there are not only these seven but also the muscles that turn the toes outward [in the direction of the little toe (*extensor digitorum brevis*)] and those [*flexor digitorum brevis*] that flex the second joint of the four [lesser] toes. For the great toe is the only one of them all to receive from the larger tendons a branch [from *flexor digitorum longus*] that is inserted on both the second and third joints in an arrangement like that in the thumb.[46] In these ways, then, the tendons in the foot resemble, and differ from, those in the hand. They resemble them in that there are five sets of tendons in each, furnishing four movements to each digit, and they differ in respect to the origins of the tendons. For in the hand only the lateral movement inward is produced by muscles [*lumbricales*] in the hand itself; the other four sources are muscles up in the forearm. But in the foot two movements originate in the leg above, and three down in the foot itself. I have given the reason for this: these movements originated in the foot because they needed [only] small tendons and consequently small muscles, and because there was space available for them in the foot itself. [I, 163] [I, 164]

Moreover, the distribution of the tendons in the foot differs from that in the hand in this respect also: in the hand there is no tendon from any other muscle joining with those that bend the first and third joints of the fingers [*flexor digitorum profundus*], whereas in the foot the tendons analogous to these do not originate from a single muscle, but are interwoven and united with one another like

[46] See chapter 17 and note 44 of Book I. Again this remark is based on conditions in the ape. See Howell and Straus (1933, 170).

the nerves issuing from the spinal cord and distributed to the arm [branching and uniting of tendons from *flexor hallucis longus* and *flexor digitorum longus*]. The nerves issuing from the spinal cord in the lumbar region and destined for the legs behave in almost the same way. Nature makes this arrangement in order that the source of the motion for instruments moved in this way may be doubled, as it were, so that if one source is injured the other at least may still be serviceable. Hence wherever the distance to be traversed is considerable or the location is dangerous, she contrives such an interlacement. Now in both the arm and leg there is a remarkably long interval between the source of the nerves and their termination, but the sole of the foot is an especially dangerous location; for the animal always walks on it and as a result the tendons there are more liable to be cut, bruised, or injured in all kinds of ways than those
[I, 165] analogous to them in the hand. This is the reason why in this location Nature has arranged for the tendons the interlacement I have described.

The extremely small muscles [*interossei*], which have been overlooked by other anatomists and by me too for a long time, flex the first joints of the digits in the feet just as they do in the hands. We should admire Nature for [all] these things;[47] we should also admire her all the more because she has not inserted any oblique muscle from the tibia into the fibula in an analogy with those that connect the ulna and radius in the arm [*pronatores*, *teres* and *quadratus*, and *supinator*]. For in the arm, as I have shown earlier, it was desirable not only to extend and flex the whole member, but also to rotate it in both directions; but since Nature's aim in constructing the legs was not diversity of movement in prehension but firmness of support, there would have been no advantage to be gained from such movements of rotation, which would besides detract somewhat from their stability. Fewer joints and simpler movements were necessary for a member that was not meant to be rotated in either direction in any vigorous action. Hence Nature has not made at the knee two articulations with the femur, one for the tibia and a separate one for the fibula, as she did in the arm, where the ulna and radius have each its own articulation with the humerus, and instead of separating the tibia from the fibula at their extremities, she bound them together at both places. For it would be extravagant in Nature to prepare for a

[47] Reading *τούτων* with Helmreich for the *τούτου* of Kühn's ext.

member movements that it did not need and articulations and muscles to produce them, just as she would be careless if she omitted any that were necessary. But she has omitted nothing in either member, nor has she indulged in vain and useless superfluities; on the contrary, everything, even the number of the muscles, bears witness to her most provident care for the animal. [I, 166]

Now I have said earlier [48] that the muscles of the forearm ought not to be either more or less numerous, or larger or smaller, or differently situated than they are. In the leg there are the heads of thirteen tendons, six at the back and seven in front, and these provide the foot with all its proper movements. If we disregard the motion of the toes, there are four movements belonging to the foot as a whole, just as there are for the wrist, and to avoid a long treatment of this subject you should recall what I have said about the wrist and notice the analogy existing between this member and the foot.[49] For just as the four movements of the wrist are produced by two aponeuroses of muscles [tendons] inserted on the inner side and two on the outer side of it, so in the leg the muscle lying at the front of the tibia [*tibialis anterior* with *abductor hallucis longus*] [50] gives rise to a rather stout tendon, which divides into two parts and is inserted into the foot in the region proximal to the great toe, and a tendon from the muscle [*peroneus brevis*] lying along [51] the fibula is inserted into the region proximal to the little toe. When both of these tendons are tensed, they raise and bend up the foot, just as I have said the tendons [of *extensor carpi ulnaris* and carpal component of *abductor pollicis longus*] analogous to them in the arm

[48] See chapter 1 of Book II.

[49] For the corresponding treatment of the wrist, see chapter 4 of Book II.

[50] In the ape, "the muscle belly [of tibialis anterior] soon splits into longitudinal halves. The more robust medial half gives rise to a well-developed tendon that passes beneath the transverse crural ligament and inserts upon the medial and plantar aspects of cuneiforme I. The lateral half produces a smaller tendon that accompanies the tendon of the medial belly for most of its course, and inserts upon the medial plantar surface of the base of the hallucal metatarsal. The latter portion is sometimes termed a separate muscle, the m. abductor hallucis longus" (Howell and Straus [1933, *162–163*]).

[51] Reading παρατεταμένου with Helmreich for the περιτεταμένου of Kühn's text.

extend the wrist. When either one acts alone, lateral movement
[I, 167] results, as in the wrist. On the back of the leg, opposite to these tendons, Nature has set two other offshoots of muscles analogous to those in the arm [*flexores carpi, ulnaris* and *radialis*] and controlling the movements of the foot contrary to those I have just described. The smaller of the two arises from the deep-lying muscle [*tibialis posterior*] and is inserted into the lower part of the foot proximal to the great toe. The other, larger one is the conspicuous tendon that is inserted into the back of the calcaneus [*tendo calcaneus* (*Achillis*)]; it is very large and stout, and even when it is the only part of the foot to be injured, lameness is the inevitable result. The bone called the calcaneus, lying directly beneath the whole leg, is the largest and strongest of all the bones in the foot, and so this tendon in pulling on it gives such stability to the whole member that when you wish to stand on one foot with the other lifted, you do not lose your balance and fall, even if some one of the other tendons has been injured, so great is the power of this tendon and so well balanced against all the rest. And why should it not be powerful when it is inserted into the calcaneus, the first and most important instrument of locomotion, and when it is the only tendon that binds the calcaneus to the tibia? In position and in the action entrusted to it, this tendon is entirely analogous to the one inserted on the inner side of the hand proximal to the little finger [*flexor carpi ulnaris*], but it has a special, important additon [52] to its usefulness acquired from the calcaneus, which,
[I, 168] as I have said before, has no analogue in the hand and which alone carries the whole weight of the body. Accordingly, Nature, realizing all this, made the tendon originate from two sources [53] [*gastrocnemius* and *soleus*]. Hence I think you will greatly admire her skill if you notice carefully what is revealed by dissection and see first that the single muscle that extends the toes serves many parts and then that all the other muscles in the foot and the whole leg, like those in the arm,[54] end in several tendons, or in the case of a small muscle, in a single one, but that the tendon reaching to the calcaneus is the only one growing out from three large muscles combining to form it [*gastrocnemius* (two heads) with *plantaris* and *soleus*], in

[52] Reading προσιὸν with Helmreich for the πρὸς of Kühn's text.

[53] Reading διττὴν and γενέσεως with Helmreich for the τρίτην and κινήσεως of Kühn's text.

[54] Reading ταῖς χερσί with Helmreich for the τοῖς ποσί of Kühn's text.

order that if one or two of them should be injured, the remaining ones or one may still be of service. Elsewhere in the body there are many places where Nature has shown the same great foresight by providing several sources for a movement that is very important to the animal, but here, where the tendon extending to the calcaneus is formed from three[55] large muscles on the back of the leg, she is particularly remarkable for her wisdom in foreseeing the importance of its usefulness and making the greatest possible provision against injury.

All anatomists before me have thought that the three muscles forming the calf of the leg [*gastrocnemius* (two heads) with *plantaris*, and *soleus*] are inserted into the calcaneus, but it is not true. For a considerable portion of one of the tendons passes beyond the calcaneus and spreads out under the whole lower part of the foot,[56] and instead of considering this to be part of the third muscle [*gastrocnemius lateralis*], perhaps it would be better to think of it as a separate, fourth muscle [*plantaris*]. But as I have also said before, I have told in the *Manual of Dissection* the reasons why my predecessors in anatomy were mistaken about all these matters.[57] They did not even know that one of the muscles that are really inserted into the calcaneus, the one [*soleus*] that arises from the fibula, remains fleshy and is inserted higher up, whereas the others [*gastrocnemius* (two heads)] arise from the heads [condyles] of the femur and end in a very strong tendon [*Achillis*] which is inserted into the tip of the calcaneus below the first muscle. But I have written about the accurate dissection of the muscles not only in the *Manual of Dissection* but also in another separate treatise.[58] [I, 169]

By learning the origins and insertions of the muscles from these treatises, anyone who wishes can very readily recognize the perfect truth of what I have said in the preceding book, namely, that Nature has placed obliquely on the members muscles controlling oblique movements and has stretched straight along the length of the mem-

[55] Reading τριῶν with Helmreich for the δύο of Kühn's text.

[56] In the ape, but not in man. See Howell and Straus (1933, *159, 162*), and cf. Galen's descriptions of the relations of gastrocnemius, soleus, and plantaris in *De anat. admin.*, II, 7 (Kühn, II, *316–317;* Galen [1956, *48*]) and *De musc. diss.* (Kühn, XVIII, pt. 2, *1015–1016;* Galen [1963, *498*]).

[57] See notes 12, 27, and 29 of Book II.

[58] *De musc. diss.* (Kühn, XVIII, pt. 2, *926–1026;* Galen [1963]).

bers muscles charged with exact flexion and extension. Indeed, it is not difficult now to discover the reason for the position, size, and number of all the muscles of the leg. For if these three muscles [*gastrocnemius* (two heads) with *plantaris* and *soleus*] move the calcaneus and hold the foot firm,[59] and if in addition to these there are three others [*flexor hallucis longus*, *flexor digitorum longus*,
[I, 170] *tibialis posterior*] which flex the toes and give to the foot the movement analogous to the one in the hand which is performed, as I have shown, by the tendon [of *flexor carpi radialis*],[60] inserted into the part proximal to the thumb, there is good reason why all six are located on the back of the leg, each one lying in a straight line with the part it is to move. We may consider that instead of six of these muscles there are only five, as anatomists before my time have thought who combined the two at the very back [two heads of *gastrocnemius*] into one because they are united for most of their course.

Moreover, they have also thought for the same reason that there are three muscles at the front of the leg, although it is better to say six, at least, or seven. They think the one that extends the four [lesser] toes is a single muscle, as indeed it really is [*extensor digitorum longus*]. On each side of it lies another muscle which divides into three heads of tendons [on one side: *tibialis anterior*, *abductor hallucis longus*,[61] and *extensor hallucis longus*; on the other: *peronei longus*, *brevis*, and *digiti quinti*]. If you examine all these and reflect on their uses, you will count them as six or seven muscles in all, as I have pointed out in the *Manual of Dissection*,[62] but in this discussion let us for the present continue to speak of them as three. Two [of the three] are muscles that bend the foot up, as I have said before; one of them [first group of three] extends to the part of the foot proximal to the great toe, and the other [second group of three] to the part proximal to the little toe. The third and last, lying between the other two, is the muscle that extends the toes [*extensor digitorum longus*]. This is a smaller muscle because it

[59] Reading *ἄτρεπτον* with Helmreich for the *ἄτριχον* of Kühn's text.

[60] Daremberg (in Galen [1854, I, *258*]) identifies this muscle as the metacarpal component of abductor pollicis longus, but he must be mistaken, for the reference here is to one on the inner side of the arm.

[61] See note 50 of this Book.

[62] II, 7–8 (Kühn, II, *318–324*; Galen [1956, *49–52*]).

moves smaller instruments, and it extends along the middle of the leg straight to the toes, which of course it was designed to move. For all these muscles, a position directly in line with the parts they are to move is best.

Hence you will not ask[63] why the muscles that lie along the fibula and tibia [second and first groups of three] and move the foot outward and inward respectively extend downward as they do; for these too had to be in the same straight line with the movements they produce. Neither will you ask why the muscle on the outer side is small and that on the inner side along the tibia is much larger; for Nature, just in everything, has made the size of the muscles to accord with the usefulness of the actions they must perform. But why is an offshoot [*peroneus digiti quinti*] from the muscle lying along the fibula [second group of three] inserted into the outer parts of the little toe, and why is an offshoot [*extensor hallucis longus*] coming from the muscle along the tibia [first group of three] and inserted into the great toe double the size of the other? I raise the question because one might jump to the conclusion that this arrangement is peculiar to the foot and opposite to what is found in the hand, but if you stop and think carefully about the matter, you will see that here too the foot and hand are perfectly analogous. For I have said that in the hand the thumb and little finger have each one movement more than the other fingers,[64] and the same arrangement is necessary for the foot as well. Certainly, if the additional movements of which I am speaking had not been provided, these fingers would have no advantage over the others and would, like them, be provided with four movements; in that case, however, they could not be separated widely from the other fingers, an advantage they alone possess, and the thumb would not have two oblique movements originating above, but only the one movement of extension like the other fingers. Thus in this respect also the analogy between the digits in the foot and hand is kept unimpaired, and no discussion is necessary to show that the nails in both members are analogous and that it is because the feet are prehensile that they have toenails.

[I, 171]

[I, 172]

Is it, then, only in the parts I have mentioned that Nature has arranged everything justly for the hand and foot, making the neces-

[63] Reading ἐπιζητήσεις with Helmreich for the ἔτι ζητήσεις of Kühn's text.

[64] See chapter 3 of Book II.

sary analogies and differences, and has she been so careless in constructing the skin as to stretch beneath the foot one that is insensitive, loose-textured, thin, and soft? Surely if you examine the skin in dissection, even if you are one of those who through ignorance of Nature's works accuse her of lack of skill, I think you will repent with shame and change your opinion for the better, agreeing with Hippocrates, who is continually singing the praises of Nature's righteousness and the foresight she displays in the creation of animals. Do you think it is profitless for the skin of the palm of the hand and the sole of the foot to grow fast to the underlying parts? Or are you totally ignorant that it is so intimately attached to the tendons beneath that it cannot be stripped off like the skin over all the rest of the body? Or do you know this and still think that it would be better if the sole of the foot were covered with a skin loose-textured and easily movable? If you say that such a skin would be better, I suppose that, instead of close-fitting sandals bound
[I, 173] tightly all around, you would prefer those that are loose and slip in every direction; for so you may assert your cleverness in everything and not scruple to cry down even what is clearly known to all men. Or do you grant that an artificial sandal must certainly be bound to the foot all around if it is to fulfill its purpose, but not that Nature's sandal itself has a much greater need to be bound on, held firmly, and closely united to the parts under which it has been placed? A man would be a veritable Coroebus [65] if he failed to marvel at works of Nature such as these and even presumed to censure them.

It is time now for you, my reader, to consider which chorus you will join, the one that gathers around Plato, Hippocrates, and the others who admire the works of Nature, or the one made up of those who blame her because she has not arranged to have the superfluities discharged through the feet. Anyone who dares to say these things to me has been spoiled by luxury to such an extent that he considers it a hardship to rise from his bed when he voids, thinking that man would be better constructed if he could simply extend his foot and discharge the excrement through it. How do you suppose such a

[65] A Phrygian, son of Mygdon and Anaximene, who came too late to the aid of Priam at Troy and hence gave rise to the proverb, "More stupid than Coroebus." See Pauly-Wissowa, *Real-Encyclopädie der classischen Altertumswissenschaft, s.v.*

man feels and acts in private? How wantonly he uses all the openings of his body! How he maltreats and ruins the noblest qualities of his soul, crippling and blinding that godlike faculty by which alone Nature enables a man to behold the truth, and allowing his worst [I, 174] and most bestial faculty to grow huge, strong, and insatiable of lawless pleasures [66] and to hold him in a wicked servitude! But if I should speak further of such fatted cattle, right-thinking men would justly censure me and say that I was desecrating the sacred discourse which I am composing as a true hymn of praise to our Creator. And I consider that I am really showing him reverence not when I offer him unnumbered hecatombs of bulls and burn incense of cassia worth ten thousand talents,[67] but when I myself first learn to know his wisdom, power, and goodness, and then make them known to others. I regard it as proof of perfect goodness that one should will to order everything in the best possible way, not grudging benefits to any creature, and therefore we must praise him as good. But to have discovered how everything should best be ordered is the height of wisdom, and to have accomplished his will in all things is proof of his invincible power.

Then do not wonder so greatly at the beautiful arrangement of the sun, moon, and the whole chorus of stars, and do not be so struck with amazement at the size of them, their beauty, ceaseless motion, and ordered revolutions that things here on earth will seem [I, 175] trivial and disorganized in comparison; for here too you will find displayed the same wisdom, power, and foresight. Consider well the material of which a thing is made, and cherish no idle hope that you could put together from the catamenia and semen an animal that would be deathless, exempt from pain, endowed with never-ending motion, and as radiantly beautiful as the sun. You should rather estimate the art of the creator of all things just as you judge the art of Phidias. Now perhaps you are struck with admiration of the decoration covering the image of Zeus at Olympia, its gleaming ivory, its massy gold, and the great size of the whole statue, and if you saw such a statue made of clay, you would perhaps turn away in contempt. Not so, however, the man who is an artist and able to recognize the art employed in the work; no, he commends Phidias

[66] Reading *ἡδονῶν* with Helmreich for the *ἡδονὴν* of Kühn's text.

[67] Reading *καὶ τάλαντα μυρία θυμιάσαιμι κασίας* with Helmreich for the *καὶ τὰ ἄλλα μυρία μύρα θυμιάσαιμι καὶ κασίας* of Kühn's text.

equally, even if he sees him working in cheap wood, common stone, wax, or clay. For the uncultivated man sees beauty in material, whereas it is the art itself that seems beautiful to the artist. Come, then, let us make you skillful in Nature's art so that we may call you no longer an uncultivated person, but a natural philosopher instead. Disregard differences of material and look only at the naked art itself, keeping in mind when you inspect the structure of the eye and the foot that the one is an instrument of vision and the other of locomotion. If you think it proper for the eyes to be made of material like the sun's or for the feet to be pure gold instead of bones and skin, you are forgetting the substance of which you [68] have been
[I, 176] formed. Bear it in mind and reflect whether your substance is celestial light or slime of the earth, if you will permit me to give such a name to the mother's blood flowing into the uterus. Then, just as you would never demand an ivory statue of Phidias if you had given him clay, so in the same way, when blood is the material you give, you would never obtain the bright and beautiful body of the sun or moon.[69] For they are divine and celestial and we are mere figures of clay, but in both cases the art of the Creator is equally great.

Who will deny that the foot is a small, ignoble part of an animal? And we know full well that the sun is grand and the most beautiful thing in the whole universe. But observe where in the whole universe was the proper place for the sun, and where in the animal the foot had to be placed. In the universe the sun had to be set in the midst of the planets, and in the animal the foot must occupy the lowest position. How can we be sure of this? By assuming a different location for them and seeing what would follow. If you put the sun lower down where the moon is now, everything here would be consumed by fire, and if you put it higher, near Pyroeis or Phaëthon,[70] no part of the earth would be habitable because of the cold. The size and character of the sun are qualities inherent in its nature, but its particular position in the universe is the work of One who has arranged it so. For you could find no better place in the whole
[I, 177] universe for a body of the size and character of the sun, and in the

[68] Reading *γέγονας* with Helmreich for the *γέγονεν* of Kühn's text.

[69] Reading *ἡλίου ἢ σελήνης* with Helmreich for the *ἥλιον ἢ σελήνην ἢ* of Kühn's text.

[70] The fiery one (Mars) and Jupiter.

body of an animal you could find no better place for the foot than the one it occupies. You should observe that the same skill has been employed in locating both sun and foot. (I am intentionally comparing the noblest of the stars with the lowliest member of the animal body.) What is more insignificant than the heel? Nothing. But it could not be better located in any other place. What is nobler than the sun? Nothing. But neither could the sun be better located anywhere else in the whole universe.

What is the grandest and most beautiful of created things? The universe, as everyone admits. But the Ancients,[71] well-versed in Nature, say that an animal is, so to speak, a little universe, and you will find the same wisdom displayed by the Creator in both his works. Then show me, you say, a sun in the body of an animal. What a thing to ask! Are you willing to have the sun formed from the substance of blood, so prone to putrefy and so filthy? Wretched fellow, you are mad! This, and not failure to make offerings and burn incense, is true sacrilege. I will not, indeed, show you the sun in the body of an animal, but I will show you the eye, a very brilliant instrument, resembling the sun as closely as is possible [for a part located] in the body [72] of an animal. I will explain the position of the eye, its size, shape, and all its other qualities, and I will show that everything about it is so beautifully ordered that it could not possibly be improved; but I will do this farther on in my discourse.[73]

11. It is, however, my present intention to speak of the foot, the construction of which is not inferior to that of the eye or the encephalon. For all its parts have been most excellently arranged to do the work for which it was made, and we should seek for better- [I, 178]
ment or improvement, not in what is entirely faultless, but only in things that fall short of perfection. The source of sensation and of all the nerves is in the encephalon, but how does this prove that the encephalon is better constructed than the foot if each of them is excellently arranged to perform the action for which it was made in

[71] Democritus, for instance. See Diels (1956, II, *153*), and cf. Aristotle, *Physica*, VIII, 2, 252b24–28: "If this [the autokinetic principle] can be found in an animal, why should it not hold for the entire universe too? If it can happen in a small world, it can also happen in a large one."

[72] Reading *σώματι* with Helmreich for the *μορίῳ* of Kühn's text. The comparison of the eye to the sun is Platonic; see *Republic*, VI, 508 (Plato [1920, I, *769*], and note 19 of Book X *infra*.

[73] In Book X.

the first place? Neither the encephalon alone without the foot nor the foot without the encephalon would be very useful, for one of them, of course, needs something to support it and the other needs sensation. Now the feet and all the other parts of the body as well provide support for the encephalon, the encephalon in turn providing sensation for them, and here again you should consider once more the principle laid down at the beginning of this work. The skin of the foot must have a share in sensation because frequently it has to rest upon hard, sharp objects which would bruise, wound, or injure it in many ways if by its ready perception it did not warn the animal to escape them. Hence first the superficial portion of the tendon which is inserted into the calcaneus [*tendo calcaneus* (*Achillis*)], and which I have said is formed from three muscles, passes on toward the lower part of the foot and grows beneath the surface of the skin on the sole of the foot [plantar aponeurosis from *plantaris*]. Then, more deeply situated beneath the skin of the foot, where also the two little muscles lie,[74] small branches of the nerves from the spinal cord are distributed [*n. plantaris, medialis* and *lateralis*]. The nerves of the hand are much larger than these because the hand, being an instrument not only of prehension but also of touch, has
[I, 179] much greater need of accurate sensation than the foot. In fact, the foot was not meant to be a common instrument of touch for the whole body but an instrument of locomotion only, and it therefore has only as much sensation as it needs to avoid being easily injured. If I should describe in detail the path of the nerves from their source all the way to the foot, and if I should show you what great foresight Nature has displayed in providing for their safety (for on account of the long distance she feared that they might be injured because they are too soft to be equal to such a journey), I am sure that I should force you to admire her skill even more, but my explanation of the foot would be inordinately protracted. I shall, however, speak separately about the nerves later on.[75]

[74] Without further information one can only guess at the identity of these muscles. There is nothing in *De anat. admin.* or *De musc. diss.* to shed any light, and Daremberg (in Galen [1854, I, *264*]) is content to leave them unnamed. Perhaps Galen means abductor hallucis and flexor digitorum brevis, for the medial plantar nerve issues from between them, and its cutaneous branches pierce the plantar aponeurosis at the same point.

[75] In Book XVI.

12. The skin of the foot is closely adherent to all the parts lying beneath it, to prevent it from being easily folded over in any direction, and the outgrowth [plantar aponeurosis] from the tendon at the heel spreads out over all the same area, also to prevent the skin from being easily folded and to give it adequate sensation. The skin is neither very hard nor very soft, avoiding both extremes, since it must not be too easily injured or too insensitive. Very hard substances, such as hoofs whether solid or cloven, the shells of crabs and crayfish, and the hide of whales and elephants are by necessity practically without sensation, whereas very soft substances must be [I, 180] very sensitive and also to the same extent more liable to injury. Hence, in order that the skin may be neither too insensitive nor too easily injured, Nature has guarded against both extremes by carefully making its texture intermediate between hard and soft. Thus in every respect our feet have been formed so as to be suitable for a reasoning animal.

13. You should not at this point wish to hear all there is to say about the location of the legs, their relations, their size whether large or small, and all their arteries, veins, and nerves. A little while ago I described completely the muscles of the leg, their number, locations, and differences in size. I must,[76] however, still explain fully the nature of both bones in the leg. The larger of the two has the same name as the whole member, *κνήμη* [tibia, leg], and the other is called *περόνη* [the fibula]. The latter is rather slender and in size falls far short of the tibia, along the outer side of which it lies. The twofold usefulness it offers to the animal is primary and necessary, but there is a third usefulness into the bargain, as one might say. This is its first use: it makes nearly all the outer [lateral] half of the articulation with the talus by means of which, as I have said, the foot is extended and flexed, just as the tibia makes the inner [medial] half. Its second use in this: it is placed as a shield [I, 181] alongside[77] all the vessels and muscles of the leg where they would be most easily injured by blows from without. Its third use has to do with the outer head [lateral condyle] of the femur, which is supported by the tibia; since the fibula is set beneath these bones as a prop, it helps considerably to protect and support them firmly.

[76] Reading *χρεὼν* with Helmreich for the *καὶ καίριον* of Kühn's text.

[77] Reading *παραβέβληται* with Helmreich for the *περιβέβληται* of Kühn's text.

If anyone thinks that the leg has no need of the fibula because the tibia alone could articulate at its lower end with the talus in the same way in which its upper end articulates with the femur at the knee, he does not realize that he is requiring the tibia to be so large that it would be comparable in size to the femur. This arrangement would be possible for an animal made of stone or wood, and besides doing no harm, I suppose it would support the parts above more firmly, just as the foot also would give better support if it had been made much larger than it actually is. But it would be quite absurd in a real animal which must move its lower parts by means of parts above them; for parts that move others must be larger and stronger than the parts that they move. And so Nature did well when she extended the fibula along the outer side of the tibia; she made of it a sort of shield for the muscles and vessels, and at the same time she placed in the space between [the two bones] many of the muscles charged with moving the foot. If she had made only one large bone in the leg, she would have surrounded it with vessels and muscles
[I, 182] unprotected on the outer side and would have made the whole member thick and unmanageable. We should not even say that it would have been better to form epiphyses at the upper and lower ends of a single bone by which it might articulate with adjacent members while the bone itself remained slender throughout the length of the leg. In fact, such outgrowths would be extremely exposed to injury, particularly those at the talus, because they would project far out from the axis of the bone. In this instance, too, is it not right to admire the foresight of the Creator, who has fashioned the parts of the whole member in such a way that they are in proper relation to one another and nicely adapted to both its uses, even though these are antagonistic? For since an upper part must be supported by one below it, there is good reason for the lower part to be the larger and stronger, as it is in columns, walls, houses, towers, and all inanimate objects. On the other hand, when the upper part must be a source of motion and the lower part must be moved by it, there is also good reason for this upper part to be the larger and stronger, as in the arrangement we find in the upper arm, forearm, and hand. It was, then, better for the tibia to be large in order to support the femur well, but small in order to be moved easily, and it was necessary to choose one of the two sizes since the tibia could not be both large and small at the same time; hence it was, of course,

reasonable to choose the more useful size without, however, neglecting the other altogether. Now in instruments formed for the sake of locomotion a construction allowing them to move readily is far [I, 183] more useful than one that makes them a safe support, and Nature therefore made the tibia smaller than the femur, but not so much smaller that it would be no longer able to support the femur safely. Here I should remind you of two things first, of the method I outlined at the beginning, when I said that the usefulness of the parts of an instrument must be related to the action of the whole instrument; second, of the fact that if in imagination we change every attribute of the parts and still find no other position, shape, size, contexture, or any of the other attributes necessarily inherent in bodies that would be better than those which the parts actually have, we must declare that their present construction is perfect and absolutely correct.

14. No one who has read attentively what I have already written could fail to recognize that everything I have discussed thus far has been carefully investigated by this method and that I shall continue to use it in the same way in what follows. By observing legs that are swollen from varices or tumors, or, at the other extreme, those that are emaciated through some other disease, one can clearly see that the size of the leg has been nicely proportioned to that of the thigh and of the foot so as best to provide for swiftness of motion without interfering with safe support. For the superfluous weight makes it difficult or even impossible to move quickly if the legs are larger [I, 184] than necessary, and persons whose legs are too thin are apt to stumble and fall, especially when they wish to move very quickly. Now as I have said before, in order to walk properly we must rest the weight of the whole body on one leg while the other is moved quickly past it. The natural size of the tibia enables it to perform both these acts; for it is large enough to support the parts above it and yet can easily be moved forward by them. It is thus already clear that the tibia should not be larger than it actually is and that, given the present size of the tibia, the fibula is of considerable assistance, articulating with the talus, extending along the outer side[78] of the tibia as a sort of shield, and in addition acting as a support for the head of the tibia.

From what I have said it is also clear that the construction of the

[78] Reading κάκ with Helmreich for the καί of Kühn's text.

fibula is very different from that of the radius, and that Nature did well to make an entirely motionless junction for the bones in a place where an instrument of locomotion would derive no benefit at all from an increase in the number of articulations; for ease and diversity of movement are advantageous for prehensile instruments, whereas firmness of support is more important for instruments of locomotion. Hence, although the radius has movable joints at its upper and lower ends, the fibula is bound rigidly to the tibia at both ends. Indeed, just as the whole animal would be supported more
[I, 185] securely on legs that were all in one piece, undivided by any articulations, so it now comes closer to enjoying perfect safety because many of the movable joints have been eliminated. If the leg were completely without movable joints, it could not be extended or flexed and so would be deprived of all the usefulness for which it was made, but if it were broken up into a great number of articulations, it would be so unsteady and shaky that we could never stand firmly on one leg, but would immediately lose our balance and fall. Hence we must admire Nature in this instance too, because from two opposite conditions, mutually repugnant and destructive, but both necessary to the leg, she has adopted only as much of each as would not sacrifice either ease of movement or firm support.

15. Certainly these things have been admirably arranged by Nature, and even more admirable is her treatment of the knee joint. The epiphyses of the thigh bone, which has the same name as the whole member itself [μηρός, thigh, femur], fit into concavities in the tibia in such a wonderful way that the contact of the bones is neither loose nor too tight to move easily. The ligaments surrounding the articulation on all sides keep it safe and hold it so firmly that the femur never draws apart from the tibia in flexion or in complete ex-
[I, 186] tension. The part called the millstone by some and the kneecap by others is a cartilaginous bone covering the whole front of the articulation; it prevents the femur from slipping forward, especially in the positions called γνύξ and ὀκλάξ (kneeling and squatting), and it is of considerable assistance in preventing falls, especially on slopes where the whole body is inclined forward. I have seen clear proof of this in a certain youth, one of those who frequented the palaestra; while he was wrestling, his kneecap was torn loose from the ligaments and, separating from the knee, moved up along the femur,

making it so dangerous for him to bend his knee and walk down inclines that he needed a staff in such places.

If I should now describe all the concavities and protuberances of the bones of the knee and show that there is no protuberance without a concavity that fits it, and no concavity without a protuberance to occupy it, but that all the concavities and protuberances correspond exactly to one another and are held together by certain rims on the outer edges of the bones themselves and by ligaments, some flat and some round, my discussion would become longer than I had intended and would be none the clearer. What I have said [I, 187] earlier in general about the construction common to all joints will suffice. Now if anyone reads this discussion as he would read an old wives' tale, even what I have said will be of no use to him,[79] but if he is willing to inquire closely into all these statements and verify them accurately by what is to be seen in dissection, I think he will admire Nature because not only in the knee but in all the other joints as well she has made the sizes and shapes of all the protuberances to correspond exactly to the concavities that receive them. He will admire her even more for increasing the protection on the outside of the joints in proportion to the strength of their actions, as I pointed out before, when I compared the articulations in the foot with those in the hand. The articulation at the knee now offers another striking illustration of this, since it differs in construction from the elbow both in the ways I have mentioned earlier [80] and in the strength of the ligaments and the presence of the kneecap. For in addition to the ligaments deep within the joint [*ligamenta cruciata genu*] and those that embrace the whole surface of the articulation, Nature has made

[79] Reading *οὐδ' ⟨ἐκ⟩ τῶν εἰρημένων αὐτῷ* with Helmreich for the *οὐδὲ τῶν εἰρημένων αὐτῶν* of Kühn's text.

[80] These differences mentioned earlier—no articulation of the fibula with the femur to correspond to that of the radius with the humerus, and the immovable (really arthroidal) tibiofibular articulation—are discussed on p. 182. Daremberg (in Galen [1854, I, *271*]) seems to have missed this allusion and thus to have failed to understand the gist of the sentence. From this point to the end of the chapter, the text of the critical edition differs in many details from Kühn's; the improved readings, too numerous to note individually, solve the awkward difficulties with which Daremberg wrestled and account for the differences in our renderings.

certain others, not perfectly round, indeed, but still sufficiently strong; one of them binds the bones together on the outer side [*ligamentum collaterale fibulare*], and the other binds them on the inner side [*ligamentum collaterale tibiale*]. In front she has placed
[I, 188] the kneecap, so that the joint is everywhere held firmly together. Now there are, of course, four sides to the joint, front, back, right, and left; the front is very much exposed and subject to greater strain than the others; next in importance is the outer side, because it is more liable than the inner to be harmed by objects which could crush or bruise the member by striking against it; the back of the joint, however, is more liable to suffer from strain than from injury. Hence on the first side [the front] Nature has placed the kneecap and on the second [lateral aspect] one of the round ligaments [*ligamentum collaterale fibulare*] together with the termination of the broad muscle [*biceps femoris*]. The third [medial] side has the other ligament [*ligamentum collaterale tibiale*], and the fourth [rear] has neither bone nor special ligament, but only the broad, thin ligaments surrounding the whole joint. Certainly, if Nature had not displayed here her greatest foresight and skill, what was to prevent her from placing the kneecap at the rear and leaving the front unprotected, with the result that the knee could not bend and the member would easily be dislocated? Or what would prevent her from changing the position of the round ligaments? But indeed, as I have said, anyone who investigates all these things will see them arranged most wisely and providently not only in the knee but in every one of the joints as well. It is unnecessary to prolong this discussion any further.

[I, 189] 16. I must tell next why there are in all nine femoral muscles, and once more it is their action that will teach us why they have been formed. Three muscles [*quadriceps femoris*] at the front of the femur are the largest muscles in this region and they extend straight to the knee. One of these [*vasti, medialis* and *intermedius*] is inserted into the kneecap with fleshy fibers, and the two others [*rectus femoris* and *vastus lateralis*] give rise to a very large tendon, which flattens out and adheres to the whole kneecap, holding it firmly in place and attaching it to the parts beneath. Then, passing over the joint, the tendon is inserted into the front of the tibia; when it is tensed, it elevates the tibia and extends the whole articulation at the knee. There are two other muscles, one on each side of the three I

have mentioned, and they are inserted into the sides of the tibia, one on the outer [*biceps femoris*] and the other on the inner side [*gracilis*]. Both control lateral movement, one drawing the leg from the outside inward [81] [adduction], and the other drawing it outward [abduction]. One of them [*gracilis*] arises from the symphysis of the public bones, and the other [*biceps*] [82] from the outermost parts of the ischium, for from such origins they are best able to move the leg laterally. In the space between these two muscles there are arranged in a row the origins of three others, which impart slight movements to the knee. The muscle [*semitendinosus*] that lies close beside the one on the inner side [*gracilis*] [83] flexes the knee and moves the tibia inward [adducts]. The muscle [*semimembranosus proprius*] [84] that touches the one on the outer side [*biceps*] [85] moves the tibia outward [abducts], flexes, and rotates it. The final muscle [*semimembranosus accessorius*], which occupies the central position, is inserted into the inner head [medial condyle] of the femur. It flexes the whole thigh and draws the whole tibia along with it, [I, 190] because it extends over the parts of the articulation as far as one of the very large muscles of the leg [medial head of *gastrocnemius*], and through this muscle it pulls upon the whole member. The last one of the nine muscles that move the knee joint [*sartorius*] is long and narrow and arises from the flank bone [*os ilii*]. It raises the tibia obliquely [86] and in particular it makes the whole leg assume the position in which we cross our legs [87] and place each foot at the

[81] I agree with Daremberg (in Galen [1854, I, 273]) that ἔξωθεν here should be taken adverbially together with ἔσω, and not as an adjective modifier of ὁ (μῦς), as Kühn takes it.

[82] In the ape biceps femoris is so called only for convenience; it lacks the short head. See Howell and Straus (1933, *153*).

[83] Galen must have been thinking of the lower portions of the muscles, not their origins. See Daremberg's note 2 (in Galen [1854, I, *273*]).

[84] In the ape semimembranosus is a double muscle. See Howell and Straus (1933, *153–154*).

[85] Here Galen means the upper portions of the muscles. See Daremberg's note 3 (in Galen [1854, I, *273*]).

[86] Kühn omits λοξήν.

[87] μαλάττοντες literally, suppling. Daremberg (in Galen [1854, I, *274*]) emends to μεταλλάττοντες on the strength of a similar passage in *De anat. admin.*, II, 4 (Kühn, II, *294–295;* Galen [1956, *38* and note 46]). But there, as Singer points out, the word required is a technical term used by wrestlers and should not be compared with the present occurrence.

groin on the other side. In addition to all these there is also a small muscle [*popliteus*] [88] that is situated behind the knee joint and flexes it. Here again Nature has displayed such wonderful foresight in providing the proper number of these muscles and the proper size, position, and insertion for each, that no movement of the knee has been omitted; her arrangements have been such that if even a single one of them I have described were altered, some movement would be impaired or completely destroyed. To those who remember what I have said, I think the greatness of her foresight is clearly indicated by the three large extensor muscles of the leg, which also hold the kneecap in place and elevate it [*quadriceps femoris*]. In these muscles must reside the control of nearly all movement at the knee; for the whole leg must be very strong and accurately tensed when in
[I, 191] walking we raise one leg and move it past the other, which remains supported on the ground and bears the entire weight of the body. But in this operation it is the extensor muscles of the knee, and the three of which I have been speaking, that must act and must be accurately tensed. Now the articulation at the knee is flexed by the posterior and extended by the anterior muscles. If, then, whenever we need the leg to be very tense we entrust to these three muscles alone the task of keeping the knee perfectly straight and of pressing back the kneecap, holding it in place, and binding it fast so that it may serve to keep the muscles vertical, it is clear that the entire control of the leg's action is vested in these muscles. In fact, the lateral movement of the legs is an extra accomplishment, since Nature always endows every member with additional action beyond what is necessary. The primary work accomplished by the legs, that for which they were made, is locomotion, and in locomotion, as everybody

[88] In *De anat. admin.*, II, 5, 9, 10 (Kühn, II, *305, 324–326, 330;* Galen [1956, *43, 53, 55*]), Galen says that popliteus was unknown before his time, implying, at least, that he himself discovered it. Cf. *De musc. diss.* (Kühn, XVIII, pt. 2, *1013–1014;* Galen [1963, *498*]), where the implication is even stronger: "The muscles I have been discussing are all those coming down from above along the femur and moving the knee joint. As I reckon, it would be more correct to say there are nine of them, but in order not to seem to differ from the older anatomists in details, [let us say] eight. For there is another small muscle hidden in the articulation, in the ham itself." An unmistakable description of popliteus follows.

knows,[89] we need most particularly the muscles extending the knee to perform the action at this joint. Hence, just as I have shown that in the foot there was good reason for inserting two muscles [*gastrocnemius*] into the back of the calcaneus with a very large tendon, so at the knee it was desirable to insert these muscles [*quadriceps*] into the head of the tibia in front. For those [two] muscles provide firm support for the foot and in the same way these [three] keep straight the extension of the whole leg. On the back of the thigh, opposite these three muscles, Nature has set three others [*semitendinosus*, *semimembranosus proprius*, and *semimembranosus accessorius*], which are not so strong, however, and which do not all combine to form a single tendon. As I have shown in my book *On the Movement of the Muscles*,[90] it is absolutely necessary for every muscle to have another set opposite it to control movement in the opposite direction, and yet extension and flexion of the knee are not equally important. Accordingly, Nature has simply set these three muscles opposite the others and made them control movements in the opposite direction, but she has not made them so powerful, nor do they end in such strong tendons as the others do. To the muscles [*semitendinosus*, *semimbranosus proprius*] that lie one on each side of the middle one [*semimembranosus accessorius*] she has given control of oblique movements of considerable magnitude; and in order that the joint may rotate in both directions, she has stretched one muscle along each side of it, one of them [*biceps*] beside the anterior muscles, and the other [*gracilis*] beside the posterior muscles. Indeed, I do not understand how it is possible not to admire Nature's skill when we find large joints moved by many large muscles and strong tendons, and small joints moved by fewer and smaller muscles and weaker tendons—unless, of course, anyone contends that it would be more suitable to provide only a few small, weak muscles for large members and joints and many large, strong muscles for small ones. Probably such a person would prefer to have oblique muscles controlling straight movements and vice versa! Certainly the size of the muscles of the thigh, their number, and position bear witness to the greatest foresight on the part of Nature. More- [I, 192] [I, 193]

[89] Kühn omits *οὐδεὶς ἀγνοεῖ* from the Greek text but translates it, *nullus ignorat*, in the Latin version.

[90] *De motu musculorum*, I, 4 (Kühn, IV, *382–387*).

over, all the muscles pass beyond the joint and are inserted into the head of the tibia, and this too is proof of no insignificant skill. For just as those who move puppets with cords attach them beyond the joints to the heads of the members to be moved, so Nature long ago used the same device at all the joints.[91] Even though she had made many other skillful arrangements for the motion of the tibia, if she had neglected only to provide suitable insertions for the tendons, the other devices would be of no use. Of course, it is perfectly evident that if the tendons had been inserted before they passed over the joint they would not move the tibia at all,[92] but it is clear too [that they would also fail to move it] if, after passing over the joint, they had not been inserted where they actually are, but had ended immediately at the very head of the tibia or had been continued far down the leg. An insertion only into the head of the tibia would not be as secure and strong, because the tendons would be endeavoring to move the whole bone with only a few points of attachment, and those few at the very tip of the member. On the other hand, an insertion into a more distal portion of the tibia at about the middle of it, such as we see in the ape, would prevent complete extension of the member. The tibia would be, as it were, bound closely to the
[I, 194] femur and suspended from the posterior parts of it, just as it is in the ape. For in this animal the muscles that come from the back of the femur [particularly the biceps] are inserted almost half way down the tibia or only a little higher. Acting in opposition to the anterior muscles that extend the member, they draw the leg back, thus preventing perfect extension at the knee. Here again you may test the truth of what I said at the beginning of the whole work, namely that in every animal Nature constructs the bodily parts to correspond to the character and faculties of its soul. As I have said before, because the ape has a ridiculous soul and is a poor mimic, the body Nature has bestowed on it is correspondingly ridiculous. For all the bones in its legs are so joined that they do not permit a good, erect posture, and so the muscles on the back of the legs are most ridiculous and not in harmony with the structure. Hence[93] the ape

[91] *Vide supra*, p. 91.

[92] Reading *ἐνεφύοντο, τὴν ἀρχὴν οὐδ' ἂν ἐκίνουν τὴν κνήμην* with Helmreich for the *ἐφύοντο, κατὰ τὴν ἀρχὴν, οὐδ' ἄν*, etc. of Kühn's text.

[93] Rejecting *καὶ ἐν τῇ παιδιακῇ τὸ μυουροῦν*, Kühn's reading, as a gloss and reading with Helmreich simply *διὰ τοῦτ' οὖν*. See Daremberg's comments

cannot stand securely and perfectly erect, but uses its legs in the same way as a man who is playing the clown and making fun of the way a cripple stands, and limps as he walks and runs. I have said nearly all there is to say about the structure of the legs; I shall discuss the muscles that move the hip joint when I am explaining the other parts in that region.[94]

(in Galen [1854, I, *267*]); this is an excellent example of the improvements in the text made possible by the use of the manuscript Urbinas 69, which was inaccessible to Daremberg.

[94] In chapter 8 of Book XV.

[I, 195]

THE FOURTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Instruments of Nutrition]

1. Since the parts of an animal must be nourished and the mouth is the only way by which food can enter the body, Nature very properly began at the mouth to make the many routes [for the food to follow]; some of these are like broad thoroughfares which serve all the parts to be nourished and others are byways, so to speak, to carry the nutriment to the individual parts. The first and largest of the main thoroughfares extends from the mouth to the stomach, as to a central storehouse established in the middle of the animal for the benefit of all the parts. Οἰσοφάγος [the esophagus] is the special name for this avenue, which is commonly called στόμαχος; for στόμαχος is the general term for any narrow passage or isthmus, so to speak, leading to a cavity.[1] This storehouse, a work of divine, not human, art, receives all the nutriment and subjects the food to its first elaboration, without which it would be useless and of no benefit whatever to the animal. For just as workmen skilled in preparing wheat cleanse it of any earth, stones, or foreign seeds mixed with it that would be harmful to the body, so the faculty of the stomach thrusts downward anything of that sort, but makes all the rest of the material, that is naturally good, still better and distributes it to the veins extending to the stomach and intestines.

[I, 196]

2. Just as city porters carry the wheat cleaned in the storehouse to some public bakery of the city where it will be baked and made fit for nourishment, so these veins carry the nutriment already elaborated in the stomach up to a place for concoction common to the whole animal, a place which we call the liver. It has a single

[1] The throat, for example, the neck of the bladder, and the cervix of the uterus are all called στόμαχος.

entrance, but this divides into many narrow passages, and long ago some man well versed in Nature's lore, I suppose, called it the porta, a name which has persisted ever since, so that Hippocrates [2] and with him the whole chorus of the followers of Æsculapius also call it the porta, approving the wisdom of the first man who likened the governance of an animal to that of a city. Just as Homer [3] sings of Hephaestus' self-moving works of art, the bellows that "poured forth their well-tempered blasts, now strong, now gentle," at the bidding of their master, and those golden handmaidens who of themselves moved as their maker moved, so you should observe that in the body of an animal there is nothing inert, nothing motionless. You should see that on the contrary every part performs its different, well-tempered action [4] by the aid of a suitable construction; that the Creator has bestowed upon each one certain godlike faculties; and that the veins do not merely convey the nutriment from the stomach, but that, because they naturally resemble the liver and take [I, 197] their origin from it, they attract the nutriment and give it a preliminary preparation for the liver by a process very like that which it will undergo in the liver itself.

3. When the liver has received the nutriment already prepared by its servants and having the crude outline, as it were, and indistinct semblance of blood, it provides the final elaboration itself so that the nutriment becomes actual blood. The impurities corresponding to the earth, stones, and seeds of wild plants in the wheat were eliminated from the food in the stomach, but this stands in need of a second cleansing from the impurities corresponding to the chaff and bran in wheat, and it is the liver which accomplishes this further purification of the nutriment. To make a more vivid comparison, it would be better to liken the chyle carried up from the stomach to the liver by the veins not to dry grain, but to a fluid or humor, preconcocted and already elaborated, but still needing its concoction to be completed. Let us, then, compare the chyle to wine just pressed from the grapes and poured into casks, and still working, settling, fermenting, and bubbling with innate heat. The heavy,

[2] *De morbis vulgaribus*, II, sectio IV, 1 (Littré, V, *122, 123*), *et alibi.*

[3] *Iliad*, XVIII, 414–425, 468–473, 528–533.

[4] Kühn omits παντοίην ἐὔπρηκτον ἐνέργειαν ἐνεργοῦντα from the Greek text but translates it, *varium expeditumque opus efficere*, in the Latin version.

earthy part of its residues, which I think is called the dregs, is sinking to the bottom of the vessels and the other, light, airy part floats. This latter part is called the flower and forms on the top of
[I, 198] light wines in particular, whereas the dregs are more abundant in heavy wines. In making this comparison, think of the chyle sent up from the stomach to the liver as bubbling and fermenting like new wine from the heat of the viscus and beginning to change into useful blood; consider too that in this effervescence the thick, muddy residue is being carried downward and the fine, thin residue is coming like foam to the top and floating on the surface of the blood.[5]

4. Now it is reasonable that the instruments constructed for these residues should be hollow to receive them easily and should be provided on each side of their cavities with a long neck like a canal,[6] one suitable for attracting and the other for discharging the residues. Moreover, these instruments must have suitable positions to take advantage of the downward movement of the residues, and the insertions of their canals into the liver must be fixed in accordance with these positions. Obviously, such arrangements have been made; for Nature has placed up at the liver the bladder to receive the thin, yellow residue, and she would have greatly preferred to place the spleen, which attracts the thick, muddy residue, right below the porta where the atrabilious residue, borne down by its own weight, would automatically sink into it. No available space, however, re-
[I, 199] mained in that region, which was already entirely occupied by the stomach, and since there was plenty of room on the left, she placed the spleen there. From the concave side she caused a venous vessel [*v. lienalis*] like a canal (*στόμαχοι*) to grow out and extended it to the porta, so that the spleen serves to purify the liver just as well as if it had been placed nearer and had attracted the residue by a short canal instead of the long one with which it is actually provided. After the humor prepared in the liver for the nourishment of the animal has deposited the two residues of which I have been speaking, and after it has been completely concocted by the innate heat, it becomes pure and red and rises to the convex portion of the liver, showing the color it has received from the cutting action of divine

[5] Galen makes this same comparison in *De nat. fac.*, II, 9 (Kühn, II, *135*; Galen [1928, *208, 209*]).

[6] *στόμαχοι*.

fire and the impression of that fire upon a moist substance, as Plato [7] has said somewhere.[8]

5. This humor is then received by one very large vein [the vena cava], which arises from the convex portion of the liver and leads to both the upper and lower parts of the body. This vein, you would say, is a sort of aqueduct full of blood, having very many conduits, both large and small, leading off from it and branching into every part of the body. The blood in it is still charged in abundance with a thin, watery fluid which Hippocrates [9] calls the vehicle of the nutri- [I, 200]
ment, making his name for it immediately indicate its usefulness. For the chyle resulting from the food could not be taken up successfully from the stomach into the veins and could not pass easily through the many fine veins in the liver unless some thinner, watery fluid were mixed with it as a vehicle. In fact, this is the reason why water is useful to the animal; for although no part can be nourished by water, nutriment could not be distributed from the stomach if it were not conducted in this way by moisture of some sort.

6. When these thin fluids have finished their work, they should no longer be retained in the body because they would become an alien burden to the veins. This is the purpose for which the kidneys have been formed, hollow instruments that attract this thin, watery residue through one set of canals [10] and expel it through another. The kidneys lie slightly below the liver, one on each side of the very large vena cava which I mentioned just now, so that all the blood entering it is cleansed at once and thus there is sent out to the whole body only blood that has already been purified and contains very little watery fluid. In fact the blood no longer needs a great quantity of this vehicle because it is carried thence in broad channels and has already been rendered more fluid by the fusion to which it has been subjected first by the heat in the liver and then by the much more intense heat of the heart. For in man and all the quadrupeds the vena [I, 201]
cava is inserted into the right ventricle of the heart,[11] and in animals that do not have this ventricle all the veins in the body acquire

[7] *Timaeus*, 80 (Plato [1920, II, *58*]).

[8] Reading *ὡς που* with Helmreich for the *ὥσπερ* of Kühn's text.

[9] *De alimento*, cap. 55 (Littré, IX, *120*, *121*).

[10] *στομάχοις*.

[11] For Galen, the atria did not form part of the heart. See Book VI, *passim*, and Siegel (1968, *32–33* and figure 1).

their share of the heat in the heart by their inosculations [12] with the arteries. All these matters, however, have been discussed in my other works.[13] As I have said at the very beginning of this treatise, it is not my present intention to explain action, but since the usefulness of a part cannot be discovered if its action remains unknown, I shall in each case remind you of the action of the part and then pass on immediately to a discussion of its usefulness. I shall begin with the stomach.

7. The stomach has the faculty of attracting material having the quality appropriate to it, as I have shown in my commentaries *On the Natural Faculties*.[14] It also has the faculties of retaining what it has received, of expelling the residues, and above all of altering material; it is for the sake of the alterative faculty that the stomach needs its other powers. Although all the other parts of the animal have these same faculties, Nature has not granted them perception of what is lacking, and they are always nourished like plants by drawing nutriment from the veins. She has granted to the stomach alone and particularly to the parts of it near its mouth [the cardiac orifice]
[I, 202] the ability to feel a lack which arouses the animal and stimulates it to seek food. And this was wisely done; for since parts throughout the body attract nutriment from the veins arising from the vena cava, which in turn attracts it from the veins in the liver, and these again from the veins bringing it up to the porta, which have themselves attracted it from the stomach and intestines, and since there is no other part that can furnish nutriment to the stomach, it becomes necessary for the animal to fill its stomach from an outer source, and in this respect animals are different from plants. Plants, of course,

[12] The cognate word would be anastomoses. Galen, however, seems not to mean anastomoses in the modern sense but to be thinking rather of junctions of the fine ends of the veins with the fine ends of the arteries. This is to be gathered from his description of the vessels of the lungs. See chapter 10 of Book VI, *ad fin.*, and *De nat. fac.*, III, 15 (Kühn, II, *207;* Galen [1928, *320, 321*]).

For a fuller understanding of Galenic physiology as set forth in this and the following books, the reader will find it helpful to consult, in addition to the standard histories of physiology and the summary in my Introduction, Meyer-Steineg (1913), Winslow and Bellinger (1945), Singer (1957), and Cirenei (1961).

[13] In *De nat. fac.*, for example.

[14] *De nat. fac.*, III, 4–8 (Kühn, II, *152–177;* Galen [1928, *236–275*]).

cannot feel want, even though like animals they possess to the highest degree the other four faculties I have just mentioned. They do not need to be nourished through a mouth because they have beneath them the earth as a storehouse of abundant nutriment, and since they grow from the earth and are united with it, they always have plenty of food. The substance of animals, on the other hand, differs widely from earth in the innate properties of the parts and is endowed besides with voluntary motion and the ability to change position and move from place to place. Hence for both these reasons it is impossible for animals to draw nourishing juice from the earth like plants; consequently they must be nourished, each according to its own nature, with grass, seeds, fruits, or the flesh of other animals, and they must receive these foods when the stomach feels the need of them. Now there is no part of an animal that of itself has an innate power of perception, as I have shown elsewhere in my writings.[15] This faculty must flow in upon the stomach from some other place, brought by certain conduits, so to speak, from the source of sensation. For this purpose a pair of nerves of considerable size [*nn. vagi*] descends to it from above. They branch and form a network [the anterior and posterior gastric plexuses] particularly in the region of the [cardiac] orifice and the parts near it, but they also extend to the other parts of the stomach as far as its lower end. [I, 203]

The stomach has not been placed immediately below the mouth, though this would of course be desirable for supplying nutriment freely. On the contrary, Nature has placed before it [16] the part called the thorax and the viscera contained in it in order that the stomach may have in its lower parts outlets for the residues and that the thorax, as it alternately draws in and expels the air through the mouth, may become the agent of the voice and respiration. But I shall treat in detail of the thorax and the viscera contained in it in the books that follow this present discussion,[17] and I return now to the stomach. We should not commend Nature only because she has placed the stomach lower than the thorax; on the contrary, we

[15] See, for example, *De nervorum dissectione*, cap. 1 (Kühn, II, *831*; Galen [1966, *328*]), and *De plac. Hipp. et Plat.*, VII, 8 (Kühn, V, *644–647*). There are many other similar passages.

[16] That is, between the mouth and the stomach.

[17] Books VI and VII. The treatment of the instruments of nutrition extends over both Books IV and V.

should praise her still more because she has placed it not exactly in the middle of the animal but more to the left side. For since it has to be located between two viscera [the liver and spleen] of unequal size
[I, 204] and importance, she assigned more space in a more honorable location to the larger and more important of the two, moving it to the right and establishing it there, and since the second viscus [the spleen] is like a napkin, so to speak, for the liver,[18] she extended it along the left side of the stomach. The liver has a position elevated so as to touch the diaphragm and the spleen is lower down for the reason which I gave a little earlier. Hence Nature very properly extended the lower part of the stomach toward the right; for otherwise this place would be unoccupied and entirely empty, the liver not reaching so far.

This is the foresight [Nature has shown] in locating these three instruments, the liver, spleen, and stomach. I shall now explain the foresight she has shown in determining their shape, their whole configuration, their contexture too, and attachments to the adjacent parts. Since the stomach was formed to receive the food and must occupy all the space between the liver and spleen, it was reasonable for it to be made both round and elongate. It is round because that shape is best protected against injury and most capacious; for of all figures having equal perimeters the circle is the most capacious of the plane figures and the sphere of the solids. It is elongate because at its lower end it has an outgrowth [the duodenum] [19] leading to the intestines and at its upper end it proceeds toward the esophagus, but where it approaches the vertebrae it molds itself upon them and its convexity is interrupted. In man the lower end of the stomach is

[18] An unacknowledged debt to Plato, *Timaeus*, 71, 72 (Plato [1920, II, *49, 50*]).

[19] Galen sometimes says that the duodenum forms part of the small intestines and sometimes, as here, considers it to be simply a connecting link between stomach and intestines. In fact, he tells us that "the outgrowth into the intestine" was the expression commonly used by anatomists for the duodenum, and he calls the jejunum "the first intestine." See chapter 3 of Book V and cf. *De anat. admin.*, VI, 12 (Kühn, II, *578;* Galen [1956, *166*]); XIII (Galen [1906, II, *126;* 1962, *138*]). In the last of these three passages and again in *De venarum arteriarumque dissectione*, cap. 1 (Kühn, II, *780–781;* Galen [1961, *356*]), he tells us that "the outgrowth" was named duodenum (the twelve-finger length) by Herophilus.

broader than the part near the [cardiac] orifice, because the lower end is directed downward by the erect posture, which man is the only animal to enjoy.[20] In other animals the stomach bends forward toward the hypochondrium, which in them is situated on their lower [ventral] side. Now I shall make clear to you the form of the stomach as a whole: Think of a perfect sphere; then imagine its lower part broadened and make two outgrowths from it, the one at the esophagus wider than the lower one. Next compress this sphere, hollowing out its convexity in back, and you will have before you a complete model of the stomach. Everything else about it is clear. [I, 205]

But what is the reason for the contrast we find between the parts [of the stomach] and its outgrowths? I ask because at the upper end the stomach itself is narrow and the esophagus broad, whereas at the lower end where the stomach is broader its outgrowth to the intestine [the duodenum] has been made narrow. The reason is first that an animal occasionally gulps down large, hard, undivided masses, and the esophagus must be made a broad highway to accommodate them. The lower end, however, is not obliged to permit the passage of anything large and hard or anything that has not been liquefied and concocted, and there is a constriction [the pylorus] there which like a good porter (πυλωρός) allows nothing to pass easily down before it has been concocted and converted into chyle. Indeed, in many animals something of a glandular nature [21] is found at this point, which increases the constriction, particularly when the stomach exercises its retentive faculty and is actively engaged in digestion, gathering itself together, contracting, and clasping and compressing its contents. At that time both openings draw very tightly together and close, but when the stomach exercises in turn the faculty called expulsive, all its other parts are drawn in, con- [I, 206]

[20] But the form here described fits the simian stomach better than the human. See Lineback (1933, *215–217*).

[21] This is a puzzling statement and there is nothing to explain it in Galen's other works. Could he have been thinking of the head of the pancreas? But if so, why the qualification, "in many animals"? In the rhesus monkey the folds of the mucosa in the pyloric canal are high and distorted (see Lineback [1933, *216–217*]) and this feature may be what was in his mind. Daremberg's note (in Galen [1854, I, *290*]) is not very clear or helpful; he seems to have thought that the peculiar shape of the pylorus in the ape—he calls it a sort of funnel which makes it much more prominent—may be what was meant.

tracted, and held tightly together, while the orifice through which the material to be expelled must pass is spread wide. These activities of the stomach, which I have demonstrated in other works of mine,[22] appear to be wonderfully consonant with its construction. In addition, there is also the gradual widening of the stomach away from the point of insertion of the esophagus, a feature showing clearly that this passage is simply a prolongation of the stomach; and there is the outgrowth, not gradual, but abrupt, of the intestine [the duodenum] from the bottom of the stomach, indicating that the intestine does not belong to the body of the stomach, but is attached to it as an individual part.

8. Moreover, the tunics of the stomach and esophagus are very much alike, but those of the intestines are different. The inner tunic of both the stomach and esophagus is somewhat membranous and has straight fibers that run longitudinally. The outer tunic is more fleshy and has transverse fibers like those found in the two tunics of the intestines. And rightly so, for the stomach must attract food and drink through the esophagus, drawing them in by means of these
[I, 207] straight fibers as if with hands, and it must use the transverse fibers to expel its contents. The intestines, however, have no need of the attractive faculty, and they are accordingly provided only with the fibers proper for expulsion.[23] Furthermore, the inner tunic of the stomach

[22] *In De nat. fac,* III, 4–7 (Kühn, II, *152–168;* Galen [1928, *236–261*]).

[23] This description of the coats of the stomach and intestines should be compared with others farther on in *De usu partium* (see chapter 17 of this Book, *ad fin.*, and chapters 11 and 12 of Book V) and with those in *De nat. fac.*, III, 8, 11 (Kühn, II, *168–177, 180–182;* Galen [1928, *260–275, 280–283*]). A study of them all makes it unlikely that Galen succeeded in distinguishing, as Daremberg (in Galen [1854, I, *290–291*]) thinks he did, the different layers of the muscular coat of the stomach; for in the stomach the longitudinal fibers are superficial and certainly not continuous with the inner coat of the esophagus. In the intestines he did a little better; for when he says in chapter 17 of this Book, "Some of the intestines have certain straight fibers stretched longitudinally on the outside," he seems to have seen the two layers of the muscular coat. However, that leaves to be accounted for, along with the inner tunic of the stomach with its longitudinal fibers, the second, inner tunic with transverse fibers in the intestines. The problem has been solved, I think, by Brock (in Galen [1928, *262*]), who says that the two coats are merely the mucous and muscular coats in both cases. In the stomach the longitudinal fibers of the inner coat (which would, of

is continuous with that of the esophagus and all parts of the mouth, and this is helpful in the attraction [swallowing] of the food contained in the mouth and in drawing downward the tongue together with the muscles in the region of the tonsils. By the tension of all these parts, the larynx is stretched upward, brought into contact with the epiglottis acting as its lid, and thus prevents a mass of liquid from escaping into the lungs. But why is the inner lining of these parts denser and harder than that of the intestines? The reason is that the intestines were made for *anadosis* [distribution, absorption], whereas the stomach, esophagus, and mouth were made resistant to injury. For we frequently swallow large, hard, rough masses which would bruise and scrape parts that had not been made hard and dense. For this very reason, this common lining of the mouth, esophagus, and stomach grows gradually softer and looser in texture toward the lower end of the stomach, so that if you compare its condition there with its condition in the mouth, it will be found to be much softer. Indeed, it is reasonable that the first instrument encountered by the food before it has received any elaboration should be the hardest.

For this same reason also there are very many veins leading to all the intestines and a few to the lower part of the stomach and to the part near the [cardiac] orifice, whereas in the region of the esophagus they are scarcely visible; for the esophagus is only a pathway for the food, but the stomach is the instrument of concoction and the intestine the instrument of distribution. Where the food is merely to be concocted, only a very few veins are necessary to receive whatever is already usable; when, however, nutriment has once been concocted, it should be distributed as quickly as possible. The pathway for the nutriment [the esophagus], on the other hand, needs veins only for its own nourishment. Hence there is good reason why very few veins have been assigned to the esophagus, a moderate number to the stomach, and a great abundance of them to the intestines. [I, 208]

Now why is the stomach surrounded by the liver? Is it in order that the liver may warm it and it may in turn warm the food? This is indeed the very reason why it is closely clasped by the lobes of the

course, be continuous with the mucous coat of the esophagus with its longitudinal folds) would be the rugae. In the intestines the transverse fibers of the inner coat would be the valvulae conniventes.

liver, as if by fingers.[24] All animals do not have the same number of lobes because they do not all have stomachs of exactly the same shape and size. The large spleen lying to the left of the stomach also warms it on that side, and at the rear there are the spine acting as a stout defense and the so-called spinal muscles [*psoas major* and *minor*, and *quadratus lumborum*], which like a soft cushion together with the surrounding fat warm the stomach. All these parts I have mentioned were formed for their own special uses, but Nature, like a
[I, 209] clever inventor, by establishing them near the stomach has made them poultices, so to speak, to warm it.

9. But the remaining side of the stomach, the front, has no part which though formed for its own special use has been placed there to be employed in this way also. Hence to serve this same purpose, namely, to warm the stomach, Nature has not hesitated to form at the front, covering it completely, a certain body that is dense but at the same time light and warm [the greater omentum]. It is dense in order to keep in the innate heat, light in order to give heat without painful pressure, and warm—well, we need give no reason why it is warm, because anything formed for heating must have this quality. Now if this body is light and at the same time dense, it must be membranous; for what other part of an animal is to be found that is lighter and denser than membrane? If it is to be warm, it must be provided with very many vessels, both veins and arteries, and with soft fat in abundance poured round about it. That fat is a warm substance is clearly indicated by the sensations of those who use it in the form of oil [for massage], but the best proof is found in the ease with which it catches fire, its nature being very closely akin to that of fire; for nothing cold is easily kindled. With this description I have now explained to you the part called the [greater] omentum, composed of two dense, fine membranes, one lying upon the other, and of many arteries, veins, and a mass of fat. You will clearly

[24] The shape of the human liver would hardly suggest such a comparison. The more prominently lobate liver of the ape or pig would be much more likely to do so. For conditions in the rhesus monkey, see Lineback (1933, *223–224*), and in other animals, especially the pig, see Ellenberger and Baum (1926, *406–409* and figures 589–594). For another account of the warming of the stomach by the neighboring viscera in order that it may digest (alter) the food, see *De nat. fac.* III, 7 (Kühn, II, *163–164*; Galen [1928, *252–255*]).

comprehend that the omentum was made to furnish heat if you will consider cases in which the patient has been wounded in the epigastric region and the omentum has escaped through the wound and become livid, forcing the physician to remove the injured part. All such persons feel cold in the region of the stomach; they concoct less and need more outer coverings, especially when the part removed was of considerable size. I myself once removed nearly the whole omentum from a gladiator who had been wounded in this way. The man recovered promptly, but he was so sensitive to external cold and so easily harmed by it that he could not bear to have his abdomen uncovered and kept himself wrapped in wool. His whole body, however, was naturally thin, particularly in the region of the stomach, and I have thought that this was the reason why he was easily chilled. Why is this part [the omentum] so very extensive in man, covering all the intestines? Is it that in man the concoctions are very feeble and the skin very soft, devoid of hair, and very easily injured? In other animals, to be sure, the omentum does not cover the stomach alone, but spreads over the intestines to a greater or lesser extent in accordance with the nature of each animal. [I, 210]

If now I append a discussion of these two points, namely, what ligaments connect the stomach with the spine, and where the omentum begins, I shall have told nearly everything about the stomach. The stomach must indeed be firmly supported, and the point of origin of the omentum should not be a matter of chance. To solve both these problems Nature has obviously made wonderful use of the peritoneum, but first I must tell what is the character of this peritoneum of which she has conveniently made use in her solutions and what its usefulness is for the animal. As regards substance, the peritoneum is a membranous body, and it is useful to the animal in many ways: first, it serves to protect all the parts lying beneath it, the stomach, intestines, and [other] viscera below the diaphragm; second, it separates these same viscera from the outer muscles resting upon them; third, it helps the residues of the dry nutriment to descend more quickly; its fourth use is to guard against flatulence in the stomach and intestines; and its fifth to bind together all the parts below the diaphragm and furnish each of them with its own special covering as with a skin. The first use is of slight account because the parts within the peritoneum can also be protected well enough by the outer parts overlying them [abdominal wall]; for the muscles in [I, 211]

this region are large, there is plenty of fat associated with them, and the skin is thick. All the other uses, however, are important, some of
[I, 212] them very important indeed and of great consequence to the animal.

The usefulness of the peritoneum as a means of separation is as follows. Many large muscles have been placed in the epigastric region to help in the emission of breath [25] and the production of the voice, and in moving the bowels and urinating, as I have shown elsewhere [26] and as I shall tell later on in this work.[27] Occasionally, some of the small intestines would insinuate themselves into the spaces between the muscles,[28] where they would cause pressure and be compressed, crowd and be crowded, inflict pain and feel it, while hindering the motion of the muscles and making it more difficult to move their own residues downward. You can see this condition in persons who have been wounded in the peritoneum and whose wounds have not been properly treated, for they will be liable to all the ills I have mentioned. But with the peritoneum surrounding the parts as it does, movements are unimpeded and there is no undue pressure caused by position either on the outer muscles or on any of the inner parts, whether intestines or other viscera.

This covering known as the peritoneum is useful in another way: [29] it is drawn close around all the inner parts (this is the reason for its name),[30] and at its upper extremities near the sternum and false ribs it meets the diaphragm stretching obliquely downward and aids to some extent the peristaltic movement of the stomach and intestines by which I have said the residues of the nutriment are

[25] Emission of breath = *ἐκφύσησις*, not simple expiration (*ἐκπνοή*), but forced, as in blowing or using the voice. It is defined by Galen in *De motu musculorum*, II, 9 (Kühn, IV, *459*), as follows: "*Ἐκφύσησις* is a sudden rush of air outward and is accomplished by the action of the intercostal muscles." The abdominal muscles, however, are also of assistance here, as he says again in chapter *15* of this Book *ad fin.* In *De plac. Hipp. et Plat.*, II, 4 (Kühn, V, *231*), he defines it as a rushing, whistling expiration, without saying what muscles are involved.

[26] *De causis respirationis* (Kühn, IV, *465–469*); *De anat. admin.*, VI, 14 (Kühn, II, *584–588;* Galen [1956, *169–171*]); *De locis affectis*, VI, 4 (Kühn, VIII, *405*).

[27] See chapters 14–16 of Book V.

[28] If it were not for the peritoneum.

[29] This is the third use listed above.

[30] *τὸ περιτόναιον*, from *περί*, around, and *τείνειν*, to stretch. Cf. *De anat. admin.*, VI, 4 (Kühn, II, *550;* Galen [1956, *154*]).

moved downward. For the parts held between the peritoneum and diaphragm as if by two hands joined above and separated below compress and push downward the residues of the nutriment.[21] Hence, if the peritoneum had been united at its lower edge with some other structure similar to the diaphragm and were separated from it above, the peristaltic movements[22] performed by those transverse fibers which I mentioned earlier would be no more likely to force the nutriment down than to force it up. This, then, is an important work of the peritoneal tunic, or membrane, or covering, or whatever those persons wish to call it who spend their entire lives disputing over names.[23] [I, 213]

For some consider it proper to call only composite coverings tunics, others use the name for thick coverings, and still others never confer it on anything that is not both composite and thick. They squabble in the same way over membranes. It is enough for

[21] For another use of the same figure, see chapter 15 of Book V, where, however, the two hands joined at the wrists and separated at the finger tips represent the diaphragm and abdominal muscles, not the diaphragm and peritoneum.

[22] As Brock (in Galen [1928, *243*, *263*]) remarks, Galen means by peristaltic movement simply contracting and dilating, without any downward wave of such contractions.

[23] In ancient times the absence of a standardized terminology led to confusion. Galen's attitude toward the multiplicity of names and their loose usage was a common-sense one. He refused to quibble and advised his students not to waste their time in this way, warning them, however, to note that "the slight significance which one assigns to nomenclature is not the same thing as if one were to pay scant attention to explanation and interpretation" (*De anat. admin.*, X [Galen (1906, II, *59*; 1962, *64–65*)]; translation by Duckworth). He felt strongly enough on the matter to write two special treatises on it, *De nominum rectitudine*, to which he refers in his *De libris propriis*, cap. 12 (Kühn, XIX, *44*), and in many other places but which has not survived, and *Adversus eos, qui contumeliose accipiunt nomina*, also lost, but referred to in *Utrum medicinae an gymnastices hygieine*, cap. 32 (Kühn, V, *868*), and *De libris propriis*, cap. 12 (Kühn, XIX, *44*). Throughout his works, his irritation with those who did quibble over names frequently breaks forth. See, for example, *De plac. Hipp. et Plat.*, II, 2, 3, III, 5 (Kühn, V, *214*, *218*, *225*, *328*); *De anat. admin.*, X, XII (Galen [1906, II, *28*, *105*; 1962, *31*, *114–115*]); and for the occurrences in *De usu partium*, consult the Index. For detailed analyses of Galen's terminology, see Simon (in Galen [1906, II, *viii–xiii*]) and Stéphanidès (1925).

some if a covering is simple, for others it must be thin, and others think both qualities are necessary if it is to be called a membrane, by no means consenting to give a covering that name unless it is both thin and simple. The Ancients called all such parts χιτών (tunic), ὑμήν (membrane), and μῆνιγξ (membrane) besides, and I shall follow their example, avoiding hairsplitting over names and keeping to my theme.

The fourth usefulness of the peritoneum, this covering drawn
[I, 214] close around all the abdominal parts and holding them in place, is to protect them from being easily afflicted with flatulence. A faculty of their own is also useful to them in this respect, for when they exercise it, as I have shown elsewhere,[34] they continually clasp and compress their contents. The peritoneum is of considerable assistance here, however, especially when the abdominal parts become too weak and incapable of compressing readily whatever food they happen to contain, when they are filled with vaporous and flatulent wind and it is clear that the food must remain unconcocted and *anadosis* must be delayed. But when these parts are all in good condition and the stomach, intestines, and peritoneum perform peristaltic movements, even though the ingested nutriment happens to be of a very windy nature, it is easily concocted and distributed. Some of the flatulence is relieved by belching, but some passes downward and whatever is vaporous but useful too is taken up into the veins. All these are the uses of the peritoneum.

10. Next I must begin at some one point[35] to describe how the peritoneum binds the instruments below the thorax together and yet invests each one separately. It covers the anterior parts of all of them alike; it passes thence down along the flanks on both the right and left sides as far as the lumbar vertebrae in such a way that it surrounds each of the intestines and other viscera and all the arteries,
[I, 215] veins, and nerves. As for its upper and lower extremities, the upper is attached beneath the diaphragm and the lower to the bones called pubic and also to those of the flanks [*ossa iliorum*], so that of the instruments situated in these two regions, the upper parts of the stomach and liver are covered by the portion of the peritoneum attached to the diaphragm, and the lower parts of the bladder and intestines by that attached to the pubic bones. I shall speak of the other instruments later on. The portion of the peritoneum originat-

[34] *De nat. fac.*, III, 4 (Kühn, II, *152–157*; Galen [1928, *236–245*]).

[35] He begins at the top of the abdominal cavity.

ing at the diaphragm and adherent to the [cardiac] orifice of the stomach on the outer side [86] unites with the portion on each side that comes from the spine [via the gastrolienal and lienorenal ligaments], and this is the origin of that third, outermost tunic of the stomach which Nature has placed around it as a covering and protection for the second, fleshy coat and which she has made into a ligament to bind the entire stomach to the parts at the spine. This will appear to you as a thick tunic, although all the other outgrowths of the peritoneum proceeding to instruments of nutrition are thin. The stomach, however, is a large part and is subject to very great distention due to food and drink, so that there is good reason why it needs strong fetters and coverings.

11. And now as regards the formation of the omentum, the subject from which my discussion [of the peritoneum] started, Nature has constructed this tunic so as to be extremely serviceable to it and very resistant to injury. For if the parts of the peritoneum arising from the spine on each side meet at the most convex and elevated portion of the stomach [the greater curvature] and find there a large artery and vein extending along it, this whole region will be the starting point of the omentum because it already furnishes everything of which the omentum stands in need. And indeed in this region we do find a large artery and vein [87] together with the two parts of the peritoneum and the part of the stomach which needs to be warmed. When Nature caused many veins and arteries to branch from the large vessels here, she extended along with them the parts of the peritoneum, and these invest and bind together the vessels where they are in contact with them. The parts of the peritoneum, lying one above the other like two folds, fill the spaces between the vessels as with a web. A great deal of fat is concentrated here; it warms the stomach, lubricates the membranes, and in times of fasting serves as nutriment for the innate heat. It is desirable for the reasons I have [I, 216]

[86] This portion of the peritoneum may well be that thin, tough sheet of connective tissue which Howell and Straus (1933, *111*) describe in the rhesus monkey as "extending from the caudal surface of the border of the diaphragm to invest the cardiac region of the stomach." The gastrophrenic ligament is also a possibility; see Lineback (1933, *216*).

[87] In man these would be the right gastroepiploic artery anastomosing with the left gastroepiploic branch of the lienal artery, and the right and left gastroepiploic veins. In the ape the place of the gastroepiploic arteries would be taken by the left gastric artery. See Lineback (1933, *255*).

given that the omentum should rest and, as it were, float upon the stomach—indeed, it is from this relationship that the omentum derives its name [38]—but it should not hang down entirely free from the other parts; for it would easily fall into folds and frequently roll
[I, 217] up and twist itself into a coil, leaving exposed many parts that are in need of a covering. It is for this reason, I suppose, that the omentum is attached to the spleen [by the gastrolienal ligament] and the part called the pancreas,[39] as well as to the outgrowth [the duodenum] [40] leading to the small intestine, the mesentery,[41] the colon,[42] and the curve of the stomach itself. If Nature had wished only to attach the omentum to these parts, it would have been sufficient to insert its membranous portion without involving the vessels, but since she had in mind something more important, she secured the connection to these instruments by means of the vessels, and I shall explain the usefulness of this device at the proper time farther on in my discourse.[43]

12. Now it would be well to take up the discussion of the liver and to remind you at the very outset of the principles I have established in my other works,[44] for they are useful not only for our

[38] ἐπίπλοον from ἐπιπλέω, to sail upon. Cf. *De anat. admin.*, VI, 5 (Kühn, II, *556–557;* Galen [1956, *157*]); XIII (Galen [1906, II, *124–125*; 1962, *137*]). For Galen's use of terms having to do with the sea and ships, see Gerlach (1936).

[39] The pancreas lies at the root, so to speak, of the transverse mesocolon, here evidently regarded as part of the omentum.

[40] This is one of the very few places where Daremberg (in Galen [1854, I, *303*]) has failed to interpret the Greek correctly. He has also failed to realize that the "outgrowth leading to the small intestine" is the duodenum (see note 19 of this book), thereby involving himself in unnecessary difficulties. The right border of the omentum is in contact with the commencement of the duodenum.

[41] Is, in fact, continuous with it.

[42] The posterior layers of the omentum separate as they ascend to embrace the transverse colon, and on the right the omentum is attached to the ascending colon.

[43] See chapter 19 of this Book.

[44] *De plac. Hipp. et Plat.*, VI, 5 (Kühn, V, *505–585;* see especially *568* ff.). For a detailed presentation of Galen's views on the liver as "the source of the veins and the principal instrument of sanguification," see Mani (1959, *67–70*). According to Cirenei (1961, *31*), modern physiology still recognizes a haematopoietic function of the liver at certain stages and under pathological conditions.

present purpose, but also for the successful completion of my whole book. I have said that in studying a composite part of the body to which some one action has been entrusted and which we call an instrument, it is necessary to find by dissection a certain part of it that resembles nothing else anywhere in the body and to regard this as the cause of the special action of the whole instrument, whereas its other parts are the causes of actions common [to all instruments]. So now we should think that this is true of the liver too, which we suppose to be the source of the veins and the principal instrument of sanguification; for in my other works I have proved this to be true. [I, 218] We must search, then, for this certain part which is the source of the veins and the cause of the formation of blood. Neither the arteries, veins, nor nerves can possibly be responsible, since these are parts common to the whole body, nor can it be the external tunic surrounding the viscus, which, as I showed just now, arises from the peritoneum. If none of these parts causes the action, it remains for us to inspect the flesh, so to speak, of the liver and the parts that receive the bile; for either the former or the latter or both must be the cause of the particular action of the whole instrument. Now it would be ridiculous, would it not, to suppose that the passages containing the bile are the instrument of sanguification or to regard them as the source of the veins? For these passages arise from the bladder at the liver which we call the gall bladder; they display a nature identical with that of the gall bladder and contain bile, not blood. Moreover, they are found not in the liver alone but outside it as well, as, for example, the duct [*ductus choledochus*] leading to the intestine and those [*ductus hepaticus* and *cysticus?*] inserted into the gall bladder itself, which is not, of course, a part of the liver. In some animals there is no gall bladder at all, but only canals that draw off the bile from the liver and convey it to the small intestine.[45]

[45] The dove is one of those animals which lack a gall bladder, as Galen says correctly in his *De atra bile*, cap. 9 (Kühn, V, *147*). But see *De anat. admin.*, VI, 8 (Kühn, II, *569;* translation by Singer [1956, *162–163*]): "The liver . . . is found in all [red-blooded animals], and those that have a liver invariably have a spleen and bile ducts, but they do not all have a gall bladder attached thereto. Those who have written on animals that, they say, do not have a gall bladder, do not tell the truth. Such is Mnesitheus *De elephanto*, for [that animal] has a gall bladder attached to the liver proportionate in size to the whole organ. And in animals that have [a gall bladder] it is always in the same

There remains, then, as the principal instrument of sanguification and source of the veins, only the so-called flesh of the liver, which is
[I, 219] certainly the characteristic substance of the viscus.[46] Indeed, if one observes carefully the nature of this flesh, it obviously seems very closely akin to blood; for if in imagination you dry out and thicken some blood by warming it, you will find that what you have produced is no different from the flesh of the liver. Its appearance is also evidence in favor of the proposition I have frequently demonstrated in my other works, namely, that all the parts which alter nutriment have as their goal, so to speak, and purpose to make what they alter similar to themselves.[47] If you think of the chyle taken up from the stomach, altered by the flesh of the liver, and changed gradually into the nature of that flesh, [you will see that] it must become thicker and redder before the resemblance is perfect. Similarly, I have also shown that it is impossible for a substance to acquire qualities either opposite or even widely different from what it has had without first passing through the intermediate stages.[48] Hence, if

---

position, namely, in the largest lobe of the liver." Galen nowhere tells us what other animals in his opinion lack a gall bladder, but it is probable that he was depending for his information on both his own experience and literary sources, of which Aristotle's amazingly accurate list (*Hist. an.*, II, 15, 506a20–23, 506b1–5; *De part. an.*, IV, 2, 676b25–35) was undoubtedly one. It is strange to find him taking issue with Mnesitheus, for the elephant was among the animals dissected by Galen, and it does indeed lack a gall bladder. See chapter 1 of Book XVII, and cf. Temkin and Straus (1946, *168*) and Singer (in Galen [1956, *249*]).

Mnesitheus was a physician and anatomist of the fourth century B.C.; he is cited by Galen in several places and especially in *Ad Glauconem de medendi methodo*, I, 1 (Kühn, XI, *3*), where he is said to have been in his time second to none in his knowledge of the art of medicine. See Hirsch (1886, IV, *252–253*) and Sarton (1927, I, *126, 146*).

[46] In *De anat. admin.*, VI, 11 (Kühn, II, *576;* Galen [1956, *166*]) Galen calls this "flesh" parenchyma, adopting, so he says, Erasistratus' term, which means literally "that which is poured in beside." In other words, the substance of the liver was supposed to be blood effused from the veins and congealed.

[47] "Digestion was shown to be nothing else than an alteration to the quality proper to that which is receiving nourishment" (*De nat. fac.*, III, 7 [Kühn, II, *165*]; translation by Brock [1928, *257*]). See also *De temperamentis*, III, 1–2 (Kühn, I, *654* ff.), and *De plac. Hipp. et Plat.*, VI, 8 (Kühn, V, *565* ff.).

[48] See *De nat. fac.*, I, 10 (Kühn, II, *20–21;* Galen [1928, *32–35*]).

it is the purpose of the flesh of the liver to transform the nutriment into its own likeness and if the change cannot take place all at once, the stage midway between the two states will be blood, which is as far from becoming the flesh of the liver as it has already progressed from its condition when it was the chyle elaborated in the stomach. These principles have been discussed in greater detail in my other works and this present statement of them is sufficient for instruction in the usefulness of the parts. The flesh of the liver, then, which is its characteristic substance, is the main instrument of sanguification. I [I, 220] say "main" because the veins leading to the stomach and to all the intestines also have a certain haematopoietic faculty which naturally inclines them to turn the juice derived from the food into blood even before it reaches the liver. The passages from the gall bladder have evidently been formed for separating the bile; the outer membrane is, so to speak, the skin of the liver; the nerve [*n. vagus sinister*] implanted in the liver serves to keep the viscus from being entirely without sensation, and its artery [*a. hepatica*] to preserve a due measure of innate heat, as I have shown in my book *On the Usefulness of the Pulses.*[49]

13. Have I now surveyed all the parts of the liver, or is there something that still needs explanation? No part has been omitted; I have mentioned them all, veins, arteries, nerves, the characteristic substance of the liver, the vessels of the bile, and the tunic surrounding all these parts. I have still, however, to discuss their position, number, size, contexture, form, and connections, and all their relations to one another. For so Nature's skill will be clearly demonstrated if she shall seem to have had some end in view when she prepared not only the essential substances of the parts, but also all their contingent attributes as well. Indeed, if you do not learn [I, 221] forthwith why she has not made a single large cavity in the liver like the two[50] in the heart, you will fail to recognize her admirable forethought. And so too [you must be able to answer the following

[49] Kühn, V, *149–180.*

It should be noted here that in his *De plac. Hipp. et Plat.*, VI, 8 (Kühn, V, *566*), Galen denies that the veins have anything at all to do with changing the nutriment into blood.

Kühn and Daremberg both start chapter 13 farther on, with the sentence beginning "I have still, however, to discuss."

[50] Two rather than four because Galen did not regard the atria as parts of the heart.

questions:] why the nerve is manifestly implanted in the tunic of the liver without penetrating any farther,[51] whereas the artery is clearly to be seen ramifying along with the veins throughout the whole substance; why the veins and arteries continuous with the porta in the concave part of the liver were established first of all, the passages for the bile come second, being placed upon the veins, and the veins continuous with the vena cava come last of all in the convex part of the liver; [52] why the artery is very small and the nerve still smaller, whereas the passages for the bile are larger than either of these, and the veins largest of all; why the veins of the convex part are not joined to those of the concave part; [53] why the tunics of all the veins in the liver are very thin; why the liver is attached to the diaphragm; why this attachment is in the vicinity of the vena cava; and how the liver is related to the neighboring parts. If you do not learn the answers to all these questions, I say that you will have no adequate notion of the usefulness of the parts and that it would be better for you never to have begun the subject at all than to have handled it

[51] Apparently because of their small size Galen failed to see the branches of the hepatic plexus accompanying the branches of the hepatic artery within the liver substance.

[52] This is a difficult sentence to interpret. Daremberg (in Galen [1854, I, *308*]) thinks that Galen is dividing the liver into three planes, with the branches of the portal vein and the arteries on the first, the biliary passages on the second, and the tributaries to the hepatic veins on the third, an arrangement hard to visualize, and he subjects the Greek to considerable manipulation to extract that meaning. It is both faithful to the original and more sensible to consider that Galen is explaining here the relative importance of the vessels and the order in which they were created. The branches of the hepatic artery and portal vein are the fundamental structures and determine the location of both the biliary passages accompanying them and the tributaries to the hepatic veins.

[53] Galen knew, of course, that there is communication between the portal and hepatic veins, but was uncertain by what means. He explains himself clearly in *De locis affectis*, V, 7 (Kühn, VIII *351–352*), where he says, "It is plain to be seen that the veins arising from the vein at the porta in the concave part of the viscus end in very fine extremities and that other extremities of the veins distributed from the vena cava in the convex part of the viscus arrive at the same place, but the junctions between them are certainly not visible. Still, nobody doubts—in fact, all proclaim as with one voice—that the nutriment to be distributed to the whole body passes through all the veins in the concave part and is taken over into those in the convex part through these very extremities."

poorly, as so many do. For some consider it enough to treat only of the origin of each part without examining position, size, contexture, form, and other attributes of the sort; it does not even occur to [I, 222] others to speak of any of these things; and some of this second group even omit a large number of the more important parts. Both groups are justly amazing; for if it is a good thing to understand the usefulness of the parts, I do not know why it is not good to understand the usefulness of all of them,[54] and on the other hand, if such knowledge is idle and superfluous, again I do not know why it is not superfluous to mention even a few of them. Now it is very easy to say, as I have said just now, that the veins in the concave region of the liver bring nutriment up from the abdominal parts and those in the convex region take it over; that the passages from the gall bladder remove the residues; that the nerve provides sensation; that the arteries preserve a due measure of innate heat for the whole viscus; that the tunic surrounds it like a protecting cloak and that this is a real tunic; and that the flesh of the liver is the source of the veins and the principal instrument of sanguification. But if we fail to give in addition the answers to all the other questions I have propounded, what we do not know about the usefulness of the parts will be more extensive than what we have learned.

To begin, then, with the first problem: Why has Nature united at the porta those many veins that bring the nutriment up from the stomach and all the intestines to the liver, only to divide them again into a great many branches? For she united them as if she needed them to be one, but she immediately divided them as if it had been useless to unite them, when she might have made one large cavity [I, 223] for the blood in the viscus and inserted into it on the lower side the vein from the porta that brings up the blood and on the upper side the vein that receives the blood and carries it to the whole body. What Erasistratus[55] says gives us to understand that the veins branch

[54] Or better, perhaps, "to understand the usefulness of all these things," that is, of position, number, size, contexture, etc.

[55] Erasistratus was an anatomist and physician of the third century B.C. and is sometimes called the founder of physiology. Galen approved his belief that Nature is artistic, doing nothing in vain, but objected vigorously to some of his other tenets, that air, not blood, is contained in the arteries, for example, that the spleen has no function, and that the parts exert no attraction, assimilation of nutriment by them being due merely to the horror vacui. See Galen, *An in arteriis natura sanguis*

in the liver in order to separate the yellow bile [from the blood], but if we examine the matter more carefully, his statement is obviously wrong because, as she has clearly shown in the kidneys, Nature is able to separate the residues without the aid of such a great interlacement of vessels. Certainly many heavy drinkers who drain whole amphoras and pass a corresponding amount of urine have no trouble separating [secreting] it, and all the blood entering the vena cava is purified very quickly and easily by the kidneys even though they have no contact with the vein. It is surprising that Erasistratus, who lectures us at great length on how the yellow bile is separated from the blood, has made no observations whatever on the separation of urine; for one ought to say nothing about either of them, or else discuss them both equally. But I have written a separate work [56] about these and all the other natural faculties, in which I have shown that every part of the body has a faculty whereby it attracts the quality proper to it, and in accordance with this principle the bile ducts attract the bile and the kidneys the urine. Hence it was not for the sake of separation that Nature made such a great interlacement
[I, 224] of the vessels in the liver, but in order to change the nutriment completely into blood by delaying it in the viscus. For if she had made a single large cavity like those in the heart to serve as a reservoir and had brought the blood in through one vein and discharged it through another, the juice carried up from the stomach would not pause an instant in the liver, but would pass quickly through the whole viscus, borne on by the force of its *anadosis*. Surely these narrow passages, like the pylorus of the stomach and the coils of the intestines, were made so that the nutriment might delay a little longer and be altered completely. The intricate coils of the arteries and veins before the testicles were made for the same reason, and also the plexus [*rete mirabile*] of arteries in the head, the so-called retiform plexus underneath the hard membrane [the dura mater]; [57] for wherever Nature has wished a material to tarry, she has made its progress difficult. If a single, large cavity had been formed in the liver, the blood would not tarry there and only a very

---

contineatur (Kühn, IV, *703–736* and *De nat. fac.*, I, 16 (Kühn, II, *60–67;* Galen [1928, *94–105*]); Hirsch (1885, II, *291–292*); Sarton (1927, I, *159–160*); Dobson (1927); Steckerl (1958, *2*); and my Introduction.

[56] *De nat. fac.*, (Kühn, II, *1–214;* Galen [1928]).

[57] For the *rete mirabile*, see chapter 4 of Book IX.

small portion of it would come in contact with the flesh of the viscus, with the result that sanguification would be impaired; for if the characteristic substance of the liver is the principal instrument of sanguification, nutriment that is more closely associated with this substance will take on the nature of blood more quickly and thoroughly. It is also for this reason that Nature made the veins themselves in the liver the most delicate of all the veins in the whole [I, 225] body, and since the other veins have nothing to do with the source of sanguification and must be resistant to injury, she very properly made them stouter. Not the least conclusive of the proofs of this statement is the fact that some of the [other] veins have been made thicker than others in accordance with their need of protection, as I shall show later in my discourse,[58] and that those in the liver are the most delicate because they run no risk of injury, being firmly established right within the viscus. Thus they are also better able to accomplish sanguification.

It also seems very clear to me that it was better for the passages that attract the yellow bile to be placed upon the veins bringing up the nutriment from the stomach and before those that take it over [tributaries of the hepatic veins]; for because of the convenient location of these vessels the vena cava will receive blood already completely purified.[59] We should also commend the location of the arteries for the same reason. Nature did not associate them impartially with both the upper [hepatic] and lower [portal] veins in

[58] There is no passage later in the work where this is done.

[59] Since Galen nowhere explains clearly his conception of the way in which the bile is secreted, it is necessary to piece together the evidence yielded by isolated passages. Here and a little above he has asserted that the bile ducts are placed upon (ἐπί) the veins, and he says it again unmistakably in *De anat. admin.*, XIII (Galen [1906, II, *132;* 1962, *145*]). In *De nat. fac.*, II, 6 (Kühn, II, *105–106;* Galen [1928, *164, 165*]), he maintains that material is attracted through the tunics of adjacent vessels, and it is a fair inference that he thought of the bile as being attracted through the thin walls of the veins of the liver into the biliary passages by the force of specific attraction. But his ignorance of relations at the "extremities" of the vessels led him to imply once (see chapter 6 of Book V, *ad fin.*) that the bile enters its ducts at their "invisible and extremely narrow extremities," even though in *De nat. fac.*, II, 5 (Kühn, II, *94–95;* Galen [1928, *146–149*]), he rejects the idea. His vagueness and inconsistency reflect, of course, his uncertainty. Of one thing, however, he is sure—the bile is *attracted.*

order to avoid cooling both regions equally, but stretched them only beneath the veins in the concave part of the liver, because she knew that in the convex part there is constant motion due to its proximity to the diaphragm. Likewise she properly made the arteries very small because they serve to cool only the concave part of the viscus and do not need to receive any blood (which has not yet parted with its residues). Neither is it necessary for the arteries to furnish as large a supply of vital spirit to the liver as to certain other instru-
[I, 226] ments or to nourish its flesh with thin and vaporous nutriment. But I shall explain this point more in detail later on.[60]

The nerve [from *n. vagus* via the hepatic plexus] which Nature has assigned to the liver is a very small one because she did not construct this instrument to furnish any movement or sensation to the animal. Indeed, the faculty of which the liver is the source and the actions entrusted both to it and to the veins issuing from it are such as we also find in plants. I have explained these matters at greater length elsewhere;[61] we must, however, bear in mind what I said and demonstrated at the very beginning of this work, namely, that it is impossible to succeed in discovering any usefulness of any part without first knowing the action of the whole instrument, and that I shall say nothing here to demonstrate any action, but shall simply remind you of the actions already demonstrated and so in every instance discuss usefulness in reference to them. Hence, when you recall my demonstrations, you will no longer be puzzled by the small size of the nerve; perhaps you will rather ask for what purpose Nature has given even this little nerve to the liver. For insofar as the viscus serves as the seat of the nutritive soul,[62] such as plants too possess, it obviously needs no nerve at all. Now whether we should speak of the nutritive *nature* or nutritive *soul* I shall leave to be determined by those whose cleverness lies only in applying names and who spend their whole lives doing it as if there were not many other more useful things for them to investigate and as if the matter were not sufficiently clarified by either term.[63] We must
[I, 227] guard against this fault throughout the whole discourse and remember Plato's advice,[64] that if we disregard names, we shall be the

[60] See chapter 15 of this Book, *ad fin.*

[61] See chapter 9 of Book V.

[62] Reading ψυχῆς with Helmreich for the φύσεως of Kühn's text.

[63] Cf. Galen's *De nat. fac.*, I, 1 (Kühn, II, *1–2*; Galen [1928, *2, 3*]).

[64] *Statesman*, 261 (Plato [1920, II, *288*]).

richer in wisdom when we reach old age. I have demonstrated in other works of mine that the liver is the source of a faculty similar to that which governs plants, but that it must also be closely associated with the two other sources and not entirely separate, just as these others are not separate from one another. For, as Plato says,[65] the liver is like a wild animal, but this integral part of ourselves must be nourished if there is to be a human race. The reasoning part of us, which is the real man, is situated in the encephalon and has as its handmaiden and servant the irascible [soul] (*θυμός*) to protect it against this wild animal. Wherefore our Creator connected these parts with offshoots [nerves, veins, arteries] and so contrived for them to heed one another. But these are loftier and more godlike themes with which I have dealt at greater length in my book *On the Teachings of Hippocrates and Plato*.[66] For the present, if you say, as I have said just now, that arteries from the heart arrive at the liver in order to preserve a due measure of heat in the viscus and that a nerve is inserted into its outer tunic to keep it from being entirely without sensation, you will make yourself clearer and more convincing to common folk. For if the liver could not feel an inflammation, an abscess, or other affections, it would [I, 228] not differ in any way from a plant. Hence it does perceive all such affections, but faintly, not clearly as the other parts of the body do, because its little nerve is distributed to the tunic surrounding the liver and either is not implanted in the viscus at all or at any rate does not penetrate throughout its whole substance. I have also shown that to some extent faculties are shared with other parts in the vicinity, and so it would be superfluous to distribute the nerve throughout the whole viscus, which could be furnished with faint sensation also by distribution.

14. I have now dealt adequately with all the characteristics of the liver. I still need to describe only the safety of its location, for which Nature long ago zealously provided. The liver is attached to the stomach and all the intestines by the veins and their enveloping tunics [the portal vein and its tributaries running in the mesentery

[65] *Timaeus*, 70 (Plato [1920, II, *49*]).

[66] *De plac. Hipp. et Plat.*, VI (Kühn, V, *505–585*). The doctrine of the three souls—the rational seated in the brain, the irascible in the heart, and the concupiscible in the liver—is Platonic. See *Republic*, IV, 435–442 (Plato [1920, I, *698–706*]), and *Timaeus*, 69–72 (Plato [1920, II, *48–51*]). See also my Introduction.

and free edge of the lesser omentum], and because of its shape and its lobes it is hard to separate it from the stomach. But these attachments are not sufficient, and so Nature supported it on all sides with certain bands as in a sling and attached it to the neighboring parts. One of these bands, the largest, which serves as the tunic covering the liver, originates from the peritoneum in such a way that it binds the liver to all the inward parts, for this tunic [the lesser omentum] extends to them all. There is another large band attaching the liver to the diaphragm [*ligamenta falciforme* and *coronarium hepatis*]
[I, 229] and other small, membranous bands that attach it to the false ribs [*ligamenta triangularia*]. The band by which I have said it is attached to the diaphragm is composed of the same substance as the peritoneum; moreover, it[67] originates from the tunic surrounding the liver and from that which invests the lower surface of the diaphragm, and, as I have said, both these tunics arise from the peritoneum.

In its thickness, however, its resultant strength, and its resistance to injury it necessarily differs greatly from the peritoneum. For when we stand erect, the liver must be suspended from the diaphragm, and there would be considerable danger that it would be easily torn loose in more vigorous movements and the animal would die immediately, because in that region the liver is attached not only to the diaphragm but, through the diaphragm, to the heart as well. Now since that hollow vein [the vena cava] of which I have already spoken distributes the blood to the whole body, of course it has to ascend to the heart, and no better route could be found for it because it must of necessity pierce the diaphragm lying between the two viscera. Hence it would not be a good arrangement to provide one set of supports for the vein and another for the viscus; on the contrary, it was desirable to make for both the vein and the whole viscus one thick, hard ligament [anterior layer of coronary ligament?] to serve as a covering for the vein and as a common ligament binding them both to the diaphragm. This place, then, would be of the greatest importance, and an injury to the vein at this point would
[I, 230] affect all the veins in the body, just as [a whole tree suffers if] its trunk is injured. For if this vein is wounded or torn loose, death

[67] Daremberg (in Galen [1954, I, *316*]) has slipped here, saying that it is the liver which originates from the surrounding tunic! Perhaps an uncaught typographical error.

ensues so swiftly that in the story when Odysseus, wisest of men, was planning his attempt to slay the Cyclops, so much larger than himself, the poet makes him intend to thrust his sword into precisely this part of the body "where the diaphragm holds the liver." And he would have done so, says the poet, if he could have hoped after the death of the Cyclops "to push away with his hands the enormous stone which had been set against the door";[68] so great was his confidence that a wound in that place would not permit life to continue even for a moment.

Nature has placed at the back the thinnest part of the large, hard band[69] that surrounds the vena cava, and the thickest part in front to prevent injury to the animal both from its own acts and from external causes; for the injuries sustained by a poorly attached vein from running or violent leaping are incurred by the animal's own act, but bruises or wounds inflicted on it by objects striking the animal are due to external causes. Now because the front of the vena cava is more exposed to such injuries, the covering of the vein did not need to be of uniform thickness, but was rightly made stronger in the parts more readily injured. Since the diaphragm is not only [I, 231] the wall of partition between the viscera above and below, as Plato calls it,[70] but also a not unimportant instrument of respiration, as I have shown in other works of mine,[71] it must not be cramped, compressed, or prevented from moving freely by any of the parts below it. Our Creator foresaw this necessity, and so wherever it was possible he separated the instruments in the vicinity as far as he could [from the diaphragm]. He did not connect the cavity of the stomach directly to the esophagus at the point where it pierces the diaphragm, but made the so-called mouth of the stomach as a receiving channel, gradually widening as if from a long, narrow isthmus; neither did he place the whole convexity of the liver in contact with the diaphragm, but elevated, arched, and lifted up the liver most in the region of the vena cava, making the two parts touch one another

[68] Homer, *Odyssey*, IX, 299–305.

[69] Perhaps Galen was thinking not only of the anterior layer of the coronary ligament but also of the vena caval foramen of the diaphragm, the tendinous margins of which are thicker and stronger on the ventral side.

[70] *Timaeus*, 70 (Plato [1920, II, *48*]).

[71] See, for example, his *De causis respirationis* (Kühn, IV, *465–469*).

only at this point.[72] Such is the great art displayed in the formation of the liver.

15. Of the subjects which it was my original intention to discuss, there remains the spleen, which, according to Erasistratus,[73] was formed by some strange intelligence for no purpose at all. Indeed, he is not ashamed to assert that Nature, who does nothing without reason (for he says so himself), had no end in view when she made this large viscus. Now I suppose, forsooth, that when Nature had
[I, 232] formed the liver in the right side of the animal while it was still contained in the uterus, she placed the spleen opposite to it on the left because she was afraid that she would be somehow unmindful of her skill and because too she wished to make something to occupy that place also. As if by extending the stomach slightly in that direction she could not have been spared the necessity of creating something useless! But then, Erasistratus argues at great length against the most stupid notions, as one can see in his books on deglutition, *anadosis*, and concoction, and makes not the slightest objection to the clearest, most firmly established opinions.[74] Sometimes he merely mentions them, sometimes he fails to do even so much and omits and passes them by as if they were not worthy of attention. Yet if for no other reason, surely for the sake of their authors, who are held in high esteem among the Greeks, he should not have treated these opinions so contemptuously, but should have opposed, refuted, and overthrown them with strong proofs.

As regards the spleen, I have shown in my book *On the Natural Faculties*[75] that it is the instrument which eliminates the thick, earthy, atrabilious humors formed in the liver. It attracts them, as I have said before,[76] by means of a venous vessel [*v. lienalis*] like a canal, and when it has done so, it does not immediately discharge them into the stomach, but first takes ample time to elaborate and alter them. For this action it uses chiefly the many large arteries

[72] At the bare surface of the liver.

[73] See Galen's *De nat. fac.*, II, 4 (Kühn, II, *91;* Galen [1928, *142, 143*]). For a summary of the opinions of the Ancients on the spleen, see Herrlinger (1958).

[74] Cf. Galen's *De nat. fac.*, I, 16, II, 9 (Kühn, II, *60* ff., *132–134;* Galen [1928, *94* ff., *204–207*]).

[75] *De nat. fac.*, II, 9 (Kühn, II, *131* ff.; Galen [1928, *202* ff.]).

[76] See chapter 4 of this Book.

extending through the whole viscus, which Nature did not assign to it idly or by chance but in order that by means of their incessant [I, 233] motion and the strength of the innate heat flowing to them from the heart the thick humors conveyed from the liver to the spleen may be elaborated, broken up, altered, and transformed. Those that have been altered into the juice most suitable for the viscus become nutriment for the spleen, but those that escape alteration there, that cannot be changed into the nature of thin, useful blood, and that are entirely unsuitable for nutriment are discharged by the spleen through another venous canal [one of the short gastric veins?] into the stomach, where they have a certain not unimportant usefulness which I shall make clear in my explanation of the residues.[77]

But now let us inspect the remaining features in the construction of the spleen and first of all its characteristic substance, which some call the parenchyma. This is the part which gives to the spleen the faculty of attracting the atrabilious humors; it is extremely loose-textured and porous like a sponge to enable it easily to attract and receive these thick humors. The arteries scattered everywhere throughout the whole viscus serve always to maintain this quality in the flesh of the spleen, and they were also formed for another important purpose which I mentioned a little while ago; for I have said that they are active in the elaboration of the humors brought [I, 234] from the liver to the spleen. In addition, however, they keep the flesh porous in this viscus, just as they do in the lung. If I was right when I demonstrated in my book *On the Natural Faculties*[78] that every part receiving nutriment attracts it from the adjacent vessels, then it is reasonable that the thinner nutriment is attracted from the arteries and the thicker from the veins. For the tunic [of the arteries] is denser than that [of the veins] and the blood contained in them is thinner and more spirituous. Moreover, it is better for porous flesh to be nourished by this kind of blood and similarly, denser flesh by blood that is thicker. But the thinness of the blood found in the arteries of this viscus is due to those thick, atrabilious residues. Hence too, although the flesh of the spleen is indeed a

[77] See chapter 4 of Book V, *ad fin.* The idea of this supposed discharge of the acid black bile from the spleen into the stomach was to persist and contribute important elements to Van Helmont's discovery of acid gastric digestion. See Multhauf (1955, *159–161*).

[78] *De nat. fac.*, II, 6–7 (Kühn, II, *105–107;* Galen [1928, *164–167*]).

porous substance, it differs widely from that of the lung, the latter being very porous, light, and almost white, as if made of congealed foam. For it is nourished by blood that is perfectly pure, bright red, thin, and spirituous; indeed, those advantages are inherent in the blood sent to the lung from the heart. But I shall discuss the nature of this viscus in a separate section.[79] Since the substance of the spleen is as porous in comparison with the liver as it is dense in comparison with the lung, it is very properly nourished by thinner blood [than the liver]. Now the blood attracted to the spleen is thicker than that
[I, 235] in the liver, but since it is elaborated by the splenic arteries and by the veins as well (and these have much thicker tunics than the veins in the liver), it is dispersed through the flesh of the spleen not all at once and as a thick liquid, but as a thin one and little by little. This is the reason why the flesh of this viscus is lighter and more porous than that of the liver, though neither redder nor paler in color; for the humor which it purifies and with which after elaboration it is nourished is atrabilious. But the liver is nourished by useful, thick blood, thanks to the thinness of the tunics of its veins and the size of the apertures.[80] To sum up, the nourishment of the three viscera is accomplished thus: the liver is nourished by thick, red blood, the spleen by thin blood which is nevertheless dark, and the lung by blood that is completely elaborated, bright red, thin, spirituous, and pure. Moreover, the flesh of each viscus corresponds in appearance to the kind of humor that nourishes it, or rather, because it was necessary for the flesh of each viscus to be such as it is, Nature has prepared a nutriment suitable for it.

These, then, are the two uses I have mentioned of the large number of arteries found in the spleen, and in addition to these there is a third which is related to the proper action and usefulness of arteries. For I have shown[81] that they are endowed with motion particularly in order to preserve the innate heat in each part; that they provide refrigeration during diastole by drawing in a cold
[I, 236] quality; and that during systole they cleanse the parts of the fuligi-

[79] See Book VI, *passim*, and chapters 1 and 2 of Book VII.

[80] It is hard to tell whether these "apertures" refer to the places where the vessels enter and leave the liver, or to the invisible "extremities" of the vessels, or to minute openings in the walls of the veins through which the attracted blood was supposed to pass, though I am inclined to think that the last-named possibility is what Galen had in mind.

[81] In *De usu pulsuum* (Kühn, V, *149–180*).

nous residues. Since, then, there must be a large amount of such residues in the spleen on account of the thick, unwholesome nature of the humors elaborated there, it is reasonable that many large arteries should be formed in the spleen. For just as the lung needs powerful refrigeration, so the spleen must have a thorough cleansing. The liver, on the other hand, has no need of this kind of cleansing because it has three other very effective methods,[82] nor does it need as powerful a refrigeration as the heart and (for the sake of the heart) the lung; hence it very properly requires [only] small arteries. These are the reasons why the substance of the spleen is loose-textured, light, and full of arteries.

16. The concave side of the spleen faces the liver and stomach and of course the convex side lies opposite the concave. On the concave side are the insertions of the arteries and veins and the connection with the omentum [gastrolienal ligament]; on the convex side where it draws away from the false ribs and the flanks no vessel is inserted, but certain fibrous connections [phrenicocolic (*sustentaculum lienis*) and lienorenal ligaments] are found in that region which attach it to other parts in the vicinity. The size and number of these connections are not the same in all animals but vary according to the species and even in individuals, for they were formed for no other reason than to hold the spleen in position, as I have said. Hence the ligaments not only of the spleen but also of the liver may in different [I, 237] animals be many or few, and strong or weak, and they may be found in different places. The tunic surrounding the spleen [peritoneal covering] is not only a ligament, but, as its name implies, a tunic as well, covering and clothing the viscus on all sides. It takes its rise from the peritoneum, as I said before, but I have also said earlier that the covering of the stomach must be thicker than that of the other instruments. I have now described the way in which the parts of the stomach, liver, omentum, and spleen are arranged.

17. I must speak next about the intestines. Now the nutriment is still undergoing concoction while it passes through them, just as blood [is produced] in all the veins. None of the intestines, however, was made for the sake of concoction, nor the veins for the production of blood, but, as I have said before, sometimes Nature gives the instruments secondary uses in her pursuit of the better, and sometimes this is a necessary result in all parts formed for a purpose.

[82] The bile ducts and bladder free it of the yellow bile; the spleen attracts the black bile; and the kidneys remove the serous residues.

Thus, just as Nature made the veins to be the instruments of *anadosis* but also placed in them a haematopoietic faculty in order that the time while the nutriment is passing through them might not be wasted, so for the same reason there is a certain faculty in the intestines for concocting food, although they were made to accomplish the *anadosis* of the nutriment into the veins. Indeed, as I have
[I, 238] demonstrated in my commentaries *On the Natural Faculties*,[83] it was quite impossible to avoid endowing each part of the animal with an alterative faculty. The substance of the intestines differs only slightly from that of the stomach and so, if they must also have an alterative faculty and one like that of the stomach, it follows of necessity that in them too the nutriment will be concocted. For just as in the liver there is a workshop, so to speak, for the production of blood, so in the stomach there is a workshop for concoction.

You may learn from the following arguments that the intestines were not made [primarily] to move the residues along or to concoct nutriment, but to transfer to the veins all the chyle that has been produced in the stomach: first, because the stomach is not so constructed in any animal as to adjoin the instruments by which the residues are voided, though certainly its lower end could have been extended directly to the part called the fundament; second, because in most animals the intestines have a large number of coils; and, third, because the nutriment is not discharged from the stomach until it has been completely concocted; for I have already shown this to be true. The fact that in animals the stomach is not connected directly to the fundament indicates clearly that there must be one instrument for concoction of the food and another for its *anadosis*. For if they were one and the same, the veins would frequently be in danger of taking up crude, unconcocted nutriment, which surely
[I, 239] ought not to happen. It is clear, then, that there must be one part for concoction and another for *anadosis*.

What I have been saying is confirmed by the circumstance that the instrument for *anadosis* does not extend straight to the fundament, its course being interrupted by many loops and coils, a characteristic given it apparently to prevent the nutriment from escaping too easily from the body. For if a second stomach should come next

[83] *De nat. fac.*, III, 1 (Kühn, II, *143;* Galen [1928, *222, 223*]). But Galen, having labored to show here that concoction continues in the intestines, remarks in the next paragraph that nutriment is not discharged from the stomach until it is *completely* concocted!

after the first and should be a storehouse for *anadosis*, just as the first is an instrument for concoction, a great deal of nutriment would not be taken up to the liver through many veins in a short time. Actually, the coils of the intestines, having countless veins from the liver inserted into them, send up all the juices concocted in the stomach. With this other arrangement, however, only a little of the chylified nutriment would be accommodated at one time in the mouths of the few veins, and *anadosis* would become a slow, time-consuming process; for the mouths of the vessels must come into close contact with the elaborated and concocted juices. If a second,[84] large stomach were placed beneath the first, it would come into close contact with a small part of the nutriment,[85] only that, in fact, which touched it, while most of the nutriment would occupy the depths of this stomach and so fail to be taken up by the veins. But as it is, the narrowness of the passage, by reducing the nutriment to small particles, forces almost all of it to come into close contact with the [I, 240] tunic of the intestines where the mouths of the veins open and so also with the mouths of the vessels. If any nutriment escapes contact in its passage through the first coil, it is caught in the second, and if it escapes in the second, then it is caught in the third, fourth, fifth, or one of those farther on; for there are very many of them. Certainly every particle of the nutriment is forced to encounter the mouth of a vessel at some point in this canal that is so long and narrow and has so many coils. In fact, the whole curved surface of the intestines is pierced by innumerable openings that extend to the inside and seize upon the useful part of the nutriment as it is going by. As a result, no juice useful for nourishment escapes and passes out of the animal, at least when the parts of the body are governed by Nature's law. This present treatise is of course concerned with the parts when they are so governed, and not with diseases, when the normal order is upset, when Nature's art is impeded, and there is need of a helping hand to intervene and remove the cause of the trouble. Surely, even if I do not make this statement in connection with every use which I have undertaken to discuss, it is not careless in me to omit it, but stupid of anyone who does not take it for granted.

I have certainly demonstrated that the coils of the intestines were formed to accomplish the complete *anadosis* of all the concocted

[84] Reading μεγάλης with Helmreich for the μεγάλῃ of Kühn's text.

[85] Reading τῆς τροφῆς ἡ γαστήρ with Helmreich for the ἡ τροφὴ τῆς γαστρὸς of Kühn's text.

nutriment. It would seem that this was the thought in Plato's mind when he said, "[The intestines were formed] to keep the food from passing quickly through and forcing the body at once to require
[I, 241] more food, thus causing insatiable gluttony and making the whole race of mortals the enemy of philosophy and music." [86] All animals whose intestines are not coiled but extend straight from the stomach to the fundament are greedy, gluttonous, and forever engaged in taking nourishment, like the plants.[87] But Aristotle has an excellent discussion of these matters, saying among other things that Nature, diverging gradually from her custom in creating plants, makes one animal after another, each more perfect than the preceding, until she comes to the most perfect of all,[88] the one that is the theme of my present discourse. Hence it is not my intention to discuss the number of stomachs in ruminants or the stomach and other instruments of nutrition in each species of animal; for Aristotle has excellent treatments of them all.[89] If life were not all too short for the investigation of the noblest subjects, perhaps some day I should supply what remains [to complete his observations] in this field. But for the present let us be content if I am able to give for man alone an accurate explanation of construction, and so let us bring our discourse back to matters related to our theme. Here too I shall remind the readers of this book not to expect to find it in demonstrations of actions, because they have all been explained in my commentaries *On the Natural Faculties*. [It is explained there] likewise that the mouths of the arteries extending to the intestines take up a small
[I, 242] amount of nutriment, but that most of it is received by the veins.[90] I have also shown in another separate work [91] that normally blood is contained in the arteries.

[86] *Timaeus*, 73 (Plato [1920, II, *51*]).

[87] See Aristotle, *De part. an.*, III, 14, 675b22–28; cf. *De gen. an.*, I, 4, 717a23–26.

[88] *Hist. an.*, VIII, 1, 588b4–23.

[89] *Ibid.*, II, 17, 507a30–509a23; *De part. an.*, III, 14, 674a9–675a30.

[90] *De nat. fac.*, III, 13, 14–15 (Kühn, II, *200, 206;* Galen [1928, *308, 309, 316–319*]).

[91] *An in arteriis natura sanguis contineatur* (Kühn, IV, *703–736*). This treatise is directed against Erasistratus, who thought that only air is contained in the arteries. There is another refutation of Erasistratus on this point in the medical writings of Anonymus Londinensis. See Jones (1947, *102–109*), and see also my Introduction, pp. 54–55.

Now I shall add whatever remains to be said about the construction of the intestines. I have demonstrated that all actions and faculties called eliminative and expulsive result from the motion of transverse fibers, whereas it is the motion of straight fibers that produces attractive actions and faculties.[92] Thus, just as the stomach needs two tunics made of different elements because it is endowed with both motions, so each intestine, having only one kind of motion, the expulsive, has only one kind of tunic, which may be resolved into transverse, circular fibers. Why, then, do the intestines have two tunics if they are both alike? I ask because one of the two would seem to be superfluous. But it is not so; for the tunic of the intestines was doubled to allow for the violence of the expulsive faculty and to make the instruments themselves resistant to injury. Now just as it was better for the food to remain for some time in the stomach in order to be completely concocted, so it was better for it not to tarry in the intestines, because its *anadosis* from the intestines to the liver is quickly completed while the food traverses the long, narrow passage. The dysenteric diseases afford particularly good evidence that the two tunics are of considerable assistance in providing perfect safety and resistance to injury for the intestines. In many persons who have been severely ill with these diseases for a long time I have [I, 243] frequently seen such putrefaction of the greater part of the intestines that in many places the inner tunic was entirely destroyed, and yet the persons survived and lived out their lives,[93] though they would not have recovered if there had not been a second tunic lying outside the one that was destroyed. Some of the intestines have certain straight fibers stretched longitudinally on the outside to protect the transverse fibers. This is true particularly of animals whose intestinal tunics are thin or whose actions are very vigorous, for in them there would be danger that the transverse fibers would be torn apart if they were not held together on the outside by straight fibers serving as a bond between them. This is also the reason why the fibers are more numerous in the rectum, since its

[92] See chapter 8 of this Book, *ad init.*, and cf. Galen, *De nat. fac.*, III, 8 (Kühn, II, *168–177;* Galen [1928, *260–275*]).

[93] Daremberg (in Galen [1854, I, *328–329*]) comments as follows: "This is a valid thesis, one that can be established in part simply by examination of the material evacuated; for Galen did not verify it by pathological dissection."

tunics must contract vigorously upon the large amount of hard residues of the dry nutriment collected there. The bond, then, superimposed upon the outer side of the transverse fibers has been made up of certain straight fibers. In most animals the whole colon is bound by strong ligaments [*taeniae*], one on each side,[94] running longitudinally from above downward. I have said earlier that in addition the peritoneum also surrounds this second tunic and serves to connect all the intestines with the bodies at the spine and with one another.[95] In short, there is no instrument below the diaphragm that
[I, 244] is not covered by a tunic arising from the peritoneum. This is enough to say about the thin intestines.

18. The situation as regards the thick intestines is as follows: Just as the thin intestine was constructed for *anadosis* and exists for that purpose (although it also concocts the nutriment and moves it on its way), so the thick intestine has been formed to prevent elimination from being a continuous process. In many of the voracious animals, however, in which the intestine is straight, it may be observed that there is no difference in width at its lower end. But these animals both feed continually and as incessantly eliminate, leading a life truly inimical to philosophy and music, as Plato has said, whereas nobler and more perfect animals neither eat nor eliminate continually. I have demonstrated that it is the coils of the intestines that keep us from needing a constant supply of nutriment; similarly it is the breadth of the thick intestine that enables us not to eliminate [too] readily, but only at longer intervals. The thick intestine is like a second stomach placed below the thin intestines, as the bladder is placed to receive the urine. For in order to prevent continual elimination and urination in animals, the bladder has been established for
[I, 245] the liquid residues and for the dry residues the so-called thick intestine which some also call the lower stomach. It begins at the caecum; at the point where the thin intestine comes to an end, the caecum extends to the right and the colon to the left,[96] passing first up along the right flank. The caecum is exactly like a thick pouch suitable for the reception of residues, and the colon is comparable to

[94] Galen missed the third one of these bands, hidden, as it is, in the mesocolon at the rear.

[95] Reading ἄλληλα with Helmreich for the ἄλλα of Kühn's text.

[96] From the point of view of the observer, looking down at the dissected animal lying on its back.

it.[97] In most birds the caecum is double because of the violence of the [digestive] action. If, then, any [nutriment] has escaped *anadosis* during its passage through the thin intestine, it is all sucked completely dry during its long stay in the caecum, and since the stomach and intestines are endowed with vigorous actions in nearly all birds, there are in them two receptacles for the residues, in order that no part of the nutriment by passing through too quickly may fail to be extracted, and that elimination may take place in a mass all at once and not continually and little by little. But in man and all animals that go afoot Nature has made a single caecum and placed it at the right flank, because she found a suitable place unoccupied in that region, the right kidney lying higher up for a reason which I shall give later on.[98]

19. Nature has arranged all these matters admirably, and in addition to them there are the muscles which close the two outlets for the residues and are like bars to prevent continual and untimely elimination. The so-called neck of the bladder is muscular [99] and the lower end of the rectum is held shut by circular muscles surrounding it [*sphincteres ani, externus* and *internus*]. This is the reason, I suppose, why some have called it the *sphincter*. For all the muscles, being instruments of voluntary motion, do not allow the residues to be evacuated except at the command of reason, and here at the two outlets for the residues is the only instance in this whole long course of the physical (natural) instruments [alimentary tract and urinary organs] where there is an instrument of the psychic soul. If in some individuals these muscles are relaxed or impaired in any other way ever so slightly, the residues flow out involuntarily and inopportunely, showing clearly how shameful and gross would be our life if from the beginning Nature had not planned something better. [I, 246]

Well, she has arranged these matters admirably, and likewise she has not idly and carelessly neglected [100] to provide that all the parts

[97] Note the omission of any description of the vermiform appendix, with which Galen, whose first-hand knowledge of human anatomy was sketchy at best, was unfamiliar.

[98] In chapter 6 of Book V, *ad init.*

[99] On the basis of a passage in chapter 16 of Book V, this muscle is to be identified as sphincter vesicae rather than sphincter urethrae membranaceae. See note 55 of Book V.

[100] Reading παρῆλθε with Helmreich for the προῆλθε of Kühn's text.

of the stomach and intestines, which serve to nourish the other parts of the body, should also be properly nourished themselves. First, in the whole mesentery she made special veins [lymphatic vessels] that were destined to nourish the intestines and that do not pass to the
[I, 247] liver; for, as Herophilus has said, these veins end in certain glandular bodies [lymphatic glands of the mesentery], whereas all the others ascend to the porta. Then, most important of all, she has constructed in addition an extremely large number of vessels in the omentum for the same purpose, to nourish everything in the vicinity. These two clever devices of Nature's are sufficient for the complete nourishment of the intestines and stomach. There are, however, two others that help to nourish them. One, which has already been demonstrated, is the digestive process itself, and the other is an ability of the parts below during long periods of fasting to attract a certain amount of nutriment even from the liver itself. When *anadosis* to the liver and exact elaboration and separation (purification?) of the nutriment undergoing *anadosis* have already been completed, the lower instruments, if they feel the need of nourishment at that time, are able to attract useful blood. Some have been surprised that useful blood should ever flow back through the same veins by which *anadosis* to the liver had earlier been accomplished, but they are ignorant of Nature's other works and do not realize how powerfully instruments attract when they are in need of nourishment. I have demonstrated this in other works of mine.[101]

20. Let us now explain the work of Nature and her skill as displayed in what still remains to be described in the parts under discussion. The mouths of a large number of veins, like the last slender extremities of the roots of a tree, open into each of the
[I, 248] intestines. Just as in trees Nature makes the slender rootlets unite to

[101] *De nat. fac.*, III, 13 (Kühn, II, *186–204;* Galen [1928, *288–315*]). From this passage it becomes clear that some of "Nature's other works" referred to by Galen are the discharge of the contents of the stomach by vomiting, the passage of the bile through the cystic duct now in one direction and now in the other, the entrance of the semen and exit of the fetus through the mouth of the uterus, the action of purgative drugs which draw material from a part through the same stomata by which it has entered, and inspiration and expiration, both accomplished through the trachea. See also chapter 15 of Book VI, *ad fin.*, where Galen says that the "venous artery" (the pulmonary vein), by which in his opinion the air reaches the heart, serves too as the channel conveying fuliginous residues from the heart to the lung; and see note 43 of Book VI.

form thicker ones, so in animals she has made the little vessels unite to form larger ones and these again join to form others still larger, continuing the process as far as the liver, where she has brought them all up into one large vein at the porta. From this vein those leading to the stomach and spleen also branch off. In the same way she has brought all the arteries up to form a single large artery at the spine.[108] It is a long distance from the beginning to the end of all the vessels and it would not be safe to conduct slender ones over it without some protection. Moreover, the vessels leading up to the porta of the liver would be suspended, so to speak, with no firm support on which to rest, and nothing else in their course to help fix and hold them in place and sustain them. How, then, has Nature provided for their safety so that they will not be crushed, broken, or harmed when the animal leaps or falls or is struck violently by some external object? From the tunic which invests the intestines and holds them together and which I have said originates from the peritoneum [*tunica serosa*], she caused [another] tunic [the mesentery] very like the actual peritoneum to grow out, and with this she covered all the vessels. In the empty spaces between the vessels she folded this same tunic upon itself, doubling it, and thus made the tunic itself resistant to injury and prepared a support and sure protection for the vessels. In most cases where the vessels are entirely pendent and ascend straight to the liver, Nature, realizing that [I, 249] they are most liable to injury where they unite, has placed there certain fleshy bodies called glands [lymphatic glands and pancreas], which are inserted like wedges at the places where the vessels divide and which furnish safe support for them, thus preventing injury from any accident. I have now completed my discussion of the mesentery. Next I should consider to what point Nature could advantageously bring down the great vein that issues from the liver and receives all the mesenteric veins. But since this book is already long enough, I shall postpone to the next my explanation of this subject and the other matters concerning the instruments of nutrition that still remain to be discussed.

[108] Daremberg (in Galen [1854, I, *334*]) identifies this artery as the celiac trunk, but since it is the intestines that are under discussion, Galen probably had the superior mesenteric artery in mind, unless he was thinking of the aorta itself. Cf. his opening remarks in Book V and note his inconsistency. See also note 3 of Book V.

THE FIFTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Instruments of Nutrition, continued]

1. Next I must consider to what point Nature could advantageously bring down the great vein that issues from the liver and receives all the mesenteric veins; for it was undoubtedly necessary for this same vein also to receive those leading from the stomach and the spleen. You will acknowledge that the same problem arises in
[I, 250] connection with the artery which I have said branches off from the large artery at the spine [the aorta]. In like manner the canals[1] leading from the bladder at the liver which are intended for the evacuation of bile must proceed, I suppose, not simply to any

[1] Note the plural. In *De anat. admin.*, VI, 12 (Kühn, II, *578;* Galen [1956, *166–167*]), Galen describes in the ape an occasional branching of the bile duct. In *De temperamentis*, II, 6 (Kühn, I, *631–632*), he says, "The canal by which the liver discharges the bile into the belly is paired in some individuals and single in others, a thing that may be seen in the dissection of quadrupeds. In most cases it is single and is inserted between the pylorus and jejunum into that part which is called the outgrowth of the stomach [the duodenum]. When it is paired, one branch, the larger of the two, is inserted into the outgrowth, and the other, smaller one into the lower part of the stomach a little above the pylorus, but in a very few individuals the upper branch is the larger and the lower is the smaller. . . . In those in whom the canal is single, the bile all flows into the jejunum [by way, of course, of the duodenum]." What Galen saw and interpreted as an occasional second bile duct is problematical. Did he perhaps sometimes get a glimpse of the pancreatic duct? Or is he merely thinking of the cystic and common bile ducts as two separate canals and not as one continuous passage?

random part of the stomach or intestines, but to some place which will make their course safe and which will not suffer from receiving such a residue. It is our present task, then, to see whether we have any better place to propose which Nature overlooked when she conducted each vessel I have mentioned to some inferior and more dangerous location.

2. We should begin our investigation with the following question: Would it be better for Nature to produce many veins from many parts of the liver and conduct one to each of the instruments beneath, or to choose one suitable place in the viscus and there produce a single large vein, deriving the others from it like branches from the trunk of a tree? It seems to me that the latter method is the [I, 251] better. For it would not be safe for veins traveling a long distance to be slender right from their source, and also it would be undesirable for the liver to have many outgrowths and apertures. Obviously it was better for it to be protected on all sides by a close tunic and to have only two stout veins in all growing out from it, the vena cava above and the portal vein below. If, then, it was better to have a single vein at the porta, let us now try to discover to what point it would be better to conduct it and how it should be subdivided. It seems to me that it should send branches to the different viscera when it has reached a point between the stomach and intestines. For if it proceeded lower [before branching], it would be much too far from the stomach, and again, if it branched higher up, in the first place it would be far from the intestines, and besides it would rest insecurely on the stomach, an instrument that changes constantly, expanding greatly when it is filled with food and contracting when it is empty. Hence, in order that the veins may be distributed equally to all the instruments of nutrition and that the vessel descending from the liver may find firm support, this vessel had to pass between the stomach and intestines and rest upon the vertebrae lying beneath it in that region. But it was undesirable for this vein to go to one place, and the artery [*a. mesenterica superior*] which was to be distributed along with it to the whole mesentery to another. For wherever no more important consideration prevents, Nature divides the arteries along with the veins in order that she may at the same time use for the arteries the membranes with which she covered the veins and fastened them to the other parts in the vicinity, and also that the vessels may have community of action and an exchange of

materials. I have demonstrated this in my other works.[2] Moreover, a branch from this same artery had to be made leading to the liver,[3] and the nerve which ramifies along with the artery and vein throughout the whole mesentery had to begin with them at the same place [*plexus mesentericus superior*]. Certainly, no safer place could
[I, 252] be found for the origin of the branch which this nerve sends to the liver [*n. vagus* via the hepatic plexus]. I shall show a little later that the canals evacuating the bilious residues from the bladder at the liver should be conducted to this same place. Since, therefore, the vein, artery, and nerve, together with the bile duct as a fourth vessel, must extend to this one place,[4] it is clear that here also must be the place where they begin to branch. Now all vessels are most liable to injury where they branch, and so if some accident due to violent motion should befall any of these vessels, it would be their points of division that would be most likely to suffer. Hence this place stood in need of much assistance if it was to protect the branching vessels distributed there. Nature, realizing this, created a glandular body called the pancreas and spread it beneath all the vessels, surrounding them with it and filling the places where they divide. As a result, no

[2] *De nat. fac.*, III, 15 (Kühn, II, *207;* Galen [1928, *320, 321*]).

[3] Daremberg (in Galen [1854, I, *337*]) remarks that this passage is *fort embarrassant;* for the hepatic artery, of course, is a branch not of the superior mesenteric artery but of the celiac trunk, and Galen so describes it farther on (see p. 711). The explanation is found in his *De venarum arteriarumque dissectione*, cap. 9 (Kühn, II, *820–821;* Galen [1961, *364*]), where, speaking of conditions in the ape, he says that the artery for the liver sometimes arises from the lower of the two unpaired arteries branching from the front of the descending aorta soon after it leaves the thorax, in other words, from the superior mesenteric. Gray (1948, *610*) says that the hepatic artery has this origin in 12 per cent of human cadavers. In *De anat. admin.*, XIII (Galen [1906, II, *153–154;* 1962, *169*]), however, Galen says that the two branches from the aorta sometimes arise as one, from a common root, but that when this is not the case, the artery for the liver invariably comes off from the upper branch, that is, from the celiac. It is sufficiently evident that in this particular passage of *De usu partium* he has chosen to describe the case which best suits his contention that the arteries, veins, and nerves supplying the instruments of nutrition should all branch from the same place.

[4] Daremberg (in Galen [1854, I, *337*]) identifies "this one place" as the porta of the liver, but it is apparent from the context that Galen means rather the general region where subdivision of all these vessels begins.

one of them is unsupported and easily torn asunder, but all are at all times kept from being bruised, crushed, or broken, because they rest on a soft, moderately yielding substance, and if they are moved with some violence, they strike against objects which are not hard and resistant but which receive them gently and gradually deaden the force of the motion. Moreover, Nature has surrounded each vessel separately and all of them together with strong membranes, investing and connecting them not only to the gland but also first and [I, 253] most particularly to the parts lying beneath them along the spine and then to all the other instruments in the vicinity. But none of Nature's devices in this region would have been effective if she had not prepared adequate space for them in advance. For if the jejunum had been attached directly to the lower end of the stomach, its coils would have narrowed the space considerably.

3. Nature, foreseeing this situation, did not throw the first of all the intestines, the one attached to the stomach, immediately into coils, but produced it stretched along the spine as far as was necessary to provide sufficient space for the structures I have been discussing. But the following part of the intestines is wound in coils and this part of them is called the jejunum (*νῆστις*) [5] because it is always found to be empty, containing not the least particle of nutriment. Now the part between the jejunum and the lower part of the stomach, which remains uncoiled for the reason I have given, is customarily called "the outgrowth into the intestine" by anatomists. Here, then, is the list of the instruments which, after the stomach, receive the nutriment:

1. Outgrowth [Duodenum]
2. Jejunum
3. Thin intestine [Ileum] [6]
4. Caecum
5. Colon
6. Rectum

[5] Both *νῆστις* and its Latin equivalent, *jejunus*, mean fasting or hungry. When Galen says, as he presently will, that the jejunum serves no useful purpose, he means that this is true of its emptiness, not of the part itself; in fact, that is the way he puts it at the close of his discussion.

[6] It is to be noted that Galen sometimes uses the term "thin intestines" to mean the duodenum, jejunum, and ileum taken together, sometimes, as here, restricts it to the ileum, and sometimes includes in it both the jejunum and ileum.

At the end of the rectum are the sphincter muscles [*sphincteres ani, externus* and *internus*] that confine the residues. And now it is evident that I have given the reasons (χρεία, usefulness) for the construction of all these parts; the outgrowth has been explained in
[I, 254] this book, and in the preceding book are the reasons for all the differences in the construction of the thin and thick intestines. If I seem to have omitted any part, you will find either that it is to be explained by the same reasoning as the subjects I have already discussed, so that even without hearing it from me anyone can easily discover the explanation because it follows from what precedes, or that although the part serves no useful purpose for the animal, as in the case of the jejunum, it is a necessary consequence of parts which have been formed for a purpose. But I shall show a little later that the jejunum was not constructed as it is for any usefulness of its own, and that its characteristics were determined by parts that were constructed for a specific purpose. If my readers should not discover by reason, each for himself, the facts that can be deduced from what I have said and should expect to hear everything from me, this present discourse would be dragged out tediously by long explanations, as anyone can see from the following very short example. When in speaking just now of the outgrowth to the thin intestine [the duodenum] I said that it extends along the spine and should not be coiled at first or until it has provided space for the parts that must be located between the stomach and jejunum, perhaps someone might inquire further, as if for something I had omitted, about what Erasistratus has written on the subject, saying, "The outgrowth to the intestine lies on the right and turns down along the spine." But, you ask, what purpose does it serve in lying on the right, and why does it turn down along the spine? The first question I answered in the preceding book, and the second needs no special explanation since I have already said thousands of times that
[I, 255] Nature leaves nothing without support. Now if this is true, it is perfectly evident that she would also not permit the outgrowth formed at the lower end of the stomach to hang free but would conduct it to the spine, give it support there first, and after that fasten it to the other parts of the body in the vicinity by membranous ligaments.[7]

[7] That is, by peritoneal folds and the ligament of Treitz. In the rhesus monkey all but the first part of the duodenum has a well-defined free mesentery. See Lineback (1933, *214*).

From a study of the jejunum you may learn that some parts have not been formed for any [specific] usefulness but are made necessary by other parts and that the former are not really parts at all, but only accidents; for in the preceding discussion I have shown that the jejunum is useful only because it is the beginning of the thin intestine, seeing that a structure containing no nutriment would be of no [direct] use to the animal. But it is a necessary consequence of certain other, more important parts which do exist for a purpose. The circumstances that have produced it are as follows. The jejunum is the first of all the intestines to receive the nutriment chylified and concocted in the stomach. It is situated near the liver and very many vessels open into it. A little farther up, in the outgrowth from the stomach [the duodenum], the bile ducts[8] discharge the bilious residue. It is from this first intestine that the liver while it is yet unfilled draws up its nutriment. Some of these circumstances are conducive to quicker *anadosis*, others to strong expulsive action. The large number of vessels, the situation of the liver close by, and the fact that the jejunum is the first to receive the concocted material and offer it to the unfilled liver cause *anadosis* to take place very freely and rapidly; and the energy of the [expulsive] action is increased by the jejunum's proximity to the place where the bilious residue first falls into the intestine. For many veins, traveling only a short distance to the liver, take up nutriment more quickly than only a few that must travel farther; *anadosis* is also more rapid if the supply of useful nutriment attracted by the veins is abundant than if it is not, and more rapid too if the veins offer it to an empty liver rather than to one already filled. Moreover, the energy of the [expulsive] action is increased when the bile is not yet mixed with residues but circulates, still pure, along the tunics of the intestines, irritating and stimulating them to evacuation. Hence, when the intestine conveying the nutriment acts energetically and the viscus receiving it takes it up readily, the nutriment necessarily passes through rapidly so that there is no lingering or tarrying there, but only a passage through, and that a swift one. However, since the nutriment received by the intestine is not always chylified to the same degree, since the liver does not attract it always with the same energy, and the inflowing bile is not always constant in quantity or quality, it is reasonable that the number of coils of the intestine [I, 256]

[8] Note again the use of the plural.

found to be empty is not always the same, but that sometimes there are more of them and sometimes less. It is clear, then, that this emptiness of the first coils of the intestines was not created for any purpose, but is a necessary consequence of other parts that were so constructed.

Thus you should not be anxious to hear my explanations of
[I, 257] everything; on the contrary, you should discover some things for yourself [9] on the basis of what I have already told you, as I said just now in connection with the turn which the outgrowth from the stomach makes toward the spine, and you should recognize that there are other things not within the scope of this present treatise. For in these commentaries I am explaining not things that are a necessary consequence of other things that have been formed for a purpose, but parts created by Nature in her original plan.

4. Bear this fact [10] constantly in mind as you listen to what follows. For I am going to demonstrate that proposition concerning the bilious residue which I postponed a little while ago, namely, that it was better for it to flow into the outgrowth from the stomach [the duodenum]. To those who have listened with careful attention to what I have said up to this point, I think it will be clear that the shortest route would be better for the duct itself which conveys the residue and which must be quick to share in the provisions that Nature has made for the safety of the vessels accompanying it in this region. You will also certainly understand that this arrangement is better for the instruments receiving [the bile] if you take into consideration the large amount of phlegmatic residues necessarily formed in these instruments. I have given a full and accurate account of the formation of these residues together with the appropriate demonstrations in my commentaries *On the Natural Faculties.*[11] After merely mentioning the fact, then, that a great quantity of such residues is formed, I may now derive from it [12] an argument to use in
[I, 258] the demonstration of the propositions I have in hand.

Have you ever seen a man who refuses to take nourishment, has an aversion for food, and becomes nauseated if forced to eat? He

[9] Reading *αὐτὸν* with Helmreich for the *αὐτῶν* of Kühn's text.
[10] The *τούτου* of Helmreich's text is omitted by Kühn.
[11] *De nat. fac.*, II, 9 (Kühn, II, *125–142;* Galen [1928, *194–219*]).
[12] Reading *αὐτοῦ* with Helmreich for the *αὐτῶν* of Kühn's text.

tolerates nothing except perhaps [13] acrid substances, and these do him no good but distend and inflate his stomach, causing nausea that is relieved only a little by belching. At times the food itself becomes spoiled, especially by changing to acid. If you have ever seen such a person and if you remember how he was cured, I think you will readily agree with what I am about to say. In case you do not remember, I will indicate the method of treating such sufferers successfully, and if you are a lover of truth, you will apply the touchstone of reason to convince yourself. Read what physicians have written of the remedies they have discovered, the main object of the treatment being to expel from the stomach the phlegm, which is naturally viscous enough and becomes even more so in disorders of this kind because it stays so long in such a warm place. I once saw a man in this condition vomit an incredible amount of the thickest phlegm after eating radishes [cooked] in oxymel [14] and immediately seem completely cured, even though for three months previously nothing about his stomach or its concoctions had proceeded properly. As I said, it has been demonstrated in my other writings that a residue of this sort has to be formed in the stomach and intestines, and a proof that it is so formed is found both in dissection and in the [I, 259] disorders commonly afflicting mankind because of an overabundance of such residues. There is only one remedy for these ills, namely, to prescribe those substances that can break down, dilute, and wash away the thick, viscous material.

At the very beginning Nature provided this assistance in the form of an acrid, detergent juice, which has to be completely evacuated from the body and which she introduced not into a part of the intestine near the anus, but into the first outgrowth in order that the parts lower down may never require external aid. As long as the animal body is in good order, it is daily relieved of all the phlegmatic residue. The best physicians concur in the opinion that if a considerable amount of phlegm accumulates on account of some bad condition of the body, the most serious abdominal [15] disorders ensue,

[13] Reading ἤπερ ἄρα with Helmreich; Kühn omits ἤπερ.

[14] Oxymel, an ancient remedy, was a mixture of vinegar and honey boiled together. Galen gives directions for preparing it in his *De sanitate tuenda*, IV, 6 (Kühn, VI, *271–274*; Galen [1951, *165–166*]). For other, older recipes, see Dioscorides, *De materia medica*, V, 22 (1829, I, *708*), and Pliny, *Naturalis historia*, XXIII, 29 (60) (1951, VI, *454–457*).

[15] Helmreich omits the καὶ τὰ ἔντερα of Kühn's text.

intestinal obstruction, lientery, and tenesmus. Hence, Nature was making no slight, haphazard provision for the health of animals when she inserted the bile duct in the proper place.

Why, then, did she not insert some part of it into the stomach, since the stomach produces a large quantity of such residues? [16] I think you will admire her providence here even more. For we very heedlessly choose a thing because it is advantageous, even though it sometimes happens to be more harmful in other respects than it is
[I, 260] helpful in gaining what we need. But never in any one of her works does Nature heedlessly or indifferently choose a great disadvantage for the sake of a smaller gain; on the contrary, she judges the proper mean in every case with perfect accuracy and always produces the good far in excess of the evil. Surely if it had been possible, she would have arranged all these matters with no drawbacks at all, but as it is, since it is impossible with all her arts to avoid the inadequacies of her material and to make her creations of adamant, entirely invulnerable, it remains for her to arrange them as best she can. Different materials admit of different arrangements; for certainly we are not made of the same substance as the stars. We should not, then, claim their invulnerability or censure Nature if among thousands of good and useful things we find some little fault. [Only] if we show first that this little fault could be avoided without disturbing and confusing much that has been well arranged, are we then in a position to blame Nature and accuse her of negligence. If the yellow bile caused no great pain in flowing into the stomach, Nature would be wrong to neglect the advantage which this juice would provide for the body by cleaning out daily the viscous residue. But if this advantage was so small that we could adequately compensate for its loss by external aid, while the ills resulting from our use of it were so great that the work of the stomach would be completely destroyed,
[I, 261] I do not see how there could be anyone more ungrateful for Nature's provident care of himself or more envious of her just praises than the person who, when faced with the necessity of singing them, accuses her instead.

Who, indeed, does not know that the faculty of the yellow bile is excessively acrid and corrosive, cleansing all that it touches? Who

[16] Here for the sake of his theory Galen is conveniently forgetting that he has elsewhere described as an occasional occurrence a branch of the bile duct opening into the stomach. See note 1 of this Book.

has ever evacuated a considerable amount of this juice without first experiencing griping pain in the intestines? Who does not know that certain other symptoms, especially heartburn, which is sharp pain at the [cardiac] orifice of the stomach, must precede vomiting of bile? Do you wish me to quote the writings of Hippocrates [17] on this subject and call to witness such a great authority to establish a fact that everybody knows? It would be quite idle and superfluous to do so. Surely, if everyone knows the faculty of yellow bile, it should not be difficult to determine that if it flowed into the stomach, the whole work of the stomach would be destroyed. For just as the bile, falling at full strength into the first intestines, stings and stimulates them and keeps the nutriment from lingering there, so in the same way it would force the stomach, which is more sensitive than the jejunum, to expel the nutriment before it was well concocted. Indeed, it is so obvious that this is what does happen that no further demonstration is necessary, for sharp, griping pains do expel the nutriment [still] unconcocted. It is quite clear, then, that when in any state of health a considerable quantity of bile enters the stomach, the food cannot possibly remain there, for the stomach, stimulated by the acridity of [I, 262] the juice, is upset and impelled quickly to evacuate its contents. If this juice rises to the [cardiac] orifice of the stomach, which is its most sensitive region, there is severe pain due to the corrosive action with nausea and vomiting; on the other hand, if it sinks to the lower part of the stomach, it passes quickly downward and always evacuates the nutriment along with itself. For if the stomach contracts vigorously while an orifice is open either at the esophagus or at the lower end, all its contents are alike expelled. Hence it is clear that if very much of this juice flows into the stomach, it will stop and completely destroy the proper action of the stomach—if, indeed, the proper action of the stomach is concoction, if it takes time for nutriment to be concocted, and if the bile does not permit the nutriment to spend that time in the stomach.

Then physicians of old were right when along with their other precepts for maintaining good health they advised that every month we should induce vomiting after eating. Some thought once a month was sufficient and others recommended that it should be done twice, but they all advised that we should at that time select food of an

[17] *Praenotionum liber*, cap. 24 (Littré, II, *182, 183*), and *De prisca medicina*, cap. 19 (Littré, I, *618, 619*).

acrid and detergent nature in order to clean all the phlegm out of the
somach and prevent the body from being afflicted by a bad condi-
tion of the humors; for these acrid, detergent foods are generally
[I, 263] bilious and unwholesome. So the physicians were right in prescrib-
ing a catharsis of the stomach that would not injure the body as a
whole,[18] and Nature had foreseen that this would be easy, whereas a
similar cleansing of the intestines would be difficult and productive
besides to some extent of injurious humors in the animal.

Now in those commentaries in which I have also explained all the other works of Nature, I have shown why the bilious residue is not taken up from the intestines into the veins and arteries,[19] and anyone who wishes an accurate knowledge of the usefulness of the instruments that have to do with the nutriment should first familiarize himself with these commentaries; for I have stated many times already and have demonstrated at the very beginning of this whole work that the usefulness of any part cannot possibly be found without a correct understanding of the action of the entire instrument. It would not be proper to digress here from my discourse on usefulness in order to write demonstrations of actions; I should rather use what I have demonstrated elsewhere as hypotheses for what is to be said in this present exposition and so bring the work to a successful conclusion. Thus, just as I have shown in other works that phlegmatic residues must be formed in the stomach and now merely remind you that they obviously do occur, so I shall proceed to treat in the same way the fact that the bile is not taken up into the body. There is very strong proof in the variation of the feces that bile is not assimilated. For in cases of jaundice the feces retain the
[I, 264] color of the ingested food, because the bile is no longer eliminated below but is carried throughout the body, whereas in health they

[18] Reading παντὸς with Helmreich for the ἥπατος of Kühn's text.

[19] It is undoubtedly *De naturalibus facultatibus* that Galen had in mind here, but there is no passage in that work in which a possible reabsorption of bile from the intestines is discussed. Daremberg (in Galen [1854, I, *348*]) suggests chapter 2 of Book II (Kühn, II, *78;* Galen [1928, *122, 123*]), but the discussion there has to do with the secretion of the bile in the liver and not with a reabsorption of it in the intestines after its passage through the bile duct. Galen may rather have been thinking that such a process would violate the principles set forth there, particularly the theory of specific attraction, by which a part takes to itself only material appropriate to it.

have a yellowish tinge because the juice of the yellow bile flows in upon them in the intestines. Furthermore if the bile really flowed back again from the intestines to the liver, it is clear that the color of the whole body as well as of the excrements would be exactly the same as in cases of jaundice.

Then let us no longer be surprised that even the part of the atrabilious residue which cannot be elaborated and transformed in the spleen is discharged not into the intestines near the anus, but into the stomach itself. Now if I shall show that this residue does no harm in the stomach and that if Nature had extended the canal receiving it to the intestines near the anus, the canal would have to be slender to correspond with the small quantity of the residue, necessarily long because of the long distance, and hence liable to injury, it will seem reasonable to you that the residue should flow through a short vessel [one of the short gastric veins?] into the stomach which lies close by. When I remind you of what I have said about the yellow bile, I think you will require no long discussion to convince you that the black bile need do no harm in the stomach; and if it is not reabsorbed by the whole body and is not injurious to the stomach in any way, what other harm can it do? That it is not reabsorbed is evident from the fact that the much thinner yellow bile is not reabsorbed, and the quality of the black bile is proof that it does no harm to the stomach. [I, 265] For it is astringent and acid, and naturally draws the stomach together and contracts it but does not upset it, as the yellow bile does. Hence it is clear that if we say the latter is injurious because it does not allow the food to remain in the stomach to be concocted, we shall find the black bile wholly innocuous and even beneficial to the action of the stomach; for it tightens and draws together the stomach and compels it to clasp the food closely and retain it until it is completely concocted. This is the foresight with which Nature has arranged the discharge of the bilious residues.

5. There remains to be discussed that thin and watery residue which we call the urine. Nature made the kidneys to secrete it and placed them near the liver; for convenience in excreting it she created first the bladder, a receptacle like a cistern, and then at the lower end of the bladder a muscle [*sphincter vesicae*] to prevent the untimely expulsion of the residues. Since it was better to place the bladder very low, in the same region, in fact, where the residues of the nutriment are evacuated and to place the kidneys near

the liver, as I said before, it became necessary to make some passages leading from the kidneys to the bladder. And so the parts called ureters were formed, long, strong canals connecting the kidneys and
[I, 266] bladder. Thus it is that urine is secreted from the blood by the kidneys and passes thence through the ureters to the bladder, from which it is discharged at a suitable time when reason gives the command. But it is not enough to know these things if we are [justly] to admire Nature's skill; it is also proper to understand the usefulness of the way in which the kidneys are placed, that is, the reason (χρεία) why the right one is higher up and frequently attached to the liver itself, and the left one is lower than the right.[20] We must also consider their shape, why they are concave where the artery and vein are inserted and accurately rounded on the opposite side. Moreover, we must investigate the sort of substance of which they are composed, their contexture, cavities, and tunic, and the reason why the artery and vein inserted into them are very large, while the nerve is extremely indistinct and hard to find. Similarly, in regard to the ureters and the bladder—the gall bladder too, as well as the one receiving the urine—I suppose it is desirable to determine their substance, contexture, size, shape, and all the other attributes which we explain for each instrument. For a man will have a greater admiration of Nature's skill if he does not allow any of these matters to escape his attention and if he strengthens his understanding of the action of each instrument with the evidence provided by all these several attributes.

In the first place, then (to begin my discussion by showing that an investigation of the usefulness of the parts refutes incorrect opin-
[I, 267] ions on actions), neither Erasistratus nor anyone else who believes that only air (πνεῦμα) is contained in the arteries would be able to explain why it is useful for the arteries inserted into the kidneys

[20] The discussion of this point comes in the next chapter. Galen's sensible arguments, however, are all nullified by the fact that in man the left kidney is usually the higher of the two. He was almost certainly describing conditions in some species of ape. Lineback (1933, *226*) says, "The kidneys of the rhesus monkey differ strikingly from those of man. The left kidney is much lower in the abdomen than the right one. . . . The condition is apparently due to the structure of the liver, which has a left lateral lobe that requires more room in this region. As a result of this the fundus of the stomach, as well as the left kidney, is forced to a lower level on this side."

to be so large. For if indeed the kidneys purify only the veins and if that is the reason why very large veins are inserted into them, although they are small, then it would be unnecessary to make the arteries comparable in size to the veins; on the contrary, perhaps the kidneys would need no arteries at all inserted into them, or if any, then very small, indistinct ones like the nerves. Now it is easy for the followers of Asclepiades when they encounter these difficulties to call Nature an aimless workman, and the followers of Erasistratus, though they always commend her for doing nothing in vain, do not really carry their point by demonstrating in every instrument that their praise is justified. They purposely pass over in silence, conceal, and omit many things in the construction of the parts. What I have said on this subject in my commentaries *On the Natural Faculties* should be sufficient.[21] In this present work I wish only to remind all my readers not to be so lazy as to omit any of the parts but in every case to endeavor, just as I am doing, to investigate the nature of the substance, the form, and the contexture of them all and to observe also the outgrowths and insertions, the large or small size of each, their total number, relationships, and positions. Then, if all these particulars clearly show the correctness [I, 268] of the reasoning about the action, they should accept it, but if it is found to be defective even in the least detail, they should regard it with suspicion to that extent and not hold by it any longer. So in my own procedure I have observed everything over a long period of time, I have weighed what all the writers have said about each instrument, and whatever I have found that agrees with the clear evidence, I have considered altogether more trustworthy than what diverges from it. This, moreover, is the method I recommend for every dissertation, not for this present one alone.

I return now to my subject. As I was saying, the insertion of the arteries into the kidneys is good evidence that I was right when I demonstrated that the arteries contain blood. For if it was not to purify the blood contained in them, I wish someone would tell me for what other reason Nature made them so large and produced them branching like the veins into the very cavities of the kidneys.

[21] It is unnecessary to cite any one passage in *De naturalibus facultatibus*. The whole work is a justification of his own views and an exposé of those of the Erasistrateans and Asclepiadeans. For a detailed discussion of Galenic physiology, see Triolo (1966).

Furthermore, the size of both kinds of the vessels is proof that I was also right in saying that the kidneys themselves relieve the blood of all its watery portion. Now if indeed the urine is [only] the residue of the nutrition of the kidneys (for Lycus the Macedonian [22] descends into such depths of ignorance as to believe even this), it is impossible to tell why the Creator, who does nothing without a purpose, inserted such large arteries and veins into the small bodies of the kidneys. Either we must accuse Nature of a lack of skill, as
[I, 269] even Lycus was unwilling to do, or we must clearly convict him of holding unsound opinions on action.

6. Why, now, is one kidney placed higher than the other? Is not this also consistent with all that I have demonstrated about them? Seeing that they purify the blood by attracting the serous portion of it, it is obvious that if they had been placed on a line with one another [23] each would prevent the other from attracting because it would exert pull in the opposite direction. But situated as they are, each acts alone with nothing to hinder its attraction, since no other part lies opposite. But why is it the right kidney that is first and placed higher up, while the left comes second and lower down? The reason is that the viscus being purified [the liver] is situated on the right side; most of the branches of the vena cava [*vv. hepaticae*] which bring the blood from the convex part of the liver open at the right; and it is easier for every body with an attractive faculty to exert it in a straight line. Moreover, I have shown earlier [24] that it was better for the spleen to adjoin the lower parts, and the liver the

[22] Most of what little is known of the anatomist Lycus the Macedonian, an older contemporary of Galen, comes to us from Galen's own works. We know, for example, from *De musc. diss.* (Kühn, XVIII, pt. 2, *926–928, 937, 939, 956, 1000, et alibi;* Galen [1963, *477–478, 480, 491, 494*]) that Lycus wrote an extensive work on the muscles, which was criticized sharply by Galen for its inaccuracy and inclusion of quite unrelated pathological matter. Meyer-Steineg (1911, *175*), however, calls this the first monographic treatment of the subject and a considerable step forward. Galen also wrote an entire treatise, *Adversus Lycum* (Kühn, XVIII, pt. 1, *196–245*), in criticism of Lycus' commentaries on the *Aphorismi* of Hippocrates. This work was so bad, he said at one point, calling all the gods to witness, that after he had read only a little of it, he couldn't bear to go on and only did so when a friend asked him to write his answer to it. See also my Introduction, pp. 36–38.

[23] Literally, "if they had been placed together (ἅμα)."

[24] *Vide supra*, pp. 209–210.

upper parts, of the stomach. Hence there was no such vacant place on the left side as there was on the right, so that it was not unreasonable for the right kidney to be placed as much higher than the left as the liver lies higher than the spleen.

Did Nature really need two instruments to remove the serous liquid? I ask because if it was better to have two, she would seem to have been negligent when she made only one spleen and one gall [I, 270] bladder, and again, if one is sufficient, she would seem to have made a superfluous left kidney in addition to the right. Or must we even in this admire her skill? Now the atrabilious residue is very scanty, the bile is more abundant, and the watery residue is many times more abundant than both the others. Furthermore, the black bile is very thick, the serous residue very thin, and the yellow bile midway between the two in density. For the scanty, thick, slow-moving residues that must travel a long distance Nature has therefore provided a very large, very loose-textured instrument and has located it on the left side of the stomach, in order that, as I have shown earlier,[25] the thick juice elaborated there may serve as the nutriment of the spleen. Although the bladder at the liver attracts a juice of average density and abundance, Nature has nevertheless made it small because it has a great advantage over the other instruments purifying the liver both in position and in the number of openings by which it attracts. In this respect, then, Nature has done only what is proper. We must still discuss the right kidney, which according to the derogatory remark made just now would be sufficient if it were the only one. It is at once clear that it would not alone suffice for the removal of such an abundant residue unless it was double its actual size. But if it had been made twice as large and the other kidney were entirely lacking, the person who accused Nature of making an unbalanced animal would not be carping but speaking the plain truth, and this too, I think, is perfectly evident. Before beginning to discuss the kidneys, I showed in the preceding book that the animal body is well balanced, thanks to the proper placing [I, 271] of the spleen, stomach, and liver. Now if in imagination we place one large kidney off center in this beautifully and justly proportioned animal, we shall make it lean to one side. Nature, however, did nothing of the kind, realizing that instead of one large kidney lying off center, it was more fitting to establish two small kidneys,

[25] See chapter 15 of Book IV, *ad init.*

one on each side. And that each is large enough so that the blood is satisfactorily purified by both together, the fact itself bears witness; for in the countless venesections I have performed day by day, I have found that very little water rises to the surface when the blood coagulates. Of course, everyone who needs phlebotomy has something wrong with his body and his natural economy is entirely deranged, but nevertheless, even in these persons, as I have said, only a very little watery material [26] rises to the surface of the coagulating blood. Hence it can be shown both from what I have said and by other, additional facts that when the body is in a healthy condition the kidneys remove the serous portion from the blood completely. I think it superfluous to spend more time in this discussion, since everyone will readily agree with my argument and will grant that the kidneys have been so constructed as to be quite equal to the usefulness for which they were formed.

Now if the kidneys together are successful in relieving the blood of its serous portion and if this residue is far more abundant than the
[I, 272] others, nothing contributes so much to removing it swiftly as the extreme thinness of the liquid to be removed; for it is also perfectly evident that in general a thin substance is attracted more easily than a thick one. Well, then, here is the cause of the denseness of the kidneys' substance, or rather the causes, for there are two: the ease of attracting such a liquid, especially when the attracting body is so near, and the necessity of nourishing the kidneys with it. I have likewise shown in my commentaries *On the Natural Faculties* [27] that the parts that attract their proper juice through wide openings cannot attract it alone in an unmixed, pure state, but only adulterated with some mixture of a different character; but if the attracting instruments end in very fine openings visible only to the mind's eye, the proper juice that is attracted will be pure and uncontaminated. There is good reason, then, why the bladder at the liver with the invisible and extremely narrow extremities of the vessels leading from it into the viscus should attract only the one juice which

[26] Literally, "nothing watery except a very little." It is evident that Galen's devotion to theory has again led him to distort the facts. See Daremberg's note (in Galen [1854, I, *356*]) on this passage.

[27] Not stated explicitly in any one passage in *De nat. fac.* but implied in many. See, for example, II, 2 (Kühn, II, *78–79;* Galen [1928, *122–125*]).

Nature has constructed it to attract, free from any other quality, but neither the spleen nor the kidneys draw in only their own, proper juice. The spleen attracts also a little blood, which before reaching the spleen is drawn upon by the veins of the omentum; the two kidneys attract a great deal of yellow bile, in fact, nearly all that their arteries and veins happen to contain, and also a great deal of blood, that is, the thinner, more watery portion of it. All the bile [I, 273] that is not too thick escapes with the urine, but the blood, like an ooze, saturates the very flesh of the kidneys. Then, penetrating gradually throughout their whole substance like a vapor, it adheres and becomes the nutriment of the kidneys.

7. In order that the blood may not escape down through the tubes of the kidneys along with the urine, as the thin bile does, it was desirable that the substance of the kidneys should be dense. That of the spleen, on the other hand, should be very porous and loose-textured, as I have shown before; for a porous substance is more suitable for attracting a thick juice from a distance, and it is not dangerous for some blood to accompany it. In fact, the spleen is meant not to discharge the atrabilious residue immediately, as the kidneys discharge the urine, without elaborating, concocting, and transforming it, but to retain it for a long time and alter it till it becomes the nutriment of the spleen. Hence it is right for the spleen to be porous and the kidneys dense. Moreover, to supply the kidneys with nutriment there was no need of a third vessel besides the two large branches [*a. renalis, v. renalis*], one from the artery at the spine and the other from the vena cava, but there is good reason why the bladder receiving the yellow bile and the urinary bladder, each of which attracts its proper residue in a pure state without any admixture, should need other vessels[28] to furnish them with nutriment. [I, 274] Since the serous liquid is much more abundant than the yellow bile, it is right for the bladder receiving it to be larger than the gall bladder, and since it was made larger, it of course needs larger veins, arteries, and nerves. And so in both bladders one may see that each [of the vessels and nerves] is of the proper size to accord perfectly with the usefulness and size of the bladders.

8. Furthermore, it was not from any chance source that Nature derived the nerve, artery, and vein for each bladder, but in this

[28] That is, blood vessels in addition to the cystic duct and ureters.

matter too she has obviously made the better choice, which is a pathway neither long nor unprotected. For the bladder receiving the urine, she produced nerves [fibers from the third and fourth sacral nerves] from the spinal medulla at the bone called the broad bone and the sacrum, because at this point it is nearest the bladder; the [vesical] veins and arteries she derived from the nearest vessels [*aa.* and *vv. iliacae internae*] where the branches for the legs are formed from the great vessels at the spine. For the other bladder at the liver, she split off from the artery [*a. hepatica*] and nerve [*n. vagus* via the hepatic plexus] inserted into the viscus itself branches [*a. cystica* and fibers from the hepatic plexus] which are both exceedingly small and hard to see, and from the vein at the porta a branch that is clear and easily distinguished [*v. cystica*]. She inserted all three vessels into the body of the bladder at the same point, the part called the
[I, 275] neck, because this place is very strong in order to receive safely the insertion of slender vessels and because it is situated near the porta. In the same way it was also the neck itself of the other, large bladder into which she inserted the six vessels, three on each side of it;[29] for so the course of the vessels themselves would be as short as possible, and it was better for the bladder to receive them in its fleshy parts.

Since you are less skillful and provident than Nature, perhaps you are assuming that these provisions I have mentioned are sufficient for the safety of the vessels, but even though Nature had conducted them over a short interval and inserted them safely, she did not hesitate to find a third clever device for their protection; for she wrapped each one separately in a membrane thin enough to be suitable to its small size and bound them all together with these same membranes. The vessels inserted into the small bladder branch all through it and extend as far as the fundus. Those inserted into the neck of the large bladder divide as soon as they reach it into two branches. One part, like the vessels of the small bladder, ramifies over the whole surface; the other turns downward, descending along the neck itself.[30] It is small in women, for it must be entirely

[29] Presumably Galen means here an artery, vein, and nerve on each side.

[30] Referring, probably, to the deep dorsal vein of the penis, which leads to the pudendal plexus, which in turn has connection with the vesical plexus; also to the dorsal and deep arteries of the penis, which, though arising from the internal pudendal artery, anastomose with branches of the inferior vesical artery.

dissipated in small branches in this region, but in men it is large because they have in addition a special part called the penis situated at the extremity of the neck of the bladder. I shall explain in detail farther on in my discourse the skill Nature has displayed in constructing the several instruments of generation.[81] Now, however, I seem to have finished the task in which I have been engaged, namely, explaining the reason why some of the instruments that have to do with the residues, like the spleen and the kidneys, are nourished by the same vessels that secrete the residues, whereas others, like the bladder, need different vessels to nourish them; for the size of the vessels, whether large or small, the ways in which they are inserted, the places whence they arise, and the safety of their paths, in short, all the things we observe in them, bear witness to the marvelous skill of Nature. [I, 276]

9. I return, then, to what is necessary to complete the discussion of these instruments. I have still to say something first about the nerves inserted into the kidneys and then about the canals for the urine. Thirdly, in addition to all this, I must explain the substance itself of the body of the bladders, just as I have done for the kidneys and all the other parts whose construction I have already discussed completely. Nerves are conferred on the kidneys[82] to the same extent as they are on the spleen, liver, and the bladder called the container of the bile; for all these parts receive exceedingly small nerves which are to be seen on their outer tunics, because Nature has granted to each one of them only as much sensation as is necessary to distinguish them from plants and make them animal parts. Now Nature had three ends in view when she distributed the nerves, to provide first sensitiveness for the instruments of sense perception, second, motion for the instruments of motion, and third, for all the others, recognition of what will cause them pain. Thus the tongue, eyes, and ears have received very large nerves so that they may perceive, and the same is also true of the inner sides of the hands and the [cardiac] orifice of the stomach; for these parts too are to a certain degree instruments of perception. The sense of touch is perfected in the hands as in no other part, though any number of [I, 277]

[81] See Books XIV and XV.

[82] About fifteen small nerves supply the kidney. They arise from the renal plexus formed by branches from the celiac plexus, and from the celiac ganglion, aortic plexus, and the lowest splanchnic nerves. See Gray (1966, *1286*).

parts have been given sensation, and the feeling we call hunger, that is, the want of what will nourish the body, is seated in the orifice of the stomach. Because all these are sensory parts, very large nerves are to be found in them. As regards Nature's second purpose, the instruments of voluntary motion, that is to say, the muscles, have received very large nerves because they were formed to move the members of the body; and since sensation is necessarily inherent in every nerve, it follows that muscles have more than they need of the ability to recognize tangible objects. The third end which Nature had in view when she distributed the nerves is perception of what will cause pain, and if anyone will look at dissections and see whether Nature was right or wrong to distribute the nerves unequally to all the parts, giving some more and others less, even against his will he will surely use the same words as Hippocrates and say that Nature is well-trained,[33] just, skillful, and provident in her
[I, 278] treatment of animals. Indeed, if it is the part of justice to examine and reward each one according to his worth, how can we fail to admit that Nature's justice is the best of all? For whenever instruments are of the same kind, as sensory instruments are similar to other sensory instruments, or muscles to other muscles, she considers the mass of their bodies, the importance of their actions, the weakness or strength of their motions, and the frequency or infrequency of their activity, and, estimating the exact worth in each case, she assigns to one part a larger nerve and to another a smaller one, each receiving a nerve of the size which is its just due. But I shall instruct you in these matters farther on in my discourse.[34]

10. In this book, however, I must tell of the instruments of nutrition and show the justice of Nature in her treatment of them. Now since no one of these is an instrument of sensation or motion, it was of course necessary to assign small nerves to them all to serve only the third usefulness [of nerves], namely, that of conferring perception of what will cause pain. For if the instruments had no such perception and were insensible of the injuries inflicted on them, nothing would prevent animals from perishing in a very short time. But as it is, when we feel a griping pain in the intestines, we hasten at

[33] Well-trained = *εὐπαίδευτος*. Hippocrates (*De articulis*, cap. 43 [Littré, IV, *186*, *189*]) applies the term not to a personified Nature but to the attendants in the operating room.

[34] In Book XVI.

once to get rid of what is causing it. If they were completely without sensation, they would all, I think, be easily ulcerated, eaten away, and putrefied by the daily supply of residues flowing into them, seeing that even now, when they are so well endowed with [I, 279] sensation and do not permit the acrid, pungent residues to remain in them for even a very short time, they are nevertheless ulcerated, abraded, eroded, and putrefied by pure bile, either yellow or black, when it merely passes through. And[35] Hippocrates says somewhere[36] that the dysentery originating from black bile is fatal. Perhaps someone may ask me if there is a dysentery originating from black bile since the intestines have so much sensation that they expel immediately what causes them pain, and it is right to answer him. It is perfectly evident that such a dysentery does occur; if you wish to know why, let me remind you of the coils that were formed, as I have shown, to keep the nutriment from passing rapidly through the intestines. Sometimes the acrid residue detained in their winding loops first abrades and then erodes them. Hence, when even now their quick sensibility is not enough to prevent injury and they frequently become ulcerated because they are eroded by the acridity of the residues or overwhelmed by an excessive amount of them like a flood, how seriously should we expect them to be injured if they were insensitive? It is for this reason that a nerve as well as an artery and vein is distributed to each coil.

Yet a very small nerve is inserted into the liver, that large and important viscus, because it does not move like the muscles or need extra sensation like the intestines; for the intestines are burdened [I, 280] with the passing of the residues, whereas the liver has four instruments to purify it, the two kidneys, the spleen, and the bladder that lies close to the liver. Thus, since no acrid, injurious liquid has to remain in the liver, it does not need extra sensation, and these same four parts that purify the liver do not need a larger share of sensation because they would not be harmed by residues proper to them; for they would not be able to attract such residues if they did not have qualities in common with them. Indeed, although an animal lives for so many years, it is always possible to find a quantity of yellow bile, sometimes more and sometimes less, in the bladder at the

[35] Helmreich omits the *θθεν* found at the beginning of the sentence in Kühn's text.

[36] *Aphorismi*, sectio IV, 24 (Littré, IV, *510, 511*).

liver. Moreover, we remove the bladder with the bile in it from the liver of a dead animal and keep it over a long period without any injury to the substance of the bladder as time goes on. So in every instrument whatever is natural and proper to it does not cause the least pain, and there was consequently good reason why Nature did not give these instruments [gall bladder, spleen, and kidneys] very much sensation, since they would never be injured by the residues contained in them.

It would, however, frequently be injurious to the large bladder that receives the urine if urine too acrid and bilious was not quickly
[I, 281] evacuated from it; for unlike the gall bladder, its substance has no affinity for the quality of the bile, but only for that of the urine for which Nature formed it. Hence, when an animal is healthy, there will be nothing wrong with any of its parts and the substance of the serous residues will not be acrid or painful to the bladder; if, on the other hand, anything is the matter with the instruments of concoction so that the blood is no longer produced in good condition, the urine and also the other residues will become so acrid and noxious that they will abrade and erode the bladder. Under such circumstances the animal does not wait for the natural time of urination but makes haste to empty the bladder at once, even before it is full. And Nature, foreseeing this situation, has bestowed on the bladder larger nerves and more of them to give it more sensitive perception.

11. There was also good reason why Nature did not determine the thickness of the outer tunics covering all the instruments I have been discussing (I have said that these tunics arise from the peritoneum) on the basis of the importance or size of the instruments, but distributed them according to their usefulness. For although the liver is large and more important than all of them, it should not on that account be provided with a stronger tunic than the bladder. On the contrary, it was better to give the stouter covering rather to the bladder since day and night it must be repeatedly filled, distended,
[I, 282] emptied again, and contracted. Indeed, a part that undergoes safely both extreme distention and collapse within a short time must be strong and able to bear alternately both these conditions, which are opposites.

Nature, then, has been just in regulating this matter and still more so in determining the kind of substance itself for each tunic. The outer [peritoneal] tunics surrounding all the instruments I have been

discussing closely resemble cobwebs, some even in actual thickness, but all in form. Hence none of them can be separated into fibers as the inner coats can which are peculiar to the instruments themselves and through which they act; they are rather entirely simple and homogeneous, and perfectly membranous. The two inner tunics constituting the very body of the parts, however, are composed in the stomach and esophagus, as I have said before, of a layer of circular fibers on the outside and a layer of straight fibers within.[87] In the intestines both layers have transverse fibers that completely encircle the intestines, and the tunics of the bladders have straight, circular, and oblique fibers; for since each bladder has only one [inner] tunic,[88] this was given a construction permitting every kind of motion. There was good reason for it to have the movement performed by the straight fibers in order to attract, that performed by the transverse fibers in order to expel, and that performed by the oblique fibers in order to clasp its contents on all sides and retain them. If only the transverse fibers are tensed, the breadth becomes less; if the straight fibers act alone, the length is decreased; but if straight, transverse, and oblique fibers all draw together at once, the [I, 283] whole part is contracted, and when they all become longer, it expands. Hence, since both bladders must have only one tunic for a reason I shall give a little farther on, it was better for them to have every kind of fiber in order that they may thus produce every kind of movement. Since the task of the intestines, however, is not to attract or retain but to push forward their contents by a peristaltic movement, they need a single motion and consequently a single kind of fiber. It is otherwise with the stomach; for it must attract what is swallowed, retain it during concoction, and expel it when concoction is complete. Hence the stomach very properly has fibers of every kind.

12. Why, then, does the outer tunic [of the stomach] contain only transverse fibers and the inner one straight fibers for the most part, with a very few oblique? And why are there two tunics when Nature is able to provide the instruments with three actions by using

[87] See note 23 of Book IV.

[88] The gall bladder has two coats besides the one derived from the peritoneum, and the urinary bladder has three. It seems probable that Galen in both cases meant the muscular coat, which does have fibers running in different directions.

only one tunic, as she has shown in the bladders and the uterus? It would be well to add these topics to our present discussion and so bring it to a close.

In speaking of the intestines I have said earlier [39] that their tunic was doubled for the sake of protection, and that frequently in severe cases of dysentery one coat is entirely eaten away and the other alone suffices the animal. I think that these statements will now be still more deserving of belief if I point out that influxes of bile are
[I, 284] naturally very antagonistic to the intestines, though the yellow bile is very appropriate to the bladder at the liver, causing no pain. It also scarcely ever becomes troublesome to the other bladder, the one that receives the urine, because an injurious, large quantity of it does not collect and it generally acts on the bladder moderately and without pain. The following consideration also belongs to this discussion: since the nutriment must be transformed in the space within the stomach and intestines and given a quality appropriate to the animal, it was reasonable that these parts should have exceedingly thick tunics; for such tunics alter, warm, and transform better than thin, cold ones. For this reason too, individuals whose abdominal parts are thin cannot concoct as well as those in whom they are well fleshed. In the instruments of the residues, however, nothing has to be concocted; hence it was reasonable for them to be thin, and in thin bodies two tunics cannot possibly be made.

There are three reasons why two tunics are found in the stomach, namely, to allow for the diversity of its action, to provide protection, and to make it thick. Similarly, the very substance of the bladders has a different nature from that of the instruments of concoction. The former is membranous, hard, cold, and almost bloodless, the latter is fleshy and warm; the former must be made able to withstand [40] the greatest expansion and contraction, the latter
[I, 285] needs more heat to concoct the food. Accordingly, for the sake of endurance, hardness was conferred on the bladders to compensate for their thinness, and in the instruments of concoction their thickness became the remedy for their softness.

13. Thus Nature has been perfectly just in these matters. It is also evident to everyone that she has displayed the same justice in making

[39] See chapter 17 of Book IV, *ad fin.*

[40] Accepting Helmreich's emendation, *δυσπαθεῖς*, for the *συμπαθῶς* of Kühn's text.

the ureters of the same substance as the large bladder that receives the urine, and the bile ducts of the same substance as the small bladder at the liver. For there ought not to be one substance for the receptacles of the residues and another for the canals that convey them; on the contrary, the substance found in both parts should be the same and equally tolerant of the residue. Certainly the method of insertion of the ureters into the bladder and of the bile duct into the intestines is beyond all praise. For they are inserted obliquely into the instruments and, still obliquely, penetrate for some distance till they reach the open space within, where they are cut off in the form of a membrane on the inner surface of the instruments, a membrane which is thrust inward and opened up when the residues flow in, but which at all other times draws together, contracts, and becomes such an accurate lid for the opening that it is impossible not only for liquids but also for air to find a way back.[41] This fact is very well demonstrated by inflating a bladder and then tying it tightly at the neck while it is full of air; for all the air within it is obviously contained and kept inside, even if one presses hard on the outer surface of the bladder. Just as [the membrane] is thrust inward by the force of material flowing in, so it is closed and held shut by material pressing against the opening from within. This arrangement too you should see as evidence of the Creator's extraordinary wisdom and foresight in his treatment of animals. These, then, are the wonderful ways in which all the instruments of nutrition have been arranged. For physicians are accustomed to include the receptacles of the residues along with the other instruments of nutrition, and so they give this name to both bladders and to the thick intestines as well. [I, 286]

14. I ought to speak next of the muscles that were formed for the sake of the residues; for in a certain sense these also are instruments of nutrition. The first and most important instruments of nutrition are those that concoct the nutriment and transmit the useful part of it. In the second class are those that purify it and those that receive the residue. In the third would be those that serve to discharge the residues. There are two kinds of these [instruments of excretion]; for some keep the discharge from occurring at the wrong time and others induce it at the proper moment. The muscles forming the

[41] See the similar description in *De anat. admin.*, VI, 13 (Kühn, II, *582;* Galen [1956, *168*]).

anus prevent the untimely discharge, and all the abdominal muscles induce it at the proper moment. One of the muscles at the anus [*sphincter ani internus*] is unpaired, extends transversely, and encircles that part in order to make an accurate, strong closure for the
[I, 287] rectum. At its outer edge it is in contact with a transverse body [*sphincter ani externus*] whose substance is intermediate between muscle and skin, as if composed of a mixture of both, like the extremity of the lips. Its usefulness is like that of muscles, except that it lacks something of the strength and vigor of their action. The two remaining muscles [*levatores ani*] are oblique and raise the anus, being situated one on each side above the round [42] muscle [*sphincter ani internus*]. They serve to draw the anus up again after it has been greatly everted in violent efforts, and when these muscles are paralyzed or weakened, it is drawn up with difficulty and pain or even remains completely everted so that it needs the help of the hand [to restore it]. These are the uses which determine the number and character of the muscles at the anus.

Two of the eight abdominal muscles are straight and run longitudinally; they extend from the sternum to the pubic bones and occupy the very middle of the abdomen [*recti abdominis* with *pyramidales*]. Two others [*transversi abdominis*] are transverse, extending crosswise and making a right angle with those just mentioned; they curve over and cover the whole peritoneum. The other four are oblique; two of them [*obliqui interni*] have fibers extending from the hypochondrium to the ilia and these are crossed to form a
[I, 288] letter Chi (X) by the remaining two [*obliqui externi*], which extend from the ribs to the hypogastrium. When their fibers are tensed, these muscles [43] all have a common task, namely, to shrink in upon themselves, with the result that the lower orifice of the thick intestine at the anus is shut tight and all the parts lying beneath the abdominal wall are drawn in and compressed. It necessarily follows that because of the closure of the parts at the anus no residue pushed on by the action of the intestines escapes inopportunely, and that because of the pressure on the abdominal parts, when, of course, those at the anus are relaxed, the contents of the large intestine are expelled.

Here too we must admire the skill of Nature in dealing with each

[42] Round in the sense that it encircles the anus.

[43] Including the sphincters, apparently.

type of muscle. Where it was necessary to close the opening at the lower end of the large intestine, she made the muscle fibers transverse, and when I was speaking earlier of the stomach, uterus,[44] and bladders, I said that transverse fibers are most suitable for closing the orifices of instruments.[45] Where it was necessary to exert strong pressure[46] on the underlying parts, however, compressing them by means of the muscles above, as if by hands, she has placed straight muscles over transverse, and oblique muscles upon other oblique muscles at right angles to them, just as we ourselves place one hand crosswise upon the other when we wish to press[47] hard or squeeze [I, 289] some object. So also Nature has determined the number in each set of muscles with great foresight, as I have already shown for those at the anus and shall now explain for the abdominal muscles. Now if the action of the instruments depends on the position of the fibers and there are four positions in all, straight, transverse, and two oblique, it is clear that the first group of four muscles includes fibers in every position. Then, since the body has two sides, a right and a left, which are perfectly symmetrical, there are four muscles on each side, making eight in all, and these are equal [each to each] in size and number and have their fibers running in the same directions so that no one member of a pair is in any way superior or inferior to its fellow. The straight muscles [*recti abdominis*] extending longitudinally originate above at the sides of the xiphoid cartilage and are carried down side by side to the pubic bones; both have straight fibers running down from above and are exactly equal in length, breadth, and thickness. Beneath them, the transverse muscles [*transversi abdominis*], one covering all the right, the other all the left, side of the peritoneum, are also equal and similar in every respect. Their tendinous part lies beneath[48] the two muscles I have been discussing [*recti abdominis*], and their fleshy part is beneath the other muscles [*obliqui, externus* and *internus*]. The latter in

[44] Omitting with Helmreich the *καὶ τῶν ἐντέρων* found in Kühn's text.

[45] But Galen always says that transverse fibers are used to expel the contents of the various instruments; see, for example, chapter 11 of this Book, *ad fin.*

[46] Accepting Helmreich's emendation, *ὑποῦσθαι*, for the *ἀπῶσθαι* of Kühn's text.

[47] Again accepting Helmreich's emendation, *ὑπῶσαι*, for the *ἀπῶσαι* of Kühn's text.

[48] The lowest fourth of the aponeurosis is in front of the rectus.

turn, lying upon the transverse muscles, also extend in so-called
[I, 290] aponeuroses to the straight muscles in the middle [*recti abdominis*]. There is no difference at all between the muscles of the right side and the left; they are identical and their fibers are similarly placed, for one pair [*obliquus internus*] has fibers passing up from the flanks [ilia] to the hypochondrium and the fibers of the other [*obliquus externus*] pass down and forward from the ribs.

Consequently, since there are in all four positions for the fibers, it was reasonable to make four muscles on each side. Hence we cannot even imagine the addition of another muscle to these; for it would lie either straight, transversely, or obliquely, and thus be superfluous. Neither would it be possible to subtract a muscle without doing great harm; for if one of the transverse muscles was removed, the tension of the straight muscles with nothing to oppose it would exert unequal, injurious pressure on the parts beneath so that they would all be forced out toward the false ribs and the ilium. On the other hand, if we suppose that one of the straight muscles has been destroyed while the transverse muscles remain intact, all the parts between the ilium and the false ribs will be forced toward the center of the abdomen. In the same way, if we remove either of the oblique muscles, the others that remain will force the underlying parts into the space left vacant by the muscle we have destroyed. And this must not happen; on the contrary, the pressure on the parts must be exerted equally from all sides. Hence we see clearly that it was better for no less than eight muscles to be formed, and I have shown
[I, 291] that there ought not to be more than eight. Thus the number of these eight muscles of the abdomen, and of the muscles at the anus as well does not exceed or fall short of what usefulness requires, but is perfectly just.

15. For me, even these things give sufficient indication of Nature's skill, but if they are not enough for you, perhaps I might convince you with the following considerations. By pressing equally from all sides, the action of the muscles in all regions of the abdomen, being evenly balanced as I have shown, irresistibly compels its contents to move toward the places that will yield. Now there are two openings, an upper one at the esophagus and one below at the rectum, at the end of which the anus is situated, as I have said. It was, of course, better for all the residues to be evacuated by way of the lower opening, but constructing the eight muscles was by no means

enough to accomplish this, since the pressure they exert cannot be directed more toward the anus than toward the esophagus. In fact, the evenness of the pressure from all sides would rather force all the contents of the instruments subjected to it toward both openings equally, if Nature had not invented another clever device to make them turn away from the upper, and follow the lower, route. The student must be attentive to understand what this clever device is and through what instrument it operates.

There is a certain large, circular muscle rightly called the diaphragm [*διάφραγμα*, barrier] since it separates the instruments of [I, 292] respiration from the receptacles of the nutriment; for it lies above all the latter and beneath the former. Besides its natural use as a barrier, it serves a greater purpose as an instrument of respiration and has a second usefulness which I shall now explain. The upper part of it begins by growing downward from the lower end of the sternum where there are also suspended the heads of the straight muscles of the abdomen [*recti abdominis*]; thence it passes down on each side along the extremities of the false ribs, and below at the rear it becomes exceedingly oblique. When the [abdominal] muscles exert their equal pressure from all sides,[49] this is the clever device that causes all [the residues] to be forced toward the anus rather than the esophagus. Imagine two hands laid one upon the other at the wrists and continually separating more and more out to the finger tips. Let a sponge be lying in the lower hand, or a lump of dough, or something else of such a nature that it will easily be squeezed out when the upper hand moves down and presses it. Now consider that the diaphragm and all the abdominal muscles are like these hands, the diaphragm being the lower and the muscles the upper hand, the straight muscles representing the elevated middle finger, and the other muscles corresponding to the other fingers on each side. Then you should realize that just as the fingers clasp and squeeze out the dough, so the muscles press upon the abdomen. [I, 293] And what is likely to be the result of this? Is it not that the contents [of the abdominal instruments] will be forced downward as if pressed by two hands, joined at the wrists but widely separated lower down? If when the hands approach each other and exert pressure on what is between them it is all squeezed out toward the part where they are separated, it is evident that here too all [the

[49] Omitting with Helmreich the *τῶν ἱκανῶς* found in Kühn's text.

residues in the abdomen] will also be forced downward; for in this region the abdominal muscles are widely separated from the midriff (now midriff is another name for the diaphragm), and they are brought into contact with it above, the long muscles at the sternum and all the others at the sides.

Are these, then, the only structures worthy of admiration which Nature has made for the evacuation of the residues, and has she not neglected or overlooked some detail, even if only a slight one? No, she has a right to our unqualified admiration, because, in addition to succeeding in such great matters, she has also not neglected to correct the inevitable harmful consequences of them. For she was not satisfied merely to make the eight abdominal muscles capable of compressing all the underlying parts precisely and forcing them inward; on the contrary, she also spread the diaphragm obliquely above to prevent any material from returning into the esophagus, and in the same way she likewise constructed the muscles we call intercostal to help the diaphragm itself. In fact, since the diaphragm
[I, 294] is only one muscle, it would of course be very easy for the eight abdominal muscles, being so large and numerous, to move it from its position, turn it back into the ample cavity of the thorax, and so destroy the force of its pressure. To prevent this, Nature constructed all the muscles at the sides of the thorax in such a way that they can be tensed and can press the thorax inward, with the result that since the whole upper [thoracic] cavity is compressed from all sides, the diaphragm has no place to which it can retire and is held firmly in place. Again, if the animal tenses all the muscles of the thorax and abdomen but keeps the larynx open, it is clear that the breath will be forcibly expelled [50] through the larynx and so the work of defecation will once more come to naught. Hence, in order that the animal may hold its breath at such a time, Nature has surrounded the larynx with several muscles, some made to open and some to close it. When I explain the parts of the neck,[51] I shall speak of these muscles, describing their nature and telling how they perform both of the actions I have mentioned. Likewise I shall speak of the intercostal muscles when I explain the thorax.[52] For the present discussion it is enough simply to recognize that Nature has never in

[50] See note 25 of Book IV.

[51] See chapter 11, *ad fin.*, and chapter 12 of Book VII.

[52] See chapter 20 of Book VII.

any way neglected anything, since she has known and foreseen the necessary [undesirable] consequences of the things she has made for a purpose and has hastened to prepare remedies for all of them. [I, 295] Moreover, her resourcefulness as shown in this apparatus bears witness to her admirable wisdom. For just as she has used the obliquity of the diaphragm's position to make it serviceable for the evacuation of the residues although the diaphragm was created for something else, so in the same way, although she made the muscles of the larynx and thorax to perform certain other important works, she has also made use of them for this same purpose. Conversely, although she made the abdominal muscles as a covering and protection for the parts beneath and as instruments for the evacuation of residues, she has used them also as agents for the forcible emission of the breath and for the production of the voice. In fact, they are also active in giving birth and in what Praxagoras used to call retention of breath.[53] But I shall make known in the proper place how each of these actions is performed.

16. In my treatment of the evacuation of the residues (for this is the subject I have chosen for my present discussion) I have now explained how the residues of the food are expelled. Next I must speak of the expulsion of the liquid residue called urine. I have shown elsewhere [54] that the transverse muscle at the anus [*sphincter ani internus*] cannot be explained in exactly the same way as the muscle at the neck of the bladder [*sphincter vesicae?*]. For the former was made simply to close the canal, whereas the latter was primarily intended to push its contents along by contracting on them, and then to close it. I shall now explain the advantage of such [I, 296] a construction. Besides having a narrow canal, the bladder is provided with all the kinds of fibers, like the stomach and the uterus. These viscera close their orifices by contracting upon their contents and so does the bladder. This is not true of the intestines, whose fibers are transverse and whose orifice is very broad. It is understandable, then, that the intestines need a muscle to close their outlet, but the bladder needs very little help for this purpose, being capable of closing even without a muscle. However, Nature has placed a

[53] See Daremberg's note (in Galen [1854, I, *376*]). For Praxagoras of Cos, pupil and successor of Diocles and teacher of Herophilus, see Sarton (1927, I, *146*) and my Introduction, pp. 20–21.

[54] *De musc. diss.* (Kühn, XVIII, pt. 2, *998, 999;* Galen [1963, *494*]).

muscle [*transversus perinei profundus* and *sphincter urethrae membranaceae?*] having transverse fibers around the outside of the very oblique urethra, in order that the urine sent into it by the pressure of the bladder may not remain there too long; at the same time this muscle would also help to close the orifice of the bladder. Here too all Nature's arrangements seem admirable. The oblique insertion of the ureters into the bladder is the reason why nothing returns to the kidneys from the bladder; the presence of all the kinds of fibers and particularly of the oblique is responsible for the fact that urination is not a continuous process. When all its fibers are tensed, the bladder contracts upon its contents, with the muscle [*sphincter vesicae?*] I have mentioned assisting and cooperating in the work, until it is full enough and becomes distressed. When, however, excretion begins,
[I, 297] all the fibers are relaxed with the single exception of the transverse, which are tensed. The muscles also somehow take considerable part in this action along with the bladder. The muscle that surrounds the urethra [*transversus perinei profundus* and *sphincter urethrae membranaceae?*] relaxes at its origin where it is attached to the bladder, and all the abdominal muscles are strongly tensed so as to force inward and compress the bladder, while the muscle at its neck [*sphincter vesicae?*] contracts, compressing and forcing out the urine which is entering the urethra.[55] Although the urine is propelled by the pressure of the muscles of the bladder and the [abdominal] muscles above, the whole quantity would not pass so quickly and completely through the urethra if Nature had not also placed this muscle [*transversus perinei profundus* and *sphincter urethrae membranaceae?*] all around the outside of the exceedingly oblique canal. At the end of urination the expression of the last drops, especially when the urine is acrid, is not the work of any of the instruments higher up, but only of this one muscle. Hence we must consider that its primary usefulness is to prevent urine from remaining in the

[55] Galen has not made himself clear in this chapter. At times he seems to consider that "the muscle at the neck of the bladder" is what I have identified as transversus perinei profundus and sphincter urethrae membranaceae, not distinguished from one another, but this one sentence makes it evident that he was thinking of sphincter vesicae as a separate muscle. He leaves us in doubt, however, as to whether he thought that both muscles had two uses, one to express urine and the other to close the orifice.

urethra, that secondarily it helps close the orifice of the bladder, and that a third use is the quick completion of urination.

Now the obliquity of the neck of the bladder and the whole urethra is another of the many necessary consequences of arrangements made to serve a [definite] purpose. Indeed, it is clear that the [I, 298] urethra is exceedingly oblique, closely resembling the Roman Sigma (S); for it grows out behind the pubic bones and in front of the rectum and the bone called the sacrum (in women in front of the neck of the uterus also), descends through this whole region in line with the long axis of the animal until it passes beyond the bones, where it turns upward along the perineum as far as the beginning of the penis, turning downward again at that point to pass through the penis. The urine would be quite unable to traverse such a sinuous channel quickly if it were propelled only by the pressure from above without the help prepared for it in the region of the urethra. In women this channel has only the one curvature which it makes at the neck of the bladder, but in men, since the pudendum is produced from the neck of the bladder exteriorly, there is in addition a second curvature. It is clear too that the obliquity of the urethra, greater in men than in women, is a necessary consequence, and to prevent any urine from being held in the urethra, this muscle [*transversus perinei profundus* and *sphincter urethrae membranaceae?*] having transverse fibers has been placed around the outside of it to force the urine from the bladder to the pudendum.

[I, 299]

THE SIXTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Instruments of the Pneuma]

1. In the two preceding books, when I was explaining the construction of the instruments prepared by Nature for the governance of the nutriment, I brought the vena cava as far as the diaphragm, postponing to the present book the discussion of its course from that point on because I thought it better to include this in my explanation of the parts contained in the thorax. I have also discussed earlier most of the characteristics of the entrance [1] to the stomach called the esophagus, but it seemed to me necessary to keep for this book the description of its passage through the thorax and the demonstration that here too Nature has neglected nothing, since she not only made for it nothing superfluous, defective, or without a purpose but also left us unable to conceive of any other construction that would be better; for to anyone who was not familiar with all the parts of the thorax, an explanation of these matters would not be at all clear. Hence even now I must not speak of them at the very beginning; I must rather explain first as much of the construction of the thorax as will when mastered make my instruction easy to understand, but would if unknown leave it very obscure.

2. All that cavity bounded by the ribs on both sides, extending to
[I, 300] the sternum and diaphragm in front and curving down to the spine in the rear, is customarily called the thorax by physicians. Its inner capacity is clearly indicated by the outer circumference which you see; for the broad space within is almost equal to the apparent size of the thorax on the outside, since subtracting the very small mass of the ribs makes little difference. In fishes the heart is the only part contained in this cavity, and so this whole class of animals is mute

[1] Reading *στόματος* with Helmreich for the *στομάχου* of Kühn's text.

because it lacks the lung,[2] one of the instruments necessary for the production of the voice. In all animals that inhale through the mouth from the atmosphere and exhale into it again, the lung, which is an instrument both of the voice and of respiration, fills the thoracic cavity. The source of its motion is the thorax, as I have shown logically in my books on respiration,[3] and I have also told in my book *On the Voice*[4] what the thorax contributes to the production of the voice.

Now, however, I propose not to demonstrate actions but to interpret the construction of the instruments. So do not think it essential for me to demonstrate here the purpose for which we breathe. I shall rather take this main principle, which I have demonstrated elsewhere,[5] as the basis for my present discussion and so describe the usefulness of the parts of the heart, the lung, and the whole thorax. Along with these parts I shall, as I have said, explain the situation of the esophagus[6] and vena cava [in the thorax], and I shall begin with the following observations. [I, 301]

[2] Always used in the singular by Galen. Cf. Aristotle, *Hist. an.*, I, 16, 495a32–33: "The lung in all animals having one is usually bipartite."

[3] These books are *De causis respirationis* (Kühn, IV, *465–469*), which is, however, probably only the surviving fragment of a much longer work, and *De motu pulmonis et thoracis*, one of the lost treatises of Galen. See Kühn, I, *xci*, *cxciii*. In *De plac. Hipp. et Plat.*, II, 4 (Kühn, V, *236–237*), Galen, who has been discussing the "instruments" of respiration and the voice, says, "But if anyone is really eager to know about all these things, he has the other works I have written about them. The first is *On the Motion of the Thorax and Lung*, in which I show that the lung is moved by the thorax; that when dilated and expanded, it attracts the outer air, and this is inspiration; and that when compressed and contracted, it expels its contents into the larynx and mouth and through them into the outer air, and this is expiration. Then [the student] has a second work, *On the Causes of Respiration*, in which I have indicated all the muscles, the instruments moved by them, and the nerves conveying the psychic faculty to them from the encephalon. In addition to these works he has still another, *On the Voice*, which deals with the muscles moving these [instruments] and also the nerves coming down to them from the encephalon." There is also *De usu respirationis;* see note 5 of this Book.

[4] Another lost work; see the preceding note and Kühn, I, *cxciii*. For a summary of Galen's mechanics of respiration, see Baffoni (1949).

[5] *De usu respirationis* (Kühn, IV, *470–511*).

[6] *τοῦ . . . τῆς γαστρὸς στομάχου*; literally, "the throat (gullet, esophagus) of the stomach." See chapter 1 and note 1 of Book IV.

I have shown that respiration is useful to animals for the sake of the heart, which to some extent requires the substance of the air and besides needs very greatly to be cooled because of its burning heat. Inspiration cools it by supplying an abundance of the cold quality, expiration by pouring forth the burning hot and, as it were, inflamed and fuliginous material contained in the heart. It is for this reason, too, that the heart has a double motion made up of opposing members, for it attracts during diastole and is emptied during systole. Here you should first observe the foresight of Nature; for since it was better for us to have voices and air is necessary for the production of the voice, she used the otherwise useless and unprofitable expired air as the material for the voice. In my commentaries *On the Voice* I have written a complete account of the instruments of the voice and what sort of motion they have, and as my discourse proceeds, I shall take from that book whatever is necessary for present purposes.

Here Nature first deserves to be praised because she has not caused the heart to attract the outer air directly through the pharynx, but has placed between them the lung as a reservoir for the
[I, 302] breath, capable of serving both actions[1] at once. For if the heart in diastole attracted the air from the pharynx and in systole sent the air back into it, the rhythm of respiration and the beat of the heart would have to be the same, and if it were, the animal would encounter many serious difficulties not only in living a good life but in maintaining life itself. The inability to speak very much at a time which would result from such an arrangement would be a considerable hindrance to living a good life, and so would the impossibility of entering the water without fear of suffocation. But the inability to hold the breath while running through smoke, a cloud of dust, or noxious, poisonous air infected by decayed animal matter or from some other cause would quickly threaten life itself and destroy the animal completely. Since, however, the heart does not attract air from the pharynx or directly from outside the body but from the lung, into which it is expelled again, it becomes possible for us frequently to use our voices continuously and frequently to go without breathing altogether with no inconvenience whatever to the heart. If the heart attracted the outer air directly through the pharynx and discharged it directly to the outside again, either one of

[1] The two actions are respiration and production of the voice.

two evils would necessarily befall us: either we should breathe in noxious air when we ought not, or if we did not breathe in at all, we should be instantly suffocated. These are the reasons, then, why Nature did not make the heart as the only instrument of respiration [I, 303] but surrounded it with the lung and thorax, which were to furnish air to the heart and at the same time produce a voice for the animal. The lung serves besides as, so to speak, a soft jumping ground for the heart, as Plato [8] says, and the thorax as a sort of well-fenced barrier to protect not only the heart but the lung as well.

Nature established the heart in the very center of the cavity of the thorax because she found this place to be most suitable for protection and for uniform refrigeration from the whole body of the lung. It is the common opinion that the heart is not situated exactly in the center but more to the left, but people are deceived by the pulsation apparent in the left breast, where that ventricle lies which is the source of all the arteries. On the right side of the heart, however, there is another ventricle, turned toward the vena cava and the liver, and hence the heart should be said not to lie wholly on the left, but to be placed accurately in the middle, not only in respect to the distance from side to side but also in respect to the other two dimensions of the thorax, depth and length. For the vertebrae in back and the sternum in front are equally distant from the heart, and so are the clavicles above and the diaphragm below. Since, therefore, the heart lies at the mid-point of all the dimensions of the thorax, it [I, 304] attracts equally from all parts of the lung, and since it is very far removed from everything that might reach it from the outside through the thorax, it occupies a very safe position.[9]

[8] *Timaeus*, 70 (Plato [1920, II, *49*]).

[9] This insistence on a central location for the heart is another example of Galen's tendency to distort facts for the sake of his theory; for none of the animals which he was in the habit of dissecting has its heart so placed. Later on, when he was writing *De anatomicis administrationibus*, he was willing to grant it a position off-center and oblique. In Book VII, chapter 7, of that work he says, "You observe further that the heart is set between the two spaces of the thorax. Its movements reveal that it lies rather toward the left, and that for a double reason. Firstly, because the cavity for the pneuma [left ventricle] is there. Secondly, because the whole organ is thus inclined, for though the base is in the middle, the apex is not" (Kühn, II, *605–606;* translation by Singer [1956, *180*]). See also Daremberg's interesting note (in Galen [1854, I, *383–384*]) on this passage, and cf. Galen, *De plac. Hipp. et Plat.*, II, 4 (Kühn, V, *228–230*).

3. The entire middle portion of the thorax is separated off and partitioned by strong [mediastinal] membranes extending longitudinally from above downward. In the rear they are inserted firmly into the vertebrae of the spine and in front into the bone at the middle of the breast [the sternum], which at its lower end has the cartilage called xiphoid near the orifice of the stomach and at its upper end [manubrium] furnishes the attachment for the clavicles. The first and most important use of the membranes is to divide the thorax into two cavities in order that even if one side is badly wounded, as I have told in my book *On the Motion of the Thorax and Lung*,[10] and the work of respiration is thus destroyed on that side, the other cavity, being unharmed, may preserve at least one half of the action. Hence an animal whose thorax is pierced by serious wounds on one side straightway loses half of its voice and respiration, but if both cavities are affected, it will be entirely voiceless and deprived of respiration.

Now although the membranes dividing the thorax provide this most important usefulness to the animal and were formed particu-
[I, 305] larly for this reason, Nature, who is skillful at making a structure created for one purpose serve another also, has cleverly made use of them as investments and ligaments for all the instruments contained in the thorax. For these membranes[11] are stretched over and cover the arteries in this region, the veins and nerves, the esophagus, and even the whole lung itself, and bind them to the thorax. Thus as attachments the membranes perform a service equally important to all these parts; for a fixed position is important to all instruments alike. As tunics and protective coverings, however, their usefulness is unequal and differs widely; for some of these parts that are naturally thick and strong, like the arteries, heart, and esophagus, do not need coverings at all and others, like the lung, do indeed need them but the need is only moderate, whereas all the thoracic veins derive the greatest benefit from the membranes that grow out and surround them. This is particularly true of the vena cava, and when at the very beginning [of this book] I proposed to discuss the vena cava, I found it necessary first to explain the parts of the thorax sufficiently

[10] See note 3 of this Book.

[11] Now also including parts of the pleura other than the mediastinal and perhaps fascial structures; cf. Galen's description of the pleura in *De anat. admin.*, VII, 2 (Kühn, II, *591–595*; Galen [1956, *173–174*]).

to learn where the heart itself is located and furthermore how partitioning membranes extend from the middle of the sternum to the spine and divide the whole thorax into two parts.

4. Well, then, the vena cava, which is of the greatest use to the animal, as I have shown in earlier books, must pass up through the middle of the diaphragm to the heart, and, as I shall likewise show, it must also ascend from the heart to the region called σφαγή.[12] Since, however, the heart itself, the lung, the diaphragm, and the whole thorax are in constant motion, a route through the midst of the open space of the thorax was not safe unless Nature devised some additional assistance by means of which the vena cava, though suspended, so to speak, and continually shaken, holds steady. Even if the animal suffers a bad fall on its back or breast or is struck by some external object, the vein remains safe and sound thanks to this assistance, as well protected in spite of its one thin tunic as an artery whose tunic is many times as thick. [I, 306]

I must now tell what devices Nature has invented to make this vein resistant to injury. Those that are common to all parts of the vena cava and to its ramifications as well are the tunics I have just mentioned, which grow out together with them all to bind them to the parts on both sides and to make the whole mass of the tunic stronger. They accompany the vena cava from the diaphragm to the throat. Assistance is provided in three ways to the various parts of the vein: in the middle of the thorax the heart extends toward it a strong, sinewy outgrowth like a hand [the right auricle];[13] in the lower part the fifth lobe of the lung is spread beneath it; and in the upper part there is the very large, soft gland called the thymus.[14] [I, 307]

[12] The primary meaning of σφαγή is slaughter; hence secondarily it means the spot where the sacrificial victim was struck, and so, the throat. It is tempting to render it "hollow of the throat." In fact, Daremberg calls it *la fourchette*, but I have preferred to avoid reading into it more than the Greek actually permits and shall continue to use simply "throat."

[13] For Galen the heart was two-chambered, consisting of the ventricles alone. Cf. *De anat. admin.*, VII, 11 (Kühn, II, *623–625;* Galen [1956, *188–189*]).

[14] Galen was aware of the gradual decrease in size of the thymus but does not say how he thought the upper part of the vena cava was to be supported after the virtual disappearance of the gland. In *De alimentorum facultatibus*, III, 6 (Kühn, VI, *674*), he says, "The gland called

The outgrowth from the heart, however, was formed not for this purpose alone, but also to be extremely useful to the heart itself, as I shall explain in the course of my discussion, whereas Nature created the fifth lobe of the lung and the thymus as well [solely] for the great vein.

I think you will marvel the more if instead of relying entirely upon words, you are willing to dissect some animal and see this wonderful thing for yourself. For you will see not only that the lobe is placed beneath the vein, but that it is also accurately hollowed out to keep the vein's contact with it from being insecure. This lobe is not interwoven with many large vessels; for the most part its substance is rather the flesh of the lung, which some call parenchyma, and in making it such, Nature has shown clearly that she created it not as an instrument of respiration, but as a soft substratum for the vena cava. For I suppose an instrument of respiration properly should have many large receptacles for the breath, whereas one that is intended to support safely and painlessly an instrument lying upon it should experience very little expansion or contraction, and no vigorous motion whatever. Indeed, the usefulness of respiratory instruments rightly depends upon movement, but that of instru-
[I, 308] ments of support on the absence of it. Moreover, Nature showed well enough what the usefulness of this lobe is when she made two lobes on the left side of the thorax and three on the right. For since the vena cava is situated on the right side of the animal because it begins on the right at the liver and passes up to the right ventricle of the heart, the lobe created for the sake of the vena cava must necessarily be placed in the right side of the thorax.

Surely it is fitting that you should extol this work of a just Nature, which, when viewed with the senses alone without the aid of reason, might seem unjust, but which is most truly just if ever anything was; for Nature has chosen equality not of appearance but of ability, and to do this is the work of a justice that is true and divine. Now when each of two instruments such as the [two] eyes, ears, hands, or feet has an equally important usefulness, Nature has made the right one exactly like the left, but when one of the pair has the advantage because of some special usefulness, she has made for it an additional

---

thymus is by no means small, but very large indeed in newborn animals, though it becomes smaller as they grow." Cf. *De anat. admin.*, XIII (Galen [1906, II, *146*; 1962, *160*]).

part, as I have shown in the preceding book in regard to the instruments of nutrition. It also seems now to be no less true in regard to the fifth lobe of the lung, which Nature has made for the sake of the vena cava, regulating its size, contexture, position, shape, and all its other attributes to accord with its usefulness. You cannot find any animal which does not have the number of lobes on the right side of the lung greater by one than the number on the left. Yet not all animals have two lobes on each side as man does; on the contrary, there are some that have even more, but in all there is one special lobe which is placed beneath the vena cava.[15] It is not my [I, 309]

[15] The reader has doubtless realized that Galen's treatment of the lobes of the lungs presents difficulties. When he speaks of three lobes on the right and two on the left, one wonders if his fifth lobe is the inferior lobe of the right lung in man with its deep concavity for the inferior vena cava, and if he has actually dissected a human lung, as he intimates here that he has done. The possibility is strengthened by the fact that in the rhesus monkey, at least, there are also three lobes in the left lung, though they are not so distinctly isolated as in the right. (See Lineback [1933, *212*].) But one's suspicion is aroused when he says that the fifth lobe is not interwoven with many large vessels and that it was clearly not created as an instrument of respiration; for these remarks hardly apply to the inferior lobe of the right lung in man. At this point it will be helpful to see what he has to say on this same subject elsewhere. "The lobes of the lungs," he says, "are not unbalanced in number as are those of the liver, but in all the animals we are discussing there are two lobes on each side. It is further agreed, if not by all at least by those who dissect carefully, that there is also a fifth small lobe in the right lung, a mere offshoot of one of the others [*lobus azygos*]. This you will find most easily by paying attention to the vena cava, for it lies under that [vessel] where it first invades the thorax, as it leaves the diaphragm. Sometimes also you can see plainly on the surface [of that lobe] a cavity in which the vein is fixed in life" (Kühn, II, *625–626;* translation by Singer [1956, *189*]). It is evident from this first that his reports of the number of lobes present are not to be relied on and secondly that his fifth lobe is the accessory azygos lobe which in the rhesus monkey is really a small seventh lobe attached by a narrow pedicle to the inferior lobe of the right lung and grooved to receive the vena cava. (See Lineback [1933, *212–213*].) This is the *lobus intermedius* described by Ellenberger and Baum (1926, *475*) in domestic animals as an *Anhangslappen* connected with the right lung and inserted into the space between the mediastinum and the mesentery of the vena cava. Thus one must reluctantly give up the hope that here for once Galen has been found basing his descriptions on human material, for he has not.

purpose to speak of the number of lobes in each of the other animals, nor is my discourse ever concerned with the construction of any other instrument in animals, except perhaps to provide a necessary point of departure for the explanation of it in man. If death does not come to me too soon, I shall some day explain construction in animals too, dissecting them in detail, just as I am doing for man.[16] For the present, however, I shall be content if I succeed in finishing this present treatise, of which more remains to be done than I have already accomplished.

So, having said enough on this subject, I shall pass on to another [and show] that in the expansion of the thorax all one part of its cavity is filled by the upper lobe, whereas the narrow, oblique part circumscribed by the false ribs below is occupied by the other, elongate lobe. With this arrangement there are two large lobes on each side, and a fifth lobe on the right side, formed for the sake of the vena cava and extending from the diaphragm to the auricle of the heart. There one part of the vena cava is inserted into the heart itself; the other, larger part ascends straight to the throat (*σφαγή*),
[I, 310] conducted for some distance by the outgrowths[17] of the heart and thereafter resting upon the part called the thymus. For Nature has spread this very large and also very soft gland beneath the upper part of the central bone of the breast called the sternum, so that the bone itself may not come in contact with the vena cava and so that all the many ramifications given off by the vena cava in this region may be supported where they first arise. Indeed, wherever Nature causes a suspended vessel to branch, she always places a gland to fill up the space at the junction.

Very large veins[18] sprout [from the vena cava] in this region and

[16] A remark hard to understand in view of the convincing evidence that the descriptions in *De usu partium* are based almost exclusively on the dissection of animals. See my Introduction, pp. 40–41. If Galen ever carried out his intention of writing on the anatomy and physiology of animals, the treatise has not survived. Cf. *De anat. admin.*, XI (Galen [1906, II, *98–99*; 1962, *108*]), and see chapter 3 of Book XIV, *ad init.*, and p. 626 *infra*.

[17] The use of the plural here is peculiar unless Galen was thinking not only of the auricle but also of the pericardial investment of the vein. See Daremberg (in Galen [1854, I, *389* and n.]).

[18] The two brachiocephalics, giving rise to the subclavians; Galen's various descriptions of the tributaries of the superior vena cava (in his

lead to the shoulder blades and arms, and before these branch, there are still others, some distributed to the upper parts of the thorax [*v. azygos* and its tributaries] and others to anterior [ventral] and inferior parts [*vv. thoracicae internae*]; most of these latter veins pass down along the breasts and extend as far as the epigastric [19] region. For all these venous branches and above all for the vena cava itself Nature has cleverly constructed a very great aid in the gland I have mentioned, placing it near the bones as a barrier very like felt to be a support and provide great safety for all parts of the vein. This is the way in which she conducts the vena cava from the diaphragm to the neck [20] in perfect safety.

5. In the part of the thorax most suitable for it Nature has placed [I, 311] the esophagus, which leads from above downward in the opposite direction from the vena cava, because the esophagus is the path by which the nutriment is conducted down from the mouth to the stomach. And now I should like you to pay me close attention, as I propose to show that the route prepared for the esophagus through the thorax not only is best for the canal itself but also causes no trouble for the instruments of respiration. Of course, when the lung, heart, and the entire thorax together with all the arteries contained in it expand and contract, nothing must hamper them in any way in

---

view the branches into which it divides) are very obscure, but a study of them in *De venarum arteriarumque dissectione*, capp. 2–7 (Kühn, II, *786–807;* Galen [1961, *357–362*]), and in *De anat. admin.*, XIII (Galen [1960, II, *140–152;* 1962, *154–167*]; Simon's notes are particularly helpful), shows that he is not describing an ungulate type, as Singer and Rabin (1946, *li*) have maintained. "Galen," they say, "describes a great vertical superior vena cava into which all four great vessels open," and they cite in support of this statement *De venarum arteriarumque dissectione*, cap. 2 (Kühn, II, *787*). But there Galen says that when the vena cava approaches the throat, it divides into *two* branches which continue obliquely, obviously the brachiocephalics, which are practically nonexistent in ungulates. He speaks in the same way in the other passages I have cited, thus leaving no doubt that he is once more describing conditions in the ape, where the superior vena cava is relatively much longer than in man but is formed by the confluence of the brachiocephalics. See Lineback (1933, *262*). It is to be regretted that Galen does not make himself clear on this point anywhere in *De usu partium.*

[19] Reading ἐπιγάστριον with Helmreich for the ὑπογάστριον of Kühn's text.

[20] This time the word is τράχηλος, not σφαγή.

either of these movements, and the esophagus itself must not pass through the midst of the open space of the thorax as if suspended, but must rest upon some firm support. Both these goals, namely, to avoid all harm to the instruments of respiration and to provide every benefit for the esophagus, Nature has attained admirably through her advantageous placing of the esophagus. For it rests upon the vertebrae of the spine, to which it is attached, and passing thus through the whole thorax, it combines the stability of its position proteced on all sides with the advantage of causing no trouble at all to the heart, lung, or any of the other parts contained in the thorax.

Moreover, the curving course of the esophagus will show you still more clearly that when Nature marked out this route for it, these
[I, 312] were the two goals for which she was concerned, namely that it should cause the instruments of respiration no trouble at all and should not itself suffer any harm. It extends along the precise center of the first four vertebrae of the back, deviating to neither one side nor the other, so that it is not obliged to crowd any of the contents of the thorax, and so that thanks to this situation it enjoys in addition particularly firm support and will not readily suffer injury from without. Indeed, since it is protected in the rear by the outgrowths of the spine called the *acantha*[21] together with the vertebrae and in front by the sternum and the whole cavity of the thorax, it is clear that nothing external will be able to strike, wound, or bruise it when it is fortified on all sides by so many strong defenses. At the level of the fifth vertebra it turns aside from its straight path downward and veers to the right, yielding the better support to a more important instrument, the largest artery of all [the aorta]. Now of course it was proper that this artery issuing from the left ventricle of the heart and being distributed to the whole body of the animal should be divided first into two unequal branches,[22] that the branch leading

[21] See chapter 15 of Book XII.

[22] Singer and Rabin (1946, *xlvi*, *xlviii*) conclude from this passage that Galen in *De usu partium* describes an ungulate type of branching from the arch of the aorta, whereas they note that in his *De venarum arteriarumque dissectione*, cap. 9 (Kühn, II, *817–818*), the type is clearly simian. They neglect, however, other passages in *De usu partium* (see chapters 4 and 10 of Book XVI) in which Galen is obviously describing in detail the type of branching in the ape. See Lineback (1933, *249–250* and figure 79). The present passage with its mere mention of an upper division must not, then, be taken in any such sense as they propose, but

downward should be much the larger because there are many more parts of the animal located below the heart than above and the parts are larger there, and that this branch should pass along the vertebrae [I, 313] in the most favorable situation, which is the center.

6. I shall tell a little later why this artery reaches the fifth vertebra and show that it was not better for it to arrive at the spine either higher up or lower down; first, however, I shall finish my discourse on the esophagus, having [already] shown correctly that it was better for it to leave its central position. Now you must give me your attention while I demonstrate that it should turn to the right rather than to the left. Though the artery is indeed carried upon the central part of the vertebrae, it does not displace the esophagus very tyrannically or greedily, but, yielding a little itself, receives and admits it to a share in the support of the vertebrae. Hence, if you imagine a line drawn down the middle of the spine and the aorta lying along this line in such a way that the greater part of it is on the left side of the animal and the lesser on the right, you will not think that my description contradicts itself when I say that the artery occupies the center of the vertebrae and at the same time does not occupy the exact center but lies more to the left. For just as I was right in saying above that because the artery is more important than the esophagus it was properly given precedence, as it were, so we should rightly understand that the esophagus is not such an unim- [I, 314] portant part as to be entirely neglected. When these two arguments are combined, you could not discover any place for either instrument better than the one it now occupies.

Now since it was absolutely necessary for the artery both to advance along the mid-line and to be displaced a little to the side, you should see here once more the foresight and skill of Nature. It was, of course, reasonable that since the artery arises from the left side of the heart, it should pass directly to the left, even if for the whole distance between the heart and spine its course was really, so to speak, suspended and unsupported, and in this dangerous situation there was no better help than the shortness of the interval. Well then, I think that if you are versed in anatomy and have yourself made observations, you will admire the way in which the artery

---

should be thought to indicate only Galen's lack of interest in a complete description at this point. See also *De anat. admin.*, XIII (Galen 1906, II, *157–158;* 1962, *172–173*]).

takes the shortest possible route between the heart and spine, showing clearly to those who have eyes and minds that it is hastening to reach the spine. And this is the reason why it is carried upon the fifth vertebra of the back; for it has its origin from the heart exactly on a level with the beginning of this vertebra. But I shall speak of the instruments of the pneuma a little farther on.

The canal of the stomach [the esophagus] is carried upon the first
[I, 315] four vertebrae of the thorax and lies on the right side of the remaining eight for the reasons I have given. But when it first touches the diaphragm, which forms the lower boundary of the thorax, it is raised to a considerable height [23] by strong membranes and crosses again above the great artery to the other side where, penetrating the diaphragm, it is inserted into the orifice of the stomach. It is raised to avoid compressing the artery during the passage of the harder masses of food, and it turns to the left because, as I have shown in an earlier book, it was better for the orifice of the stomach to be located in that region, and surely also [24] an oblique route would be far safer than a straight one for the nerves [*n. vagus*] leading from the brain along the esophagus to the stomach. For since these nerves are soft and slender and extend for a long distance in a straight line, and since most of them hold the stomach suspended, which must be filled with food, they would always be stretched by its mass and weight and would easily be torn away. To avoid anything of the sort, and for the various other reasons which I gave just now as well as for the safety of the nerves, Nature has given an oblique position and curving course to the esophagus itself, along the sides of which she has caused the nerves to grow; and in addition, as the nerves themselves approach the stomach, she entwines them about the esophagus before inserting them. But I shall tell more about the nerves later on.

[I, 316] 7. Now, however (for I have already finished discussing the situation of the vena cava and esophagus), I shall pass on to a consideration of the instruments of the pneuma and show how well Nature arranged them all, bestowing on each one the very best position, contexture, conformation, mass, and shape, and regulating most justly its softness or hardness, its heaviness or lightness, and all the other qualities inherent in bodies. Moreover, with what great fore-

[23] That is, it is moved ventrally; the observer is looking down at the dissected animal lying on its back.

[24] Accepting Helmreich's emendation, εἴ γε.

sight she arranged the relationships of the parts to one another, causing some to coalesce and linking others together, encompassing some and investing others, and making every contrivance that would conduce to their safety—all this will I explain, beginning once more with the heart.

Well, then, it is clear from what I have already said that the heart should be placed in the middle of the thorax, surrounded on all sides by the lung, and clasped by its lobes as if by fingers, and that both the lung and heart should be enclosed in the thorax. I have not yet told why the heart is not perfectly spherical and why instead, beginning at the broad, circular base above, which is called the head, it gradually decreases in size, very like a cone, and becomes narrow and slender at its lower end. This is the very point at which I should begin my whole exposition of the heart. All parts of it do not need an equal amount of protection because they have not all been entrusted with the same usefulness. Those at the base are devoted to the production of vessels; those extending laterally from the base to [I, 317] the lower end were made as walls, so to speak, for the ventricles; and the lower end itself is a strong, dense process, formed to serve as a lid for the ventricles and at the same time as a defense for the whole heart, so that in its more vigorous movements it may never be impeded or suffer harm [25] by striking violently against the bones of the thorax lying in front of it and so be compelled to confuse and destroy the rhythm of its motion. This part of the heart is the least important; that which is to give rise to the vessels is the most important of all. The intervening parts have importance depending upon the worth of the parts they are near. Thus the parts near the base want but little of being the most important; those near the apex are almost the least; and the intervening parts fall short of and exceed the worth of the two ends, depending on their distance from them. Hence it is not at all surprising that the heart should be cone-shaped or that its head, being most important, should occupy the safest position, whereas its bottom, being least important, is most exposed to injury.

Now when I say that a certain part of the heart is least important, I do not suppose that anyone will be led so far astray from the truth as to take that part to be entirely without importance. Indeed, you

[25] Reading ἐμποδίζηταί τε καὶ πονῇ with Helmreich for the ἐμποδίζηται καὶ πῇ καὶ πονῇ of Kühn's text.

[I, 318] would not find in the heart any part at all, even its lower end, that does not surpass in importance all the parts found, for example, in the arms or legs. You would, however, find that although all parts are important, we must think of some as being more and others less so when we compare them with one another. In order that you may follow my discussion both now and later without misunderstanding, I wish to go over with you the criteria which must determine whether a part in the body of an animal is important or not. This can be decided in both cases by the usefulness. Now there are three kinds of usefulness; for a part is useful either for maintaining life itself, or for making life better, or for preserving the race.[26] Hence those that conduce to life itself should be regarded as absolutely essential, and of the two other less important kinds of parts, those readily affected along with the essential parts should be considered less trivial than those which are not.

Accordingly, since the heart is, as it were, the hearthstone and source of the innate heat by which the animal is governed, every part of it is *ipso facto* important, but those are more so whose usefulness is to preserve the life of the whole animal. These are the mouths of the two vessels attached to the left ventricle, which physicians are wont to call the pneumatic ventricle.[27] For through these orifices the heart is connected with the arteries, the smaller one [the left atrioventricular opening] [28] connecting it with the arteries of the lung [*vv. pulmonales*], and the larger [aortic opening] with those of the whole animal. The orifices of the other [right] ventricle
[I, 319] of the heart, called the sanguineous ventricle, are less important. Nevertheless, these too are more important than other parts of the

[26] Reading εἰς τὴν τοῦ γένους φυλακήν with Helmreich for the εἰς τὴν τούτων φυλακήν of Kühn's text.

[27] According to Galen the left side of the heart is devoted to the production of the vital spirit or pneuma from the blood and the altered air conducted to it by the pulmonary veins. See my Introduction, pp. 47–48. Hence this side of the heart may be called pneumatic. The right side, existing, as he thinks, for the sake of the lung's nutrition, receives only the blood from the vena cava and is therefore called sanguineous.

[28] Since for Galen the heart consisted of only the ventricles, the pulmonary veins and the vena cava communicated with it through the atrioventricular openings, and the atria were merely the terminal portions of these vessels. I suppose that this is the reason why he speaks of a pulmonary vein instead of pulmonary veins.

heart, for one [the right atrioventricular opening] is the entrance admitting the blood, and the other [the opening of the pulmonary artery] is the exit for blood going to the lung. Since these vessels and openings are all of remarkable size,[29] it is reasonable that this part of the heart should also be very large and should occupy the middle of the whole thorax as the place that is safest because it is farthest removed from the blows of exterior objects striking against it. For everything that would crush, cut, heat, or chill the animal or injure it in any other way must necessarily first harm and pass through all the parts of the thorax, lung, and heart itself before reaching the parts I have been describing.

8. That is what I have to say about the shape of the heart and the position of each of its parts. Next I shall discuss its general substance. The heart is a hard flesh, not easily injured. It is composed of many different kinds of fibers and although it seems closely to resemble the muscles, it clearly differs from them in both the following respects. The nature of the fibers is uniform in muscles, for they have only straight ones, running either longitudinally or transversely across their breadth, and no muscle has both kinds together. But the heart has both and a third kind, the oblique fibers, in addition. Moreover, in hardness, tension, general strength, and resistance to injury, the fibers of the heart far surpass all others; for no other instrument [I, 320] performs such continuous, hard work as the heart. Hence the substance of its body very properly was constructed for strength and resistance to injury; the complexity of its fibers, however, which is found in no muscle but in many other instruments, such as the uterus, the bladders, and the stomach, was prepared by Nature to produce a variety of motions, as I have shown in the preceding book. Now each muscle has one simple motion, as I have also demonstrated in other writings of mine.[30] But the stomach, uterus, and both bladders attract, retain, and expel just as the heart does, and for this reason they all have the different kinds of fibers, as I have

[29] Kühn omits *τῷ μεγέθει*.

[30] *De motu musculorum*, I, 4 (Kühn, IV, *382–387*). In this same work (I, 3 [Kühn, IV, *377* ff.]) Galen discusses more fully his reasons for denying that the heart is a muscle. He says, for example, that the motion of a real muscle is under the control of the will whereas that of the heart is not. For an excellent analysis and summary of his position, see Meyer-Steineg (1911, *179–181*).

shown, in order that by the contraction of the straight fibers they may attract, by means of the transverse they may expel, and by the clasping action of all the fibers at once they may retain their contents.

You can observe such a motion of the fibers in the heart in two ways, either by examining it when it has just been removed from the animal and is still beating, or by cutting out the bone called the sternum lying in front of it by the method I have described in the *Manual of Dissection.*[31] When the longitudinal fibers contract and all the others relax and stretch, the length decreasing and the overall breadth increasing, you will see the whole heart dilate, but when the
[I, 321] longitudinal fibers relax and the transverse contract, you will see it reduced in size again. Between these two movements there is a short pause while the heart is clasping its contents closely and all the fibers, particularly the oblique, are tensed. Systole is greatly aided, or rather is for the most part performed, by the bands [*columnae carneae*, *musculi papillares*, and *chordae tendineae*] stretched on the inside of the heart through the ventricles themselves. These bands are exceedingly strong and when they contract are capable of drawing inward the tunics [the walls] of the heart. For between the two chambers of the heart there is something like a diaphragm [*septum ventriculorum*] at which these stretched bands terminate and which they connect with the bodies called the tunics of the heart that form the outer covering of the two ventricles. When these tunics approach the diaphragm [*septum ventriculorum*], the heart grows longer and its breadth decreases; when they withdraw to their greatest distance, its breadth increases and its length becomes less. Indeed, if diastole and systole of the heart are nothing more than the very great extension and collapse of the width of its ventricles, we have now discovered how each of these actions is accomplished. The reason, then, why the heart has strong bands and fibers of all kinds is
[I, 322] this, namely, to adapt itself readily and with no difficulty to three conditions, enlarging when it desires to attract what is useful, clasping its contents when it is time to enjoy what has been attracted, and contracting when it desires to expel residues. I have discussed these matters in greater detail elsewhere in many of my works, particularly in my treatise, *On the Usefulness of Respiration,*[32] and it is

[31] *De anat. admin.*, VII, 12 (Kühn, II, *626–632;* Galen [1956, *190–192*]).
[32] *De usu respirationis* (Kühn, IV, *470–511*).

unnecessary here to spend any more time talking about the motion of the heart.[33]

9. Now I shall explain the number of vessels at the heart, expound the form of their orifices, say something too about the number of ventricles, and recount all the other consequents. The number of ventricles of the heart—for it is proper to begin with this subject—is not the same in all animals. Those breathing air through the pharynx, nostrils, and mouth naturally have a lung as well, and naturally, too, they also have a right ventricle of the heart, but all others lack both the lung and the cavity in the right side of the heart. For the loss of the lung necessarily always entails the loss of these two things, namely, the animal's voice and the right ventricle of the heart, and hence it is clear how very useful both the lung and right ventricle are, since the right ventricle was formed for the sake of the lung and the lung itself is the instrument of respiration and the voice. Aristotle,[34] therefore, was wrong when in determining the number of ventricles in the heart he referred it to the large or small size of [I, 323] the animal's body. In fact, very large animals do not all have three, and the very small only one; the largest horse has a heart constructed in exactly the same way as that of the smallest sparrow, and whether you dissect a mouse, a beef, or any other animal either smaller still than a mouse or larger than a beef, they will all have the same number of ventricles, and the construction of their hearts will be the same in other respects also. Nature pays no attention to the large or small size of the body when she varies the form of instruments; on the contrary, her guide in construction is difference of action, and she measures the actions themselves in turn by their principal usefulness. Thus there is produced a wonderful series of actions and uses succeeding one another, as I have demonstrated in what I have already said and as my present discourse will show no less clearly to those who will study it with some degree of care.

[33] Kühn's text adds νὴ Δία (by Zeus!).

[34] *De part. an.*, III, 4, 666b21–35; cf. *Hist. an.*, I, 17, 496a4, 19–25; III, 3, 513a27–35. In *De venarum arteriarumque dissectione*, cap. 9 (Kühn, II, *817*; Galen [1961, *364*]), Galen says that Aristotle's third ventricle lies where the smaller (right) coronary artery is distributed in the broader part of the heart and that it is a small part of the right ventricle. Is this perhaps the conus arteriosus? Ogle (1911) in his note on the first passage cited is of the opinion that it is rather the left atrium. See also Pagel (1963, *121*).

The sum of the matter is this: Of course, since fish live in the water, they have no use for a voice, nor can they breathe by way of the pharynx any more than we ourselves can when we are under water. Hence it was better for them not to be provided with a single, very large channel for respiration and the voice, as animals that fly and walk are. Instead, the structure called gills performs in fish the office of a lung; for the gills are pierced by many fine openings
[I, 324] which are permeable by air and vapor, but too fine for a mass of water, and thus they keep out the latter while readily admitting the former. In addition, fish have a colder nature, so that in them the heart does not need powerful refrigeration. There are many other indications of their temperament, but their lack of blood is the most striking; for they have either none at all or at most very little. And for this reason all warm, full-blooded animals living in the water, such as the dolphin, seal, and whale, breathe air in a certain marvelous kind of respiration which I may relate in detail some time hereafter when I shall explain the structure of animals as I am now explaining that of man. It is time now to return once more to my subject, having mentioned only so much of these matters as was sufficient to show the usefulness of the lung and the right ventricle of the heart.

10. The heart seems to supply the lung with nutriment from the blood as a sort of exchange and to do the lung this service in return for the air which the heart receives from it. Now of course even the lung needs nutriment, but it was not better for the blood to enter it directly from the vena cava, even though the vena cava passes by in contact with it, because to nourish the lung another kind of vessel must be constructed which does not resemble the vena cava at all and which must have an outgrowth of membranes [pulmonary semilunar valves], as indeed it does. The vessel could not acquire these characteristics from any source but the heart. Now when
[I, 325] Nature, who is wise in all things, interchanged the tunics of the pulmonary vessels, making the vein [*a. pulmonalis*] like an artery and the artery [*v. pulmonalis*] like a vein, she was not acting in any idle or haphazard manner, any more than she ever does in making any other structure in any animal. Though an artery may be similar to a vein in all its other parts, in the thickness of its tunics it is not the same. On the contrary, it is so different that Herophilus seems to have calculated correctly when he declared that an artery is six times

as thick as a vein. Of all the instruments and parts the lung is the only one in which the artery has the tunics of a vein and the vein those of an artery.

First I must explain why Nature resorted to this device, then I must speak about the outgrowth of membranes [pulmonary semilunar valves] and then show that an arterial vessel and membranes of this kind could not be produced from the vena cava. For if all these things are not discussed first, the reason (χρεία, usefulness) for forming the right ventricle of the heart cannot be demonstrated. I shall begin accordingly with the first point and show that it was better for the lung to have its artery like a vein and its vein like an artery. This problem too seems to be double or twinned, so to speak. In fact, when a person proposes to leave no difficulty unsolved and no one of Nature's works obscure or unintelligible, it is his task to show not only that it is better for the lung if the tunic of its vein [*a. pulmonalis*] is extremely thick and that of its artery [*v. pulmonalis*] very thin, but also that it is better for every other part of the animal if the tunic of its artery is thick and that of its vein thin. [I, 326]

I suppose that no long discussion is necessary to prove that throughout the body of the animal it was better for the blood to be contained in a thin, loose-textured tunic and for the pneuma to be confined [85] in a tunic that is thick and dense; for it is enough to remind you of the character of the two substances, blood being thick, heavy, and sluggish, and pneuma thin, light, and mobile. The danger was that the pneuma would be easily dissipated and lost from [the body of] the animal [86] if it were not guarded by tunics that were thick, dense, and altogether impenetrable. In the case of the blood, on the other hand, if the tunic containing it were not thin and loose-textured, it would not be easily distributed to the adjacent parts and thus its whole usefulness would be completely destroyed. Our Creator, having perceived these things, devised for the vessels tunics that are opposite in character to the materials [they contain] in order to prevent the pneuma from being carried off prematurely and the blood from being held in check for a very long time.

Why, then, did he not in the same way make the vein in the lung

[85] Kühn omits the στέγεσθαι of Helmreich's text.

[86] Reading αὐτὸ τοῦ ζῴου with Helmreich for the αὐτὸ τοῦτο of Kühn's text.

thin and the artery thick? I suppose that doubtless here too the pneuma is thin and light and needs to be closely confined; here too the blood is thick and heavy and must be distributed to all parts of the lung. And the lung has a greater need of nutriment than other
[I, 327] parts of the body, both because of its incessant motion and because of the large amount of heat which it enjoys from its close proximity to the heart and from the ceaseless motion itself. In this respect[87] also, I think, you will admire the foresight of the Creator. Surely it is evidence of wonderful foresight for him to have given the lung a special construction, different from that of all the other parts of the body, since it alone possesses such a strong instrument as the thorax, moving so vigorously and surrounding it on all sides. I have shown in my book on their[88] motion that the lung has no motion of its own and is always set in motion by the thorax; that when the thorax contracts, the lung contracts too because of the pressure from every direction and the squeezing which occurs during expiration and the production of the voice; and that when the thorax expands, the lung once more keeps pace with it and expands in all directions at the proper time for inspiration, just as the thorax does. It is not necessary, however, during either inspiration or expiration for the veins to expand as the arteries do, because the same service has not been entrusted to them. For Nature devised the arteries to receive the pneuma and thus they must be filled easily during inspiration and readily emptied during expiration and the production of the voice; the veins, on the other hand, she made as a storehouse for the nutriment and thus they do not need to expand during inspiration or contract during expiration. Hence it was good to make the arteries
[I, 328] [*vv. pulmonales*] of a soft substance and the veins [*aa. pulmonales*] of a hard one, if indeed it was better for the former to obey promptly both actions of the thorax and for the latter to pay no heed to them at all. But again, if I was right when I showed in another work of mine[89] that bodies are nourished by attracting blood through the tunics of the vessels, the lung will perhaps be in want of a vessel to nourish it, since the tunic of its vein [*a. pulmonalis*] has been made exceedingly impenetrable. Here too, however, I

[87] Reading ταῦτά with Helmreich for the τάχα of Kühn's text.

[88] Reading αὐτῶν with Helmreich for the αὐτοῦ of Kühn's text. The reference is to *De motu pulmonis et thoracis*. See note 3 of this Book.

[89] In *De nat. fac.*, II, 6 (Kühn, II, *103–106;* Galen [1928, *162–165*]).

think you will find still further evidence of Nature's admirable foresight, if I remind you of what I demonstrated in that other work of mine,[40] namely, that some parts of the body must be nourished by thick and, so to speak, muddy blood, whereas others require blood that is thinner and more spirituous; and moreover, that all other parts including the arteries and veins partake of all [kinds of nutriment]. The arteries use a little thin, spirituous blood, and the veins themselves a very little pneuma, thick and mistlike. If, then, these things are true, as they are, and the substance of the lung must be nourished with nutriment that is not muddy and thick like that for the liver, but thin, light, and spirituous, the Creator of animals has obviously made all his arrangements admirably. For each part is nourished by nutriment similar to itself and this too I have demonstrated. The substance of the lung, light and loose-textured, looks as if it was composed of congealed, bloody foam, and therefore it needs [I, 329] blood that is spirituous, thin, and pure, not thick and muddy like that required by the liver. Hence the nature of the vessels of the lung is opposite to that of the vessels of the liver in particular and also to those of the other parts of the body. Since in the latter the tunic of the vessels supplying them is thin and porous, a great deal of thick blood is readily distributed to the surrounding parts, but since the tunic of the vessel supplying the lung is thick and dense, it permits nothing but the thinnest blood to pass through. Elsewhere in the body the arteries, having been made thick and dense, permit the surrounding parts to attract an exceedingly small amount of spirituous blood. Only to the lung do they release a very large portion of such blood, being unable to retain it because they are thin and loose-textured.

Thus the plan for the nutrition of the lung is the precise opposite of that for all the other parts of the body, just as its substance too is the opposite of theirs. You will not find any other part that is so loose-textured, light, and airy, nor one nourished with blood that is nearly so pure, thin, and spirituous. Whatever is lacking in the

[40] That each part attracts what is appropriate to it from the nutriment offered it and rejects the rest is one of the central themes of *De naturalibus facultatibus;* but see III, 15 (Kühn, II, *209–210;* Galen [1928, *322, 323*]), where Galen says that the proposition that different parts of the body should be nourished by different kinds of blood is to be demonstrated in *De usu partium!*

amount of nutriment furnished to the lung by the thick, dense veins is entirely made up for by the arteries which transmit to it thin, pure, spirituous blood in abundance. But even this is not enough for such a warm, active viscus, and Nature accordingly made the veins in it very large in order that whatever is wanting to nourish it
[I, 330] sufficiently on account of the density of their tunic is made up for by their size. Moreover, she recognized that there would of necessity be three other things to aid in providing the lung with plenty of nutriment: first, the great quantity of innate heat which breaks up and disperses the mass of nutriment into fine particles, so that it vaporizes more readily; second, the distention of the lung in inspiration, which forcibly draws material out even from the densest instruments; and third (the most important of all), the fact that the lung is the only part to which the heart sends blood which it has already perfectly elaborated and attenuated.[41]

This is not the only reason why it was better for the lung to be nourished from the heart; on the contrary, as I promised to show at the beginning [of the chapter], it was better because the veins in the lung must have the tunics of arteries and certain outgrowths of membranes [pulmonary semilunar valves], neither of which could be derived from the vena cava. The first of these propositions has already been demonstrated.[42] It is time now to pass on the second, namely, that it was better to locate at the mouth of this arterial vein [*a. pulmonalis*] the same sort and the same number of membranes that we actually do find there. Even though the vessel has been made as thick and hard as possible, so that it does not easily expand and contract, it is still not so hard as to avoid being completely overcome by such a large, strong instrument as the thorax, that acts so vigorously, especially when we breathe out all at once, talk in a loud
[I, 331] voice, or in some other action draw the thorax inward on all sides by strong tension of all the muscles. For at any such time it is impossible to keep the branches of this vein from being to some extent compressed and from collapsing, and if they are compressed and contracted, the blood will readily run back out of them all to the original orifice and will return whence it came. This would be

[41] That is to say, the other parts receive their share of nourishing blood directly from the liver via the veins, without benefit of a trip through the heart.

[42] That is, the necessity of arterial tunics.

harmful in three ways. To no good purpose the blood itself would move incessantly in a sort of double course, flowing out during the expansion of the lung and filling all the veins there, and, when the lung contracted, moving like an ebb tide in the manner of [the sea in] a tidal strait, forever changing, back and forth, a motion in no way suitable for the blood.[43] This is perhaps of little account, but the

[43] In accounts of Galenic physiology we have frequently been told that Galen in his ignorance of the circulation of the blood thought that it washed back and forth in both the arteries and veins; see, for example, Brock (in Galen [1928, *xxxv-xxxvi*]); Singer (1959, *99–100*); and Premuda (1966, *57–63*). This passage seems to make such an idea untenable, though, as Wilson (1959, *300*) points out, Galen's various treatments of the subject are not altogether consistent because he is usually arguing as a special pleader for some doctrine and emphasizes or ignores now one aspect of the problem and now another, never presenting a full and dispassionate account of his position. Pieced together, however, from passages in many of his works (*De plac. Hipp. et Plat.*, *De nat. fac.*, *De anat. admin.*, here in *De usu partium*, and elsewhere), this position may be summarized as follows: When the venous blood flows out from the liver and the arterial from the heart, it is used up in the parts attracting it and thus makes room for more to follow. A very small amount, as he will soon say, passes from the veins into the arteries, which are joined by very fine openings, and the arteries give in exchange a little pneuma to the veins. Only in the portal system of veins did he allow that the blood might return whence it came, and this only at certain times and under special circumstances; see *De nat. fac.*, III, 13 (Kühn, II, *186–204*; Galen [1928, *288–315*], and chapter 19 of Book IV of this work.

The blood coming through the pulmonary artery to the lungs also has in his view two fates, as he will shortly explain. The larger part is used for the nutrition of the lung, which needs a great deal, since it is such a porous, highly active viscus, but some of it is forced by the compression of the thorax in expiration through the minute inosculations into the pulmonary veins. Thus it will be seen that Galen had a very rudimentary conception of a pulmonary circulation; see in this connection Prendergast (1928, *1846–1847*).

One peculiar feature of Galen's theory, on the other hand, and one which perhaps may account for the erroneous idea of the tidal motion of the blood, should not be overlooked. In the passage cited above from *De naturalibus facultatibus* he asserts unequivocally that the residues of the nutrition of the parts travel back through the veins at times until they reach the stomach and intestines, from which they are then excreted. Unless we assume what he never says, namely that this reflux takes place when the veins are temporarily empty of blood, such a notion seems absurd and mechanically impossible, and even if there

accompanying impairment of the usefulness of respiration itself would by no means be a small matter. If it is granted that it is better for a very large amount of air to be attracted in one action when we breathe in, and expelled when we breathe out, that this cannot happen unless the arteries dilate and contract as much as possible, and that the veins impair and reduce the size of the arteries' motion to the same extent that they act in concert with them, then it is clear

---

were such occasions, to think that the residues actually flow back through the vascular network of the liver is quite unworthy of Galen's usual clear-sightedness. As Hall (1960, *399*) says, "His double motion of fluid in the veins may well be hydrodynamically absurd. . . . Mechanistic ideas of fluid flow have little place in Galen's physiology." But I think that for three reasons this feature of his physiology need not be taken very seriously. In the first place, in the passage where he expounds it he is concerned only to show that during long fasts the stomach and intestines are able to attract nutriment from the liver back through the portal system. That is to say, here he is once more acting as a special pleader, seeking not too scrupulously whatever he can find to bolster his argument. If he could have been pinned down in debate, I doubt very much that he still would have insisted that residues really thread their way back through the labyrinth of the liver. In the second place, this reflux is supposed to take place only under abnormal conditions, either in disease or in purgation. And finally, I am the more convinced that this far-fetched idea formed no very vital part of his theory because when he discusses the problem of these residues elsewhere, it is never mentioned, and evacuation is said to be accomplished by other means. See, for example, chapter 1 of Book IX and chapter 14 of Book XVI of this work. In the first of these passages it is claimed that the vaporous, fuliginous residues from all the bodily parts (the heart, lungs, and alimentary canal excepted, since, I suppose, they have their own arrangements) need no special pathways for their evacuation, but rise to the head and escape through the sutures of the skull; in the second he says that the material "flowing away" from the parts is quickly resolved into vapor by heat and quickly destroyed and exhaled. No mention here of a laborious return through the liver. And, at any rate, in all this there is no suggestion that it is the blood which returns through the veins, save in the portal system, but only undesirable residues.

Hence it seems unnecessary to postulate from the behavior of the residues an ebb and flow in the motion of the blood, to which Galen attributed under normal conditions rather a motion in one direction only, from the source to the parts needing to be nourished. For full analyses of this problem from different points of view, see Meyerhof (1935); Fleming (1955, 1955a); Wilson (1959, 1962); Hall (1960); Siegel (1962; 1968, *29, 40, 87–104*).

how great an injury will be inflicted on respiration as a whole if the instruments of nutrition [44] expand and contract. For they must remain completely at rest, as if they were not there at all and were not cutting down in the least the space in the thorax in which the instruments of the pneuma expand and contract. Indeed, it is an [I, 332] advantage if this whole space is left free for these instruments alone, in order that they may expand as much as possible in inspiration and attract a very large amount of the outer air, and also that in expiration they may contract again as much as possible and expel it. Moreover, a third serious inconvenience would result from the backward flow of the blood in expiration [which would occur] if our Creator had not devised the outgrowth of membranes. What this outgrowth is and how it prevents the blood from flowing back, you shall hear clearly described a little later on. Now, however, you should attend while I tell what harm it would do to the animal if the membranes had not been formed. Here, too, I shall take what I have demonstrated in other works of mine [45] as a basis for the discussion.

All over the body the arteries and veins communicate with one another by common openings and exchange blood and pneuma through certain invisible and extremely narrow passages. But if the large orifice of the arterial vein [*a. pulmonalis*) always lay uniformly open and if Nature had not found some device that could close and open it again at the proper times, the blood would never be taken over into the arteries through the little, invisible orifices when the thorax contracts. For attraction and expulsion are not naturally the same for every material and every place; on the contrary, just as a light substance is attracted more easily by expanding instruments than a heavier one and also expelled more easily when they contract, so also attraction and expulsion too are accomplished through a broad passage more readily than through a narrow one. When the thorax contracts, the venous arteries [*vv. pulmonales*], pushed in- [I, 333] ward and compressed from all sides, instantly force out the pneuma they contain and receive in exchange a portion of blood through those fine openings, an exchange that would never take place if the

[44] That is, the "veins"—the pulmonary artery and its branches; Galen has a convenient blind spot here, when he neglects the obvious pulsation of this artery. The pulmonary veins, in his view, are collapsed by the pressure of the thorax and expand when it expands.

[45] *De nat. fac.*, III, 14–15 (Kühn, II, *204–209;* Galen [1928, *314–323*]).

blood were able to run back through a very large opening, such as that of the vein [*a. pulmonalis*], into the heart. As it is, however, when the blood is compressed and cut off from returning through the large orifice, some of it trickles through those fine openings into the arteries. Perhaps it is already clear to you what an excellent thing this is for the lung, if you remember what I have said about its nourishment, but in case you do not, I shall explain it after I have finished the whole subject now before us.

11. Now that I have demonstrated the very great usefulness of these membranes and the even greater usefulness of making the vein that nourishes the lung itself [*a. pulmonalis*] exceedingly thick and hard, I must show next that it was impossible to derive either an arterial vessel or such membranes from the vena cava. It is perfectly evident to everyone that an arterial vessel cannot possible be derived from a venous one; for a vein has one tunic, and that a thin one, whereas the tunic of an artery is neither single nor so thin. It has, in
[I, 334] fact, two tunics. The inner one is exceedingly thick, dense, and hard, and is divisible into transverse fibers; the outer one is soft, fine, and loose-textured, like that of a vein.[46] Hence it was impossible to derive a thick, double tunic from a thin, simple one like that of the vena cava. And indeed, although the heart itself is thick, arterial and venous vessels do not issue from every part of it [indiscriminately]; on the contrary, soft, thin vessels with single tunics are derived from the softer, finer parts, and thick, hard vessels with double tunics from the denser ones.

Neither was it possible to produce in any part other than the heart[47] membranes of the size and character of those actually located at the orifice of the arterial vein [semilunar valves at the orifice of the pulmonary artery]. For they had to have a firm foundation on which to take origin and be established, in order that by remaining erect and unbending they may oppose the backward flow of materials when the strong action of the thorax surrounding the lung on all sides presses it together and contracts it, and likewise squeezes and compresses the veins. In fact, even though the tunic of the veins is as thick as possible and resists movement, it is nevertheless not so

[46] This description makes it evident that Galen overlooked the tunica intima. His "inner tunic" with its transverse fibers is the tunica media, and his soft, fine, loose-textured "outer tunic" is the tunica adventitia.

[47] Literally, "to produce without the heart, membranes," etc.

completely immovable as to be entirely unaffected by the action of so many large, strong muscles and so many hard bones containing no marrow. When all these muscles and bones act in a more vigorous constriction of the whole thorax and exert pressure on the lung, the veins are necessarily squeezed and compressed to some extent, but [I, 335] without being emptied by the backward flow of their contents through the orifice, because this has already been closed by the membranes; for the more vigorously the thorax presses inward, squeezing out the blood, the more tightly the membranes shut up the orifice.[48]

They lie facing from within outward, surrounding the whole circumference of the orifice, and each has such an accurate shape and size that when they are all tensed and stand erect, they become a single, large membrane obstructing the whole orifice. When they are turned back by a flow from within to the outside and fall outward against the tunic of the vein itself, they permit a free passage by opening wide the orifice to its greatest extent. If, however, there is a flow from the outside inward, this very flow pushes the membranes together, so that they overlap one another and make of themselves a gate, as it were, accurately closed. In fact, upon all the orifices of the vessels issuing from the heart membranes have grown, overlapping one another and so accurately placed that if they are tensed and stand erect, they entirely close off the orifices. They all have a common usefulness, to prevent the reflux of material, and each kind has its own special use; in vessels conducting material away from the heart they act to keep it from returning, and [I, 336] in those conducting material to the heart they serve to prevent its escape. For Nature certainly did not wish to tire the heart with useless labor by causing it sometimes to send material out to some part from which it should rather be attracted, and frequently to attract material from a part to which it should be sent. Now there are four orifices in all, two for each ventricle, one of which is an entrance [atrioventricular openings] and the other an exit [pulmonary and aortic openings]. I shall speak of them a little later

[48] It will have been noted that throughout this discussion of the closing of the semilunar valves at the orifice of the pulmonary artery Galen has assigned only the pressure of the thorax in expiration as the cause, neglecting the diastole of the right ventricle. He takes account of this later on, however. See chapter 15 of this Book, *ad fin.*

and explain everything else about them [49] and about the membranes growing upon them, how many there are and what their shape is; I shall explain too that it was better to have neither more nor fewer membranes and to have them neither larger nor smaller, neither thicker nor thinner, and neither stronger nor weaker than they are. Thus far I have said only that these membranes have an indispensable usefulness and that they must take their rise not from the vena cava but from the heart itself, as they do.

And indeed, if you sum up all the main points of my discussion, what I have been saying now together with what precedes, you will see that I have demonstrated what I proposed at the beginning. The lung would not be nourished better by any other vein, and no branch with such tunics and membranes could be derived from the vena cava. From all this it is clear that it is much better for the lung to take its nutriment from the heart. Now certainly, if one vessel
[I, 337] with a simple tunic is inserted into the heart and another with a double tunic issues from it, there must be a common space, a cistern, so to speak, in which they both terminate, the blood being attracted to it through one of the vessels and expelled from it through the other. This common space is the right ventricle of the heart, formed for the sake of the lung, as my discussion has proved. It is for this reason that animals without a lung do not have a two-chambered heart and that in them there is instead only the one ventricle which governs the motion of all the arteries. For the veins arise from the liver,[50] as I have also demonstrated in several places in my book *On the Teachings of Hippocrates and Plato*,[51] and all the arguments are consistent and bear witness to the truth. I have now brought to a fitting close my discussion of the right ventricle of the heart, the presence or absence of which in all kinds of animals depends on the presence or absence of the lung.

12. If anyone cares to learn the reason why the physicians and philosophers who have spoken incorrectly about the number of chambers in the heart were so ignorant, he will find all such matters

[49] Reading τὰ κατ' αὐτά with Helmreich for the κατ' αὐτὸ of Kühn's text.

[50] Omitting with Helmreich the οὐ τω καὶ ἀρτηρίαι ἐκ τῆς καρδίας of Kühn's text.

[51] *De plac. Hipp. et Plat.*, I, 7, VI, 3, VIII, 1 (Kühn, V, *199, 522, 531* ff., *657* ff.).

treated elsewhere, in my book *On All Disagreement in Dissection.*[83] For just as demonstrations of actions are prior to the treatise I am now engaged in, so in the same way, demonstrations of disagreement in dissection and manuals of dissection are prior to demonstrations of [I, 338] actions. Hence in this treatise it is unnecessary to mention the controversy over the number of tunics of the arteries and veins or over any of the other things I have already discussed or shall in the future discuss. I have demonstrated all these matters separately in order that this present dissertation of mine may keep within its own limits and avoid touching on other questions. In the whole extent of it I am using the conclusions reached in those other works as the bases for my discussions and explaining in detail only the usefulness of each part, without refuting here except in passing the absurdity of what others have said incorrectly—unless, of course, treating of such things should be absolutely necessary to many of my teachings or of general interest. Thus I have indeed decided to mention at this point the errors Asclepiades has made in speaking of the vessels of the lung and to show that no one can escape the law of Adrastea,[84] even though he may be a great rogue and clever at speaking, and that on the contrary at some time or other he himself confesses his roguery and becomes a witness to the truth, to be trusted much more confidently than others because he is an involuntary witness.

The first cause of everything that has been formed is the purpose of its action, as Plato has pointed out somewhere.[85] If, then, anyone asks you why you have come to market, it is hardly admissible to pass over the real reason and give another more elegant. For it would be ridiculous if a man instead of saying that he had come to buy [I, 339] some article or a slave, or to meet a friend, or to sell something, should pass over all that and say that he had come to market because he had two feet capable of moving easily and supporting him in safety on the ground.[86] He has, perhaps, given one cause, but not the real, first one; on the contrary, his is an instrumental cause, one

[83] A lost work, also referred to by Galen in *De anat. admin.*, I, 4; VII, 11 (Kühn, II, *236*, *625*; Galen [1956, *9*, *189*]), and in *De ordine librorum suorum* (Kühn, XIX, *55*); see also Kühn, I, *cxciii*.

[84] Adrastea is Nemesis, goddess of retributive justice.

[85] *Phaedo*, 97–100 (Plato [1920, I, *482–484*]).

[86] Omitting τούτοις ἐναλλὰξ ἑκατέρῳ τῶν εἰρημένων τοδῶν, bracketed by Helmreich.

without which [an action cannot be performed], or rather, one that is not [really] a cause. Thus Plato rightly understood the nature of cause. But in order to avoid seeming to quibble over names,[56] I grant that there are several kinds of causes: first and most important, that for the sake of which a thing is formed; second, that by which; third, that from which; fourth, that by means of which; and fifth, if you wish, that in accordance with which.[57] We shall expect those who are really natural philosophers to take each one of these causes into account when dealing with all the parts of the body. Now, as for me, when anyone asks me for what purpose the vessels of the lung have exchanged natures, that is to say, why the vein has been made arterial and the artery venous, I shall give the true, first cause, namely, that it was better in this viscus alone for the vein to be dense and the artery loose-textured. Erasistratus, however, gives a different answer, saying that the vein [*a. pulmonalis*] arises where the arteries
[I, 340] distributed to the whole body have their origin and is inserted into the blood's ventricle [the right ventricle] of the heart; and the artery [*v. pulmonalis*] in turn arises where the veins begin and is inserted into the ventricle of the pneuma [the left ventricle].[58]

[56] See note 33 of Book IV.

[57] (1) Final; (2) Efficient; (3) Material; (4) Instrumental; (5) Formal. Four of these are, of course, the four causes of Aristotle, for which see *Physica*, II, 3, 194b16–195a3, and *Metaphysica*, A, 3, 983a25 ff. See also Daremberg's admirable note (in Galen [1854, I, *420–422*]) on this passage. Observe that Galen is indifferent about the inclusion of his fifth or formal cause, perhaps thinking with Aristotle (*Physica*, II, 7, 198a14–198b9) that it coincides very frequently with the first or final cause. Note also that he includes the instrument in his list, though he has already indicated that he thinks very little of it as a cause.

[58] In this passage Erasistratus appears to be saying that both veins and arteries arise from the lungs. The "veins," carrying blood and uniting to form one vessel (the pulmonary artery in our terms), arrive at the right ventricle of the heart, which then sends the blood out all over the body by way of the vena cava and its branches. Similarly, the "arteries," carrying air taken over from the branches of the trachea, arrive at the left ventricle, from which the air is then distributed to the whole body by way of the aorta and its branches. See Daremberg's excellent note (in Galen [1854, I, *422–423*]) on this passage. Elsewhere (*De plac. Hipp. et Plat.*, VI, 6 [Kühn, V, *547–560*]) Galen reports Erasistratus as having thought that the heart is the source of both veins and arteries and that the blood, already prepared in the liver, is conveyed thence to the heart, where it is perfected before being sent out to all parts of the body.

13. Asclepiades passes by two causes, that derived from the providence of the Creator, which I have called the first cause, and the second, called the material cause,[59] so to speak, and arrives at a sort of cause which is the most insignificant of all and which I believe anybody versed in the philosophical method would call not a real cause, but one that is contingent or consequential, exactly like a counterfeit drachma. He thinks that he is persuasive and clever, being unmindful, I suppose, of the law of Adrastea, because no other reasoning refutes so well the absurd things he teaches as that very argument which he thinks he has cleverly discovered.

"Now of all the instruments," he says, "the lung is the only one in which the arteries [*vv. pulmonales*] have two motions, one of which is proper to them and derived from their own substance, that is, the pulse; the other they acquire from the act of respiration, since the lung is always in motion. For this reason the arteries of the lung labor excessively and grow very thin, whereas in the other parts of the body they move moderately with only their one proper motion and thus become well nourished and strong. The veins throughout the body, on the other hand," he continues, "remain without motion and so logically waste away like a lazy slave that takes no exercise, but those in the lung [*aa. pulmonales*] acquire the motion of this viscus and so grow strong like persons who exercise moderately." [I, 341]

But oh, Asclepiades, wisest of men, to refute the other fallacies in your reasoning is a work requiring too much time. These errors, which no child would fail to recognize, not to mention a man so full of his own importance, are of two kinds. One stems from a disregard of dissection, the other from ignorance of logical speculation. For if you were experienced in anatomy, perhaps you would realize that an artery differs from a vein not only in the thickness but also in the number and quality of its tunics. The thick, hard, inner tunic which has transverse fibers is not found at all in veins.[60] But you, quite untroubled by its presence or absence, have the effrontery to proclaim as if you knew them well matters of which you know nothing clearly, you who spit upon the dissections of Herophilus, condemn those of Erasistratus, and give little heed to Hippocrates. Are you actually ignorant of the fact that the veins [61] of the lung do not have

[59] But the material cause is number three in Galen's list given above.

[60] See note 46 of this Book.

[61] Here Galen really means the pulmonary veins.

the hard inner tunic? Or, knowing this, do you think that when a part becomes thin it is not the thickness of its tunics but the number of them that is diminished? If so, the stomach will have only one tunic in very thin people and four in persons that are in excellent condition! Similarly too, persons with phthisis will perchance have three tunics of the eye (for the eyes are greatly wasted in such
[I, 342] cases); victims of other diseases will have four, we who are healthy will have five, those of us who are in excellent condition maybe six, athletes seven, and Milon, Polydamas, and their fellows even more! [62] It would be a fine thing if we had more fingers on our hands in good health and fewer when we were ill! So too, it would be a sight worthy of the wisdom of Asclepiades to see Thersites with perhaps three fingers, Ajax with seven, Achilles with still more, and Orion and Talos with more fingers, I suppose, than an *iulus* has feet! [63] Oh, most noble Asclepiades, a man using unsound bases for his teachings cannot escape making himself ridiculous at every turn. There is an Intelligence ordering and arranging all these things, not merely corpuscles combining with one another automatically. Hence the arteries of the lung are venous and the veins arterial because it is better so; the heart has two chambers in animals having a lung and only one in animals without because this too is better. There are membranes at each of the orifices in order that the heart may not labor in vain, and the lung has a fifth lobe in order to support the vena cava, and so with all the other parts. The clever Asclepiades does not tell the reason why any of these arrangements was made, because he does not know it; he gives a reason, however, in one single case [the pulmonary vessels], having, as he supposes, discovered a convincing argument. I grant, [sir], that you have spoken

[62] Milon of Croton, the most famous athlete of antiquity, lived in the sixth century B.C. and had a very large number of victories in the Olympic and Pythian games to his credit. Polydamas of Skotussa in Thessaly, who was another famous athlete, won his victories late in the fifth century B.C.

[63] Thersites was a boor and trouble-maker with the Greeks before Troy. Orion, the might hunter beloved of Artemis, was by a tragic error slain by her hand and was placed by her among the stars. Talos was the man of brass made by Hephaestus and given by Zeus to Minos to guard Crete. For the details of the stories of all these persons mentioned in this and the preceding note, see Pauly-Wissowa, *Real-Encyclopädie der classischen Altertumswissenschaft.*

nobly on the vessels of the lung; attempt, please, to say something about the other parts of the body as well. [I, 343]

Now in discussing every part I tell not one kind of cause alone, but all of them, the first and most important one, that it is better so, and following that, the causes derived from instruments and material used by the Creator to confer the better form[64] on everything he brings into being, making the arteries of the lung loose-textured and the veins dense for the reason I have given. Since it was better to have done so, he derived the veins [of the lung] from the arterial parts of the heart and the arteries from the venous parts. Since it was necessary to provide suitable material for both vessels, he opened the arteries into the ventricle[65] of the pneuma and the veins into the other one. Since it was better to confer on the vessels a shape less easily injured, he made them round. Since they had to be made of some material and by means of instruments, he made a certain plastic juice like wax by mingling the moist with the dry and used this material as the basis for the future vessels. Combining the hot and the cold, he prepared them as efficient instruments for the material and by means of them he dried out one part of it with the heat, stiffened another part with the cold, and by mixing these parts produced a well-tempered pneuma; then, breathing through the material and inflating it in this way, he made a long, hollow vessel [I, 344] and poured out more of the material when it was better for the vessel to be thick and less when it was to be thin.[66] In this account you will find all the causes, those derived from the end, the maker, the instruments, the material, and the form.

Even if you [Asclepiades] wish to neglect the most important causes, that for the sake of which and that by which a thing is formed, you might at least tell what the others are in the case of each part. But you do not do so, and indeed I do not think it possible to discover plausible arguments for every particular if the bases of one's reasoning are unsound. This is that same error which, as I hinted before, arises from an ignorance of logical speculation. It would have been better in every case to omit the cause of the formation of the

[64] Reading *βέλτιον* with Helmreich for the *βέλτιστον* of Kühn's text.

[65] Omitting with Helmreich the *ἀριστερὰν* which follows *κοιλίαν* in Kühn's text.

[66] Strongly reminiscent of Plato's explanations in *Timaeus*, but not borrowed from him. Plato did not distinguish veins from arteries.

part, in order that you may be supposed to have kept silence purposely. Persons who undertake to speak of the arteries and veins of the lung and give not the divine kind of cause, as Plato calls it, but [only] the necessary cause,[67] while they omit all the others, have attained such a degree of stupidity as not to realize that when they explain a part in terms of one or two causes, their silence on the others becomes suspicious. For they do not venture to explain that the heart must be placed as it is, or that in some animals it must have two chambers and in others only one, or that animals having no lung must lack the right ventricle, or any of the other problems, but
[I, 345] when they have invented some plausible nonsense [to explain a situation], they waste our time with it. If Asclepiades had not descended into such depths of idiocy that he not only has laid himself open to the grave suspicion that he would have difficulty in dealing with all the other causes because he seems to have clear knowledge of only one, but has also been further convicted of not knowing what is to be seen in dissection, I would not have lost time in attempting to refute him but would have pressed toward the goal I have set myself, just as I have done from the beginning, and would have left all his mistakes uncorrected.

Now, however, since certain adherents of this school of thought are bragging of what should rather shame them, I have thought it necessary to refute their reasoning in order to keep more people from being deceived. My refutation, as I have said before, is twofold, one part stemming from anatomy, the other from logical consequence. The clever Asclepiades is obviously ignorant of both these arts, since he does not know either that arteries differ from veins not only in thickness but also in the number of their tunics, in hardness, and in the position of their fibers, or that when he talks freely of certain things he is thereby convicted of having nothing to say about others. In order to refute him conclusively, let us tell him once more a little of what is to be seen in dissection.

[67] "Wherefore we may distinguish two sorts of causes, the one divine and the other necessary, and may seek for the divine in all things, as far as our nature admits, with a view to the blessed life; but the necessary kind only for the sake of the divine, considering that without them and when isolated from them, these higher things for which we look cannot be apprehended or received or in any way shared by us" (Plato, *Timaeus*, 68–69; translation by Jowett [1920, II, 47]).

He himself agrees that no embryo breathes. But I say, even if he does not, that if you take any newborn animal or one still carried in the uterus and dissect it, the arteries of the lung are found to be [I, 346] venous and the veins arterial. Now surely these things[68] are not consistent with one another. For how could anyone still say that because of the motion of respiration the arteries were laboring excessively or the veins were moderately exercised when in the embryo even before respiration begins they are obviously such [as they are later on]? But I shall speak a little later of the marvelous things to be seen at the whole base of the heart in the embryo. Asclepiades knew nothing about them, and if he had known, he would have been unable to discover their causes because he referred the first principle of everything that is formed to atoms and a void. In this present discussion—for I have determined to make sport of him and show that I am not unaware of how much or what sort of experience in anatomy and knowledge of consequents and contradictions the man has—I shall again call the thorax and heart to his attention. Now because of its distance from the lung perhaps he has forgotten the encephalon, in which the veins are not arterial nor the arteries venous, although it is constantly in motion. At any rate, the whole thorax moves and according to Asclepiades himself certainly moves much more vigorously than the lung, if indeed the latter is moved to and fro by the passage of the air, like a funnel,[69] and the thorax has not only this motion but also a very great expansion and contraction. The veins of the thorax, however, are not arterial nor its arteries venous. And yet I suppose that the former, which are set [I, 347] in moderate motion, must grow thick, while the latter, which labor excessively, must grow thin! What should I say in addition about the heart itself, which is the part that moves most vigorously of all and which nevertheless has arteries and veins [the coronary vessels] like those in all the rest of the body, just as the entire thorax and encephalon do, as I have said? All the [other] parts, then, those that work very hard or only moderately, and those that are entirely at rest, have the same sort of veins and arteries, because it is better so;

[68] That is, Asclepiades' theory and the condition of the pulmonary vessels in the fetus.

[69] A strange comparison, but apparently inescapable; the two emendations suggested in two of the manuscripts are unacceptable. One expects a comparison with bellows, but this is paleographically impossible.

only in the lung (and this, too, because it is better) is the form of the tunics of the veins and arteries interchanged. Thus our Creator in every case has only one object in mind when he molds the parts, namely, to choose that which is more excellent. This is what I have to say about Asclepiades and it is perhaps more than was necessary.

14. Let us now speak of what logically follows my earlier discussion and has been put off [in order to refute Asclepiades]. There are four openings in the heart [the two atrioventricular openings and the mouths of the aorta and pulmonary artery], and three membranes are found at each with the single exception of that for the venous artery, where there are two [*valvula bicuspidalis* or *mitralis*]. All the membranes grow out from the openings themselves, but from that origin some [*valvulae, bicuspidalis* and *tricuspidalis*] project inward into the ventricles of the heart in such a way that they are also attached to them with strong ligaments [*musculi papillares, columnae carneae,* and *chordae tendineae*], and the others [aortic and pulmonary valves] turn outward at the points where the vessels first emerge from the heart. At [the opening of] the arterial vein [*a. pulmonalis*], which I have said nourishes the lung, there are three membranes [pulmonary semilunar valves], which are inclined from
[I, 348] within outward and which from their shape are called sigmoid [70] by those practicing dissection. At [the opening of] the vein that introduces the blood [right atrioventricular opening] there are also three [*valvula tricuspidalis*], but these are inclined from the outside inward and are much thicker, stronger, and larger than the preceding membranes. There is no third opening in the right ventricle, since the vein nourishing the lower parts of the thorax [*v. azygos*] and the vein that crowns the heart [*sinus coronarius* and *vv. cordis magna* and *parva*] (for that is what it is called) make their exits beyond the membranes. In the other ventricle of the heart there is one opening which is the largest of all, that of the great artery, from which all the arteries of the body arise. This opening also has three sigmoid [semilunar] membranous outgrowths directed from within outward [aortic semilunar valves]. There is one other opening [left atrioventricular], that of the venous artery [*v. pulmonalis*], which ramifies in the lungs; this has two membranous outgrowths [*valvula bicuspidalis* or *mitralis*] directed from the outside inward, and no anatomist

[70] See note 53 of Book II.

has attempted to compare their shape to any known object,[71] as in the case of the sigmoid [semilunar] membranes. Those who call the latter tricuspid have taken the name not from their individual shapes but from their mutual arrangement; for when they are in contact, they look exactly like the barbs of darts. Now we can properly give this name to the three membranes situated at the opening of the vena cava [*valvula tricuspidalis*], but no one would be right in calling those at the opening of the venous artery tricuspid, since there are only two of them. I shall tell a little later why this is the only opening with two membranes; for Nature has shown no negligence here. [I, 349]

I shall now try to show that there was good reason why the membranes at the vessels introducing material into the heart should be large and strong and those at the vessels discharging it should be weaker, and I shall tell too about the other devices Nature has prepared to attract and expel material. It is hard clearly to express such things even when the parts can be inspected, and almost impossible without inspection, but I must nevertheless attempt to explain them as clearly as possible. The ends of all the membranes directed from the outside inward, which I have said are large and strong, are fastened to the heart itself, being held by stout ligaments [*musculi papillares*, *columnae carneae*, and *chordae tendineae*]. When the heart dilates, these ligaments are tensed by its expansion and draw the membranes in their direction, reflecting them, so to speak, toward the body of the heart itself. When all three membranes are reflected upon the heart in a circle, the mouths of the vessels are thrown open and the heart easily draws in through the broad passageway the material contained in them. In this operation it attracts both the contents and the vessel itself, tensing and drawing it forward through the membranes. Indeed, when the membranes are attracted by the heart, the vessel continuous with them cannot remain insensible of the attraction. Thus by the single action which the heart performs in dilating, the membranes, pulled by the ligaments, bend into the ventricle of the heart itself, and when they are folded back in a circle, the orifice is open; at the same time the vessels are pulled by the membranes toward the heart and the [I, 350]

[71] Needless to say, the comparison with the bishop's miter came much later. See Hyrtl (1880, *328–331*).

material in the vessels streams freely into the ventricle itself, since there is no longer anything to prevent and since all the causes that produce the swiftest transference of material are acting together. For anything that is moved must be either pulled, or propelled, or conducted by something. All these conditions are met for the material [in the vessels] when the heart dilates. For the heart itself attracts, the cavities of the auricles lying before the heart propel, and the vessels conduct it. And for the movement of all these parts there is a single source, the dilation of the heart itself.

15. The auricles, which are sinewy, hollow outgrowths placed before the openings, are relaxed to begin with and therefore hollow, but when the heart dilates, they are tensed like the membranes and contracted, and they therefore compress the material and propel it into the heart. Because the mouths of the vessels adjacent to the auricles are drawn powerfully inward by the heart, they carry with them the material propelled by the auricles. The heart itself, having all imaginable attractive faculties, snatches and, as it were, drinks up the inflowing material, receiving it rapidly in the hollows of its chambers. For [think if you will] of a smith's bellows drawing in the air when they expand, [and you will find] that this action is above all characteristic of the heart; or if you think of the flame of a
[I, 351] lamp drawing up the oil, then the heart does not lack this faculty either, being, as it is, the source of the innate heat; or if you think of the Heraclean stone [72] attracting iron by the affinity of its quality, then what would have a stronger affinity for the heart than air for its refrigeration? Or what would be more useful than blood to nourish it?

It seems to me that when the heart exerts its full powers of attraction, it would actually tear a vessel to pieces if our Creator had not in this instance too contrived a protection against such an accident by placing outside each opening that admits material another separate cavity like a storehouse for nutriment, so that the vessel may not be in danger of rupturing when at times the heart attracts suddenly and violently and the vessel alone, because it is so narrow, cannot furnish abundantly all that the heart demands. For just as anyone would break a vessel if he used too much force when he exhausted it by sucking all the air out through the opening with

[72] The loadstone was so called from Heraclea in Lydia.

his mouth, so in the same way, I believe, when the heart needs to fill all at once a cavity many times broader than that of either of the vessels, it would rupture them and tear them to pieces by the violence of its attraction if another, exterior cavity, such as we have in each of the two auricles, had not been placed before it. Thus the auricles of the heart were not formed in vain, though no good sense was used in naming them;[73] for they seem to have no inconsiderable usefulness for animals. Indeed, if it is a very great thing to ensure that the artery ramifying in the lung [*vv. pulmonales*] and the vena cava suffer no injury, then the usefulness of the auricles for animals [I, 352] is also very great.

For the rest, both these vessels have thin tunics, the one because it is obviously a vein, and the other because it is better, as I have shown, for the artery of the lung to be venous. But a vessel that is thin and soft is both better suited to contract readily and also more easily ruptured when it is tensed. Hence both vessels furnishing material to the heart would be easily ruptured, since they have thin, soft tunics and are attracted violently by the heart's dilation, if Nature had not contrived for them some protection such as they actually have, namely, the cavities of the two auricles. When these had been provided, the tunics of the vessels were freed from any danger of injury and in addition tunics and auricles worked together to fill the heart quickly. For it is reasonable that the difference between the speeds with which hard and soft tunics contract is the measure of the difference between the speeds with which the heart would be filled by two such tunics. If the tunics, however, stood alone without the adjacent cavities, they would not suffice to fill the heart, and when they were tensed in the effort, they would be easily ruptured by the heart. But with the cavities to help them, they succeed in filling the heart before they are excessively tensed, and thus they have obtained no little aid in avoiding injury to their soft substance.[74] You have here the demonstration of another reason why

[73] τὰ ὦτα, the ears; cf. *De anat. admin.*, VII, 9 (Kühn, II, *615–616;* Galen [1956, *184–185*]).

[74] Daremberg (in Galen [1854, I, *436*]) translates, "Mais avec le secours de ces cavités, elles ont rapidement rempli le coeur avant d'être tendues excessivement, trouvant dans leur substance lâche une protection efficace contre les lésions." The Greek seems capable of either interpretation, but I cannot think that Galen would say that the softness of a substance would protect it from injury.

the artery of the lung must be venous;[75] for the same reason, I believe, the auricles have been made thin and at the same time
[I, 353] sinewy. In fact, their softness is of the greatest assistance in contracting easily and the strength of their substance in avoiding injury, since a sinewy substance is very strong. The auricles have been named not for any usefulness or action, but on account of a slight resemblance, because they lie on either side of the heart just as the ears of an animal lie on either side of its head.

It was better for the membranes attached to the vessels introducing material to be as much stronger and larger than those attached to the vessels by which it is expelled as the strength of the motion of dilation exceeds that of contraction; for when the heart dilates, it must necessarily attract more forcibly than it expels when it contracts. Indeed, the formation of three membranes at each orifice to open and then close it accurately and quickly was a marvelous provision of Nature. For if there were only two membranes, their large sinuses would not allow the orifices to open or close either accurately or quickly. If there were more than three, both these actions would be performed much more quickly and exactly because the sinuses would be so small, but, also because of this small size, the actions would necessarily be weak and easily disrupted. Hence for the orifices to open and close quickly and at the same time strongly and accurately, three membranes had to be formed at each of them, since no other number could offer all these advantages at once: less
[I, 354] than three would make the action less accurate and slower, and more than three would make it weaker.

There was good reason, then, why two outgrowths of membranes were formed at only one orifice, that of the venous artery. For it was better for this one opening not to be accurately closed, because it was better that this one alone should give access to the lung for the fuliginous residues from the heart which necessarily accumulate there on account of the abundance of the innate heat and which have no other, shorter outlet. From this it is clear that I was right in saying that the membranes were constructed to serve as lids for the openings and at the same time as instruments of attraction. For because the tunics of the vessels have been tensed by the heart by means of the membranes, as I have said before, they contract more

[75] The first reason was the special arrangements necessary for the nutrition of the lung.

readily and propel more easily when the heart is attracting material. Again, this same tension attracts from their bases the membranes directed from within outward [aortic and pulmonary valves], bends them inward toward the heart itself, sets them all erect, and thus closes the orifices of the vessels. Hence the action of the heart in diastole, which I have already shown to be the cause of many factors contributing to the attraction of material, now also appears as the cause which closes the orifices of the arterial vein [*a. pulmonalis*] and great artery. And all parts of the heart seem to display the height of foresight and skill.

16. Now the substance of the left side [of the heart] is all exceedingly thick and hard, because it was made to be the covering of the pneumatic ventricle,[76] and the substance of the right side is thin and soft, in order that the two substances may be appropriate each to its own material and that at the same time the heart may be evenly balanced; for it was better for the pneuma to be confined in a thicker tunic and for the weight of the blood in the right ventricle to balance the mass of the left. If Nature had filled with blood the same ventricle which she had made thick, the whole heart would certainly be tipped to that side. As it is, however, since the lighter material is surrounded with a thick body mass and the heavier material with a lighter one, the heart becomes evenly balanced on both sides. And so, though no ligament binds it to the adjacent parts, it nevertheless remains always upright and unwavering, suspended in the middle of that strong tunic called the pericardium. [I, 355]

This tunic is exceedingly broad where it arises from the head of the heart, but then, growing gradually narrower, it too ends, as the heart does, in the apex of a cone, where it is attached to the sternum. It is not rightly called a tunic if one is careful about correct nomenclature, but is rather a sort of habitation or safe enclosure thrown about the heart. It lies well removed from the heart on all sides, enclosing as much space between itself and the heart as is sufficient to accommodate the latter when it dilates. To have made this space any larger would have been to encroach on the breadth of the thorax which is devoted to the inward and outward motion of the breath in respiration. There comes to your notice here still another of Nature's marvelous works, this pericardium, a tunic, membrane, [I, 356]

[76] See note 27 of this Book.

habitation, or whatever else you wish to call it; it has the same shape as the very viscus it surrounds and a size such that it neither harms the thorax by taking up more of its breadth than necessary nor cramps the heart by providing insufficient space for its motion. How could one fail to admire the perfection of proportion achieved in the thickness and strength of the tunic? For since it must touch the bones of the thorax, which are hard, of course, and the lung, which is the softest of all the viscera, there was danger that if it had been made harder than it actually is, it would make trouble for the viscus, which it would compress and crush, and that if it were softer, it would itself suffer injury from the bones. Hence, just as it is midway between two extremes as regards its position, so its substance also is the mean between two extremes; for it is as much softer than bone as it is harder than the lung. And for this reason its proximity to both parts causes no pain, since it is not distressed by the bones and does not itself injure the lung.

Well, the pericardium is certainly marvelous, but the skill displayed in the openings of the heart is as much more so as their
[I, 357] actions are the more important. Indeed, nearly all the work of the heart is accomplished by means of them. So let us turn back again and speak of them once more, elucidating whatever was obscure in my earlier treatment and adding whatever was not fully explained. I have already said and demonstrated that the heart, by attracting the roots of the membranes when it dilates, opens the orifices of the vessels admitting material and closes those of the vessels that expel it. I have also said that lighter materials yield more readily to every[77] attracting force and that three membranes are situated at each orifice with the exception of that for the venous artery [*v. pulmonalis*] because this is the only one which must allow the fuliginous residues to pass through when they are conveyed from the heart to the lung. Perhaps one might surmise from this that nothing at all passes back at the other three orifices of vessels, but it is not true. For while the membranes are closing, blood and pneuma are necessarily already being attracted into the heart [from the aorta and pulmonary artery], and before the membranes have closed in the contraction [of the heart], blood and pneuma must in turn be discharged [into the

[77] Reading ἅπασι with Helmreich for the ἅπαντα of Kühn's text; the Latin version of the latter, however, reads as if he had translated ἅπασι rather than ἅπαντα.

vena cava and pulmonary vein] while they are closing. But even when the membranes have already closed, it is sometimes possible during more violent movements of the heart for some air and pneuma and even some blood to slip past. Just as I have shown [78] in speaking of the rough artery [the trachea] that a little of the liquid we swallow cannot but filter through, so the same conditions must be considered to prevail here and we should think that Nature found means to prevent a large quantity of blood and pneuma from flowing past, but was unable to find anything to stop the flow altogether of the smallest possible quantity. For I have shown in other works of mine that "All is in all," as Hippocrates [79] used to say, and that the arteries have their share of thin, pure, spirituous blood, and veins contain a little mistlike air.[80] So, too, I have shown that when we swallow and breathe in, air penetrates by way of the esophagus into the stomach,[81] that in general none of the parts of the body is absolutely pure, and that everything shares in everything else, though not equally, of course, but in such a way that some parts are [primarily] instruments of the blood or other nutriment, and others are instruments of the pneuma. In the same way, when the thorax is opened, both ventricles of the heart are observed to pulsate, but they do not both contain blood and pneuma in the same proportion; for in the right ventricle the substance of the blood strongly predominates, and in the left ventricle the pneuma. [I, 358]

17. Nearly everyone agrees that if many important arteries are damaged at the same time, blood flows out of them. Hence even those persons who, like Erasistratus, do not allow the arteries any blood at all, nevertheless agree that the arteries and veins have common openings. Then, though they think that Nature has constructed everything skillfully and has made nothing in vain, they do not realize that they are thus admitting that these inosculations have been made to no purpose. And yet it would be a slight matter if they had simply been made in vain and served no useful purpose for the animal, but it would be more serious and one could no longer consider it an insignificant fault of Nature's if in addition to being of [I, 359]

[78] In *De plac. Hipp. et Plat.*, VIII, 9 (Kühn, V, *713–719*). See also chapter 17 of Book VII of this work.

[79] *De locis in homine*, cap. 1 (Littré, VI, *278, 279*).

[80] *De nat. fac.*, III, 14 (Kühn, II, *204–206;* Galen [1928, *314–319*]).

[81] *De nat. fac.*, III, 8 (Kühn, II, *176;* Galen [1928, *272–275*]).

no use they also did very great harm, and by logical consequence this is what these persons believe.

Erasistratus himself teaches us carefully that no inflammation can arise unless blood finds its way from the veins into the arteries. Certainly, however, if inflammation could arise in no other way and these inosculations were removed, animals would never be afflicted with pleurisy, phrenitis, or peripneumonia; moreover, if there were no inosculations, there would be no ophthalmia, no inflammation of the throat or larnyx,[82] and of course no inflammation of the liver, stomach, spleen, or any other part. And what conclusion can we reach other than that most of the most serious diseases would not occur without the inosculations, which a provident Nature has made to furnish nothing useful to the animal and to be the instruments giving rise to deadly diseases! If there were no inosculations, no inflammation would occur in wounds, no one would be feverish with plethora, or suffer from inflammation of the liver, stomach, heart, or any other part, the impairment of which causes swift death to mankind.

[I, 360] Since I have already shown, not once or twice but several times and in many places,[83] how flatly the assumptions of Erasistratus concerning the arteries contradict and are at variance with all the evidence, I consider it superfluous to go over it again. Nature did not construct the inosculations of the arteries with the veins idly and to no purpose; on the contrary, she made them in order to confer the benefit derived from respiration and the pulse not only on the heart and arteries but on the veins as well. I have told in other works of mine[84] how great a benefit this is, and the recognition of it is sufficient for our purpose in this present treatise.

Furthermore, not long ago I mentioned that necessarily all parts

[82] Συνάγχη, here translated "inflammation of the throat," and κυνάγχη, "inflammation of the larynx," are very frequently used synonymously for "sore throat," but Galen makes the distinction clear in his *De locis affectis*, IV, 6 (Kühn, VIII, *248–250*). Cf. *Hippocratis de acutorum morborum victu liber et Galeni commentarii*, IV, 27 (Kühn, XV, *790*), and *Hippocratis aphorismi et Galeni in eos commentarii*, XXXIV (Kühn, XVII, pt. 2, *706*), and see also Holmes (1885, *49–50, 73–74*) and Goldbach (1898, *42–43*).

[83] Particularly in his *An in arteriis natura sanguis contineatur* (Kühn, IV, *703–736*).

[84] *De usu respirationis* (Kühn, IV, *470–511*).

of the body are not nourished with the same nutriment, and this fact shows the reason (χρεία, usefulness) for forming different kinds of vessels. For if only one kind of blood vessel had been formed, all the parts would be nourished with the same sort of nutriment. And certainly it would be most irrational and absurd if the liver and lung, for example, were to make use of the same kind of blood to nourish them, if the heaviest and densest viscus were to be nourished like the lightest and most porous! Hence Nature did well to make not only arteries but also veins in the bodies of animals. And hence too the liver is nourished almost entirely by veins (and those the finest and most loose-textured) and the lung by arteries. For indeed, the veins nourishing the lung resemble arteries, as I [I, 361] have also said a little earlier. Here too, then, we should marvel at the foresight of Nature, who has made two kinds of vessels and joined their adjacent extremities by common openings and, more than this, has joined by common openings the very chambers of the heart, as I have also demonstrated in other works of mine.[85] For it is my intention at present to show not that this is done in the body of an animal, but why it is done; since, however, *that* a thing is, is necessarily prior to *why* it is, as Aristotle[86] too has said, we cannot explain usefulness unless we first recall what the action is.

The pits to be seen in the heart, especially in the partition [*septum ventriculorum*] dividing it, were formed for the sake of the communication of which I have spoken.[87] For, not to mention other

[85] For example, in *De nat. fac.*, III, 15 (Kühn, II, *207–209;* Galen [1928, *320–323*]).

[86] *Analytica posteriora*, II, 1–2, 89b23–90a34; *Metaphysica*, VI, 17, 1041a6–1041b11.

[87] These pits were probably the deep depressions between the columnae carneae. An Arabian physician, Ibn an-Nafis, who lived from 1210 to 1288 (see Bittar [1955]; Siegel [1962]; Wilson [1962]), seems to have been the first to reject Galen's contention that the interventricular septum is pervious. Vesalius too definitely denied it; he writes, "The surface of each ventricle is very uneven and is sown with many pits, so to speak, deeply sunk into its fleshy substance. . . . Though these pits are sometimes conspicuous, none of them, so far as can be perceived by the senses, penetrates through the septum of the ventricles from the right ventricle into the left. I have found no openings—not even most obscure ones—making the septum of the ventricles pervious, even though they are described by professors of dissection, because these men consider it most convincing that blood is taken over from the right

reasons, it was better for the arteries to take over blood already elaborated in the veins in order that the veins may be for the arteries what the stomach is for the veins. Indeed, the idea is not at all untenable that the psychic pneuma is a sort of exhalation of useful blood. I have explained this, too, more in detail in my other writings.[88] For my present purpose it is sufficient merely to tell the reason (χρεία, usefulness) why the arteries need to contain thin, pure blood, namely, that such blood is intended to nourish the psychic pneuma. All these facts, then, are weighty proof that Nature did well to make two kinds of vessels, and besides these there are also the considerations that the arteries, which must be constantly in motion, need strong tunics, that a tunic cannot be strong and thin
[I, 362] at the same time, and that if, on the other hand, it is made thick, many parts of the body cannot be properly nourished. So Nature has managed all these things excellently both throughout the body of the animal and especially in the heart itself by contriving communication between veins and arteries through those small orifices. This is the reason why the vein [the vena cava] inserted into the heart is larger than the one [*a. pulmonalis*] issuing from it, even though the latter receives blood fused by the heat of the heart.[89] Since a considerable quantity of blood is taken over through the central partition and its perforations into the left ventricle, there is good reason why the vein [*a. pulmonalis*] inserted into the lung is smaller than the one [the vena cava] that introduces the blood into the heart. Similarly, the artery [*v. pulmonalis*] conveying air

---

ventricle into the left. Hence . . . I find myself in no little doubt about the office of this part of the heart" (*Utriusque ventriculi superficies perquam inaequalis est, & multis quasi foveis in carneam substantiam penitus impressis obsita. . . . Utcumque interim hae foveae sint conspicuae, nullae tamen, quod sensu comprehendi potest, ex dextro ventriculo in sinistrum per eorundem ventriculorum septum permeant: neque etiam mihi meatus vel obscurissimi occurrunt, quibus ventriculorum septum sit pervium, quamvis illi a dissectionum professoribus enarrentur, quum sanguinem ex dextro ventriculo in sinistrum assumi persuasissimum habent. Unde etiam fit . . . de cordis hac in parte officio, me haud mediocriter ambigere* [1555, 734]).

[88] *De usu respirationis*, cap. 5 (Kühn, IV, *501–502*).

[89] And hence expanded and occupying more space than it did previously.

from the lung to the heart is itself much smaller than the great artery from which all the arteries of the body arise, because the great artery receives in addition some of the blood from the right ventricle and because it must be the source of all the arteries throughout the body of the animal.

Since the substance of the heart is thick and dense and needs thicker nutriment, it is nourished by blood from the vena cava before it enters the heart;[90] for when it arrives there the blood will have to become warm, thin, and spirituous. Now in this connection, although it has seemed unreasonable to some, it will be found to be most logical that the heart prepares nutriment for the lung, but not for itself; for the lung requires thin, spirituous blood, but the heart [I, 363] does not. The heart, being the source of its own movement, must have a strong, thick, dense substance, whereas it was better for the lung to be not heavy and dense, but light and loose-textured, because it is moved by the thorax. Since each viscus uses nutriment similar to itself, it is logical for the heart to require thick blood, and the lung spirituous blood. This is the reason why the heart does not nourish itself and why before the vena cava is inserted into it, a part just large enough to nourish the heart [*sinus coronarius*] branches off to curve around the head [base] of it on the outside and be distributed to all its parts. It is reasonable too that an artery [*aa. coronariae*] should accompany the vein as it curves around and should branch along with it, and that this should be a branch of the great artery just as large as is necessary for cooling the vein I have just described and for preserving the proper temperament of the innate heat in the outer parts of the heart. The whole body of the heart, which is exceedingly thick and dense, could not be sufficiently cooled by the vessel inserted into it which comes from the lung [*v. pulmonalis*]. For, as I have also shown in my book *On the Natural Faculties*,[91] material can penetrate a body itself to a certain small extent, but can go no farther without the help of a broad passageway, and it is for this reason that arteries and veins are all placed at moderate intervals

[90] Galen, not recognizing the atria as parts of the heart, thought of the coronary sinus opening into the right atrium as a branch of the vena cava, and of course in his view the flow was out of the vena cava into the sinus.

[91] *De nat. fac.*, III, 15 (Kühn, II, *209–212;* Galen [1928, *322–327*]).

[I, 364] not only in the heart but also throughout the animal, an arrangement which Nature would not have made if it were possible for material to penetrate very far without a broad passageway.

18. An artery and vein, then, encircle the whole body of the heart, but no nerve is seen to ramify in it, just as no nerve ramifies in the liver, kidneys, or spleen. Only its covering [membrane], the pericardium, is seen to receive branches of slender nerves [branches of vagus and phrenic nerves and sympathetic trunks, derived from the cardiac plexus], and when these ramify, there are to be seen some insertions even into the heart itself, perceptible and clear, at least in the larger animals.[92] Certainly it is not possible to perceive by the senses how they branch in the heart, but in the way in which they are attached and in their order of size they resemble very closely the nerves of the liver, kidneys, and spleen. For in these parts, as I have said before, the nerves that can be seen are inserted on the tunics and one cannot perceive clearly that they ramify in the actual substance of the parts. In the preceding book, I have written an adequate account of the distribution of nerves in all the viscera, so that if you paid careful attention then, you will not need to hear any more now about the reason why the heart, which performs a natural
[I, 365] work, needs very few nerves. For just as all the muscles need large nerves because they are instruments of psychic action, so the heart, to which no psychic action has been entrusted, has need of a nerve supply like that of the other viscera I have mentioned, and the same is true of the lung. All viscera receive their share of nerves in order that they may have some sensation and may not be altogether plants, and in particular the liver and heart receive nerves because they are the sources of certain faculties, the one of the concupiscible soul, the other of the irascible soul. I have shown in my book *On the Teaching of Hippocrates and Plato*[93] that these sources must give heed to one another, be connected to some extent, and communicate with one another.

19. Since in large animals a bone is found at the head [base] of the heart, it would not be proper to omit mention of its usefulness. That

[92] Note that in this and the following chapters Galen abandons his expressed intention to confine himself to a discussion of conditions in man.

[93] *De plac. Hipp. et Plat., passim;* see, for example, VII, 3 (Kühn, V, 600 ff.).

told by Aristotle [94] is perhaps reasonable. He says that the bone is a support and foundation, so to speak, for the heart and hence is found in large animals. For it is clear and reasonable that a large heart suspended in a large thorax certainly needs some such part. But a heart [95] like that would be better described as follows: Nature everywhere fastens the ends of ligaments to cartilage or to cartilaginous bone. She would not, then, neglect either the ligaments of the heart (for that is the character of the membranes situated at the mouths of the vessels) or the tunic of the arteries [fibrous rings], which in the substance of its body resembles a ligament; on the contrary, she [I, 366] attached the ends of all of them to that cartilaginous bone, as I have showed in my *Manual of Dissection.*[96] Hence in large animals there is a cartilaginous bone and in very small ones a neuro-cartilaginous body.[97] Every heart has at the same location some hard substance, formed for the sake of the same usefulness in all animals. That larger hearts need such a substance to be harder is nothing strange; for in a large heart a harder substance is better suited to furnish a safe attachment for the ends of the ligaments and a foundation for the whole heart.

20. These are the parts of the heart in animals that are already fully formed. In animals still confined in the uterus there are to be observed certain inosculations of the vessels of the heart, which I promised earlier to explain but of which I have not yet spoken; for I thought it better to finish first the whole treatment of [the heart and lung in] animals that are fully formed. Since I seem now to have reached the end of it, I must keep my promise and I shall begin my discussion thus: I have shown that the arteries of the lung are venous and the veins arterial so that the lung may be nourished with suitable nutriment and so that in addition the arteries [*vv. pulmonales*] may contract easily and the veins [only] with difficulty. In regard to the

[94] *De part. an.*, III, 4, 666b17–21; *Hist. an.*, II, 15, 506a8–10.

[95] Perhaps, "But this *usefulness* would be better explained as follows." The text has only the feminine demonstrative pronoun, ἥδε, which could refer either to καρδία, which is nearer, or to χρεία, several lines above.

[96] *De anat. admin.*, VII, 10 (Kühn, II, *618–622;* Galen [1956, *186–188*]).

[97] According to Ellenberger and Baum (1926, *615*), the horse, pig, and dog have a "heart-cartilage" and the beef two "heart-bones." In old horses and pigs the cartilage has frequently ossified; in the dog it is very small or wanting altogether.

[I, 367] membranes adnate to each opening of the heart, I have shown that those directed from within outward were formed to prevent the reflux of material and that those directed from the outside inward were formed for that reason too and are also instruments of attraction.[98] Now these arrangements, which are excellent in fully formed animals, all seem to be worthless in animals still confined in the uterus. Hence my opponents, who suppose that Nature has made nothing with skill, cite precisely this one fact in their argument because, as they think, it completely overthrows my opinion. For they say that in the embryo the pneuma is conducted not from the lung to the heart but from the heart to the lung. Indeed, it is probable that when the animal does not as yet breathe through its mouth but is still supplied with both nutriment and pneuma from the mother by way of the vessels at the umbilicus, pneuma moves not from the heart into the great artery that lies along the spine but from the artery into the heart and that the lung itself is supplied from the heart, not the heart from the lung. And certainly, they say, if the outgrowth of membranes at the orifice of the great artery is so constructed that nothing at all or [only] a very small amount of material passes from the artery into the heart, and again if at the orifice of the venous artery [*valvula bicuspidalis* or *mitralis*] the outgrowth of membranes is also so constructed that here too very little material goes from the heart to the lung, it is clear that neither heart nor lung receives any pneuma. They maintain too that in the

[I, 368] same way what has been said about the vessels of the lung seems false and silly, for these vessels are the same when an animal is still confined in the uterus as they are after birth, even though [before birth] there is as yet no respiration by way of the mouth. According to them, the argument explaining the usefulness of interchanging the vessels is based on conditions in animals already breathing through the mouth. They think it is therefore clear that Nature exercises no foresight in her dealings with animals and that everything I say is plausible but untrue.

[98] Both Kühn and Daremberg (in Galen [1854, I, *450*]) make Galen say here that the membranes directed from the outside inward (the atrioventricular valves) were formed *not* to prevent the reflux of material but to be instruments of attraction. But there is no negative in the Greek, and Galen (*vide supra*, p. 305) has made it clear that he thought that the valves at all four "orifices" were formed for the same reason, namely, to prevent the return of blood which has passed them.

We must in part excuse these men who thus inveigh against me and the works of Nature, but we should in part also censure them; excuse them because they are not reasoning sophistically and do not go astray in their logic, qua logic, as they so frequently do; censure them for their neglect of anatomy, their ignorance of which is the reason why they dare to say such things. They have the same difficulty as the man who in counting his donkeys forgets the one on which he is mounted and then accuses his neighbors of stealing one, or as the man who is searching for something he holds in his own hand. I myself once saw this happen and laughed at a man who was making an uproar and turning everything in the house upside down in confusion while he searched for the pieces of gold that he himself held wrapped up in a bit of papyrus in one hand. Just as anyone who was calm and collected would say little, I suppose, in answer to the loud shouts of these men and would show one of them the donkey on which he was mounted and bid the other touch his left hand with his right, so in the same way I think that if my [I, 369] accusers have eyes, I shall point out to them the branch [*ductus arteriosus*] of the great artery and the orifice [*foramen ovale*] of the vena cava, both of which lead to the lung in animals still confined in the uterus. And if they are blind, I shall place the vessels in their hands and bid them touch them. In fact, neither vessel is small or the result of accident; on the contrary, they are very broad and have notable lumens, which could not fail to be recognized not only by anyone having eyes but even by anyone having a sense of touch, provided that he wished to busy himself with dissecting. These [accusers of mine], then, and not Nature, deserve to pay the penalty of idleness.[99] For Nature is not idle or without foresight; rather, as they themselves admit,[100] she considered carefully and realized that while the lung is still being formed in the uterus and is without

[99] "It was this king Amasis who established the law that every Egyptian should appear once a year before the governor of his canton, and show his means of living; or, failing to do so, and to prove that he got an honest livelihood, should be put to death. Solon the Athenian borrowed this law from the Egyptians, and imposed it on his countrymen, who have observed it ever since. It is indeed an excellent custom" (Herodotus, *History*, II, 177; translation by Rawlinson [1930, I, *206*]). See Hofmann (*1625*, *126–127*) for other references to the laws against idleness.

[100] See Daremberg's note (in Galen [1854, I, *452*]) on this passage. The accusers are the Erasistrateans; see pp. 232, 257.

motion, it does not need the same governance as a lung that is fully formed and already moving, and so she opened the strong, thick, dense vessel [*a. pulmonalis*] into the great artery and the weak, thin, loose-textured one [*v. pulmonalis*] into the vena cava.

But these men are completely ignorant and careless about inquiring into the works of Nature; for one need only see these things and admiration of her skill will immediately follow. Who, indeed, would not admire her skill when he heard the arguments which these men use to accuse her and then saw her find a remedy for such absurdities in just a little device? They vociferate that it is all wrong to govern
[I, 370] the fetal lung like one fully formed and the fully formed lung like one that is fetal, saying that a breathing, moving lung must be governed in one way and a lung at rest in another. But Nature simply by her works without any uproar or shouting [101] shows her justice, which I am sure anyone will admire who only hears about it, though certainly hearing it does not call forth as great an admiration as seeing it, and one should with his own eyes make trial of both these things and the others of which I speak.

21. These, then, are the just arrangements Nature has made for the lung both in animals already breathing and in those still confined in the uterus. I shall now tell how she corrected her arrangements for the heart by means of the same clever device. She opened the great artery into the thick, dense vessel of the lung [*a. pulmonalis*] and the vena cava into the thin, loose-textured vessel [*v. pulmonalis*], and by so doing, as I have said, she bestowed its fair share of both materials [blood and pneuma] on the lung, at the same time relieving the heart of the responsibility of serving it. Hence, since the heart is sending no blood or pneuma to the lung and is not supplying the arteries throughout the body, as it does in fully formed animals, there is no longer any cause for wonder if it needs very little pneuma simply to support its own life. This small amount I think it is certainly able to take from the great artery itself; for, as I have shown before, Nature invented the outgrowth of membranes [the aortic valve], not to prevent any material at all from entering the heart, but to keep a large quantity from entering all at once. And
[I, 371] in fact, the heart is able to attract mingled blood and pneuma from the lung too through that opening which I have said is the only one

[101] *ἄνευ θορύβου καὶ βοῆς*, Plato's expression in *Timaeus*, 70 (Plato [1920, II, 49]).

to have placed upon it two tunics growing from the outside inward [*valvula bicuspidalis* or *mitralis*]. For in animals confined in the uterus this vessel [*v. pulmonalis*] receives blood from the vena cava by way of an inosculation of remarkable size [*foramen ovale*]. I have shown before that in fully formed animals this vessel gets its share of blood from instruments that are sanguineous in fully formed animals and pneumatic in fetuses [*a. pulmonalis* and its branches] by way of many fine inosculations that escape the sight, and in animals still confined in the uterus it would get its share of pneuma [by the same route] more readily.[102] For this condition that appears in the embryo must be added as no inconsiderable evidence that the two kinds of vessels do inosculate with one another and that to some extent the veins do share in the pneuma.

If while the fetus is still attached to the mother you cut open the mother's abdomen and uterus in the manner I have described in my *Manual of Dissection*[103] and ligate the arteries at the [fetal] umbilicus, all the arteries of the chorion will be deprived of pulsation, although those of the embryo itself continue to beat. But if you ligate the veins at the umbilicus as well, the arteries of the embryo will no longer pulsate. From this it is clear both that the faculty

[103] This difficult sentence, the treatment of which by both Kühn and Daremberg (in Galen [1854, I, *453–454*]) is unsatisfactory, yields if τοῦτο τὸ ἀγγεῖον, is understood from the preceding sentence as the subject of ἐδείχθη. It then fits logically into Galen's scheme and completes his argument. The pulmonary artery and its branches are certainly the instruments that carry blood in the adult and pneuma in the fetus (according to Galen); he has indeed shown (*vide supra*, pp. 303–304) that in the animal after birth the pulmonary vein gets blood from the pulmonary artery via the minute inosculations in the lungs; and he would then be justified in thinking that in the fetus the vein could get its pneuma from the same source.

The foramen ovale and ductus arteriosus are described again in chapter 6 of Book XV, and also in *De venarum arteriarumque dissectione*, cap. 10 (Kühn, II, *828;* Galen [1961, *366*]), and *De anat. admin.*, XII (Galen [1906, II, *109–110, 161, 163;* 1962, *119–120,* 177, *179*]). For a full account of their rediscovery in the sixteenth century, see Franklin (1941, *58*). It is not known whether Galen was the discoverer of these structures; Kilian (1826, *4*) says that Herophilus knew them, but he fails to give the evidence for this assertion. On the other hand, if Galen had been the first to distinguish anything so striking, he might be expected to have said so. See also Hyrtl (1880, *191–192*); Lindberg (1964).

[104] *De anat. admin.*, XII (Galen [1906, II, *110–113;* 1962, *120–123*]).

moving the arteries of the chorion originates from the heart of the fetus and also that by means of their inosculations with the veins the
[I, 372] arteries are supplied with the pneuma by which at least for a time the innate heat can be preserved. It is therefore not impossible that in the [fetal] heart itself the advantage of the innate heat in its left chamber—for the sake of which, as I have shown, animals need respiration and the pulse—comes to it from the vessel containing the blood [*v. pulmonalis*]. From this it is at once manifest that Nature has constructed everything with foresight, that truth everywhere confirms itself, and that when Erasistratus says that the materials [blood and pneuma] never mingle, his assertions agree neither with what we see nor with one another.

In fact, what I have just been saying shows that the arteries do not dilate because they are filled with pneuma from the heart; that they attract something from the veins at each dilation; and that in the fetus when the venous artery [*v. pulmonalis*] receives blood from the vena cava, a considerable quantity must be attracted (that is, when the heart dilates) from the venous artery into the left ventricle, since the outgrowth of membranes [*valvula bicuspidalis* or *mitralis*] does nothing to prevent; for the membranes obviously grow from the outside inward. Hence not only in animals already fully formed but also in those still confined in the uterus the heart clearly appears to supply to the arteries the faculty that moves them, but certainly does not inflate and fill them as wineskins are filled. In other works of mine [104] too I have shown that the arteries
[I, 373] do not dilate because they are filled, but are filled because they dilate [105] and this also appears to be true from what I have now said. I think it is perfectly obvious that if they do not dilate because they are filled like wineskins but are filled because they dilate like the smith's bellows, then they must necessarily attract something from the veins, since even Erasistratus himself agrees that the veins and arteries do inosculate. But if it is not clear, then I have demonstrated this too in other works of mine.[106] Hence, I

[104] *De plac. Hipp. et Plat.*, VI, 7 (Kühn, V, *560–563*).

[105] This first half of this sentence is lacking in Kühn's text and hence in both his version and Daremberg's.

[106] *De usu pulsuum*, cap. 5 (Kühn, V, *164–169*); *De nat. fac.*, III, 15 (Kühn, II, *206–210;* Galen [1928, *318–325*]).

need not tarry longer; those who think that the inosculation of the vessels of the heart was formed for the reasons (χρεία, usefulness) I have mentioned may find further substantial proof of this in the demonstrations occurring in other works of mine.

Just as Erasistratus was unable to tell the usefulness of many other parts, so in the same way, I suppose, he could not tell it in the present instance. For whether or not these inosculations exist, the discussion would not be easy for him; if they do exist, then the materials are of necessity mingled in the left ventricle of the heart, and if they do not, it is difficult to tell how the [fetal] heart gets its share of pneuma and much more difficult to tell how the lung is governed without injustice alike in the fully formed animal and in the fetus. But there is nothing[107] difficult in truth itself, neither in this situation nor in any other occurring in the body of an animal; on the contrary, everything is very easy, clear, and consistent, at least [I, 374] for anyone who is not fundamentally wrong in his investigation of actions. Well, this is not the place to discuss these matters.

Now just as Nature with the passage of time dries up the vein [*v. umbilicalis*] that leads from the umbilicus to the liver and the arteries [*aa. umbilicales*] that pass to the region of the spine, and makes them like slender cords [*ligamentum teres* and *ligamenta umbilicalia lateralia*], so in the same way she causes these inosculations of the vessels of the heart to disappear once the animal is born, and this, I think, is the very greatest of all her wonders. For she utterly refused to permit the existence of things which would be of no use at all to an animal no longer confined in the uterus, and it seems to me a much greater thing for her to destroy what she has made because it has ceased to be useful than to have made something for the fetus beyond what she made for fully formed animals. I shall write the whole account of the arrangements for the fetus which differ from those for fully formed animals in connection with my explanation of the usefulness of the parts[108] of the uterus, after I have first finished the whole work in which I am now engaged. In fact, I should not have mentioned such matters here if there had been no attack on the things I say about the membranes [valves] at the heart and the

[107] Reading οὐ τί γε with Helmreich for the οὔτε of Kühn's text.
[108] Reading μορίων with Helmreich for the χορίων of Kühn's text.

interchanging of the vessels of the lung. And so, turning back to my theme again, I shall explain what remains. There is nothing left, I think, to tell about the heart itself, but much that concerns the lung and thorax. I shall explain it all in the following book and add an
[I, 375] account of the parts of the larynx to that of the lung, since the larynx is the upper end of the rough artery [the trachea].

THE SEVENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Instruments of the Pneuma, continued]

1. I have said before that the lung is an instrument both of respiration and of the voice. In the present book I shall tell why it was formed with the number and kind of parts of which it really is composed. I shall show too that it was better for it to have neither more nor fewer of them, and that it should not be different from what it is in mass, form, structure, or contexture. As usual I shall begin with the actual investigation of the parts of the lung, as is reasonable, and of course it is perfectly clear to everyone that we ought to make such an investigation by dissecting animals[1] and ought not to think any words able to teach us as well as the senses all that appears in the viscus. We should not, however, hesitate on this account to explain in words the construction of the lung, refreshing the memories of those who have dissected and giving advance instruction to those who are totally uninformed.

2. Like the liver, this viscus too is a plexus of very many vessels with the spaces between the vessels filled with soft flesh like padding. One of the vessels originates from the left ventricle of the heart[2] [*v. pulmonalis*], another from the right ventricle [*a. pulmonalis*], and another from the pharynx [the trachea]. Then, as they proceed, they all divide in very similar fashion, at first into two branches because one part of the lung lies on the right side of the [I, 376]

[1] Here is an excellent example of Galen's untroubled assumption that in order to discuss a structure in man it is sufficient to have dissected it in animals. See my Introduction, pp. 40–41.

[2] One more instance to illustrate Galen's ignoring of the atria.

animal and the other on the left, the two parts being separated by strong [mediastinal] membranes. Thereafter each branch divides again into two other branches because in each part of the lung there are two lobes, and in this way the branches, now four in all from each of the vessels I have mentioned, divide multifariously in the four lobes of the lung. Since, lying in the free space on the right side of the thorax, there is a small, fifth lobe,[3] which I have said forms a support and bed, so to speak, for the vena cava, little offshoots of the vessels distributed in the large lobe adjacent to it are conducted [into it] and branch in every direction. All the lobes are surrounded on the outside by a thin membrane [the pleura], which receives some portions of the nerves [*nn. vagi*] descending along the esophagus to the stomach. This is the nature of the lung. When I was discussing the right ventricle of the heart, I clearly proved that it was better for the vein of the lung to be arterial and the artery to be venous.

3. I shall now tell why Nature joined to these vessels a third one [the trachea] which originates from the pharynx and is called the
[I, 377] rough artery by some and bronchus (*βρόγος*, windpipe) by others. First, of course, I shall explain fully its construction in order to make my discussion clear. There is in the animal body a certain simple part of which I have spoken before, when I was discussing the hand.[4] Though it is softer than bone, it is harder than all the other parts, and nearly all physicians give it the name *chondrus* (*χόνδρος*, cartilage). Nature used a great deal of this cartilage in constructing the rough artery and bent every piece of it accurately into the circumference of a circle, in such a way that the outer side which we touch is convex and the inner concave. Then, when she had placed the pieces one upon another lengthwise of the neck and filled the whole space between the larynx and the lung with them, she united them with strong, membranous ligaments [fibrous membrane] very like those uniting the shells[5] of the crayfish.[6] But where these structures [the supporting rings] would have to rest upon the underlying esophagus, Nature did not make cartilage; instead, in this region she left a gap in the circle, and thus each cartilage is like a Sigma,[7] which is the reason, I suppose, why some

[3] See note 15 of Book VI.
[4] See chapters 11 and 15 of Book I and chapter 12 of Book II.
[5] Probably the chitinous abdominal segments.
[6] Reading *καράβων* with Helmreich for the *κοράκων* of Kühn's text.
[7] See note 53 of Book II.

people call them sigmoid. Another tunic, perfectly circular, extends on the inside down along these ligaments, the other, circular ligaments, and the cartilages themselves too, making a lining for all [I, 378] these structures. It is close-textured and dense, having straight fibers running longitudinally, and I know I have already mentioned somewhere [8] that it is continuous with the tunic lining the inside of the whole mouth, the esophagus, and the entire stomach. Moreover, there is a membrane surrounding all these structures on the outside like a garment and a covering for the whole artery.[9]

This is the nature of the artery of the neck, by means of which animals breathe in and out, make sounds, and blow.[10] As soon as it has passed the collar bones and reached the free space in the thorax, it divides and proceeds to all parts of the lung, being distributed along with the vessels from the heart into all the lobes. Its character here, however, is no different from that of the upper part and none of its branches changes in any respect. On the contrary, many sigmoid cartilages, united by membranous ligaments, persist in all of them alike to the farthest lobes of the viscus.[11] This is the only vessel in the lung that contains no blood at all. Erasistratus thinks that the other artery, that is, the smooth one [*v. pulmonalis*], also lacks blood, but he is wrong, as I have often said before; for it does contain a considerable quantity of pure, thin, spirituous blood. The rough artery, on the other hand, is completely devoid of blood, at least in the natural state of the animal. When, however, there is some break, inosculation, or erosion in a vessel of the lung, blood then

[8] *Vide supra*, pp. 212–213; and cf. *De anat. admin.*, X (Galen [1906, II, *56–57*; 1962, *62–63*]).

[9] "These ligaments" are the fibrous membrane of the trachea where it closes the gaps in the rings; "the other, circular ligaments" are those parts of the fibrous membrane between successive rings; the lining tunic is of course the mucous membrane; and the outer, investing membrane is once more the fibrous membrane where its outer layer coats the outside of the rings and joins with the inner layer between the rings.

[10] ἐκφυσᾷ. See note 25 of Book IV.

[11] In man (see Gray [1966, *1157*] the larger divisions of the intrapulmonary bronchi are covered with a coat of fibrous tissue in which are only irregular patches of hyaline cartilage. In the rhesus moneky (see Lineback [1933, *211*]) the rings persist deep within the lung tissue, and in other animals (see Ellenberger and Baum [1926, *477, 498*]) they are present at the beginning but very soon degenerate into small pieces of various shapes. It is thus clear on what animal Galen was basing his description.

[I, 379] streams out even into this artery [the trachea] and causes trouble for the air by obstructing its passages. When this happens, the animal coughs and the blood rises through the pharynx into the mouth.

4. I shall now explain why Nature did not make this artery [the trachea] either entirely cartilaginous or entirely membranous but placed the cartilages and membranes alternately, and why instead of making the cartilages complete circles she left a small gap in each one. And first of all I shall show that the instrument of the voice absolutely must be cartilaginous; in fact, I demonstrated in my commentaries *On the Voice* that simply striking the air is not sufficient to produce a sound and that there must be a certain proper relationship between the substance of the thing that strikes and the strength [of the thing struck],[12] so that the air offers a little resistance and is not overcome, conquered at the first shock. Now cartilage provides this proper relationship in animals, for softer substances deaden the impact on the air by their weakness and harder ones so readily overcome the air that when it receives the shock, it does not tarry or resist, but recedes and escapes, giving the impression of a flow rather than an impact. You should not ask at this point to hear demonstrations of these facts, just as you should not ask here for a demonstration of any other action. For it is only after writing separately about each action that I have turned my attention to this latest treatise on the usefulness of parts, a treatise which requires, as I showed at the
[I, 380] very beginning, a previous knowledge of all the actions.

The cartilage of the rough artery, then, is the special instrument of the voice itself, and the rough artery would have been made entirely of cartilage, needing neither ligament nor tunic, if it were not obliged to move when the animal breathes in and out, blows, or utters a sound. As it is, however, since the rough artery in all these actions must become longer and then shorter again, and also narrower and then wider again, it is reasonable that instead of being made of cartilaginous substance alone, which is incapable of expanding and contracting, it should receive in addition membranous substance too in order that it may be readily set in motion in these ways. For when the whole thorax expands in inspiration, as I have shown

[12] A cryptic sentence, which might be rendered, "between [the air and] the substance and strength of the striking agent." Daremberg (in Galen [1854, I, *462*]) prefers this, but in either case something must be imported in order to make sense.

that it does in my book *On the Movement of the Thorax*,[13] and then causes the entire lung to expand to fill the space left vacant,[14] the membranous parts of these arteries [the trachea and its branches] readily increase in breadth and length. The parts filling up the sigmoid shape of the cartilages increase in breadth, and those uniting the cartilages increase in length. You can clearly see this for yourself even after the animal is dead, if you blow air[15] through the rough artery into the whole lung and then empty it out again by pressure. For during inspiration and the filling of the whole lung the bands [I, 381] uniting the cartilages will be seen to stretch and to separate the cartilages as far as the nature of the bands permits them to be extended, and during expiration the bands relax into folds again and shrink together so as to permit the cartilages to touch one another. Moreover, when during inspiration the bands that fill up the sigmoid shape of the cartilages are inflated, they become broader and convex toward the outside, and during expiration they relax in turn and fall inward. From this it is clear that the increase and decrease in the length of this viscus [the trachea] is effected by the parts uniting the cartilages, and its increase and decrease in breadth by those filling up their sigmoid shape.

5. Hence, thanks to the rough arteries, the lung lacks nothing necessary for an instrument both of the voice and of respiration, since these arteries have their cartilages to make them instruments of the voice and their bands uniting the cartilages to make them instruments of respiration. Let the larynx be your best proof that this cartilage is the principal instrument of the voice. The larynx is the name we give to that part which joins the rough artery to the pharynx and is seen protruding in the region of the neck. It is hard to the touch and rises when we swallow.

I have demonstrated in my book on the production of the voice

[13] See note 3 of Book VI.

[14] Reading *κενούμενον* with Helmreich for the *κινούμενον* of Kühn's text. This is the horror vacui and an echo of Erasistratus. Galen recognizes it as one of the two forces causing a hollow organ to be refilled, but he considers the attraction which the part has for the entering substance as the more important. See *De nat. fac.*, *passim*, and particularly I, 16, and II, 6 (Kühn, II, *62–67*, *98–99*; Galen [1928, *96–103*, *154–157*]).

[15] Kühn's text omits *τὸ πνεῦμα*.

that this larynx is the first and most important instrument of the
[I, 382] voice. No discussion is necessary to show that it is made entirely of cartilage, for this is plain to be seen. I pointed out in the same book that the [rough] artery provides a preliminary regulation and preparation of the voice for the larynx, and that when the voice has once been produced in the larynx, it is amplified by the roof of the mouth lying in front [of the larynx] and acting as a sounding board and by the uvula acting as a plectrum. Moreover, I pointed out too that the voice is not produced by a simple expiration; that the special material of the voice is an emission of breath;[16] wherein this emission differs from expiration itself; that it is caused by the muscles of the thorax; and in what way it and the voice too are produced. As I have said, however, I do not intend to demonstrate any of these things here, but to use them as facts in showing that no other construction could possibly be better for a part which serves both respiration and the voice.

These present demonstrations of mine would probably also be good evidence that my previous demonstrations of actions were correct too. For instance, I have shown in that book [*On the Voice*] that the voice is prepared for the larynx by the [rough] artery, though it is by no means completed there. Yet truly, when I now explain that the cartilaginous part of the rough artery is what furnishes the preliminary regulation of the voice, I am thus providing good evidence first that I was right when I showed that the larynx is the principal instrument of the voice, and second that the cartilaginous part of the [rough] artery is an instrument of the voice
[I, 383] and all the rest an instrument of respiration.

And it is clear that one instrument could not possibly serve the two actions better if it were constructed otherwise than as it is. For it was absolutely necessary for the [rough] artery to be composed both of motionless parts and of parts that move, since on the one hand an instrument of the voice could not expand and contract because it must be too hard to undergo such alternate changes, and on the other an instrument of respiration could not be made hard enough to regulate the voice because its principal work is motion. But as it is, since the moving and motionless parts are placed alternately, the voice is produced by the motionless parts and respiration

[16] See note 25 of Book IV.

by those that move. Actually, however, the motionless parts do have a sort of contingent motion along with the moving parts, being carried along with them because they are united. This [rough] artery, then, is a part appertaining specially to the lung, and fish necessarily lack both this part and the lung as well, since, being aquatic, they have no use for a voice. To refrigerate the heat of the heart (and this is the reason why we need respiration) Nature constructed gills for fishes; I have said something of these structures earlier and shall speak of them again at greater length in their proper place when I write my book about all the animals. But now, since I have shown that all the true statements I have made about usefulness in this treatise and about actions in earlier ones are consistent and [I, 384] corroborate one another, let us proceed to discuss the remaining parts of the lung.

6. I have said that the cartilage of the rough artery is an instrument of the voice; that the membranous bands are instruments of respiration; that what both structures combine to form, namely, the [rough] artery, is a part serving both respiration and the voice at the same time; and that no other construction could possibly be better for it, if, indeed, no substance either harder or softer than cartilage serves better to produce sound. Moreover, if it were bound up together in some way other than as it is, it would not alter its breadth and length any better, expanding during inspiration and contracting during expiration. If in imagination you destroy either one of these components, you will straightway destroy the whole action along with it. If you remove the cartilages, you destroy the voice; for the substance of the membranes, tunics, and all soft parts is like wet string, unsuitable for the production of sound. If in imagination you remove the bands, you destroy respiration by entrusting it to instruments that do not move. If you remove some of the parts and keep the others, you destroy as much of the whole action as depends on the parts you have removed. For when the bands uniting the [cartilaginous] rings are lost, the [rough] artery's increase in length is lost, and if is the bands filling up the sigmoid shapes that are [I, 385] destroyed, the increase in breadth is lost.

7. Well then, has Nature, who made these works of hers with the utmost skill, been careless in the placing of them when she put the rounded part of the cartilages on the outside [ventrally], and the bands that fill the gaps left by the cartilages and make the circles

complete, on the inside [dorsally]? Or is this too an example of the same skill, that she placed the band uniting the cartilages underneath, where the [rough] artery must touch the esophagus, and that she put the cartilage itself as a defense in front where the artery must encounter blows falling upon it from without, in order that the esophagus may not be compressed by the hard cartilages and the artery itself may not be easily injured by having its softer parts encounter external objects? For, as it is actually arranged, with its hard parts limited to the front of the neck, and its soft ones touching the esophagus, Nature has admirably contrived to protect each instrument from injury, the esophagus from being injured by the [rough] artery, and the artery by external objects.

Is this, then, the only advantage Nature has gained for animals from the way she placed the cartilages of the [rough] artery? Or is there another even greater, one that has to do with swallowing the larger masses of food and drink? To me, indeed, she seems to have been wonderfully skillful in securing this advantage also. For if she had made each cartilage a complete circle, not only would it com-
[I, 386] press the esophagus, but by thrusting its convexity into the esophagus [17] it would also considerably narrow the lumen available for swallowing large masses. But as it is, the tunic of the [rough] artery in this region is displaced at such times by what is swallowed, and is turned back into the broad cavity of the cartilages, so that it allows the whole circle of the esophagus to become available for the passage of the nutriment. At such times, on the other hand, the convexity of the cartilages, encountering the distention of the esophagus, would have closed off a large part of its breadth and in so doing would have narrowed the passageway for the food.

Now if we were able to swallow and breathe at the same time, the present arrangement not only would fail to be at all advantageous, but also would be actually harmful, because the passageway for respiration would be narrowed by the extent to which the convexity of the esophagus projected into the broad cavity of the [rough] artery. Actually, however, since the action of respiration takes place at one time and that of swallowing at another, the [rough] artery and the esophagus share their available space with one another, so that a very large quantity of the appropriate material is conveyed

[17] Reading αὐτὸν with Helmreich for the αὐτὴν of Kühn's text.

through each passage in a short time. Moreover, it was an excellent provision that both instruments were made round, in order to allow a very large amount of material to pass through a very restricted space and also to protect them from injury. For I have shown before that this shape is best protected against injury and is the most capacious of all shapes having equal perimeters, and if this is so, large [I, 387] amounts would thus be able to pass easily [18] through instruments of very small size.

And surely it is wonderful that these instruments are connected by a common tunic [the mucous membrane] with one another and with the mouth. I have shown that in the esophagus this tunic contributes very greatly to deglutition; it lines the inside of the cartilages of the [rough] artery, and in an action very like that of the device we call a well sweep, it draws the rough artery along with the larynx up toward the pharynx when the animal swallows. Why was it better for such a tunic to line the cartilages of the [rough] artery? The reason is that the useless serum of the phlegm from the head [19] must often flow into it, and when we swallow, a little liquid is continually falling into it and sometimes even bits of food. At times, too, air acrid in quality and charged with smoke, ashes, charcoal, or some other poisonous faculty must be inhaled, and occasionally we have to cough and evacuate malignant, corrosive pus or some other juice, such as yellow or black bile, or salty phlegm, that has grown putrid within the body; and by all of these things the cartilage would necessarily be abraded, eroded, and ulcerated. You may learn from physicians, even if you yourself do not practise medicine, that affections of the cartilages are either entirely [I, 388] incurable or terribly hard to heal; indeed, you would have no need of their instruction to tell you this if you had already had experience to teach you. Well, the tunic spread beneath the cartilages of the [rough] artery is extremely easy to treat, and every affection arising in it readily subsides [20] unless some part of it has been eaten away in a severe mortification and left the cartilage completely bare. Such a condition is no longer easy to treat, not, of course, on account of the tunic, but because the affection has reached the cartilage. This rarely

[18] Reading *βαδίως* with Helmreich for the *βᾶον* of Kühn's text.

[19] See chapter 3 of Book IX.

[20] Daremberg's comment (in Galen [1854, I, 471]) on this statement is an exclamation point in parentheses.

occurs under ordinary circumstances, but it would happen continually if the cartilage were normally unprotected.

But why was the tunic made thin, yet at the same time dense and moderately dry? The reason is that making it thicker than it is would have served no useful purpose and besides, it would then occupy a considerable part of the breadth of the whole [rough] artery. If it had been made loose-textured, it would not prevent the moisture flowing through from reaching the cartilage beneath and would itself easily become soaked and make the voice hoarse. For the same reason it is also moderately dry; for drier bodies make better sounds than very wet ones, and so, too, perfectly dry bodies produce less pleasant tones than those that are [only] moderately dry. In all burning fevers the parts of the pharynx and [rough] artery become very dry, and the voice as a result is what Hippocrates [21] calls κλαγγώδης (shrill, strident). We find the same effect
[I, 389] in animals having long necks and dry cartilages, like the crane, and this is the reason why Homer [22] in alluding to cranes has written:

They fly o'er ocean's stream with strident cries.

So when the instrument is dry, it produces that sort of unpleasant tone. In catarrh and coryza, however, the voice becomes hoarse from a superabundance of moisture. Our Creator knew all these things and for this reason made the tunic placed beneath the cartilages moderately dry, avoiding both extremes. This is the character of the lung's artery, which is composed of βρόγχια, for that is what physicians usually call the cartilages of the artery, just as they call the whole artery the bronchus, and its upper end the head, another name for which is the larynx. But I shall discuss the structure of these parts a little later.

8. As far as one could tell from my discussion thus far, and if one surveyed such matters too negligently, the lung would seem to have already everything it needs, thanks to a single instrument, the rough artery, that is, if it is able by means of this instrument to produce the voice, to blow, and to breathe in and out. But if you would consider carefully that this same instrument [the lung] has no supply of

[21] *Coacae praenotiones*, 550 (Littré, V, 708, 709), and *Praedicta*, I, 17 (Littré, V, 514, 515).
[22] *Iliad*, III, 5.

blood to nourish it unless some veins [*aa. pulmonales*] are attached to it, and that the heart has no way of profiting by respiration unless [I, 390] the lung is connected with it by other arteries [*vv. pulmonales*], you would realize that Nature did well to mingle and interweave two other kinds of vessels with the rough arteries and also that a suspended vessel cannot possibly be divided without danger unless there is placed at the point where it divides some soft, spongy substance like padding to fill up the empty spaces between all the vessels and be a support and safeguard for the weakness at that point. You would [then] realize that it was right and provident to form the flesh of the lung. This flesh has still another not unimportant usefulness, of which I shall speak a little later.

I have already shown frequently that the smooth arteries [*vv. pulmonales*] serving to connect the rough arteries with the heart contain thin, pure, spirituous blood and are not instruments of the pneuma alone, and my present discussion gives excellent confirmation of their role. Now if they are completely without blood like the rough arteries (and Erasistratus assumes that they are), why do not the rough arteries penetrate directly to the heart? Why are small branches of the veins [*aa. pulmonales*] inserted on the rough arteries and not on the smooth? For if this is so, Nature, who even according to Erasistratus himself makes nothing in vain, would seem to have made not only the smooth arteries but also the veins of the lung to no purpose; the former, because the heart could be attached directly [I, 391] to the rough arteries and so would have no need of smooth ones, and the latter, because according to Erasistratus the tunics of these arteries and of the arteries of all the parts of the animal in general are interwoven with a vein, artery, and nerve, so that each tunic, being nourished by the simple vein it contains (which is visible only to the imagination!) has no need of this large, composite vein [*a. pulmonalis*]. If, then, the left ventricle of the heart contains only air, as the rough artery does, if on that account the lung has no need of the smooth arteries, and if the arteries do not need nutriment brought in from outside by a vein, it would be reasonable for the lung to be formed of rough arteries alone. Now, not to mention other reasons, no one attempting to defend the position of Erasistratus could say that the rough arteries could not be attached to the heart because they are composed of cartilages. For just as the cartilages are attached to one another by means of the membranous bodies between

them, so, of course, they could be attached to the heart too in the same way. Why then was the lung not formed from a single kind of artery? Erasistratus would find it difficult, too, to tell why it also needs veins, just as he had difficulty in explaining why the tunic of the arteries [of the lung] is venous, and that of the veins arterial, but it is not hard for me.

Moreover, my arguments concerning usefulness clearly corroborate my demonstrations of actions. Since all the other arteries
[I, 392] throughout the body of the animal contain a portion of blood, as the left ventricle of the heart does too, and since the rough arteries, being the only ones devoid of blood, are connected with the heart by way of the smooth arteries, their orifices [25] have been given such a nicely proportioned size by Nature, who does nothing without good reason, that they admit vapor and air, but remain impassable to blood and other such thick substances. And if ever they lose their natural adjustment of size and open more widely, blood passes from the smooth to the rough arteries and immediately causes coughing and raising of blood. But when conditions are normal, very little actual air is taken over from the rough into the smooth arteries and the flesh of the lung appears light and full of air, showing plainly that it was made to concoct the air, just as the flesh of the liver was made to concoct the nutriment. For it is reasonable that the outer air does not become the nutriment of the pneuma in the animal's body suddenly and all at once; rather, it is altered gradually, just as the food is too, and over a period of time acquires the quality proper to the innate pneuma, the principal instrument of this alteration being the flesh of the lung, just as I have shown the flesh of the liver to be responsible for changing the nutriment into blood.

Now when it becomes necessary to account for suitable and
[I, 393] unsuitable qualities in air, Erasistratus for some reason or other says that they are caused by its thinness or thickness and supposes that this is the reason why people die in Charonian caverns [26] or in houses freshly coated with lime, and why some die of [inhaling] the odor of burning charcoal or other such vapors, that is, they die because the

[25] That is, the supposed pores connecting the branches of the trachea with the pulmonary veins.

[26] Caves filled with mephitic vapors and thought to be entrances to the underworld, hence Charon's caves; cf. the parallel passage in *De usu respirationis*, cap. 4 (Kühn, IV, *496*).

air, being too thin, cannot be retained in the body. It would be better to think that just as the qualities of foods such as legumes, vegetables, bread, and other viands of the sort are suitable to us, whereas other substances such as cantharides, sea-hares, and the like are unsuitable, so there is a certain quality in air suitable and favorable to the pneuma of the animal, and another unsuitable and destructive. Now if Erasistratus had once mastered this idea, he would not have dared to say that charcoal's smoky flame is lighter than pure air, when everyone clearly perceives that it is heavier, and he would, I suppose, have investigated the parts prepared by Nature for the concoction of air. But of course it is altogether ridiculous to expect that a man who says nothing about the formation of blood or other juices will inquire so deeply into natural causes as to understand the alteration and concoction of the pneuma. I have, however, refuted him more in detail on these matters elsewhere.[35] The outer air drawn in by the rough arteries receives its first elaboration in the flesh of the lungs, its second thereafter in the heart and arteries, particularly those of the retiform plexus [*rete mirabile*], and a final one in the ventricles of the encephalon, where its transformation into psychic pneuma is complete. [I, 394]

This is not the proper time to explain the usefulness of this psychic pneuma or to tell how it is that we who confess that we are still completely ignorant of the nature of the soul (ψυχή, psyche) nevertheless venture to call this pneuma psychic. But now that I have reminded you that the flesh of the lung fills up the empty spaces at the division of the vessels and at the same time concocts the outer air; now that I have spoken again of the veins [branches of the pulmonary artery] inserted into the rough arteries (I spoke of these veins a little while ago) and have said that because these arteries are completely without blood, the veins are properly inserted on their outer coats, that if Nature had intended to have no blood contained in the smooth arteries, she certainly would somehow have provided for their nourishment too, and that, moreover, it was better for the vein to be arterial and the artery venous, as I have shown before—now that I have reviewed

[35] In *De naturalibus facultatibus* and *An in arteriis natura sanguis contineatur*, found in the second and fourth volumes respectively of Kühn's edition.

these main points, it will be time for me to pass on to the next subject, adding only the one further remark that it is for the reasons I have given that Nature has placed the rough artery between the smooth artery and the vein.

It must indeed be associated with both of them: with the smooth artery because by means of it the rough artery provides the heart
[I, 395] with the advantages of respiration, and with the vein because from it the rough artery must receive its nutriment. These, then, are the reasons why it has been placed between the other two vessels. But why is the vein [*a. pulmonalis*] behind it near the spine and the artery [*v. pulmonalis*] in front? The reason is that it was not safe to produce the artery with its thin, weak tunic too far from the heart. Hence, Nature has caused this vessel to emerge from the heart and branch immediately, as it should, into the lung, while the other, stronger vessel she conducts farther from the heart, behind the [rough?] artery.[26] That is the reason for these arrangements.

It is time now to explain the next subject. I have shown that the tunic of the veins was made hard because they should not contract and dilate easily in respiration and because the lung should be nourished not by thick, turbid blood but by blood that is thin and spirituous. This inability of the veins to dilate and contract was shown to be useful for two reasons, first in order that the whole space within the thorax might be available and devoted to the instruments of the pneuma, and also in order that the blood might not be forced to run back out of the veins into the heart. Indeed, I have shown that Nature has made no slight provision against this, as is also evident from the outgrowth of membranes [valves]. Moreover, I have demonstrated that the tunic of the arteries was made thin in order that the lung might be nourished with a very large

[26] I have been unable to determine how this passage is to be reconciled with the actual relations in this region; for in the root of the lung the pulmonary veins are indeed ventral, but the bronchi are dorsal, and the pulmonary arteries lie between the other two. See Gray (1966, *1149* and figures 965 and 966) and Lineback (1933, *212* and figure 62). It has doubtless been noted that nothing has been said of the bronchial arteries in Galen's treatment of the vessels of the lung, though it is certain that he knew one of them. See *De venarum arteriarumque dissectione*, cap. 9 (Kühn, II, *820;* Galen [1961, *364*]), and *De anat. admin*, XIII (Galen [1906, II, *156–157;* 1962, *172*]). Dr. Charles Goss suggests that perhaps "the other, stronger vessel" might be the aorta.

amount of naturally pure, thin, spirituous blood derived from the arteries, and also that the pneuma might flow easily into the heart attracting it. Hence, if anyone wishes to learn the demonstrations of these things, let him read carefully the preceding book. [I, 396]

9. It is time now for me to speak of the remaining points. For since I have shown that the first and principal usefulness of respiration is the custody of the innate heat by which animals deprived of refrigeration are instantly destroyed, and since I have said that a second, lesser usefulness is the nourishment of the psychic pneuma, it is proper at this time to marvel at the way in which Nature has constructed the lung so as to be suitable both for these purposes and at the same time for the production of the voice. Now Nature is justly to be praised because she opened all the smooth arteries [*vv. pulmonales*] into one source, the left ventricle of the heart, which is the source of the innate heat, since in so doing she prepared perpetual refrigeration for the heart. It is likewise proper to sing her praises because in the contraction of the heart she pours off all that is sooty and fuliginous in it through these same arteries and even more through the great artery into the others, thus providing safely that the heat in the heart should never be smothered by noxious residues and quenched. And we are right to admire her also because she made the flesh of the lung soft, loose-textured, and foamy in order to perform the preliminary concoction of the outer air; for so she provided suitable nutriment for the psychic pneuma. Furthermore, she should be praised because, although there are three vessels, that is, one vein and two arteries ["rough" and "smooth"] which are interwoven to form the lung, she caused all the air to be attracted into the rough arteries and to be discharged from them again when we speak, in order to enable us to say a great deal at one time without needing to breathe in continuously; for thus, since each breath is sufficient for a considerable time, she has in this instance once more made the best possible provision. I shall demonstrate the fact itself and by my discourse teach you the reason for it. It remains for you to praise the Creator of these structures, that is, if you do not begrudge deserved praise. [I, 397]

Well, then, you have learned from my commentaries *On the Motion of the Thorax and Lung* that the lung occupies all the available space in the thorax, and that when the thorax expands and contracts, the lung as a whole expands and contracts too. You have

also learned in the same treatise that in all instruments which attract by means of the tendency of a vacuum to be refilled,[27] light material responds sooner than heavy; that the instruments are filled more readily if their openings are wide; that, moreover, for all the rough arteries there is a single very large opening into the pharynx; that there is another opening leading from the smooth arteries into the left ventricle of the heart and another leading from the veins into the right ventricle; that only air is attracted from the pharynx into the rough arteries; that only blood is attracted from the right ventricle into the veins; and that a mixture of both air and blood is attracted
[I, 398] from the left ventricle. If you remember all these things and comprehend them, you will easily follow the demonstration I am about to give.

Now when the lung expands, first the lightest material, that is, of course, the outer air, will respond and fill the rough arteries; second, the material from the left ventricle of the heart will fill the smooth arteries; and after these, third and last, the blood will flow. Nothing, however, can be conveyed into either of the other vessels before the rough arteries are completely full of air. If this is true, there is room for material from the heart to flow into the smooth arteries only if the thorax continues to expand after the rough arteries have already reached their greatest distention. If the thorax stops expanding as soon as the rough arteries reach their greatest distention, there will be no time left for either the smooth arteries or the veins to dilate. For if the lung were no longer expanding because the thorax had ceased to expand, none of its parts would be able to dilate further. Hence it is clear that if I should show that the distended rough arteries alone caused the greatest expansion of the lung, it would at once be proved that only the rough arteries are filled during inspiration. How, then, is this to be demonstrated? If, when the animal is already dead you blow air in through the larynx, you will, of course, fill the rough arteries, and you will see the lung expanded
[I, 399] to its greatest extent while the smooth arteries and the veins in the lung maintain their size unchanged. This makes it evident that Nature has created the rough arteries capable [28] of causing the expansion of the lung to its greatest extent and that by this one device she has

[27] See note 14 of this Book.

[28] Accepting Helmreich's emendation, *ἱκανὰς*, for the *ἱκανῶς* of Kühn's text.

made it necessary for the outer air (τὸν ἔξωθεν ἀέρα) to enter only the rough arteries during inspiration.

At what time, then, is the air (τὸ πνεῦμα) attracted into the heart? [29] Clearly, the answer is: when the heart dilates, just as it is expelled again when the heart contracts. For it is necessary for the smooth arteries to be subservient to the movements of the heart and for the rough arteries to be subservient to those of the lung.[30] I have pointed out many times that the two sources of these movements are totally different in character and that the movements of the heart are produced by Nature and those of the thorax by the soul. Moreover, I showed in the preceding book that it was better for respiration to be our own work, always subservient to the will of the animal. Thus, all parts of the heart and lung seem to reveal the height of foresight and skill on the part of the Creator. I think there is nothing yet remaining for me to say except one thing, and even without my help anyone could see that who remembers what I said earlier, when I was speaking of the distribution of the nerves into all the parts. For he will see from that discussion that it was better for the lung, as well as for the heart, liver, spleen, and kidneys, to receive very small nerves.

10. I have spoken about the division of the lung into lobes. It is necessary only to remind you in regard to them of the main points: The principal usefulness of the lobes is similar to that of the lobes of the liver; for just as the liver clasps the stomach more safely with its fingerlike lobes, so in the same way the lung clasps the heart. Next, there are two lobes on each side, one of which occupies the upper part of the space in the thorax above the diaphragm, and the other the lower part. Moreover, the small, triangular, fifth lobe on the right side was formed for the sake of the vena cava. Another [I, 400]

[29] An excellent passage to show Galen's feeling for these two words. Crude air begins to become penuma after it has undergone its first elaboration in the lung. See my Introduction, pp. 46–48.

[30] There are lacunae and inconsistencies in the argument here. One is left to infer that the blood also fills the "veins" of the lung when the heart contracts; and Galen has claimed (see chapter 10 of Book VI) that the pulmonary "arteries" have thin, veinlike coats in order that they may expand and contract with the expansion and contraction of the thorax and lung in respiration, whereas here he is saying that their motion is independent of the motion of the thorax and lung and dependent only on the heart.

purpose of the division into lobes was to make it possible for the whole viscus to expand and contract more easily and with less risk of injury. For if it had been formed with all its parts continuous, one of them might perhaps suffer during more vigorous inspiration when the lung is under the necessity of filling the whole space within the thorax all at once. The division into lobes also makes the lung better adapted for insinuating itself easily into the narrow parts of the thorax. This is what I have to say about the parts of the lung.

11. I should speak next about the parts of the larynx,[21] for it too is an instrument of the pneuma. As I have said before, it is called not only larynx but head of the windpipe (*βρόγχος*) as well; for the rough artery itself is also called the *βρόγχος*. The larynx is composed of three large cartilages which have not the slightest resemblance to the cartilages of the rough artery either in size or
[I, 401] shape. It is moved by muscles, twelve of them forming part of its own structure [intrinsic] and eight others associating it with adjacent parts [extrinsic]. The largest of these cartilages is the one in front where we touch the larynx. It is convex on the outside and concave on the inside, very like a shield for defense, not the kind that is perfectly round, but the longer, so-called *θυρεός*.[22] In fact,

[21] From his accounts of the larynx and recurrent laryngeal nerves in many of his works, but particularly in *De anat. admin.*, XI (Galen [1906, II, 78 ff.; 1962, 85 ff.]), it is evident that Galen dissected them in various animals, including the ape, pig, goat, and birds with long necks, though he worked on the birds after he had finished *De usu partium*. He tells his students that they must dissect them in a dead man, a dead ape, or other dead animal before attempting vivisection, and he says that the plan of the larynx is essentially the same in all, but that his demonstrations are usually made on the pig because of the relatively large size of the larynx in this animal. Whatever may have been his experience in dissecting human material, we know from a passage in his *De locis affectis*, I, 6 ([Kühn, VIII, 55]) that he had two opportunities of observing this whole region in man, when he watched operations in which the recurrent nerves were accidentally cut. In spite of this, however, he has apparently chosen here in *De usu partium* to describe conditions in the pig. Attention will be called to the details that lead to this conclusion as they occur in the text. And at least two will be found indicating that at those points he was also thinking of the ape.

[22] This is the first piece of evidence that Galen is describing conditions in the pig. The *θυρεός* was a shield shaped like a door (*θύρα*), and the pig is the only animal whose thyroid cartilage is doorlike, being roughly rectangular and considerably longer than it is wide. See Ellenberger and Baum (1926, 505 and figures 701–705, 775).

the cartilage has been named for its likeness to this shield by anatomists, who call it *thyroid*. The second laryngeal cartilage [cricoid], which is as much smaller than the first [thyroid] as it is larger than the third [arytenoid], is placed on the inner [dorsal] side where the esophagus lies. It fills the gap where the large [thyroid] cartilage falls short of forming a complete circle. For the part of the larynx which is next to the esophagus is not membranous as the corresponding part of the whole rough artery is.

This is how the cartilages are situated with respect to the parts above and below: The cartilage I have called the second [cricoid] is placed before [above] the last cartilage at the top of the rough artery and is everywhere in contact with it, in front, in back, and at the sides. The thyroid cartilage begins a little above the anterior parts of this [second, cricoid] cartilage, which withdraws farther from it behind. At the sides they articulate with one another, and certain membranous, sinewy ligaments [*conus elasticus;* middle and lateral cricothyroid ligaments] extend from the first to the second. On the upper edge of the inner side of the smaller [cricoid] cartilage lie two small convexities [articular facets for the arytenoid cartilages], and it is here that the third [arytenoid] cartilage begins.[33] It has concavities that fit accurately over the eminences of the [cricoid] cartilage, so that the placing together of these two cartilages makes a double articulation. Moreover, the upper part of the second [cricoid] cartilage is narrower than its base,[34] and as a result of this the lower end of the whole larynx where it is in contact with the [rough] artery is broader than its upper orifice, where it ends in the pharynx. And again, the third [arytenoid] cartilage ends in a very narrow point and most anatomists call its upper extremity arytenoid because it is shaped like those ewers [I, 402]

[33] In the ape (see Geist [1933, *195–196*] the arytenoid cartilages are connected at their apices by cartilage extending across the mid-line, and in the pig the large corniculate cartilages, not distinguished by Galen from the arytenoid, also fuse medially (see Ellenberger and Baum [1926, *505*]). This is probably the reason why he thought of the two arytenoids as one. Goldbach (1898, *8–9*) thinks that here he may have been describing conditions in the horse, where the two lie so close together that they seem to be one (see Ellenberger and Baum [1926, *489–490*]), but in view of the rest of his description this does not seem likely.

[34] Accepting Daremberg's (in Galen [1854, I, *485*]) interpretation; the text is certainly corrupt.

which are now sometimes called ἀρύταιναι. The concavity of this cartilage too is turned toward the passageway for the air, so that the three cartilages combine to form a hollow tube like a pipe. Within this tube of the larynx lies a structure [*glottis*] [35] shaped very much like the tongue of a pipe, but formed of a peculiar substance unlike anything else in the body, for it is at once membranous, fatty, and glandular. Such is the composition of the body proper of the larynx; for the inner tunic lining it is the same as that of the [rough] artery and the esophagus.

I have shown in my other writings [36] that the voice is first formed
[I, 403] in the larynx and that the aperture at the top dilates and contracts to the greatest extent, opening and sometimes closing completely. I shall try to show here that no other construction could possibly be better for the larynx than the one it actually has. Indeed, there is no substance other than cartilage alone from which the instrument of the voice could be better constructed, as I have shown in discussing the rough artery. Neither would it be better if, though formed from cartilage, the larynx had been constructed as a single piece entirely without joints; for it would then be altogether motionless so that it could not open and close or dilate and contract at all. Hence it is clear that there was good reason for forming the larynx of several cartilages bound together and for it to move not naturally, as the arteries do,[37] but at the bidding of the animal's will. For if the larynx was to be useful in inspiration, expiration, the total checking of respiration, the forcible emission of breath, and the production of the voice, and if it was better for all these things to be under the control of our will, then it was of course reasonable for the movement of the larynx to be voluntary and to occur when the animal so desired. But I have shown that Nature has prepared the muscles to perform all such movements, and hence it is clear that the cartilages must be moved by muscles.

Let me tell now what muscles these are, how many of them there
[I, 404] are, whence they take origin, and how they open and close the larynx. I shall begin with the more important ones that are common to the three cartilages. There are four of these [*cricothyroidei, pars obliqua* and *pars recta* of each side] which connect the first

[35] See note 41 of this book.

[36] Probably *On the Voice*. See notes 3 and 4 of Book VI.

[37] That is, involuntarily. See chapter 9 of this Book, *ad fin.*

[thyroid] and second [cricoid] cartilages in animals with loud voices, of which man is one; in all animals there are four more [*cricoarytenoidei, posterior* and *lateralis* of each side] connecting the second [cricoid] and third [arytenoid] cartilages; and there are two others [*thyroarytenoideus* of each side] connecting the first thyroid] and third [arytenoid]. This is how the muscles are produced from the first cartilage, the thyroid, and inserted into the second [cricoid]: At the lower extremities of the two cartilages where they are in contact with the rough artery and with one another [articulation of the inferior cornu of the thyroid with the cricoid] two muscles [*cricothyroideus, pars obliqua*] extend on the outside and two [*cricothyroideus, pars recta*] on the inside of the large [thyroid] cartilage to the second [cricoid] one. They are exactly equal on the two sides, the one on the outside equaling the other on the outside, and the one on the inside equaling the other on the inside. These accurately constrict the lower end of the larynx by drawing the first [thyroid] cartilage close to the second [cricoid]. The four others, those that connect the second [cricoid] and third [arytenoid] cartilages [*cricoarytenoidei, posterior* and *lateralis*], open the upper end of the larynx; the posterior muscles bend the arytenoid cartilage back and the lateral ones draw it far apart toward the sides. The two remaining muscles [*thyroarytenoideus*], having both an action and position opposite to these four [*cricoarytenoidei, posterior* and *lateralis*], accurately close the upper orifice of the larynx by pulling in toward the inner space the first [thyroid] cartilage, as a purse is drawn shut by the large number of sinewy membranes which surround it. These, then, are ten of the [twelve, [I, 405]
intrinsic] muscles I mentioned which are common to the three cartilages. The other two [*arytenoideus*] lie at the base of the arytenoid cartilage, and they are not present in animals with weak voices, of which the ape is one.[88] The other [extrinsic] muscles are much larger than these and involve the thyroid cartilage alone. Two of them [*thyrohyoideus*] grow out from the lower sides of the hyoid bone and are then inserted along the whole length of the first [thyroid] cartilage in front. Two others [*sternothyroideus*] grow out from the cartilage and are directed toward the sternum, uniting

[88] Arytenoideus obliquus is indeed lacking in the rhesus monkey, but arytenoideus transversus is present. See Geist (1933, *198*).

with two others only in those animals whose thyroid cartilage and whole larynx are large.[39] The two remaining muscles are transverse [*constrictor pharyngis inferior*]; they grow out from the lateral parts of the thyroid cartilage, encircle the esophagus, and arrive at the same point.

12. Such is the construction of the cartilages and muscles of the larynx. I should speak next of their usefulness, beginning with the cartilages. Indeed, not without good reason did Nature determine their number and character. Since two kinds of articulations and movements were necessary in them, one to expand and contract, and the other to open and close them, the articulation of the first [thyroid] with the second [cricoid] cartilage was made to perform the first kind of movement, and that of the second with the third [arytenoid] cartilage to perform the second kind. There being no need of a third kind of movement, there was no need of a third
[I, 406] articulation or, consequently, of a fourth part. This is the reason, too, why the muscles common to the three cartilages are ten in number. The first two [*cricothyroideus, pars recta*] I mentioned connect and close the front parts of the large cartilages of the larynx; the next two [*cricothyroideus, pars obliqua*] close the inward parts. Four [*cricoarytenoidei, posterior* and *lateralis*] of the other six open the arytenoid cartilage; and the remaining two [*thyroarytenoideus*] close it. Assisting these there are in most animals two transverse muscles [*arytenoideus*], which are joined to one another and hold together the base of the third [arytenoid] cartilage.

All these muscles are contained in the larynx and are not attached to any of the adjacent instruments. The other eight muscles[40] that connect the larynx to other bodies in the vicinity control another movement by which the whole passageway for the air is widened and contracted. Those [*thyrohyoideus*] that descend from the

[39] "The m. sternothyroideus [of the pig] orginates . . . at the manubrium of the sternum; about midway of its length there is a transverse, tendinous stripe, and from this point on, the muscle divides into two limbs, one of which ends at the caudo-dorsal, the other at the cranioventral, part of the lateral surface of the thyroid cartilage" (Ellenberger and Baum [1926, *388*]).

[40] The eight are: thyrohyoideus (2), constrictor pharyngis inferior (2), and the two limbs (in the pig) of sternothyroideus (4).

hyoid bone pull the first [thyroid] cartilage forward and up and thus draw it away from the cartilages at the rear and enlarge the passageway. The muscles [*sternothyroideus*] which are placed and act in opposition to these extend obliquely from the thyroid cartilage to the parts below; they press upon the lower parts of the cartilage and draw it gently downward, while at the same time the rough artery is compressed and constricted, so that it is not folded to any extent, or wrinkled, or widened too much when the animal wishes to use its voice. The remaining [two] muscles [*constrictor pharyngis inferior*] grow out from the side of the thyroid and [I, 407] compress these parts of the first cartilage, folding it around the second [cricoid], so that the passageway is narrowed.

I have demonstrated all these things in my treatise *On the Voice*. At the present time, however, as I have already said very frequently, it is my purpose to explain not actions but usefulness to those who already have an understanding of actions. Now when parts act, their usefulness straightway becomes evident at the same time, and anyone who is explaining usefulness need only mention their action. But for those parts which perform no action manifestly useful to the animal as a whole (for this is how you should always understand usefulness) but which subserve parts that do have such an action, I must give in this treatise an explanation in greater detail; for this is its special purpose. The muscles, then, and the nerves act, and all the other parts of the larynx, each with its own particular usefulness, are moved by them.

13. I have finished my discussion of the muscles and cartilages of the larynx; let us speak next of the other parts of it. In its inner chamber, through which the air passes in and out, there is a certain body [*glottis*] [41] which I mentioned a little earlier as having a substance and shape unlike anything else in the whole body. I have also described this part in my book *On the Voice*, where I showed that it is the first and most important instrument of the voice, and I shall tell as much about it here as is necessary for my present

[41] The whole inner structure of the larynx comprising ventricular folds, ventricles, and vocal folds is called γλωττίς by Galen. I have used a transliteration of his term because there is no sufficiently inclusive modern name for this entire assemblage, but I have indicated by italicizing that I do not mean by it what is now meant by "glottis." See Hyrtl (1880, *244–245*).

[I, 408] purpose. It resembles the tongue of a pipe,[42] particularly when viewed from above or below. By below I mean where the [rough] artery and larynx are joined together, and by above, the orifice formed by the upper ends of the arytenoid and thyroid cartilages. Instead of comparing this body to the tongue of a pipe, it would perhaps be better to compare the tongue of a pipe to this body; for indeed I think Nature is prior in time to art and acts more wisely.[43] Hence, as this body is a work of Nature's and the tongue of a pipe is an invention of art, the pipe's tongue may then be an imitation of this body, invented by some clever man capable of understanding and imitating the works of Nature. It is an obvious fact that a pipe is useless without its tongue, and you should not require me to give the reason in this treatise, since I did so in my work *On the Voice*, where I also plainly demonstrated that the voice cannot be produced unless the passageway is narrowed. I said that while the whole passageway is expanded to its greatest extent, while the first two cartilages [thyroid and cricoid] are relaxed and stand apart from one another and the third one [arytenoid] lies open, no voice can ever be produced; that if the air passes out gently, expiration is accomplished without a sound; that if the air passes out suddenly and violently, the sound called a sigh[44] is produced; and that for the animal to make a sound it does indeed absolutely require a sudden
[I, 409] blast of air from the parts below, but it requires just as much a narrowing of the passageway in the larynx, and not a simple narrowing at that, but a gradual change from a wide passageway to a narrow one which then gradually grows wide again.

This is exactly what is accomplished by the body now under discussion, which I call *glottis* and tongue of the larynx, the body of which is necessary not only to the production of the voice by the larynx, but also to the act called holding the breath. This term is applied to the occasions when we do not breathe but also to those when we contract the thorax from every side and at the same time

[42] Hyrtl (1880, *245–246*) describes an ancient type of pipe or flute with a mouthpiece containing two small, tongue-shaped, somewhat concave strips of wood facing each other across a lancet-shaped slit. Obviously Galen had some such instrument in mind.

[43] An idea not original with Galen; see, for example, Aristotle, *Physica*, II, 3, 194a21–22, and *Meteorologica*, IV, 3, 381b6.

[44] Reading ἆξαν with Helmreich for the στενάξαν of Kühn's text.

vigorously tense the muscles situated in the region of the hypochondrium and the ribs. The action of the muscles of the whole thorax and of those that close the larynx is then very forceful. In fact, the latter in closing the arytenoid cartilage vigorously oppose the air that is being pushed out, and in this work the nature of the aforesaid *glottis* is of considerable assistance. For the parts of the *glottis*, both left and right, come together in such a way that they fall accurately the one on the other and close the passageway. If a small portion [*glottis respiratoria*] is left open, as in those animals especially whose whole larynx is rather broad (and I have shown that this is so in animals with loud voices), it is not an instance of neglect on the part of an improvident Nature; for she has made an aperture at each side of the *glottis* and placed an inner cavity [*ventriculus laryngis*] of considerable size below each aperture.[45] [I, 410] When the air enjoys the use of broad passageways to enter and leave the body, none of it is thrust aside into these cavities. But when the passage is obstructed, the confined air is thrust laterally with violence and opens the orifice [entrance to the ventricle] of the *glottis*, which has hitherto been closed by the folding over of its lips [vocal and ventricular folds of the same side].[46] This very thing—I mean the folding over of the lips—is the reason why the orifice in question has escaped the notice of all anatomists before me. But when the cavities [ventricles] of the tongue of the larynx [*glottis*] have been filled with air, the mass of them of course necessarily spreads out into the passageway for the air and closes it completely, even though it was previously only slightly open.

This skill of Nature's in her treatment of the tongue of the larynx [*glottis*], its general shape, its size and position, and its apertures and cavities has achieved the height of accuracy. If you should contrive a larger *glottis*, you would obstruct the air passages just as they are usually obstructed in inflammations, but if it were made smaller and

[45] This description is one more piece of evidence leading to the conclusion that Galen is basing what he has to say on conditions in the pig, where, according to Ellenberger and Baum (1926, 505), "each vocal fold is divided . . . into a stronger, oral limb and a weaker, caudal limb. Between these there is a long slit from which a small, round opening leads into the large laryngeal ventricle that extends as far as the ligamenta ventricularia."

[46] Or in the pig perhaps these might be the two limbs of the vocal folds.

fell much short of average size, the animal would be entirely mute. If it lacked only a little of the proper size, the animal's voice would be weaker and less agreeable to the same degree that the *glottis* fell below the average size. Similarly, if you alter its position or the size of the aperture [entrance to the ventricle] or of the cavity [ventricle], you will destroy its whole usefulness. For example, there is an aperture on each side, as I have said, and it is elongate
[I, 411] from above downwards and like a thin line, although it is not really narrow. The membranous substance of the lips,[47] however, falls back, so to speak, into the underlying cavity and so the aperture appears more like a wrinkle before the lips are spread open. But when the lips are open, both the aperture and the cavity lying beneath it immediately become clearly visible. Since this is the character of each aperture, situated the one on the left and the other on the right,[48] the air flows past them, having no occasion to open the orifices or fill the cavities. On the other hand, when the air is forced violently up from below and is checked from above, since it is no longer able to go forward, it experiences a sort of whirling motion and turns toward the sides of the passage. It strikes violently against them, easily turning the membranous outgrowths of the openings into the underlying cavities toward which they naturally incline, and filling and inflating the whole *glottis*. Thereupon the passage necessarily closes completely.

The actual substance of the *glottis* was made membranous in order that when filled with air it may not rupture, but may yield to opposite conditions of the larynx as a whole and run no risk of rupture when the larynx either widens or contracts. This substance is not simply moist, but at the same time somewhat sticky and greasy, in order that it may at all times be wet with the moisture appropriate to it and may not stand in need of outside help, like the tongue of a pipe which is continually drying out and needing addi-
[I, 412] tional moisture. For a thin, watery liquid, being quickly resolved into vapor, is easily dispersed and immediately flows off, particularly when the channel is sloping, but a sticky, greasy liquid lasts for a

[47] Again the ventricular and vocal folds of each side, or in the pig perhaps the two limbs of the vocal folds.

[48] Or, "Since this is the character of each aperture, the air flows past on the right and left." Daremberg (in Galen [1854, I, *496*] and Kühn both prefer this.

long time, since it does not readily flow off or dry out. Hence, even though Nature had constructed the larynx admirably in all other respects, if she had neglected only to provide a moisture of this sort, our voices would be ruined because the *glottis* together with all parts of the larynx would quickly dry out, a condition which is actually liable to occur only on the rare occasions when Nature's governance is vanquished by violent causes. For persons with high fevers and those who have passed through blazing heat cannot speak aloud without moistening the larynx.

14. I have now said enough about the tongue of the larynx [*glottis*]. I return once more to the muscles moving the larynx, particularly to those [*thyroarytenoideus*] that close it, the subject from which my discussion has just now been digressing. Whoever stops to think will find it amazing when he considers the size and number of the muscles that contract the thorax; for to oppose them all there are the two small muscles [*thyroarytenoideus*] that close the larynx, though the *glottis* assists them, as I have shown. The Creator of animals has displayed here too an extraordinary skill, which, like almost everything else in the structure of the larynx, is unrecognized by anatomists. For the muscles closing it [I, 413] [*thyroarytenoideus*] arise from the middle of the base of the thyroid cartilage and extend straight, sloping upward, backward, and to the sides so as to arrive near the articulation of the third [arytenoid] cartilage [with the cricoid]. It is perfectly clear, then, that their heads are the ends at the thyroid cartilage and that the posterior extremities are the ones by which they move the arytenoid cartilage.

In all muscles, of course, the nerve conveying the faculties of sensation and motion from the encephalon or spinal medulla is inserted either into the head of the muscle itself, or at least into some part close under the head and certainly not beyond the middle of it. No nerve is inserted into its farther extremity; for if this should happen, that point would become the head and not the farther extremity. Nerves like those of the diaphragm that are inserted into the middle of a muscle and distributed from that point to all parts of it draw all the fibers toward the center, thus making the center the head of the muscle. Moreover, it is a characteristic common to all muscles that the nerves when divided in them extend in the same direction in which the muscle fibers act.

Now if you have an accurate understanding of all that I have said,

I think you will be persuaded that in the case of the muscles [*thyroarytenoideus*] closing the larynx the nerve to be inserted into them must necessarily come from the parts below them. I think it also just as necessary for nerves from below to enter the other two pairs of muscles [*cricoarytenoidei, posterior* and *lateralis*] that open the orifice of the larynx. For the origins and heads of these too are below, and their extremities, by which they close[49] the arytenoid
[I, 414] cartilage, are above. But the nerves for the two muscles closing the larynx certainly ought not to be of the same size or power as those for the muscles opening it, since the former are the ones that oppose all the muscles of the thorax when the breath is held. On the other hand, the work of the four muscles [*cricoarytenoidei, posterior* and *lateralis*] is not without an object, for they yield a ready obedience to the muscles of the thorax by providing an easy passage for the air strongly forced out by these muscles. This can be provided, however, even without the concurrence of the muscles, by the force of the flow, the third [arytenoid] cartilage being easily turned back because it is so small. Hence for the muscles [*thyroarytenoideus*] closing the larynx the strength of the action also makes it necessary that the nerves should be sent into them from below in a straight line with their origins, in order to exert traction on the arytenoid cartilage through the intervening muscles.

Now if the heart were the source of the nerves, as some[50] think

[49] Galen must have meant to write "open" here instead of "close." The sense calls for "open"; he has just said, and he has expressly stated earlier, that cricoarytenoideus "opens" the arytenoid cartilage; and κλείουσι can readily be accounted for as an error on the part of a scribe whose eye was caught by the other κλείουσι two lines below.

[50] Aristotle, for example; see *Hist. an.*, III, 5, 515a27–34. Galen devotes a large part of the first book of his *De placitis Hippocratis et Platonis* (Kühn, V) to an elaborate refutation of this doctrine.

The following description of the discovery of the recurrent laryngeal nerves and their function is a classic. In his splendid article, "Galen's Discovery and Promulgation of the Function of the Recurrent Laryngeal Nerve," Walsh (1926, *183*) says that he has no doubt that it embodies the actual lecture given by Galen and taken down stenographically on the occasion when he demonstrated publicly the structure of the larynx, the muscles moving it, and their innervation. As for the importance of the discovery, Walsh (*ibid.*, *179*) says, "This discovery established for all time that the brain is the organ of thought, and represented one of the most important additions to anatomy and physi-

who know nothing of what is to be seen in dissection, it would readily move these six muscles [*thyroarytenoideus* and *cricoarytenoidei, posterior* and *lateralis*] by sending nerves directly into them in a straight line, but this would confront us with the same difficulty in regard to the other muscles, which have their heads at their upper ends and are inserted at their lower ends into the parts which they move. Actually, however, since every nerve obviously takes origin either from the encephalon or from the spinal cord, all the other muscles in the vicinity of the head and neck are easily moved. For nerves from the encephalon are manifestly inserted into muscles which extend from above downward, and nerves from the cervical region of the spinal medulla and from the seventh pair [*n. hypoglossus*] are inserted into oblique muscles, since the seventh pair also grows out obliquely.[51] The other six muscles [*thyroarytenoideus* and *cricoarytenoidei, posterior* and *lateralis*], of which I have spoken before, could not receive nerves from either of these sources; for inasmuch as they extend straight along the length of the larynx from its lower parts upward, they had no need at all of oblique nerves. They could not receive straight nerves from the heart and could receive them from the encephalon [only] if they followed a reversed route. Thus, these were the only ones of all the muscles that ran no small risk of being without nerves to supply them with sensation and motion. [I, 415]

I would not wish to tell how Nature corrected this fault by inventing a clever device unless I first permitted the disciples of Asclepiades and Epicurus to search out the way in which they would have conferred nerves on these muscles if they had been in the place of the Creator of animals; for I am in the habit of doing this sometimes and of granting them as many days or even months as they wish for deliberation. One cannot do so, however, when writing a book and cannot compare the wisdom of these gentlemen with Nature's lack of skill or show how the Nature they rebuke for being unskillful is so much more ingenious than they are with all their

---

ology, being probably as great as the discovery of the circulation of the blood. If he never did anything but this he would deserve a place beside Erasistratus, Herophilus, Vesalius, Harvey and Virchow." See also my Introduction, pp. 63–64.

[51] For the list of the cranial nerves according to Galen's scheme, see note 20 of Book IX.

cleverness that they are unable to conceive of the skill with which she works. Hence I find it necessary to tell now about the devices Nature has employed in order to give the muscles in question their share of nerves and motion.

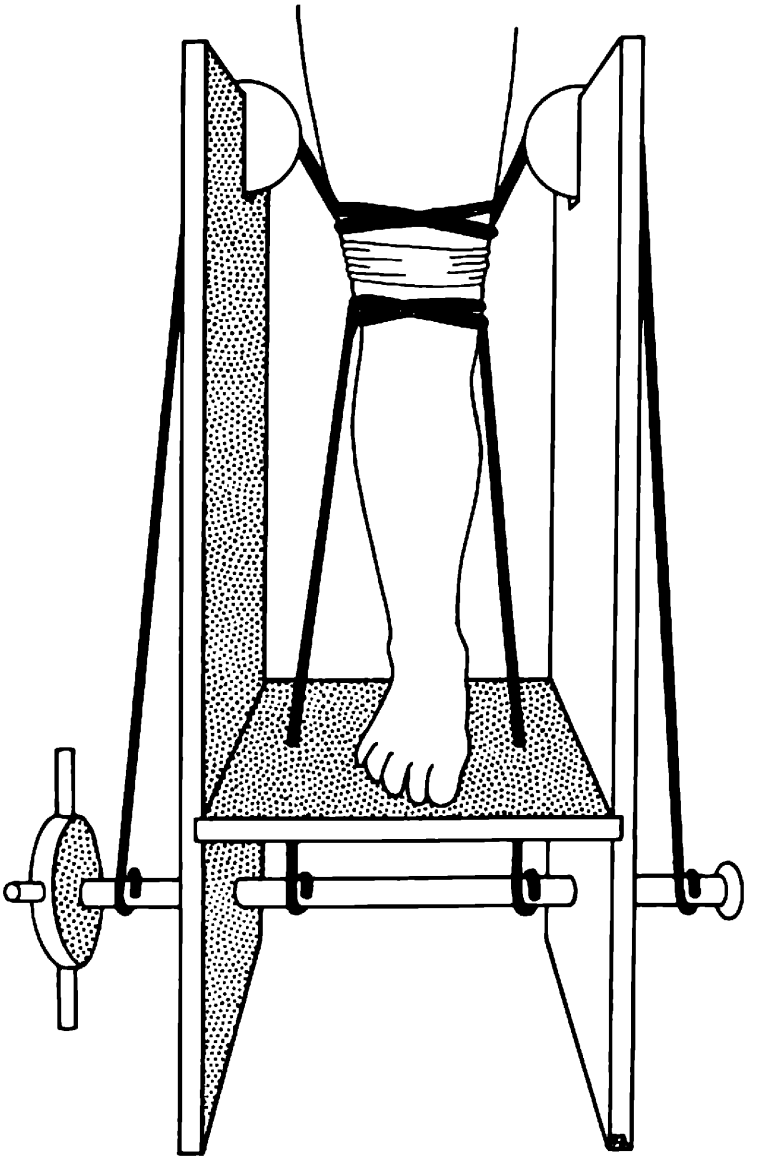
In order that my discourse may be clear, you must first under-
[I, 416] stand this reversed motion, which is made use of in many devices both by those architects called engineers (*μηχανικοί*)[52] and by those physicians called technicians (*ὀργανικοί*).[53] For this is the sort of motion that Nature, who is prior to these arts, has used to provide action for the muscles. Probably someone among my readers already understands the method of producing reversed motion and so will perhaps be irritated by my stopping to discuss it, being eager to learn at once the clever device which Nature has used in this instance to provide suitable nerves. But of course this discussion is not aimed at being clear to one person only, or to two, three, four, or any definite number of persons; rather it aims to instruct in orderly fashion all who concern themselves with it. Hence, for the sake of the many who do not know what reversed motion is, the few [who do] must wait a little and allow me to explain the idea of it as exemplified by a common device familiar to most physicians and called by them the instrument *glossocomion* (box splint).[54]

It is long in order to accommodate the whole human leg, like other instruments customarily and frequently used for [reducing] fractures of the femur and tibia. These are the special parts of the device *glossocomion:* At the lower end is a roller to which extend the ends of the cords encircling the member, and in the instrument

[52] See Daremberg's note (in Galen [1854, I, 500]).

[53] That is, surgeons, the users of instruments (*ὄργανα*), as distinguished from other types of physicians, who practised internal medicine.

[54] The primary meaning of *glossocomion* is a case to hold reeds for musical instruments. Galen (*Hippocratis de fracturis liber et Galeni in eum commentarius*, II, 64 [Kühn, XVIII, pt. 2, 502–506]) says that the Athenians gave the name *glossocomion* to a filing case for their papers and to luggage taken on a journey, but that the *glossocomion* of which he is speaking, the box splint, must of course be longer and narrower than ordinary ones. It was, in fact, little wider than the leg to be inserted in it. The description given there tallies nicely with the one here in *De usu partium.*



The glossocomion

itself are several pulleys, each for its proper use as the case requires. This is how it is operated: When the limb has been carefully bandaged in the customary manner for fractures, a noose is placed around it on each side of the break, one around the upper part of the member and another around the lower part. The noose most suitable for this purpose is one consisting of two continuous pieces; [55] indeed, noose made of two continuous pieces is the old name for it. Some [I, 417]

[55] Accepting Helmreich's emendation, *διανταίων*, for the *διαντέων* of Kühn's text. The emendation is made on the strength of the parallel passage cited in the preceding note. One of the two continuous pieces is above the fracture, the other below it.

call it the wolf, because such a noose has four legs, so to speak. Now of course this makes two legs on the right side of the limb and two on the left, and it is better to carry those of the lower noose directly to the roller and fasten them carefully around it so as to draw the broken member downward, whereas those of the other noose, the upper one[56]—for I suppose this must stretch the member in the opposite direction to the first one—should of necessity be carried up, passed outward, placed over the pulleys, and then brought down and fastened to the roller. Thus it comes about that since the ends of both nooses have a common axle, they produce the proper extension of the broken limb, because both are tensed and relaxed in the same way, being controlled by the turning of the roller. The legs of the lower noose are subjected to a single tension, those of the upper noose to a double one, since the path from the lower noose is a
[I, 418] straight line, while that from the upper one is bent in a double course.[57]

Nature was the very first of all to devise this double course, [using it] for the nerves coming down through the neck from the encephalon above and thus providing a reversed motion for the muscles in question; for of course they had to receive their nerves either from the cervical region of the spinal cord or from the encephalon itself. Now since the origin from the cervical region must be oblique, it was most necessary to avoid this and choose rather the better one of the upper origins. There are two of these, one perfectly straight, which Marinus[58] counts as the sixth pair [*n. vagus*] and the other, the seventh pair [*n. hypoglossus*], which is not straight; the seventh would be of no use at all to straight muscles, and although the sixth might be useful insofar as its course is straight, it would be not only

[56] Omitting τὰ σκέλη εἰς τάναντία τῷ ἄξονι ἄγεσθαι, bracketed by Helmreich.

[57] A double course (δίαυλος) was a course which turned a goal at its mid-point and brought the runner at the finish back to the starting point.

[58] For the anatomist, Marinus of Alexandria, who flourished about the beginning of the third century of the Christian era, see Sarton (1927, I, *281*) and Singer (1957, *45–46*). Galen mentions him several times and always with respect. See in particular *De anat. admin.*, II, 1 (Kühn, II, *280, 283;* Galen [1956, *31, 32*]; *ibid.*, XIV (Galen [1906, II, *167–168;* 1962, *183–185*]); *De musc. diss.* (Kühn, XVIII, pt. 2, *926;* Galen [1963, *477*]); *De plac. Hipp. et Plat.*, VIII, 1 (Kühn, V, *650*); and see also my Introduction, pp. 31–34.

useless but also actually injurious because it comes from the opposite direction. For if, having such a course, it were inserted into the muscles under discussion, it would make their upper ends the heads and their lower ends the extremities—and I have shown that the opposite arrangement is necessary.

I want you now to pay me closer attention than you would if you were being initiated into the mysteries of Eleusis or Samothrace or some other sacred rite and were wholly absorbed in the acts and words of the hierophants. You should consider that this mystery is in no way inferior to those and no less able to show forth the wisdom, foresight, and power of the Creator of animals, and in particular you should realize that I was the very first to discover this mystery which I now practise. Certainly no other anatomist has known about any of these nerves or about the things of which I have [I, 419] spoken earlier in the construction of the larynx, and this is the reason why they have erred so greatly in determining actions and have not told a tenth of the utilities of the parts. Accordingly, even if you have not done so before, fix your mind now on holier things, make yourself a listener worthy of what is to be said, and follow closely my discourse as it explains the wonderful mysteries of Nature.

At the back of the encephalon there is a straight outgrowth of nerves [*n. vagus*] which passes down the whole length of the neck, and there is another, small nerve joined to it on each side of the rough artery.[59] With the exception of these six muscles [*thyroarytenoideus* and *cricoarytenoidei, posterior* and *lateralis*] which I am discussing, the other muscles of the larynx and certain other straight muscles in the neck receive branches from this outgrowth, some large and some small. Even though this sixth pair of nerves gives off a great many branches to these muscles, nevertheless, since it is very large, no small portion of it traverses the whole [length of the] neck and descends into the thorax. Here it immediately gives off to the thorax itself the first pair of nerves [sympathetic trunk?] extending along the roots of the ribs and then other branches, some to the heart, others to the lung, and still others to the esophagus. Now if I should go over with you all the offshoots which these nerves distribute as they pass downward to the stomach, liver, and spleen and which they bestow on all the parts in their path

[59] In ruminants and in the pig the cervical portion of the sympathetic trunk is enclosed with the vagus in a sheath. See Ellenberger and Baum (1926, *909*).

[I, 420] like a most generous giver, I think you would be surprised that no branches are given off from them to the six muscles of the larynx, although they pass close by in their course through the neck and do provide a nerve for some of its[60] muscles. But I have already shown earlier that these muscles [of the larynx] ought not to receive their nerve in a downward direction, and I shall now explain to you that, far from forgetting the six of them, the Creator has assigned them a portion of sufficient size from these same large nerves that pass them by, and that thus they too are given their share of sensation and motion.

Attend carefully to my discourse as I attempt to explain to you a matter well nigh impossible to express and scarcely demonstrable. You will also make considerable allowance for anatomists before my time if a spectacle so difficult to see has escaped their sight. As the [vagus] nerves pass through the thorax, a branch [*n. recurrens*] is given off by each of them and returns upward, following the same route by which it has just descended, thus running a double course, as it were. I want you to think again of the reversed motion of which I spoke a little while ago and remember too the runners in the double course; for the route of the nerves resembles both of these things, reversed motion because the source of the nerves is attached to the encephalon, and when the will chooses to tense the muscles of the larynx by reins, so to speak, the motion travels down from this
[I, 421] source above through the whole neck to a point well down in the thorax, where it turns upward again as far as the larynx. Here, the nerves being inserted into the six muscles in question, each one of them is drawn downward as if by hands. Just as in the instrument for the leg [the *glossocomion*] the source of the movement, which lies in our hands on the roller, draws on the legs of the noose as far as the pulleys, and from the pulleys the motion travels from above downward again to the part of the leg to be stretched, so the nerves of the larynx behave in the same way. The roller which receives the source of the motion is in this case represented by the outgrowth of the nerves from the encephalon; the pulley, by that part of the thorax where the nerves begin to turn back. But if you compare

[60] "Its" is no more ambiguous here than the Greek equivalent, *αὐτοῦ*, which may refer either to *τοῦ τραχήλου*, the neck, in which case the nerve would be the pharyngeal branch of the vagus, or to *τοῦ λάρυγγος*, the larynx, in which case it would be the superior laryngeal.

their path to the double course, you will speak of that part not as a pulley but as what we call the turning-post, around which the runners of the long race turn in a circle to run again in the opposite direction the same course which they have just finished.

Now the reason why the nerve does not turn back sooner, although it traverses such a long path through the whole neck and a not inconsiderable part of the thorax besides, is that it had no part which could serve it as a turning-post or pulley. Such a part had to be firm and smooth in order to make the passage over it safe both for the nerve and for itself, but in the interval [between the larynx and the thorax] there was no such part other than the clavicle and the [I, 422] first rib where there was a membranous covering and where the nerve could possibly be conducted around the convexity of the bones as if they were pulleys. Here, however, it would lie exposed, close under the skin and easily harmed by every mischance. Moreover, it would not be safe for a small nerve growing out from the large one to turn back in this way toward the larynx without a turning-post; for with nothing to wind itself around, it would certainly be broken off. If, then, it had to wind around something and there was nothing suitable before it reached the vicinity of the heart, [Nature] properly did not hesitate to conduct the nerve down for a long distance, even though it must turn back again over much of the path. Now this did not make the nerve weaker; quite the contrary, because, though all nerves are soft and resemble the brain itself when they first grow out from it, they become harder and harder as they proceed. Consequently, these nerves too derive no little strength from their long journey, when, after turning, they are conducted up again almost as far as they have already been conducted down.

15. It is time now to speak of that wonderful part which may fitly be called either the pulley, turning-post, or goal for the nerves of the larynx. For at present it is not my purpose to go hunting for beauty in names or to waste time over trifling, insignificant matters when I am seeking to discover such great and noble beauty in the works of Nature. There are, of course, in this region large veins and arteries [I, 423] leading from the heart up to the neck. Some of these are vertical and some oblique, but none is transverse as a turning-post for the nerves should be. For a nerve coming down from above would never turn around a vertical vessel, since nerve and vessel would come to their meeting from opposite directions. It is in some measure possible for

the nerve to wind around an oblique vessel, but it would be easily dislodged and unstable, most particularly so when the obliquity is far removed from the transverse position and approaches the vertical. I confess myself unable to praise as they deserve the wisdom and power of the One who has created animals. Greater not only than commendation but even than hymns of praise are works such as these; before we see them, we are convinced they are impossible, but when we have seen them, we realize that our understanding was deficient, especially when with very little trouble and by the use of only one little instrument their Creator has produced such an absolutely perfect, flawless work as we can see in the turning-post for these nerves.

For Nature did not hesitate to produce the left [recurrent] nerve for a long distance and wind it around the largest artery [the aorta] right at that point where this first issues from the heart and turns down along the spine. The nerve would thus have everything of which it stood in need, a smooth, round turning-post in a transverse position and a goal that is very strong and secure. The [recurrent]
[I, 424] nerve on the right side, however, having nothing of the sort to rest upon in its part of the thorax, was compelled to wind around the oblique artery [*a. subclavia dextra*], which in that region leads up from the heart to the right axilla. Whatever disadvantage there was in not turning around a transverse artery was overcome by the large number of the outgrowths of the [vagus] nerve on either side and by the strength of the ligaments. In fact, all the nerves [thoracic branches of the vagus] which Nature had to send out into the right side of the thorax she produced right in this region and implanted them in the instruments receiving them as if she were rooting the nerve like slips in the ground. So she placed that [recurrent] nerve for the larynx in the midst of all the roots to protect it with them on both sides, and she bound it with membranous ligaments to the artery and to adjacent bodies in order that, being limited so to speak by these, it might turn safely around the back of the artery as if it were winding around the wheel of a pulley.

When immediately after the turn these nerves are mounting straight upward, the large nerve extends to them an outgrowth,[61] as

[61] The large nerve mentioned here is certainly the vagus itself; for in chapter 4 of Book XVI he mentions this helping hand extending to the recurrent nerve again and says that it comes from the "sixth" pair. Since

if reaching out a hand, and by means of this it draws and pulls them up. From that point, by the same route that they followed earlier, both [recurrent] nerves pass upward to the head of the rough artery without giving off even the smallest branch to any muscle, because there is none that needs to receive another source of movement from its lower side.[62] Instead, each nerve is distributed accurately and justly to the muscles of the larynx on its own side, the one on the right to the muscles of the right side, the one on the left to the other three muscles, both taken together being distributed to the six muscles [*thyroarytenoideus* and *cricoarytenoidei, posterior* and *lateralis*] by which it happens that the larynx is opened and closed. In particular, as I have shown, the strongest action of any of these six muscles is that of the two [*thyroarytenoideus*] that close the larynx, in order that when we hold our breath [63] they may not be overcome by the numerous, powerful muscles contracting the thorax, and the larger part of the nerves is accordingly distributed to these two. Moreover, a firm nerve [*n. laryngeus superior*] passing down from above along each muscle reaches the same point at their extremities, and bodies [epiglottis, base of the tongue, etc.] in the vicinity of the larynx receive parts of it; but the rest [filament from internal branch of superior laryngeal nerve] is attached to the muscle's own nerve [*n. recurrens*] and contributes to its strength and security. [I, 425]

16. I suppose, then, that your admiring curiosity will no longer be aroused by the things which aroused that of all physicians and

---

no mention is made of it in *De nervorum dissectione* and no further light is ever shed on it either here or in *De anat. admin.*, XIV (Galen [1906, II, *189;* 1962, *207*]), where it is described once more, I have been unable to determine what may have misled Galen. Neither Daremberg (in Galen [1854, I, *507*]) nor Simon (in Galen [1906, II, *344*]) has a satisfactory explanation. The former suggests "the superior cardiac nerves, or perhaps the anastomotic branch"; the latter says that it may be "certain connecting twigs which Galen had seen at the point of reflection, going from the recurrent to the vagus." I cannot find these connecting twigs described elsewhere. Dr. Charles Goss, however, tells me that "the vagus in the neck of a pig in a recent atlas is labelled vagosympathetic trunk. This gives ample opportunity for communicating fibers." Cf. Ellenberger and Baum (1926, *874*).

[62] As Daremberg (in Galen [1854, I, *508*]) intimates, Galen is being ridden by his own theory here. The recurrent nerve does, of course, give off various branches as it ascends.

[63] *Vide supra*, pp. 358–359.

philosophers before me, who wondered how it happens that the liquid we drink falls not into the rough artery but into the esophagus and who gave the motion of the muscles at the root of the tongue as
[I, 426] the cause, supposing that these muscles make the larynx rise up against the epiglottis. Since the larynx closes so accurately that the breath violently forced out by the thorax does not open it, we need seek no other reason why the liquid we drink is not carried into the lung. It would have been more natural for my predecessors, when they saw that the orifice of the larynx must have a cavity [vestibule of the larynx] because of the shape and usefulness of the *glottis*,[64] as I have shown in my book *On the Voice*, to think that when we swallow, the food and drink would accumulate there, so that the next time the larynx opened in inspiration, not only the liquid but even the solid food would straightway fall into the canal for the air. They should have thought too that this was the reason why provident Nature placed the epiglottis before the orifice of the larynx as a lid, to stand erect during all the time when the animal breathes and to fall down upon the larynx when anything is swallowed. For what is swallowed first falls upon the root of the epiglottis and then is carried along its back, thus forcing it to bend and fall down because it is made of cartilage, and very thin cartilage at that.

If you look closely at the whole construction of the epiglottis, I am sure you will think it wonderful. It is rounded, cartilaginous, and
[I, 427] a little larger than the orifice of the larynx; it faces toward the esophagus, having a position opposite the third (arytenoid) cartilage, and obviously it would not be so situated if it did not grow out from the opposite side. Moreover, if it were not cartilaginous, it would not open during respiration or be turned back by the food. For bodies softer than necessary would be forever falling down; bodies that are too hard are difficult to turn back; and neither of these things should happen to the epiglottis, which must be erect during inspiration and turned back when we swallow. Even if it had these qualities, however, but was smaller than the opening of the

[64] Reading γλωττίδος with Helmreich for the ἐπιγλωττίδος of Kühn's text. It will be noted that in the following explanation of the closing of the epiglottis Galen is attributing it solely to mechanical factors and neglecting the action of arytenoideus, arytenoepiglottideus, and thyroarytenoideus, thus missing the truth by fully as much as the predecessors whom he is criticizing. For a fuller presentation of his position, see *De anat. admin.*, XI (Galen [1906, II, *93–95*; 1962, *101–104*]).

larynx, nothing advantageous would be accomplished by its falling down, and this would also be true if it were much larger; for in that case it would block the esophagus as well. Now food makes the epiglottis sink down onto the opening of the larynx, and material that is vomited affects the arytenoid cartilage in the same way. For this cartilage too faces toward the open space in the larynx, so that the rush of material up from the esophagus, falling upon its dorsal surface, easily turns the whole cartilage back into the unresisting open space.

17. At this point you should subject the construction of this [arytenoid] cartilage to the same scrutiny that we gave to the one I have been discussing just now,[65] that is, the epiglottis. For it is evident that if the size [of the arytenoid cartilage] were not what it actually is, if its shape and substance were different, and if it were [I, 428] not situated as it actually is, considerable material would accumulate near the cavity of the larynx and be carried down into the rough artery when we vomit. As it is, however, Nature has constructed for the larynx these two wonderful lids, which are closed by the very materials which they prevent from falling into it; for she has contrived here something very like the device I described earlier, the membranes [valves] at the orifices of the heart. But just as in speaking of them I mentioned that Nature made an outgrowth of that character not in order to prevent all material at all times from entering the orifices it encounters, but to prevent a large quantity from entering all at once, so in this case too I should mention what I demonstrated in my book *On the Teachings of Hippocrates and Plato*,[66] namely, that a little of the liquid we drink is carried down into the rough artery, being applied to the tunics at its periphery, not passing through the middle of its free space, and that there is just enough of this liquid to be taken up at once and moisten the whole lung. Furthermore, the glands [salivary, thyroid, thymus] adjacent to the larynx give indication of the truth of this same idea; for they are more spongy than other glands, and nearly all anatomists agree that Nature created them to moisten all parts of the larynx and pharynx. Hence it would be surprising if, having constructed them to [I, 429] moisten these parts, she should altogether exclude the liquid we drink from the passageway leading to the lung. All I have said, then,

[65] Reading μικρῷ with Helmreich for the μακρῷ of Kühn's text.

[66] *De plac. Hipp. et Plat.*, VIII, 9 (Kühn, V, 713–719), and see also chapter 16 of Book VI, *ad fin.*, of this work.

proves sufficiently that food cannot fall into the opening of the larynx, but is not sufficient to prove that a very small amount of moisture does not slip through. I wished these things which I have demonstrated in other works of mine to be mentioned here also, in order that we may perfectly understand the subject under discussion.

18. Let us turn back again to the remaining uses of the parts that we find appearing in the larynx. I have said earlier that the membranous ligament filling up the sigmoid parts of the cartilages is the one that makes contact between the canals of the esophagus and rough artery, and I have also said that if the [rough] artery were rounded on this side too, it would narrow the passage for the food. Hence in the region of the larynx, all sides of which are cartilaginous, the space for the esophagus is necessarily narrowed. How, then, [does Nature keep] it from being narrowed when food is swallowed? How else than by drawing down the esophagus while the larynx rises up? For they change places in such a way that the esophagus begins in the region of the rough artery and the larynx rises up into the pharynx.

[I, 430] 19. Well, Nature has arranged all these matters wonderfully, and in addition to these, there is also the bone called hyoid (shaped like an upsilon, Y), which in spite of its very small size is useful in a great many very important ways. For from this bone arise most of the muscles of the tongue, also the anterior pair [*thyrohyoideus*] of the muscles of the larynx, of which I have spoken earlier, and certain other long, narrow muscles [*omohyoideus*] extending to the shoulder blades. Besides these, there is another strong, double muscle [*sternohyoideus*] leading down to the sternum, and then there are two other oblique muscles [*mylohyoideus*] that reach to the jaw.[67] The remaining [two (*stylohyoideus*)] are exceedingly small and extend to the roots of the outgrowths [styloid processes] which some liken to a cock's spurs and others to the points of pencils, barbarizing their Greek and calling them styloid.[68] You may if you

[67] If Galen means two on each side instead of a pair, the second would be geniohyoideus. In the rest of the passage, however, he has carefully included the muscles of both sides in his count.

[68] Cf. *De anat. admin.*, XIV (Galen [1906, II, *183*]; translation by Duckworth [1962, *201*]): "Herophilus calls the process of the skull which others call awl-pointed or needle-pointed, and which is a slender

wish call them *graphoid* (pencil-shaped) or *belonoid* (needle-shaped). These last mentioned muscles and those mentioned just before [*mylohyoideus*], by which the hyoid bone is connected with the lower jaw, belong to this part and give it oblique movements that are antagonistic to one another, that is, they draw it in opposite directions. None of the other muscles belongs to the hyoid bone itself, for some [*genioglossus*, *hyoglossus*, and *chondroglossus*] are inserted into the tongue and were formed for its sake, and the double muscle [*sternohyoideus*] that extends to the sternum is opposed to these, since it draws the hyoid bone down again whenever the latter is dragged up too violently by the muscles above. This muscle [*sternohyoideus*], like the hyoid bone itself, protects the thyroid cartilage and is also drawn close along the rough artery and directs it. Moreover, the muscles [*omohyoideus*] that extend to the shoulder blades give them[∞] a motion toward the neck. But this [hyoid] bone, riding upon the convexities of the larynx and haled in many directions by the many muscles of which I have been speaking, is supported as in a sling by these very muscles; for Nature, just in everything, has made the muscles that oppose one another of equal strength. [I, 431]

Since any one of these muscles, particularly those placed in front of the larynx, might possibly be cut through or paralyzed, and since in such accidents there would be danger that the [hyoid] bone would move toward the strong muscle, be rolled away from its central position at the larynx, and turned far to the side, Nature knew it was better not to entrust its balance to the muscles alone, but to construct certain strong ligaments, not incidentally, but in order that they might perform only this one not unimportant work. It seems to me that she was not satisfied with forming the ligaments [*ligamentum hyothyroideum laterale*] at the two sides of the hyoid

---

cartilaginous process, styloid. That is because many people in Alexandria, and many others besides them among the peoples inhabiting the regions of the Orient, who speak bad Greek, call 'styloi' the pens with which one writes upon waxed tablets." Properly speaking, a stylus was a pillar.

∞ "Them" = *αὐτῶν*. Daremberg (in Galen [1854, I, *512*]) expands it as "the hyoid bone and trachea," but Galen means the shoulder blades themselves, as is quite evident from his treatment of omohyoideus elsewhere. See chapter 13 of Book XIII, *ad fin.*, and cf. *De anat. admin.*, IV, 10 (Kühn, II, *470–471*; Galen [1956, *117–118*]).

bone to accomplish this purpose, but made other, cartilaginous outgrowths [the lesser cornua of the hyoid bone] and attached them with round ligaments [*ligamentum stylohyoideum*] to the spurs [the styloid processes].[70] The hyoid bone is also attached with membranes to the larynx [*membrana hyothyroidea*] and epiglottis [*ligamentum hyoepiglotticum*] and with muscles in many animals not only to the epiglottis but also to the esophagus.[71] Besides these, there are at once the supports [*ligamentum stylohyoideum*] attach-
[I, 432] ing it to the head; in some animals these are made more bony and in others cartilaginous, depending on the size of the muscles arising from the bone. And such are the arrangements for the parts of the larynx and the rough artery.

20. Next I should speak about the thorax, though here too I should first remind you of what I have demonstrated in my book *On the Causes of Respiration.*[72] As I have said elsewhere, at the very beginning of this [present] treatise, it is always after the action of the instrument as a whole has first been recognized that one should explain the usefulness of its parts; for the construction of all of them has a single goal, namely, the action of the whole instrument, and obviously anyone is altogether wrong who supposes that he will discover anything valid about the usefulness of the parts before

[70] There is wide variation here and in the next sentence between Kühn's and Helmreich's texts. Even Helmreich's is probably not a completely successful restoration. Note that the stylohyoid connection is called a ligament, indicating that here Galen is reporting conditions in the ape. As he goes on to say, in other animals it becomes cartilaginous or even bony. See Ellenberger and Baum (1926, *78*). Of course, it is also ligamentous in man, but the chances, as we have seen, are only fair for Galen's knowing this.

[71] This is obscure and lends support to the suspicion that the text is corrupt. Perhaps constrictor pharyngis medius, previously unmentioned, may be the muscle attaching the hyoid bone to the esophagus, if one takes into consideration that the origin of the esophagus is higher in animals than in man, though it is hard to understand why Galen qualified his statement with "in many animals." But when he spoke of muscles extending to the epiglottis, he may easily have had in mind hyoepiglotticus, absent in man, but present in the domestic animals, among them the pig, of course. See Ellenberger and Baum (1926, *362, 375, 393–394*).

[72] Kühn, IV, *465–469;* probably only a fragment of a much longer work.

learning that action thoroughly. Well, then, in that treatise [*On the Causes of Respiration*] I have demonstrated the many wonderful devices Nature has employed in the action of the thorax. I have shown that in inspiration some of its parts are moved upward and others downward, and that in expiration those that were earlier moved downward rise back up again, and those formerly elevated return now to their original position. I have shown, too, that there are many sources for the movement of the thorax, that one kind of respiration is unforced and another forced, and that each kind has its own proper muscles. After giving the actions of these muscles, I also demonstrate their usefulness, and I shall give [here] only the main points.[78]

The intercostal muscles do not have longitudinal fibers, as all the others do, but fibers extending crosswise from one rib to the next, and not in any simple fashion at that, as all anatomists before me have thought, but with a slight inclination toward the oblique. Nor do they all have one form, as my predecessors in their ignorance of this too have thought; for one can see the fibers on the inner side placed contrary to those on the outside, and those at the sternum where the ribs are cartilaginous are seen to be contrary to those where the ribs are bony as far as the vertebrae. No one before me has recognized this fact, and certainly not the usefulness of it. I have explained this usefulness in that same treatise and also the usefulness of the articulations of the ribs. I have likewise spoken about the cartilaginous parts of the ribs, the reason why they are so, and what motion they have; for the discussion of these things is closely bound up with the action of the thorax as a whole. Moreover, I have explained the nerves that move all the muscles, demonstrating right at the beginning of my treatment that it would not be better for the nerves to take origin from any other place. But in the sixteenth book I shall speak again of all the nerves, arteries, and veins. [I, 433]

21. I shall explain next those parts of the thorax which have no action of their own, but which are of service to the parts that do act. The proper substance of the diaphragm is muscular, but it has two membranes clothing it, the summit of the peritoneal tunic on its lower side, and on its upper side the bottom of the tunic that lines

[78] For detailed descriptions, see *De musc. diss.* (Kühn, XVIII, pt. 2, *988–991;* Galen [1963, *492*]) and *De anat. admin.*, V, 3–5, VIII, 1–9 (Kühn, II, *491–504, 651–698;* Galen [1956, *127–133, 201–222*]).

[I, 434] the ribs [the pleura]. In fact, this latter tunic covers the whole inner surface of the cavity of the thorax, where it lines the ribs and provides protection for the lung by preventing its striking against the bare bones in the act of respiration. It also lines the parts called intercostal, where it is formed for the sake of the muscles and vessels in that region; for the muscles it is a tunic, as it is for the diaphragm, and for the vessels it provides a support and foundation, so to speak.

Earlier in this present work [74] I have demonstrated that the obliquity of the diaphragm contributes to the elimination of the dry residues, and in my books on respiration I have shown that it is of the greatest help in breathing. Now why did not the diaphragm grow out from the edges of the false ribs, and why instead does a part of them lie above it, extending toward the hypochondrium like a palisade? Or is it not that in likening them to a palisade I have already mentioned their usefulness too? For this palisade protects the diaphragm itself, the liver, and many of the other parts in this region as well. Why has an abundance of cartilage been poured about the end of each false rib? Was it not to protect against injury first and foremost the ribs themselves and through them the underlying parts? For cartilage, when compressed, is not broken or shattered in the least, and hence it was better to make the more prominent parts of the bones of this substance. This is the reason, too, why the so-called sword-shaped (xiphoid) cartilage was caused to grow upon
[I, 435] the end of the sternum. It is obviously a bulwark for the orifice of the stomach, the part of the diaphragm in that region, and even the heart. The reasons why seven of the ribs terminate at the sternum and five at the diaphragm, and why the total number of ribs is twelve will be told when I discuss the vertebrae of the back. You should refer for the reason why the sternum itself is made up of many bones to my discussion of the hand which you will find at the beginning of the second book of these commentaries. The number of the ribs articulating with the sternum tells why it is composed of seven bones; for there is one bone of the sternum for each rib.[75]

[74] See chapter 15 of Book V.

[75] The seven components of the sternum of the rhesus monkey are described by Sullivan (1933, *62*). Vesalius (1555, *114*) gives an account of a sternum composed of seven bones and then adds, "This, to be sure, is the plan of the breast bone in dogs and apes, and when you have

Why should not this wonderful work of Nature's in not making the thorax entirely of bone or entirely of flesh, but alternating bone with muscle in it—and this although the abdomen is made entirely of muscle and the cranium entirely of bone—rank among her very greatest? Indeed, we must give more than passing notice to the fact that, of the three principles [encephalon, heart, liver] governing the animal, Nature surrounded the first with immovable bone without any muscles, the third with muscles only, and the one between the other two with both bones and muscles. Now the encephalon needs no muscles whatever for any purpose because it is itself the source of voluntary motion for all the other parts,[76] and it was accordingly reasonable for the cranium to surround it like an immovable wall. But if any such wall had been formed to encircle the parts in the region of the liver and stomach, where would food and drink be [I, 436] received? Where would the mass of the fetus be kept? And how would the residues be expelled if no muscles were set over them? As for the thorax, if it were made entirely of bones, it would lose all its motion, and if it were made entirely of muscles, these, having nothing to hold them steady, would fall in upon the lung and heart. Hence, both to make plenty of room inside and at the same time to let the whole instrument move, muscles were placed alternately with bones. This immediately makes a great difference in the safety of the heart and lung; for they are now better protected than they would have been if only muscles had been formed. Moreover, how can it be improvident for the bones not to be passive,[77] but to have at each end an articulation by means of which the whole thorax may be moved?

---

compared Galen's description of it with what we have just given, you will agree that this is what he has seen. . . . For, as I can state with certainty, I have never found seven bones in the human breast bone" (*Huiusmodi sane pectoris ossis in canibus & simijs est ratio. quam Galenum spectasse annues, quum ipsius de pectoris osse historiam, his quae modo praelibavimus, contuleris. . . . Numquam enim, quod certo affirmare possim, in humano pectoris osse mihi septena occurrerunt ossa*). Jacobus Sylvius (1555, *83–84*), horrified as usual at such heresy, attempts to defend Galen, but his defense, also as usual, is a weak one.

[76] Reading τοῖς ἄλλοις ἐστὶν with Helmreich for the τοῖς ζώοις ἐστὶ τοῖς ἄλλοις of Kühn's text.

[77] "Passive" = ἀργόν; the manuscripts are unanimous here, but I would like to suggest that Galen perhaps wrote ἄναρθρον, meaning "without joints."

But perhaps someone will say, "What, then, would be undesirable about it if the abdomen should have a similar construction? For if a thorax such as surrounds the heart were placed around it, expansion and contraction would be taken care of in just the same way, and in addition there would be greater safety." The person raising such a question should be taught that it would not be possible for the abdomen to expand and contract very much if bones were placed around the outside of it. If they were, in the first place women could not conceive; then, too, we could not eat enough at any one time to satisfy, and eating would have to be a continuous process like respiration. Now so to need continuous respiration is not at all
[I, 437] improper for an animal living in the air, but if we needed food in the same way, we should be terribly deprived of philosophy and the Muses and should have no leisure for the best things in life. In addition to other considerations, it is characteristic of the benefit we receive from respiration that it does not last for a long time, whereas when we are once filled with food and drink, we have enough to last a whole day and night without discomfort, so that here too Nature deserves our admiration. I think that for the present this is sufficient to explain the parts of the thorax. For if I have omitted any little detail, it will very easily be discovered from what I have said, if only anyone reads carefully my work on respiration.

22. After I have also mentioned the mammae, because these too are placed upon the thorax, I shall bring this present book to a close. Now milk is a residue of useful nutriment and hence in animals in which most of the residues in the upper parts of the body are used up in making horns, teeth of large size, flowing manes, and other structures of the sort, it was naturally impossible for another useful residue to be collected in the region of the thorax. Accordingly, in these animals Nature moved the mammae down from the thorax to the abdomen, so very far down on the abdomen in certain cases as to
[I, 438] be near the hind legs. For multiparous animals she made many mammae, but for those not multiparous, [only] two. In animals in which the residue is not used up in the upper parts of the body, she located the mammae on the breast, two of them if one or two offspring are conceived, and if more, she put two on the breast and others lower down. In man (for to explain man is my present task) the mammae are properly placed upon the breast, first, because this is the most suitable location for them if there is nothing else to

prevent; second, because the breasts, placed one on each side of the part called the sternum, afford additional protection to the heart lying beneath it; and third, because it is possible in man's case for a residue of useful nutriment to accumulate very abundantly in this location.

I must first demonstrate the truth of the first reason I gave, namely, that this situation is the most suitable for the formation of mammae. If they are formed for the sake of the milk and offer this as their first and greatest usefulness to animals, and if milk is a perfectly elaborated nutriment, the mammae must be located in that place where a quantity of milk perfectly elaborated can be gathered together most easily and quickly. Well, what other place than that destined for the mammae in man is more able to enjoy the benefit of the heat which is innate in animals and of which the heart is the source? What part other than the breasts receives blood already elaborated in the arteries and veins? Do you not see that when [I, 439] Nature was bringing the very large vein which is called the cava up through the diaphragm from the liver, she could have made an outgrowth from it to the mammae, but did not do so, even though it was near them? Instead, she conducted it first to the heart, made it traverse the whole thorax, and then, when it was already near the clavicles, made two important venous offshoots [*vv. thoracicae internae*] from it, and along with them two other arterial offshoots [*aa. thoracicae internae*]. All four of them she led down through the whole breast and then inserted them, two into each mamma, planning simply that by such a long path as this the blood would be concocted in the vessels as much as possible. For of course as it goes up it passes by the heart, and on its way back down it encounters the heart again; it is continually agitated by the motion of the thorax and heated during all this wandering by its long stay in a part that is always in motion; and all these circumstances contribute to concocting it completely.

Surely, then, this is the best and most suitable location for the mammae. And among the works of Nature, surely this is particularly admirable, that she manages to make every instrument formed for a certain usefulness to the animal also serve some other purpose. What is more useful or more just than that the mammae, having enjoyed such great benefits from the heart, should make some slight recompense to it, the only recompense indeed which they can make? That [I, 440]

is, they can be an outer, protective covering for it. For they are glandular in nature, and like something made of felt, so that they are a defensive screen for the heart, and at the same time they in their turn warm it, like the woolen mantles we throw around us, which are cold when we put them on but then are warmed by our bodies and a little later warm us in return. In the same way the glandular substance of the mammae covers the heart, is warmed by it, and warms it in return. Since in women the mammae are raised up into a large mass, they provide the heart with both benefits [protection and warmth] to a greater degree than in men, and in addition they are of service to the underlying viscera in the region of the hypochondrium, which are not as warm in women; for it has been shown that the female body as a whole is colder than the male.[78]

As for the third reason I mentioned, namely, that the nutriment of the upper part of the thorax is not used up in making a flowing mane, teeth, horns, or other structures of the sort, abundant residues would of course accumulate in women, so that for this reason too the human mammae have the very best location. In most animals, however, Nature, guarding against a scarcity of nutriment, has of necessity transferred them to the hypogastrium. She saw at once that

[78] The notion that the male is warmer than the female is not original with Galen, being much older. It appears in the Hippocratic corpus, which also, however, contains the opposite statement. One author says that woman has hotter blood than man and is therefore hotter (*De mulierum morbis*, I, 1 [Littré, VIII, *12*, *13*]), but another says that in general males are hotter and drier, females moister and colder, and that this is because men are active and women indolent (*De victus ratione*, I, 34 [Littré, VI, *512*, *513*]). On the authority of Aristotle (*De part. an.*, II, 2, 648a25–31), Parmenides is said to have held that women are warmer than men, whereas Empedocles thought the opposite. But for a discussion of Empedocles' views and a criticism of Galen's citation of Empedocles on this subject in *Hippocratis Epidemiorum VI. et Galeni in illum commentarius*, II, 48 (Kühn, XVII, pt. 1, *1002*), see Longrigg (1964, *297–300*). Aristotle himself believed that the male has a much greater supply of vital heat, which enables him to produce perfect semen, whereas the colder, imperfect female is capable of producing only the imperfectly concocted catamenia. See his *De gen. an.*, IV, 765a34–b35, 766b16–26, and cf. I, 19, 726b30–727a1. Galen elaborates his theory in chapter 6 of Book XIV of this work; cf. *De semine*, II, 4 (Kühn, IV, *623–624*). For a detailed review of the origin and history of the idea of a fundamental difference in temperature between the sexes, see Lesky (1950, *1255–1262*).

in animals the heart had less need of assistance from the mammae; for animals do not stand erect on two feet, as man does, but in every case walk prone, like those that creep, a fact which I have demonstrated at some point in my explanation of the legs. Hence in animals all the parts in the region of the spine are exposed to objects striking [I, 441] them from without and defend the opposite parts, those in the region of the breast and abdomen. Moreover, when the mammae are located on the breast, they persist in the male as well, but not when they are located only on the abdomen, unless the offspring resemble the mother rather than the father, as Aristotle [79] too has observed to be the case in the horse. Why the breasts in the male are not greatly elevated, as they are in the female, is a physical [physiological] problem, and so this is not the place to discuss it, but it can be said here in this present book that, like everything else, this too has been arranged by a Nature that is provident. I shall treat of all these matters again, when I describe in detail the parts pertaining to generation.[80] Since I am discussing the instruments of the pneuma, among which, of course, are the thorax and heart, I have mentioned the mammae also at this time, because they have been placed on the thorax and form a protective covering for the heart. But it will be necessary to speak of them again along with the other parts which are properly called female.

[79] *Hist. an.*, II, 1, 500a30–32; cf. *De part. an.*, IV, 10, 688b30–34.
[80] In Books XIV and XV.

[I, 442]

THE EIGHTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Neck, Head, Encephalon, and Senses]

1. It would be better before explaining all the several parts of the head and neck—for this is the next subject to be treated after what I have been saying—to make a general survey of the members themselves in order to discover for what purpose they have been formed, and this is particularly desirable because there are many animals that have neither or that have only a head. The Carabi (spiny lobsters),[1] Astaki (smooth lobsters), Paguri,[2] and Carcini have neither, and fish all have heads but no necks. Now it should not be difficult to discover why the neck was formed; for obviously its loss is accompanied by the loss of the lung. Thus no fish has a neck because they all lack the lung, and all animals having a lung have a neck too.[3] If this is so, when we have looked to see whether there is one part of the neck (or more than one) that may be closely related to the lung, we shall have discovered the reason why the neck as a whole had to be formed.

Now some of its parts are not at all conformable to the substance of the lung, such as the vertebrae at the back, the spinal medulla contained in them, certain ligaments and tendons, many muscles, nerves, and glands throughout the neck, and the canal of the stomach called the esophagus. Other parts of it, however, such as the

[1] For Carabi, Astaki, and Carcini, see Aristotle, *De part. an.*, IV, 8, 683b25–29, and Ogle's note (1911) on this passage .

[2] Probably the common, edible crab; Carcini is a more inclusive term. See Aristotle, *Hist. an.*, IV, 2, 525b3–6.

[3] Strongly reminiscent of Aristotle, *De part. an.*, III, 3, 664a13 ff.

arteries and veins, are indeed conformable to the lung, but since the lung receives arteries and veins from the heart, for what does it still need the neck? Well, there yet remains the category of the rough arteries, which is common to the neck and lung; for three vessels are [I, 443] interwoven to form the lung, a vein, a smooth artery, and, third, a rough artery. The first two are common to the whole body, so that you would not find any part that does not contain them both, but the category of the rough arteries is found only in the neck and lung, one very large one in the neck and very many in the lung, as the very large artery divides to form them. Accordingly, all animals having a lung breathe in through this [rough] artery into the lung and breathe out again through the same artery. Also the emission of breath,[4] which I have shown to be the material of the voice, is its work too. Without it no voice is produced, and the principal and most important instrument of the voice, called the larynx, is the upper end of the rough artery, which is also called the pharynx, the same name as is given to that part lying in front of the larynx.[5] Hence no animal lacking a neck has a voice. This is the way in which the pharynx [the trachea] is related to the lung; this is its great usefulness for the animal, and for its sake the neck was formed.

[4] See note 25 of Book IV.

[5] In the passage which is cited above in note 3 and which Galen is following here, Aristotle speaks first of the *pharynx* and esophagus as the parts to which the neck is subservient; a few lines farther on he says that the pharynx *and* the windpipe are constructed of cartilage; still farther on he mentions the bad position of the *pharynx* in front of the esophagus; in *Hist. an.*, IV, 9, 535a29–32 he uses "pharynx" and "larynx" interchangeably; and in *De anima*, II, 8, 421a4, he remarks that fish are mute because they have no *pharynx*. It is thus clear that for him "pharynx" did not have its modern meaning, but might be used at will for either the larynx or trachea.

Hippocrates, however, seems definitely to have understood the pharynx to be "that space lying in front of the esophagus and larynx." See his *Praenotiones*, cap. 23 (Littré, II, *175*, *176*), and Galen's *Hippocratis Prognosticon et Galeni in eum librum commentarius*, III, 16 (Kühn, XVIII, pt. 2, *264*). Rufus of Ephesus (1879, *140*, *141*, *174*) too uses "pharynx" for the trachea, which he also calls the bronchus, but he has no name at all for the larynx, saying simply that the upper end of the pharynx is enlarged. See also Hyrtl (1880, *293–294*, *407*). Fortunately, Galen does not persist beyond this chapter in calling the trachea the pharynx.

Indeed, since the lung is contained in the thorax and the rough artery emerges from the lung and ends necessarily at the mouth, the whole interval between the ends of the thorax and the beginning of the mouth was made for the sake of the rough artery. For when the thorax and mouth were made separate and distinct from one another,
[I, 444] all the intermediate space became a pathway both for what passes down and for what passes up. Passing downward are the nerves, esophagus, muscles, and spinal medulla; passing upward, the veins, arteries, and of course the pharynx [the trachea] itself. The vertebrae surround the spinal medulla to protect it; glands fill in the places where the vessels divide; there are also membranes and ligaments that protect and at the same time bind together these parts of which I am speaking; and the skin as a common covering surrounds them all. Such is the neck, formed, as my discussion has shown, for the sake of the pharynx [the trachea], a part that has to do with producing the voice and with respiration.

Nature, however, who is clever at making a thing formed for one purpose serve another also, has caused the neck to provide in many animals the usefulness of a hand. Hence animals that take nutriment from the earth with their mouths have necks as long as their legs.[6] Man and animals like him, however, have necks for the sake of the pharynx [the trachea], and the pharynx for the sake of the voice and respiration, so that man is given[7] a neck of the size necessary if the pharynx is to perform these actions. Of course the parts in the region of the shoulder and upper arm, and the forearm and hand as well, must receive nerves from the cervical portion of the spinal medulla, and it will be shown later on that the diaphragm must too. The production of these nerves, therefore, is another reason why
[I, 445] other vertebrae, which frame the neck, had to be placed in the space between the head and thorax. Fish, however, have neither a rough artery nor any of these other parts, and one would say that on this account they have either no neck at all or an extremely short one composed of only the first two vertebrae. Just as fish have a short neck or none at all, so those animals in which it serves as a hand have a long one, and those in which, though formed for the sake of the voice, it serves in addition to produce the nerves for the anterior members, have a neck of moderate length. Man, whose structure it is

[6] Cf. Aristotle, *De part. an.*, IV, 12, 692b19–693a3.

[7] Reading δοθῆναι with Helmreich for the δεηθῆναι of Kühn's text.

now my particular purpose to explain is, of course, one of the last named. This is enough to have said about the usefulness of the neck.

2. To most people the head seems to have been formed on account of the encephalon and for that reason to contain all the senses, like the servants and guards of a great king. But the Carcini (crabs) and the other crustacea do not have a head; the part controlling the senses and voluntary motion is certainly placed directly in the thorax where all their instruments of the senses are located. Hence what in us is the encephalon, in those animals would be that part to which these instruments lead; or if the heart and not the brain is the source of all these, it would be right in animals without heads for the instruments of the senses to be in the breast because they would extend to the heart lying near by, but it would not be right in other [I, 446] animals for them to be attached to the encephalon. To those who hold this opinion it will seem all the more that the head has been formed to no purpose, because they cannot name the usefulness of the encephalon, nor can they locate the senses near it.

For the supposition that the encephalon was formed for the sake of the heat in the heart, to cool it and bring it to a moderate temperament, is utterly absurd, since in that case Nature would not have placed the encephalon so far from the heart. Rather, she either would have entirely surrounded the heart with it, as she has with the lung, or would at least have placed it all down in the thorax, and she would not have attached the sources of all the senses to it. But even if she had been so negligent as to place the encephalon far away and attach the senses to it when there was no need of doing so, she would certainly by no means have walled up the encephalon and heart separately in two such strong, safe enclosures, placing the whole cranium around the encephalon and the thorax around the heart. And even if she had been negligent in this respect too, at least she would not have placed the neck between the two, and this in the warmest animals and those called animals with saw teeth,[8] where the neck is long enough, and in birds, where it is still longer so that the encephalon is as far from the heart as the feet are. This teaching would be as much as to say that the heels were formed for the sake of the heart.

[8] Apparently the carnivora; see Aristotle, *Hist. an.*, II, 1, 501a8–21; *De part. an.*, III, 1, 661b16–24.

But joking aside, you will see if you look carefully that refrigeration would reach the heart more quickly from the heels than from the encephalon; for even if the heels seem to have been placed
[I, 447] farther away from the heart in man (though for that matter they certainly are not so in all animals) they are by no means separated from it by two bony enclosures like strong walls, because the lower side of the thorax is the only one where it is not bony, where instead there has been placed a membranous, muscular substance called the diaphragm, very well suited for transmitting refrigeration. And truly you would not find the heels any warmer than the encephalon, because, even if nothing else can,[a] its constant motion can warm the encephalon, not to mention the great number of large veins and arteries in it—and no other part of an animal's body is warmer than they are. Moreover, there is also the fact that the encephalon is covered with two membranes and in addition with very hard, dense, thick bone; for that is the character of the bone at its base, through which and certainly not through the crown of the head the refrigeration would have to pass to reach the heart. These things necessarily increase the heat in the encephalon and render the path of the cooling refrigeration to the heart difficult and even completely impassable.

But why should anyone think it necessary for the encephalon to provide the heart with refrigeration, when we see that respiration, a work so continuous and incessant, is able as long as the animal lives to cool the heart in two ways, first by supplying an abundance of the cold quality in inspiration, and second by pouring forth fervent material in expiration? Unless, perchance, one should think that the air is warmer than the encephalon and that for this reason the heart
[I, 448] is less effectively cooled than is fitting and needs in addition the help of the encephalon, which, I suppose, is colder! But these are the doctrines of men who either shout down the truth or are ignorant of the facts. For the encephalon is always found to be much warmer than the air, whether we are treating a man with a fractured skull or wish for practice to take some animal, break open the cranium, cut through the meninges, and touch the encephalon. Moreover, everybody knows that when we excise the bones of the head, we consider

[a] Accepting Renehan's emendation (1965, 63), ἄλλο, for the ἀλλά of Helmreich's text.

it of the greatest importance to act[10] quickly in order to avoid chilling the encephalon, and that if it is chilled, it is the worst thing that can happen to the man with the fracture. Certainly, if the air were warmer than the encephalon, the encephalon would not be chilled by it, whereas actually even in summer the encephalon is easily chilled and needs even then to be warmed quickly not only because it is not a cold body itself but also because it does not endure contact with a cold substance without being harmed. But, they say, the damage occurs not because of the encephalon, but because of the chilled meninges, especially the thin one [the pia mater], which has a very large number of veins and arteries and pulsates as a whole continually, a condition which is not found apart from fervent heat. Then, O most noble gentlemen, if you think that the thin membrane is warm, do you still venture to declare that the encephalon is cold, when it is so closely interwoven with the membrane that you will find no part of the encephalon without it? Or are you ignorant of this and think that the encephalon is simply contained in this membrane and not in fact embraced by it and everywhere interwoven [I, 449] with it? And yet, even if the encephalon were simply contained in the membrane, it would not, of course, be capable of refrigerating the heart, since it is so far removed and separated from it by two barriers of bone. Rather, ought not the encephalon to be warmed by the membrane everywhere closely associated with it—unless a warm part is somehow incapable of warming whatever is in its vicinity, while a cold one can cool everything, even what is not in its vicinity! For I suppose people necessarily talk such nonsense who do not have a greater regard for the truth than for advocating the doctrines which they have set up for themselves, and necessarily they do not trust to their senses or to agreement with reason and are not ashamed of what is at variance with it.

3. Others who hold this doctrine are less to be wondered at, but it is impossible not to be altogether amazed at Aristotle, who does not neglect the things to be seen in dissection, who is not untrained in their usefulness, who says himself that some questions require solution, others correction, and still others the testimony of the senses,[11] and who yet is found distrusting his sense perceptions and unmind-

[10] Accepting Helmreich's emendation, *ἐνεργεῖν*, for the *ἐνεργειῶν* of Kühn's text and the manuscripts.

[11] *Topica*, I, 11, 105a3–9.

ful of himself. For the encephalon is always discovered to be warmer to the touch than the air around us, but Aristotle says it was formed to cool the heat of the heart,[12] and he forgets that he himself has said that respiration takes place for the sake of this cooling;[13] it is right, however, to praise him when, following Hippocrates,[14] he gives a
[I, 450] true account of the usefulness of respiration. He is no longer correct when he forgets he has said elsewhere[15] that the air is naturally warm—or is he right to forget what he has said incorrectly, and wrong to think that the heart is not sufficiently refrigerated by the air alone and needs in addition a viscus which is not cold, like air, and which, even if it were colder, is not capable of transmitting refrigeration, because it is so far away and there are so many dense substances intervening? Now by the gods! Is there anyone who understands that the air itself passes through the lung to the heart, or if not the air itself, then certainly the essential quality of it, who sees that the process is continuous and incessant, and who yet thinks that the heart needs any other help to refrigerate it? And if other help is needed, it is far better to say that this is supplied from the lung and to attribute it to the softness of this viscus, as Plato[16] does, or to its coldness. For once you dare disregard your senses, it is not impossible to say this. Indeed, anyone showing that the lung is warm would not in this instance be crediting his sense of touch, but would be crediting it when he showed that the heart itself is warm.[17] How can the encephalon not be warmer than the air when it is fatal for it to become as cold as the air? How can the encephalon be capable of refrigerating the heart and the heart not much more capable of
[I, 451] warming the encephalon lying above it, that is, if all heat has a tendency to rise? Why is the outgrowth of the encephalon extending to the heart an obscure one, while all the instruments of the

[12] *De part. an.*, II, 7, 652b6–27, and see my Introduction, pp. 51–52.

[13] *De part. an.*, III, 6, 668b33–669a6, and cf. *De respiratione*, cap. 17, 479a7–15.

[14] *De flatibus*, cap. 4 (Littré, VI, *96, 97*); *De natura pueri*, capp. 12, 15 (Littré, VII, *486–489, 492–495*); *De alimento*, capp. 29, 30 (Littré, IX, *108, 109*); *De morbis vulgaribus*, VI, sectio VI, 1 (Littré, V, *322–323*); *De carnibus*, cap. 6 (Littré, VIII, *592–593*).

[15] *De gen. et corr.*, II, 3, 330b4.

[16] *Timaeus*, 70 (Plato [1920, II, *49*]).

[17] This sentence is bracketed by Helmreich as an importation into the text.

senses obviously receive a large share of the encephalon? For one could hardly say that it was formed by Nature to refrigerate the heart, but is useful for a different reason to the instruments of the senses. In fact, I should suppose that a part formed to refrigerate the heart and being, as it were, a fount of coldness, would necessarily refrigerate everything in its vicinity. Thus the encephalon would be a marvel if it were the only one of all the instruments capable of refrigerating through many intervening bodies parts far removed from it and very warm,[18] while incapable of producing the same effect on parts close by, that are less warm and are united with it.

"But," says he, "Not all the instruments of the senses extend to the encephalon."[19] Aristotle! What a thing for you to say! For my part, I am certainly ashamed even now to mention the subject. Does not a nerve [*n. vestibulocochlearis*] of considerable size along with the membranes themselves enter each ear? Does not a portion of the encephalon much larger than that proceeding to the ears come to each side of the nose?[20] Do not one soft nerve [*n. opticus*] and one hard one[21] come to each eye, the former inserted into its root and the latter into the muscles moving it? Are there not four nerves extending to the tongue, two [*n. lingualis* from the mandibular division of the trigeminal] of them soft, that reach it by way of the palate, and two [*n. hypoglossus*] hard, that descend beside the ears? Hence all the instruments of the senses—if we are to believe our eyes that see and our hands that touch them—communicate with the encephalon.

[18] Reading θερμότατα with Helmreich for the θερμότερα of Kühn's text.

[19] *De part. an.*, II, 7, 652b3–5.

[20] This is the olfactory lobes rather than the olfactory nerves, which Galen did not know. In Book IX, chapter 9, he says, "Accurate anatomists count this [the palatine nerves] as the fourth pair, of course not counting in along with the others the pair that leads to the nose, because this does not have nerves growing out from it and does not issue from the bones as the others do." Cf. *De anat. admin.*, XIV (Galen [1906, II, *172*; 1962, *188*]). It should be remembered that in the animals he was dissecting (the ruminants and pig, probably) he found the olfactory lobes relatively much larger than they are in man. Throughout this Book and the next, attention will be called to the accumulating evidence that Galen describes the brain of the beef. This evidence is well summarized by Woollam (1958).

[21] But see note 31 of Book IX.

[I, 452] And what of the other parts making up the structure of the encephalon? What will be the usefulness of the choroid bodies [*plexus choroidei*], the retiform plexus [*rete mirabile*],[22] the pineal body,[23] the pelvis, the infundibulum,[24] the vaulted body [the fornix], the vermiform epiphysis[*vermis cerebelli*], the numerous ventricles and their connecting passages, the diversity of form, the two meninges, the outgrowths into the spinal medulla, and the nerves branching off not only to the instruments of the senses, but also to the pharynx, larynx, esophagus, stomach, all the viscera, all the intestines, and all parts of the face? Of none of these parts has Aristotle attempted to tell the usefulness, any more than those[25] who think the encephalon is the source of everything attempt to tell the usefulness of the parts of the heart. For if the encephalon were formed only for the sake of refrigeration, it would have to be like a sort of sponge, inert and formless, having no very skillfully contrived structure, and if the heart is not the source of the arteries and innate heat, it should not exist at all, let alone have a complex structure. In both these examples of prodigious wisdom there is something marvelous to be detected, particularly in the fact that these men not only deprive the encephalon of being the source of the nerves or the heart of being the source of the arteries, but also declare one or the other part to be completely without usefulness. Some, like Philotimus,[26] confess it openly, and others, like Aristotle,
[I, 453] imply such an opinion by circumlocution. For when a person[27] says that the only characteristic of the encephalon is one which is not by any means present in it at all, and considers that it was not formed for the sake of any of its other characteristics, he is obviously accusing it of being completely without usefulness, though he is ashamed to say so openly. This is not the proper place to discuss actions. Yet what I said at the beginning of the whole work becomes manifest in very fact, namely, that it is impossible to explain cor-

[22] For the *rete mirabile*, see chapter 4 of Book IX.

[23] *τὸ κωνάριον*, the little pine cone.

[24] In chapter 3 of Book IX, Galen equates pelvis (a term not now in use) and infundibulum. Why both are named here is not clear.

[25] Reading *ἐκεῖνοι* with Helmreich for the *ἐκείνων* of Kühn's text.

[26] For Philotimus, pupil of Praxagoras and promoter of gymnastics, see Sarton (1927, I, *146*); Steckerl (1958, *108–123*).

[27] Reading *ὁ* with Helmreich for the *ὃ* of Kühn's text.

rectly the usefulness of any part without first finding out the action of the whole instrument.

4. Let us, then, assume for the present discussion propositions demonstrated in other works of mine. I have shown in my book *On the Teachings of Hippocrates and Plato* [28] that the source of the nerves, of all sensation, and of voluntary motion is the encephalon, and that the source of the arteries and of the innate heat is the heart. Relying on these demonstrations, which are like foundations [29] for my discussion, I shall explain the usefulness of the parts of the head and first, of course, the usefulness of the head itself as a whole. This is what I set out to investigate at the beginning of this book, having now been able, I think, to push the inquiry far enough to ascertain that the head was not formed for the sake of the encephalon, even if we assume that the encephalon is the source of sensation and voluntary motion. We have ascertained also that it is impossible not to disgrace ourselves in the entire discussion and not to be at a loss in trying to discover the usefulness of the several parts if we deprive the encephalon of those characteristics which make it the source of the things I have mentioned, and if we thus suppose it necessary to investigate it [to find] the purpose for which the head was formed. For the Carcini (crabs), all the tribe of crustacea, also moths, and [I, 454] many other similar animals have either no head at all or only a rough outline of one, so to speak, and yet these animals have all the senses located in the breast, since obviously the source of them would have to be placed there.

This source should not be spoken of as analogous to the encephalon, as Aristotle [30] is wont to do in such cases, being at times deceived by names which are derived [31] not from the essence of the thing, but from accidental characteristics. This is also true of the term ἐγκέφαγος (encephalon, something in the head), since this name is derived from the location of the encephalon. When Plato [32]

[28] *De plac. Hipp. et Plat.*, I (Kühn, V. *181–210*).

[29] ὑποθέσεσιν τισι, things placed under, hypotheses.

[30] *De part. an.*, II, 7, 652b23–25; IV, 5, 681b12–17. Galen means that this source is not simply *analogous* to the encephalon, but *is* the encephalon in these animals, though the name is not well chosen, since they have no heads.

[31] Accepting Helmreich's emendation, κειμένοις, for the κινούμενος of Kühn's text and the manuscripts.

[32] *Timaeus*, 73 (Plato [1920, II, *51–52*]).

wished to make clear what he thought to be the true nature of its substance, he called it μυελός (marrow, medulla). Even if it is medulla, however, there is still something lacking in this appellation; for there is a spinal medulla and another medulla in the bones, and these are not sources of all sensation and motion. Hence many call the encephalon the encephalic medulla, just as they say spinal medulla, and others think fit to call it not encephalic, but the medulla of the encephalon.[33] But these designate the part not by a name but by a phrase, and what I said at first is still true, namely, that it has no name that is characteristic of its essence, as the eyes, ears, tongue, heart, lung, and almost all the other parts have. One
[I, 455] can say of them that the instrument of sight is called the eye, that of hearing, the ear, and similarly with each of the others, but we cannot in the same way call that which governs impulse and motion[34] what it ought to be called. It is not simply medulla, since every medulla does not have this faculty, nor is it simply an encephalon (something in the head), since certainly it is no encephalon in animals that have no head. Surely we ought not on this account to call it something analogous to an encephalon, if we are careful about nomenclature; for we do not say that eyes and ears in the Carcini are analogous to eyes and ears, even if they do occupy other positions. In fact, no instrument has a certain essence because of its position, even though it is named from its position. Hence, though the encephalon most particularly derives its name from its position (for it is called ἐγκέφαλος because it lies ἐν τῇ κεφαλῇ, in the head), I shall not say that it is something else and analogous to the encephalon when I find it situated in the parts of the thorax in animals that have no head. I shall say that it is the encephalon itself and that its antiquated name is not suitable.

To appreciate more clearly and plainly the significance of what I have said, call the encephalon by its Roman name, which was not taken from its position or from any other accident but is indicative of the very essence of it, and you will see clearly that there is
[I, 456] nothing to prevent your saying that in man the *cerebrum* (for that is what the Romans call it) is in the head, and that in crabs it is in the

[33] Helmreich brackets ἐγκεφάλου.

[34] Kühn's text omits from ἕκαστον through ὁμοίως, but his Latin version contains the translation of the omitted material.

breast. Well, now, instead of *cerebrum*, let us call it *skindapsos*,[35] and just as we call any instrument of vision the eye not only when it is in the head but also when it is situated on the breast, so any part of an animal that controls sensation and voluntary motion for the other parts will be called *skindapsos*. Now if the encephalon is the source of the will[36] and motion, and if animals having no head but having an encephalon or something analogous have will and motion of a sort, it is clear that this did not happen through the presence of a head. Shall we then still be able to say that the Carcini have an *analogue* to the *skindapos?* Most certainly not, since it is proper to call all the instruments of one action by the same name. It is right to call all instruments of vision eyes, even though they are subject to variations of form in particular instances; by the same reasoning instruments of hearing should always be called ears and instruments of smell, noses. So likewise, then, the instrument in control of sensation and motion is one and the same in all animals, even though it is found in different locations.

Moreover, just as this part has been placed in the breast in the animals I have mentioned and it thus seems unnecessary for a head to be formed for its sake, so also it seems that a head need not be formed for the sake of a mouth; for the same animals also have the mouth located in the breast. Neither is a head necessary for the sake of ears, for these too have the same location, and similarly the nose and all the other instruments in headless animals are situated in the breast. [I, 457]

5. It seems to me that the thing for the sake of which Nature has made a head in most animals is to be found in no other way than as we have already begun to search for it. For if we find which of the parts situated in the head is lacking in the breast of those animals that do not have a head, it would not be unreasonable to say that this is the part for the sake of which the head was formed. This is the method of discovery; what we are searching for can be found and is

[35] Coined nonsense word, thing-a-ma-jig; Galen uses this same device and the same word in *De differentiis febrium*, II, 6 (Kühn, VII, *348*), also a corresponding verb form in *De pulsuum differentiis*, III, 4 (Kühn, VIII, *662*).

[36] Here, and a little farther on in this sentence, I am reading προαιρέσεως and προαίρεσιν with Helmreich for the αἰσθήσεως and αἰσθεσιν of Kühn's text.

to be found as follows: In the Carcini (crabs), Phalainae (moths), Carabi (spiny lobsters), and all animals without heads the eyes are on long stalks, since, unlike the mouth, nose, and ears, they could not be placed low down, needing as they do, an elevated location for their work. This is the reason why lookouts for the approach of enemies or brigands go up on high walls, towers, or hills. Moreover, sailors that climb to the yardarms see land before the passengers in the ship. Indeed, anyone walking on high ground sees a greater expanse of country than can be seen from lower places. Now since the animals in question have a hard, testaceous skin, their eyes could safely be placed on elevated stalks because the eyes themselves were to be hard and could have an outer investing tunic derived from the
[I, 458] skin and, like the skin, very hard. In man and other animals resembling him, however, the eyes as a whole must of necessity be soft on account of the substance of the body, and, what is more, the outer membrane surrounding them must be soft like the whole skin. It was therefore too dangerous to place projecting eyes on long stalks; for even in testaceans themselves the eyes do not always project but are withdrawn into a cavity, and if perchance these animals become alarmed at something bearing down upon them, or if at some other time they do not need the action of the eyes, they rest them, reposing safely against the breast in a pocket prepared for them there by Nature. Accordingly, since putting our eyes in a low place would disregard their usefulness and placing them on exposed stalks would be unsafe, and since Nature wished neither to hinder their usefulness nor to destroy their safety, she contrived to make for them a part which is both elevated and capable of protecting them. Above them she placed the brows, below, she raised up the so-called arch of the cheeks, on their inner sides she placed the nose, and on their outer sides the processes called zygomatic.

But the assemblage of these parts does not constitute a head, though they cannot[87] exist without a head. What, then, makes it necessary to locate here the other parts which combine to form what is called the head? Each of the sense instruments needs a soft nerve. It needs a nerve because nerves are the instruments of sensation, and a soft one because, if there is to be sensation, a sense
[I, 459] instrument must somehow be acted upon and affected by the exte-

[87] Kühn's text lacks the negative.

rior objects encountered, and a soft substance is better suited to receive impressions, whereas a hard one is more suitable for acting. This is the reason why the sense instruments need soft nerves and all the other parts, that are moved by appetition,[88] need hard ones. Those sense instruments, however, that are moved by the will, like the eyes and tongue, have both kinds, unlike the ears and nose, which have only soft nerves. As a result, if either of the nerves [of the eyes or tongue] is injured, the part is disabled only in respect to the usefulness depending on that nerve.

Not infrequently, in fact, the tongue has been observed to be deprived sometimes of its motion and sometimes of its power to distinguish and apprehend flavors. Moreover, the hard and soft nerves do not have the same upper origins from the encephalon itself and do not follow the same paths to the sense instruments; for the soft nerves grow out from the soft parts of the encephalon and proceed straight to the sense instruments, whereas the hard nerves grow out from the hard parts and have a circuitous route. Thus some [*nn. linguales*] coming down to the tongue grow out from the lower, anterior parts of the encephalon and are inserted directly into the tongue, and other, harder ones [*nn. hypoglossi*] grow out from the posterior and lateral parts and first circle around in the neck. The soft nerves are distributed to the outer surface of the tongue and the hard ones to the muscles. For it is the superficial parts of the tongue that are associated with flavors, but it is moved by the muscles, and so, properly, the nerves intended for perception have been inserted into the parts better suited to perceive, and the other, [I, 460]
hard nerves into the instruments of motion, the muscles. So too the hard nerves of the eyes are inserted into the muscles, whereas the others [*nn. optici*] are inserted into the principal, most important instrument of sight, the crystalline humor. After leaving the cranium none of the soft nerves extending to the eyes, tongue, ears, and nose can be seen to proceed very far, as the other, hard nerves do; for they would be broken off at once and easily crushed not only by blows from external objects, but also, and much sooner, by the very parts of the body with which they are associated.

Hence for this reason all the sense instruments must be close to the encephalon itself, and if so, here now is the end for which we have

[88] Kühn's text lacks *ὅσα καθ' ὁρμὴν κινεῖται*, though the Latin translation of the clause is given in italics.

been searching from the very first. For the encephalon seems to have been placed in the head because of the eyes, and the other sense instruments to have been placed there because of the encephalon. Moreover, as regards the mouth, it will already be clear that it too had to be assigned to the head, since it must enclose the tongue; for it was better for the tongue not to be exposed without any covering at all, and better also for it to be covered with the mouth rather than with anything else, since in that location it would distinguish flavors more effectively, serve as the instrument of speech, and be of no little help in chewing and swallowing.

[I, 461] 6. I have now finished my discussion of the head as a whole. Next in order it is proper for me to examine the usefulness of its several parts, beginning with the encephalon itself. In substance the encephalon is very like the nerves, of which it was meant to be the source, except that it is softer, and this was proper for a part that was to receive all sensations, form all images, and apprehend all ideas. For a substance easily altered is most suitable for such actions and affections, and a soft substance is always more easily altered than one that is harder. This is the reason why the encephalon is softer than the nerves, but since there must be two kinds of nerves, as I have said before, the encephalon itself was also given a twofold nature, that is, the anterior part [the cerebrum] is softer than the remaining hard part [the cerebellum], which is called the *encranium*[39] and *parencephalis* by anatomists. The two parts are separated by a fold [*tentorium cerebelli*] of the hard membrane [the dura mater] and are connected only by the channel[40] lying beneath the crown of the head and by the bodies associated with it. Now the anterior part had to be the softer because it was intended to be the source of the soft
[I, 462] nerves leading to the sense instruments, and the posterior part had to be the harder, being the source of the hard nerves distributed to the whole body. Since the association of a soft body with a hard would not be at all harmonious,[41] Nature has set each one apart by itself,

[39] Reading ἐγκράνιον with Helmreich for the ἐγκεφαλίδα of Kühn's text. This clause varies widely in the different manuscripts. For an excellent summary of the early nomenclature of the parts of the brain, see Daremberg (1841, *9–13*). See also chapter 11 of this Book.

[40] Not the aqueduct; see note 76 of this Book.

[41] Reading σύμφωνος with Helmreich for the ἀσφαλής of Kühn's text. As Meyer-Steineg (1911, *199*) remarks, Galen seems in the very next sentences to have distinguished the cortical and medullary substances of

placing between them the hard membrane [the dura mater of the tentorium cerebelli] that will also surround the whole encephalon made up of these two parts. Moreover, the parts of the anterior encephalon itself that adjoin the covering called the hard, thick meninx were with good reason made harder, and the parts in the middle contained by these were made softer; for the outer parts had had to be so constructed as to resist injury and give off the harder nerves, whereas the inner parts, being protected from injury by their situation, became a suitable source for the soft nerves.

Now no soft nerves at all grow out from the *parencephalis*, but some hard ones—like those moving the eyes, I suppose—must of necessity grow from the anterior encephalon. In consequence, although the latter are close to the soft nerves, Nature did not make them grow out from the deep parts, as the soft nerves do, but from the hard, superficial parts. All the nerves, then, are harder than the [I, 463] consistency of the encephalon, not as if they were made of some different sort of substance, but as if they were of the same nature, only differing in dryness and density. The sensory nerves [*nn. optici*] extending to the eyes are somewhat denser than the encephalon, but they do not seem to be very much harder. These are the only ones of all the nerves that will seem to you to have been made by compressing rather than by drying out the substance of the encephalon. Moreover, these nerves alone obviously contain perceptible channels.[42] Hence many anatomists [43] speak of them as channels,

---

the brain, though he naturally failed to see the real physiological significance of the distinction.

[42] Here Galen has persuaded himself that he has seen what he needed to see for the support of his conception (to be found in *De plac. Hipp. et Plat.*, VII, 3–4 [Kühn, V, *600–617*]) of the physiology of the nervous system. He believed that psychic pneuma, elaborated in the brain and collected in its ventricles, travels thence through the nerves and is distributed to all parts of the body in order to provide them with sensation and motion. All parts with the exception of the eyes require relatively small amounts of this pneuma, and so the channels conveying it in the nerves are so minute as to be imperceptible. Indeed, the smallest nerves, the size of cobwebs, may lack a lumen entirely. But the eyes are instruments so bright and radiant that a great deal of luminous psychic pneuma must flow to them, so that in the optic nerves much larger channels, large enough in fact to be visible, are necessary.

The problem is to discover what Galen was looking at when he decided that the optic nerves really had the lumen he was sure they

saying that two channels from the encephalon are inserted into the roots of the eyes, one into each eye, and that the netlike tunic [the retina] is formed by them as they break up and spread out. They say too, of course, that there are nerves leading to the muscles of the eyes.

There are four sense instruments in the head, namely, the eyes, ears, nose, and tongue, all of which take the source of their sensation from the encephalon, and although in this respect at least they seem to be similar, they differ specifically in the sensitive faculties them-

---

must have, and he himself helps us to the solution when in the following passage from the discussion cited above he gives directions for finding the orifices at the ends of the nerves. "For in dissections of large animals," Galen says, "it can be seen that a luminous pneuma is carried in those [optic] nerves, since they have distinct orifices both at their beginning above and at their insertion into the eyes. Most anatomists know the lower orifice at the eyes, but nearly all of them are unaware that the upper source of these nerves is where the anterior [lateral] ventricles turn laterad; for each ventrical has its lower [anterior] end narrow and elongate where the root of the channel to the nose is. But the upper extremity, where it extends toward the middle [third] ventricle, grows broader and a turn is made there laterad, [the ventricles] inclining gradually downward toward the base. They do not reach it, however, but becoming narrower little by little, they come to an end in the shape of a horn, not exactly straight but turned slightly back. The source of the optic nerves extends to this end of the ventricles and has an orifice that is hard to see. But you will see it if you take these three things into consideration: first, the animal should be large; second, you should dissect it as soon as it has been killed; and third, the surrounding air should be clear. For if after such preparations you expose all the bodies lying upon the ventricle and remove the end of it suitably without tearing or crushing the outgrowth of the nerve, you will see the orifice at its beginning" (*De plac. Hipp. et Plat.*, VII, 4 [Kühn, V, *611–614*]; *vide infra*, p. 687, for a similar description).

The orifice at the lower end of the nerve, "known to most anatomists," may doubtless be assumed to be the porus opticus, but that at the upper end presents greater difficulty. It is clear that Galen knew the optic tract and had traced it back to where it merges into the lateral geniculate body. If a beef brain is dissected as Galen directs, it is possible to see that he might well have thought that the groove at the upper edge of the optic tract as it emerges from the lateral geniculate body, especially when this groove is viewed through the choroid fissure, of which it might actually seem to be a continuation, was the desired orifice, particularly as he was quite certain to begin with that it must be there. Some lingering doubt in his mind may be indicated by

selves and in the bodies [nerves] through which the faculties reach them. For these faculties are able severally to distinguish odors, flavors, sounds, and colors. The pathways leading to the nose are long extensions of the two cavities [the lateral ventricles] of the encephalon and do not differ from the other cavities;[44] the pathways leading to the eyes are somewhat different and are not exactly nervous; those [*nn.* linguales] to the tongue are perfectly nervous, but soft; those [*nn. vestibulocochleares*] to the ears are not so soft, [I, 464]

his statement that this orifice is hard to see. It should be borne in mind that in the beef the lateral ventricles have no posterior horn. I append an account written by Dr. Marcus Singer of the dissection he made of the fresh beef brain to verify this point for me:

"Cut away the occipital lobe until the descending portion of the lateral ventricle appears. Enlarge the opening dorsally and ventrally until the lateral ventricle is fully exposed. Looking into the descending portion from behind, one sees the prominent hippocampus along the medial wall of the descending horn. If one pushes the hippocampus medially, thus enlarging the view into the depths of the ventricle, one observes a deep slit which terminates at the choroid fissure and along whose medial wall is the fimbria. At the choroid fissure is the massive choroid plexus. Directly beneath the fimbria of this region and in intimate contact with the choroid fissure is the lateral geniculate body and the termination in it of the optic tract. This is especially evident if the temporal lobe and the hippocampus are separated from the rest of the brain along the natural and weak breaking-point of the choroid fissure. Along the most rostral and dorsal point of termination of the optic tract in the lateral geniculate body there is a perceptible groove or slit which lies just at the overlying choroid fissure. This slit could be interpreted, particularly in a soft, fresh brain, as an opening from the optic-nerve–optic-tract system into the descending part of the lateral ventricle."

Finally, it should be noted that Galen claims in *De anat. admin.*, XIV (Galen [1906, II, *170;* 1962, *187*]) that he has actually probed this supposed channel in the optic nerves with a hog's bristle. Vesalius (1555, *517–518*), however, says that though he searched for it in dogs, both living and dead, in other, larger animals, and in a man just beheaded, he was unable to find it.

[43] Among them, Herophilus and Eudemus; see Galen's *De symptomatum causis*, I, 2 (Kühn, VII, *88–89*); *De libris propriis*, cap. 3 (Kühn, XIX, *30*); chapter 12 of Book X of this work, *ad init.;* and my Introduction, pp. 25, 29.

[44] In the animals dissected by Galen, including the beef, the lateral ventricles are prolonged into the olfactory bulbs. See Ellenberger and Baum (1926, *789*).

yet are certainly not hard. The fifth sort of pathway for the faculty from the encephalon is a nerve perfectly strong and hard, and hence suited to motion and the sense of touch (which is less delicate than the other senses), but incapable of the more accurate distinctions characteristic of the other sense instruments.

It is absolutely necessary for each of the latter to be altered if sensation is to occur. They are not, however, all altered by every perceptible thing; rather, the bright, luminous sense instrument is altered by colors, the airlike instrument by sounds, the vaporous instrument by odors, and in a word, like is perceptible by like. The airlike sense instrument can never be altered by colors, for if an instrument is to undergo alteration by colors easily and simply, it must be radiant, pure, and bright, as I have shown in my book *On Vision*,[45] and, further, it may not be turbid and vaporous, moist and watery, or hard and earthy. Hence none of the sense instruments
[I, 465] except the instrument of vision will be altered by colors; for vision alone has a sense instrument that is radiant, pure, and glistening, namely, the crystalline humor [the lens], as I have also demonstrated in my book *On Vision*. But it would be of no use for this alteration to take place unless it was recognized by the ruling principle which forms images, remembers, and reasons. Accordingly, the encephalon extends a part [*n. opticus*] of itself to the crystalline humor in order to know how it is being affected, and this outgrowth is properly the only one to have a perceptible channel, because it alone contains a very large amount of the psychic pneuma. I have discussed the substance, faculty, and formation of this pneuma in my book *On the Teachings of Hippocrates and Plato*.[46] As I have already said innumerable times, I am not demonstrating any actions here, but (and this too I have shown right at the beginning) because it is impossible to find the usefulness of the several parts if one is still ignorant of their action, it becomes necessary to remind you of actions.

Surely, then (for we must return to the subject under discussion), since the sense instrument of vision must be made bright and radiant, a great deal of pneuma is properly sent to it from the source, and from the encephalon itself there is extended to it a pure, unaltered offshoot [the optic tract, chiasma, and nerve], which is soft like the

[45] A lost work.

[46] *De plac. Hipp. et Plat.*, VII, 3–4 (Kühn, V, *600–617*).

encephalon[47] until it reaches the pathway leading to the eye, but which, when it must issue from the cranium, is compressed and becomes denser and harder in order to prevent injury. As soon as it enters the cavity which lies under the brows and which, of course, is called the socket [the orbit] of the eye, it is greatly extended, flattened, and thinned out, thus regaining its original character, so that it appears to be the real encephalon in color, consistency, and all the other qualities of which I shall speak more in detail farther on, when I explain in its own place the usefulness of the parts of the eye. Here I have said only as much about the structure of the eye as is necessary for my discussion of the parts of the encephalon. [I, 466]

Unless the alteration in each sense instrument comes from the encephalon and returns to it, the animal will still remain without sense perception. You could learn this by observing persons stricken with apoplexy, whose sense instruments are all uninjured, but who, for all that, receive no benefit from them in distinguishing sensations. As regards the eyes, even though they are covered as closely as possible on all sides, alteration from external colors easily reaches the part of the encephalon [the retina] contained in them. For the hornlike [membrane—the cornea] is so thin, clear, and pure, that it closes off neither this part nor the alteration that passes through it, and after the cornea, directly at the pupil, comes the crystalline humor [the lens], to which the part of the encephalon contained in the eye is adnate. It is now clear why some of the unaltered substance of the encephalon forms offshoots to the eyes, why these become denser as they issue [from the cranium], why they are again resolved and flattened out in the orbits, and why they are the only ones of all [such offshoots—the cranial nerves] to have a perceptible channel. [I, 467]

It was entirely necessary for offshoots [*nn. vestibulocohleares*] of the encephalon to descend to the ears too in order to receive the external impressions falling upon them. Since, however, these impressions were noises or sounds caused by the air striking against something or being struck (it makes no difference which, so long as we agree on this one thing, namely, that the motion resulting from the stroke must proceed like a wave and ascend to the encephalon),

[47] Helmreich adds the necessary emendation, *μαλακὴ μὲν ἐγκεφάλου δίκην ἐστί*, lacking in Kühn's text, but translated in his Latin version.

it was not possible here, as it was in the eyes, to interpose a covering in front of the nerves. For of course such a covering would greatly hinder the moving air from striking against them, especially if the movement were small, as it is when sounds are not loud. But it certainly was not permissible to leave the nerves completely bare and exposed so that they would be readily injured by everything that struck against them from without, and neither was the remaining, third choice permissible, namely, to make the covering so thin and loose-textured that the air could penetrate and pass through it.
[I, 468] For if this were done, not only would the nerves be easily injured in various ways, but also the encephalon itself would be chilled. Now Nature knew that if the barrier were strong, such a construction would protect the sense instrument, but make it insensitive; that without a covering it would be extremely vulnerable; and that if she could perhaps add some moderate protection to ensure safety, the third type of construction alone would be satisfactory. Accordingly, she added a dense, hard bone and bored through it with oblique coils like a labyrinth, being careful gradually to dull by intricate deflections the direct force which the cold air would have if the pathway were straight, and to check the impact of all other, hard [48] bodies. If the bodies were larger than the passage, they would not even touch the sense instrument, let alone injure it, and if they were smaller, some that were moving swiftly and violently in a straight line would probably encounter first the coils, and others that rolled, so to speak, gently through the coils, would touch the covering softly and without violence. Not only did Nature provide by this device the greatest possible protection against injury for the acoustic nerves; she also was not unmindful of the structure proper to them, for she made them as hard as circumstances permitted. If they had been made perfectly hard, they would have been less vulnerable, but exceedingly insensitive; on the other hand, if they had been made soft like the nerves leading to the eyes, they would have been highly
[I, 469] sensitive, but extremely vulnerable. There is nothing that Nature avoids as she does exposure to injury, since she knows that it involves loss of action too, and I have already often said so. This is the reason, then, why the acoustic nerve has been made harder than is suitable in view of its action.

Again, for the opposite reason, the nerve [*n. lingualis*] leading to

[48] Reading *σκληρῶν* with Helmreich for the *σμικρῶν* of Kühn's text.

the tongue was made softer; for here Nature could surround it with the mouth to keep it safe. And yet I have put this sense instrument in fourth place, since it is able to distinguish neither qualities of brightness, nor movement of the air, nor vapors. However, because of the safety of its situation it was given the sort of nerve it needed, whereas the instrument of hearing was constructed with a view to its protection rather than to is sensibility for the reasons I have mentioned.

There still remains the olfactory sense instrument, which is the only one of them all to be made inside the cranium, right in the anterior [lateral] ventricles of the encephalon, which contain a vaporous pneuma. The perceived material proper to this sensation must, in fact, alter a portion of the encephalon. It was necessary too that this portion should be surrounded by a covering such as would be capable of protecting it and yet would not prevent the passage of the material to be perceived. But if it was not to prevent this, the covering had to be made as much looser-textured than the covering of the auditory instrument as the material to be perceived by the olfactory instrument is denser than the material to be perceived by the ear. Indeed, vapor is nearly as much inferior to air as regards the fineness of its particles as air is to brightness.[49] Also, from what is [I, 470] plainly to be observed in daily life, we can understand how broad the pores of the covering in this region must be. For when occasionally the nostrils are obstructed by something, as Plato [50] says somewhere, "No odor filters through and only the air, free of odors, follows [the path]." Surely it is clear, as such an observation proves,

[49] Cf. *De plac. Hipp. et Plat.*, VII, 5–7 (Kühn, V, *625* ff.). The relations of the coverings of the sense instruments to one another and to the materials by which they are designed to be affected may be clarified by the following scheme:

Sense	Medium	Character of medium	Character of membrane
Vision	"Brightness"	Etherial	Dense
Hearing	Air	Denser	Loose-textured
Smell	Vapor	Still denser	Still looser-textured

[50] *Timaeus*, 66 (Plato [1920, II, *46*]).

both that the [particles of] vapor are larger than the obstructed pores, and that the covering of the olfactory sense instrument must be made looser-textured than the vapor. Moreover, it becomes apparent that this is the case when one removes this covering from a dead animal, stretches it in all directions, and holds it up to a bright light; for while it is wrinkled and relaxed and the material around the pores falls together, the perforations disappear, but when the material is pulled apart by stretching, they are readily disclosed, unless the trial is made with material that has been hardened or dried out by excessive cold or by standing for too long a time. In fact, even if the animal has been recently killed, it is better to make this trial after soaking the covering in warm water.

Excellent proof that the covering in this region is loose-textured is also found in the fact that large quantities of residues from above are frequently evacuated [through it]. The Ancients called these residues βλέννα (rheum) and κόρυζα (coryza), but in modern times
[I, 471] they have been called μύξα (mucus). Now particularly in circumstances where one instrument can properly perform many actions and serve many uses, it is always Nature's clever habit never to omit any of them. And so it is in this instance too; for since the cavities situated up in the encephalon often necessarily receive residues flowing in from the bodies surrounding them, animals would frequently be dying of apoplexy if Nature had not cut a path here[51] by which the residues could suitably be discharged, and certainly no better path could be imagined than one that was broad and downhill. Passing outward from within through the pores in the nostrils are the residues, whereas passing in from outside are the objects to be perceived by the olfactory faculty, and one instrument serves for both these uses, one of which is necessary for life itself, the other for the better life. There are two other steeply inclined ducts[52] which empty the residues of the whole encephalon through the palate into the mouth, and when the encephalon[53] is in good condition and prevails over its nutri-

[51] Again the extension of the lateral ventricles into the olfactory bulbs in the animals Galen dissected.

[52] See note 2 and chapter 3 of Book IX.

[53] Kühn (III, *650*) and Daremberg (in Galen [1854, I, *549*]) both say, "When the *animal* is in good condition," but the following sentence shows clearly that the unexpressed subject of the verb should rather be taken to be the encephalon.

ment these alone are sufficient. Hence the principal usefulness of the channels connecting the encephalon with the nostrils, the usefulness for which in particular they were formed, is not the evacuation of the residues; on the contrary, this is an extra assistance to the encephalon when it is not in good condition. Superior to this use is the recognition of odors, and still more important and indeed necessary to life itself is inspiration into the encephalon. Indeed, not without good reason does Hippocrates [54] mention this fact (or [I, 472] any other, for that matter). For all these reasons, then, and particularly for those of which I am about to speak, the olfactory sense instrument is the only one to have been formed in the encephalon itself. The covering for this sense instrument had to be very porous and loose-textured in order readily to transmit to the encephalon air for respiration and vapor for distinguishing odors and in order to expel large quantities of residues all at once if ever the need should arise. Such a construction would necessarily make the covering itself very vulnerable and result in great injury to the encephalon, that most important viscus, and so Nature put close to it a bone [*os ethmoidale*] that is intricately perforated like a sponge, to keep hard bodies from inflicting blows from the outside and untempered cold from entering directly the ventricles of the encephalon when we inhale. For certainly we cannot always breathe in air that is moderately cold; there are times when it is very cold indeed, and this, entering directly and encountering the encephalon, would chill it excessively and endanger life itself.

7. These bones lying in front of the meninges, the intricately perforated, porous bones that anatomists call ethmoid, were made to guard against such injury. It would be better, however, to call them not *ethmoid* (like a colander), but *spongoid* (spongelike), which was Hippocrates' [55] comparison; for their perforations are intricate [I, 473] like those in a sponge, and are not bored through in straight lines like those in a colander. Now the hard membrane itself [the dura mater] covering the encephalon is indeed perforated like a colander, but the perforations in the bones lying before it are more intricate, like those in a sponge. The channels [of the two structures] do not lie in a straight line with one another and they are not all entirely straight; some of them are, but most are crooked and winding, so that if

[54] *De morbo sacro*, cap. 7 (Littré, VI, *372*, *373*).

[55] *De locis in homine*, cap. 2 (Littré, VI, *278*, *279*); *De carnibus*, cap. 16 (Littré, VIII, *604*, *605*).

anything is to pass through them and reach the encephalon, it must first wander far and make a long, circuitous journey.

Here too I seem to be pointing out another instance of great wisdom on the part of the Creator of animals. I have praised him before, because he has frequently made a single instrument capable of performing many tasks; now, however, I have something more to point out, namely, that these tasks are of no little use to one another. In fact, once these spongelike defenses had been formed to ensure the safety of the encephalon, there would be danger of their impairing the olfactory instrument if it did not in addition gain respiration.

Nothing, indeed, that is impelled only by the momentum of its own body can pass easily through spongelike substances; for even when water, whose nature it is to sink down and move in that direction, is contained in them, nothing flows out, whereas water
[I, 474] immediately escapes through instruments like colanders. Similarly, spongelike coverings set above vapors prevent them from rising and escaping, whereas coverings like colanders do permit them to pass up. For the latter only break up the continuity of the vapors, but any spongelike covering also checks their proper motion. Hence, if anything is to escape quickly from such a substance, it must either be compressed on all sides, as when a sponge is squeezed in the hand, or be attracted forcibly, as when one applies the lips and sucks it out strongly, or be propelled by something that drives it forward from behind, as when one blows into such instruments and so frees them from obstructions.

Thus the actions of inspiration and expiration would be beautifully accomplished in those spongelike bones; for the one occurs when the encephalon attracts the air inward and the other when it propels the air outward. But the residues could not be purged unless they were filtered through gradually over a considerable length of time, and the vapors would not ascend at all, because on account of their slow passage they would first commingle, intertwine, crowd together, and return once more to the original state from which they had been comminuted. As it is, however, with the actions combined, the perception of odors is a byproduct[66] of inspiration, and the expulsion of residues is a byproduct of expiration; for in these
[I, 475] actions the force of the air's motion carries along with it many

[66] Reading παρεμπόρευμα with Kühn for the παρ' ἐμπόρευμα of Helmreich's text.

things that could not force their own way through by their motion alone. Again, the perception of odors itself contributes in turn no inconsiderable assistance to respiration as a whole by not permitting noxious vapors to escape our notice and enter along with the pure air; for our sense, offended by them, compels us to do one of two things, either to get away from them as quickly as possible, or to hold to our noses something that will keep out the vapors while admitting the air.

Moreover, the cleansing of the olfactory passages, sometimes obstructed by thick, viscous residues, could not possibly be better accomplished by any construction other than the one we have. For since these passages were formed to be not only olfactory but also respiratory, they are cleansed as the air goes in both directions, once as it passes in and again as it passes out. And if ever the obstruction is greater than can be cleared out by the moderate, ordinary motion, we perform the so-called blowing out, which is expiration in a rush, and so by the violence of the motion dislodge all that has been solidly impacted. Thus it is no small recompense or common exchange that the many actions and uses found together at the extremities of the anterior [lateral] ventricles make with one another, and Nature has invented this association of them that the animal may live, and live a better life. Also there is in addition no small advantage in the fact that not as many instruments are needed as there are uses, and frequently a single instrument suffices for many actions and uses.

8. Similarly, the thin membrane [the pia mater] both supports [I, 476] the encephalon and at the same time is a covering for it, and in addition to these uses, it is the bond which holds together all the vessels of the encephalon. Indeed, it is like the chorion of the fetus and the animal's mesentery; for both these structures are composed of many arteries and veins lying close to one another, with a thin membrane forming a web in the intervals between them. In the same way the membrane [the pia mater] binds together all the arteries and veins of the encephalon in order that, even though their base is unsupported because they rest on such a soft, moist, almost fluid substance [the encephalon], they may not slip aside, become entangled, and be displaced by the motion. This is the reason why the membrane [the pia mater] not only surrounds the encephalon but also insinuates itself into the depths of it, traverses it through and

through, is interwoven with all parts of it, and accompanies the vessels everywhere, even into the inner cavities of the ventricles.

In this connection I do not know how it is that most anatomists, even when wide awake, call that part of the thin membrane which undergirds the inside of the ventricles choroid plexuses and choroid clews, but are unwilling to make the same comparison for the other parts of it or give them a similar name. I at any rate am pointing out and declaring that its nature and usefulness are the same as those of the chorion and mesentery, and I say that whereas those membranes
[I, 477] bind together the arteries and veins, this one here binds together both the vessels and the encephalon itself as well. What I am now about to tell will be sufficient proof that the encephalon is confined and bound together by the thin membrane.

Take the encephalon of any animal you choose (it is better to choose one of the larger ones) and when it has already been exposed on all sides but is still resting upon, and held together by, the parts at its base, try to strip off the thin membrane; you will see forthwith that every part, when laid bare, falls away and flattens out to the side, and that as soon as the encephalon has been denuded, it is no longer compact and globular but becomes flat, its elevated parts sinking down and flowing off laterally. And yet, since you are of course doing this when the animal is dead, much pneuma and a very great deal of vapor has already escaped, all the innate heat is absolutely gone, and whatever blood, phlegm, or other moisture is contained in the encephalon has all been congealed by the cold, so that for all these reasons it has become [comparatively] hard and dry. Nevertheless, I have clearly proved that even under these circumstances it still needs to be confined and held together by the choroid membrane [the pia mater]. Then how much more necessary this was when the animal was alive! For the encephalon, having this as its natural covering, needed it much more when still moist and
[I, 478] soft than in the condition in which it appears now, when the animal is dead.

9. The thick membrane [the dura mater] is also a covering for the encephalon, or rather it should be called not simply a covering but a defensive bulwark, so to speak, exposed to contact with the cranium, whereas the thin membrane is really the covering that is united with the encephalon. For the thick membrane is separated from it,[57] being

[57] Reading *αὐτοῦ* with Kühn for the *αὐτῆς* of Helmreich's text.

connected only by the emerging vessels, and if Nature had not placed the thin membrane between them, the proximity of the thick membrane would have been painful to the encephalon. Now just as Plato [88] says that God has interposed both water and air between earth and fire, which have natures widely different from one another, so I say that because the encephalon and cranium have widely different substances, Nature has placed two meninges between them, not being content with a single bond of union for the association. For that which is truly a mean must occupy the middle not only in respect to position but also in respect to character, and a thing is a mean in respect to its character when it is separated proportionately from the extremes. Neither membrane is distant proportionately from both the encephalon and the cranium; the thin membrane falls short of the hardness of the bone by more than its consistency in turn exceeds that of the soft encephalon, and again, the thick membrane is very much harder than the encephalon, but only a little softer than the bone. Hence, if Nature had created only the thin membrane, it could not have associated unharmed with the cranium, [I, 479] and if she had created only the thick membrane, in that case the encephalon itself would have been afflicted. In order, then, that neither the encephalon nor its covering might suffer, the thin membrane was formed first and above that the thick one, which is as much harder than the thin membrane as it is softer than the bone; and the thin membrane is as much softer than the thick one as the encephalon is softer than the thin membrane. Thus, by using a double mean Nature was able to place the bone and the encephalon close together without causing any pain, even though their [89] qualities differ very widely.

Now the choroid membrane [the pia mater] is a covering united with the encephalon just as the skin is with the animal, but the thick membrane is not so united with the thin one, though adherent to it at many points. In turn, the bone which surrounds the thick membrane and which they call the cranium (*κρανίον*) encloses it like a helmet (*κράνος*). For Nature has neglected none of these things, but just as good workmen, who cannot indeed unite a helmet [with a head] and yet need to make it enclose the head as firmly

[88] *Timaeus*, 31–32 (Plato [1920, II, *15*]).

[89] Reading *ὑπάρχοντα* with Helmreich for the *ὑπαρχούσαις* of Kühn's text.

as possible on all sides, prepare suitable bonds of union at convenient points on the circumference and thus fit it so accurately that it seems no different from one that might have grown there naturally, so too, since Nature could not, although she needed to do so, make the [thick] membrane actually unite with the cranium because their substances are so unlike, she did the only thing still
[I, 480] left to her to ensure their safety, that is, she contrived more bonds of union than there were in the helmets cunningly made by Hephaestus.[60] Hephaestus's bonds were able only to attach, but these others in addition to attaching have other and greater uses as well.

Then what are these bonds of union? How do they wind about the cranium? How do they attach the cranium to the hard membrane? And what other benefits do they confer on the animal? They are ligaments[61] growing out as thin membranes from the [thick] membrane itself. The paths they follow in passing outward are the sutures of the head. Each ligament extends around the same side [of the head] from which it has arisen; as they proceed, they meet and become attached to one another, grow together, and are completely united, so that there is produced from all of them one common membrane, called the pericranium. That it attaches the hard membrane to the cranium reason already makes evident, even before you see it in dissection, but this would not be the proper time to tell what other uses it offers to animals; for my discourse, like a runaway horse forgetting the goal, has already gone farther into these matters than is necessary. Let us, then, again be mindful of our theme and return once more to the encephalon, from which I have been diverted by the logical sequence of these subjects, as I joined to the explanation of the thin membrane that of the thick, and to that in turn added the explanation of the cranium and pericranium.

[I, 481] 10. Now let me explain first about the ventricles of the encepha-

[60] Emending τοὺς . . . τεχνηθέντας to read τὰ τεχνηθέντα. Perhaps there is an allusion here to the headpiece worn by Odysseus on the raid in the tenth book of the *Iliad*, cunningly made and secured by many straps. Or it might refer to the πῖλος, the close-fitting cap worn by Hephaestus. I have not found a mention of a helmet made with many "bonds of union" by Hephaestus, though of course he made numerous helmets—for example, those for Achilles and Aeneas.

[61] δεσμοί, probably the adherence of the dura mater to the cranium at the sutures.

lon, about the size, location, and shape of each, about the channels that connect them with one another, and the total number of ventricles; afterwards I shall speak of the parts lying upon and beside them. The two anterior [lateral] ventricles perform inspiration, expiration, and the blowing out of the breath from the encephalon. I have demonstrated this elsewhere.[62] I have also shown that they elaborate and prepare the psychic pneuma for it. Moreover, I said a little while ago that in the lower parts of them toward the nose are both the olfactory instrument and a conduit, so to speak, suitable for the discharge of the residues. It was better that there should be two [lateral] ventricles rather than one, because there are two channels leading downward, the sense instruments are all paired, and the encephalon itself is double. This duality also has another usefulness of which I shall speak when I turn to consider the sense instruments, but the principal and most general usefulness of pairing all instruments is to make it possible, in case one of them is injured, for the remaining one [still] to be of service. At Smyrna in Ionia I once saw an incredible sight, a youth who had suffered a wound in one of the anterior ventricles and yet survived, apparently by the will of God; if both had been wounded at the same time, however, [I, 482] he could not have lived even for an instant. Hence in the same way, if some trouble other than a wound affects one of the ventricles while the other remains healthy, the animal will be in less danger of its life than if both are affected at the same time. Surely if there are two ventricles and both are affected together, it is the same thing as if there were only one from the beginning and that one was affected. Therefore, it is safer whenever possible to make a part paired rather than single. However, it is not always possible; for example, two spines could not possibly be formed in one animal. If this is true, then there could not be two spinal medullas either, and if so, then the ventricle [the fourth ventricle] of the *parencephalis* from which the spinal medulla sprouts could not possibly be paired.

11. Now since all the nerves distributed to parts of the body below the head grow out either from the *parencephalis* or from the spinal medulla, the ventricle of the *parencephalis* had to be of considerable size and had to receive the psychic pneuma already elaborated in the anterior [lateral] ventricles. Hence a canal [63] had to

[62] *De usu respirationis*, cap. 5 (Kühn, IV, *501–511*).

[63] Not the aqueduct; see note 76 of this Book.

be formed leading from these two into the ventricle of the *parencephalis*, which is indeed seen to be large. The canal entering it from the anterior ventricles is also very large and forms the only connection between the encephalon [here the cerebrum] and *parencephalis*.

[I, 483] Now these are the names the followers of Herophilus are accustomed to use for these two parts, giving the anterior part the same name as the whole because of its size; for although the encephalon is paired, as I have said, each of its parts is far larger than the entire *parencephalis*. The posterior part was named, however, because the anterior part had already appropriated the name of the whole, and it was no longer possible to find any name for the *parencephalis*[64] more suitable than the one it now has. But again, others call it not *parencephalis*, but *encranis* and *encranion*.[65] These men should not be blamed if they invent names to make their meaning clear, seeing that all our lives we name many things for their pre-eminence in point of size, power, virtue, or honor.

Since, then, the encephalon is separated from the *parencephalis* by a fold of the thick membrane [*tentorium cerebelli*], as I have said earlier, but needs to be attached at one point at least, in order to form the canal I have already mentioned, it has made its two ventricles end first in one space [the third ventricle],[66] which some anatomists have reckoned as a fourth ventricle of the whole encephalon [here the entire brain]. There are some, however, who call it the connection between the two ventricles and do not grant that it is proper to think of it as another ventricle. I myself think that it does nothing either to help or to hinder the course of our discussion of this question if one wishes to interpret this place as a meeting place of the two [lateral] ventricles or as a third ventricle in addition to

[64] The literal translation of the term is, "beside the encephalon." Aristotle (*Hist. an.*, I, 16, 494b32) had already used it for the cerebellum.

[65] Later on, in chapter 13 of this Book, and again in *De plac. Hipp. et Plat.*, VII, 3 (Kühn, V, *603*), Erasistratus is said to have called what we know as the cerebellum the *epencranis*.

[66] Galen usually calls the lateral ventricles of the cerebral hemispheres anterior ventricles; our fourth ventricle is his third and vice versa, except that here, two sentences farther on, he calls our number three the third ventricle. He also frequently calls our third ventricle the common space between the two anterior ventricles.

these, but I do consider it worth while to know why the anterior [lateral] ventricles come together in one place. The reason for it is the formation of the canal connecting them with the *parencephalis;* for, beginning at that hollow place [the third ventricle], the canal receives the pneuma contained there and transmits it to the *parencephalis.* [I, 484]

The part [the body of the fornix] of the encephalon above the common cavity [the third ventricle], like the roof of a house, is rounded up to look like a hollow sphere and seems not without good reason to have been called a little vault or arch, since master-builders are accustomed to call such structures in buildings arches and vaults. Those who consider this cavity to be a fourth ventricle say that it is the most important one in the whole encephalon. Herophilus, however, seems to regard, not this ventricle, but the one [the fourth ventricle] in the *parencephalis* as the more important. But I have said enough in my commentaries *On the Teachings of Hippocrates and Plato* [67] about what opinion should be held on these matters. Here I shall be content to explain in detail the uses alone, and not even all of these with demonstrations; for I shall at once accept as proved those that follow of necessity from the principles previously demonstrated in that work and merely remind you of the principles from which they proceed. The usefulness of that vault-shaped body [the body of the fornix] should be assumed to be no different from that of actual vaults in buildings. Indeed, just as those are more suitable than [I, 485] any other shape for carrying the load resting upon them, so too this vault-shaped body holds up without distress all that portion of the encephalon that lies above it; for a rounded body is everywhere most similar to itself, hence of all shapes the most resistant to injury, and yet the most capacious of all the shapes having an equal perimeter. This is no small advantage for vessels, canals, ventricles, and everything that is formed to receive some substance; for the best of them are those that hold the most and yet are the smallest in proportion to the bulk of their bodies.

Thus you could also mention the same advantages (*χρεῖας*, use-

[67] *De plac. Hipp. et Plat.*, VII, 3 (Kühn, V, *604–611*), where on the basis of experiments performed on living animals Galen agrees with Herophilus. He also credits Erasistratus with having seen and described the *four* ventricles when he was an old man, though obviously from this passage in *De usu partium* they were likewise known to Herophilus.

fulnesses) for the shape of the canal between the ventricle [the third ventricle] lying beneath the vault-shaped body and the one [the fourth ventricle] in the *parencephalis;* for its rounded form is most resistant to injury, most capacious, and best suited for supporting a load. You could say the same thing too about all the canals throughout the body, all the arteries and veins, and all the cavities. For they are all spherical, and although their branchings, outgrowths, the places where they rest upon something, their adhesions to neighboring bodies, and their mutual inosculations destroy the perfection of a sphere, the rounded form still remains.[88] Indeed, if you inspect the middle portion of any cavity, you will find this in particular the most nearly spherical, because it is not
[I, 486] yet spoiled by branchings but still preserves the true semblance of its shape. So, likewise, if you will imagine that you have removed from the anterior [lateral] ventricles themselves the vault [the body of fornix] of the hollow space in the middle [the third ventricle], the branches leading down to the nose, and those [the descending horns] leading down and to the sides,[89] the usefulness of which I shall discuss in their turn, you will find that what you have left is perfectly spherical. Moreover, if you remove from the posterior [fourth] ventricle (the one in the *parencephalis*) the insertion of the canal I have mentioned earlier and the outgrowth into the spinal medulla, you will find that it too is spherical.

12. This is enough to have said about the shape of the ventricles. As regards their size, I may say that not only here but also throughout the body the cavities receiving the more turbid substances are properly larger and those receiving substances that are more potent, as one might say, are smaller. In fact, there is a great deal that is superfluous in both [kinds of] material, and when this has been separated off and excreted and the useful residue has been provided with the appropriate quality, the Creator can rightly be said to have reached his appointed goal. Hence the ventricle of the *parencephalis* [the fourth ventricle] too has with good reason been made smaller than the anterior [lateral] ventricles, and even if the space [the third

[88] Kühn omits from *καὶ τὰς ἐπὶ* through *συμφύσεις τε* of Helmreich's text.

[89] It should be noted once more that in the animals on which Galen's descriptions are based the lateral ventricles are prolonged into the olfactory bulbs and the posterior horns are lacking.

ventricle] common to the anterior ventricles should be counted separately and reckoned as a fourth ventricle of the encephalon, the ventricle of the *parencephalis* [the fourth ventricle] is also smaller than that one.

The choroid membrane [the pia mater], which I have said undergirds the inside of the ventricles, reaches as far as the cavity [the third ventricle] in the vault-shaped body [the body of the fornix]. The bodies [pineal body, corpora quadrigemina, pons] that come next after these cavities and surround the canal have a constitution hard enough of itself not to need girding and so do the bodies that surround the whole posterior [fourth] ventricle.[70] For I have said earlier that the *parencephalis* is much harder than the encephalon. [I, 487]

Here I am moved to wonder not only at the absurd doctrines of the followers of Praxagoras and Philotimus, but also at their ignorance of what is to be seen in dissection. For they consider that the encephalon [the entire brain] is a sort of excresence or outgrowth of the spinal medulla, and they say that this is the reason why it is composed of long convolutions; and yet the posterior part of the encephalon continuous with the spinal medulla has very little of any such structure and the anterior part very clearly exhibits it to a high degree. Moreover—and this is a still greater error on their part—they do not know that the spinal medulla is continuous only with the parts at the base of the encephalon, which are the only parts of it not convoluted. For, being hard, they have in themselves a firm foundation and do not need to be girded and supported by the thin membrane. Thus it is that even the best of men necessarily disgrace themselves when they dishonor truth and wish to abide by the doctrines they have established for themselves in the beginning. Likewise, those who say that the encephalon is shaped by the cranium seem not to know that the encephalon is separated from the hard membrane [the dura mater], and that the latter does, to be sure, touch the cranium, but is not fused with it; neither do they know that the hard membrane must be the first of the two to be shaped or that the cranium itself is such as it is.[71]

13. Since I have reached this point in my discourse, I must not [I, 488]

[70] Here it is evident that Galen failed to see or chose to ignore the choroid plexus of the fourth ventricle.

[71] As Daremberg (in Galen [1854, I, *562*]) suggests, this sentence is probably corrupt.

leave unexplained the form of the *parencephalis*.[72] It is composed not of large convolutions separated by the thin membrane [the pia mater] like the encephalon [the cerebral hemispheres] but of many very small bodies differently arranged from those in the encephalon. Now since, as I have shown in other works of mine,[73] much psychic pneuma is contained throughout the substance of the encephalon and not just in its ventricles, we ought to think that the *parencephalis* too, which must be the source of the nerves for the whole body, contains a very large quantity of this pneuma, and that the intervening regions that connect the parts of it are pathways for the pneuma. Erasistratus was right when he declared that the *epencranis* (for this is what he calls the *parencephalis*) has a more intricate structure than the encephalon. On the other hand, when he says that the *epencranis* itself and along with it the encephalon are more complex in man than in the other animals because man's intelligence is greater than theirs, it seems to me that his understanding is no longer so correct; for even donkeys have an exceedingly complex encephalon, whereas, judging by their stupidity it ought to be perfectly simple and uncomplicated. Hence it would be better to think that intelligence depends on the good temperament of the substance of the thinking body, whatever this body may be, and not an intricacy of structure. Indeed, it seems to me that perfection of
[I, 489] intellect should be ascribed not to the quantity of the psychic pneuma but rather to its quality. Now, however, unless we restrain this discourse with a curb, so to speak, it will run off the course and lay hold on greater subjects than my proposed theme warrants. And yet it is impossible to avoid altogether saying something about the substance of the soul if one is explaining the structure of the body that contains it, but though this is impossible, we can nevertheless turn back quickly when it is unnecessary to linger.

14. Coming back, then, to the subject of the parts behind the middle [third] ventricle, let us examine the body [the pineal body] which lies at the beginning of the canal connecting the middle ventricle with the posterior encephalon and which is called κωνάριον (little pine cone) by those versed in anatomy, to see for what use-

[72] The reader has probably realized that the term *parencephalis* may be applied either to the cerebellum alone or to the cerebellum and the brain stem in that region taken together.

[73] *De plac. Hipp. et Plat.*, VII, 3 (Kühn, V, 605 ff.).

fulness it was formed. This body is a gland to judge by its substance, but in shape it very closely resembles a pine cone, and from this it takes its name. Some think it has the same usefulness as the pylorus of the stomach; for they say that the pylorus too is a gland and prevents the nutriment from being taken over from the stomach into the thin intestine before it is concocted, and that this gland, the pineal body, standing at the beginning of the canal that transmits the pneuma from the middle [third] ventricle to the one in the *parencephalis* [the fourth ventricle] is a guardian and housekeeper, as it were, regulating the quantity that is transmitted. I myself, however, have told earlier what opinion we should hold concerning the pylorus of the stomach, and I believe that this [I, 490] gland resembling a pine cone and filling up the bifurcation of the large vein [*v. cerebri magna* (*Galeni*)] from which nearly all the choroid plexuses of the anterior ventricles arise was formed for the same usefulness as other glands that support veins as they divide. Indeed, its position is the same in every respect as that of such glands, for its apex is firmly established at those parts of the vein where it first divides [beneath the splenium of the corpus callosum]; all the rest of it increases in size to correspond with the distance between the vessels [*vv. cerebri internae*, veins of Galen] resulting from the division; and it proceeds as far as the vessels extend in a suspended condition. As soon as these veins pass onto the body of the encephalon itself [at the posterior boundary of the third ventricle], the pineal body abandons them, and the body of the encephalon in this region becomes a support for both the pineal body itself and the veins.

The notion that the pineal body is what regulates the passage of the pneuma is the opinion of those who are ignorant of the action of the vermiform epiphysis [*vermis superior cerebelli*] and who give more than due credit to the gland. Now if the pineal body were a part of the encephalon itself, as the pylorus is part of the stomach, its favorable location would enable it alternately to open and close the canal because it would move in harmony with the contractions and expansions of the encephalon. Since this gland, however, is by no means a part of the encephalon and is attached not to the inside but to the outside of the ventricle, how could it, having no motion of its [I, 491] own, have so great an effect on the canal? But perhaps some one will say, "What is to prevent it from having a motion of its own?" What,

indeed, other than that if it had, the gland on account of its faculty and worth [74] would have been assigned to us as an encephalon, and the encephalon itself would be only a body divided by many canals and would be like an instrument that was suited to be of service to a part formed by Nature to move and capable of doing so? Why need I mention how ignorant and stupid these opinions are? For this part, which people imagine must be a part of the encephalon itself near the canal, this part which must be such as to control and govern the passage of the pneuma and which they cannot discover, is not the pineal body but the epiphysis [75] [*vermis superior cerebelli*] that is very like a worm and is extended along the whole canal. Those versed in anatomy have named it for its shape alone and call it the vermiform epiphysis.

Its position, character, and relations with the parts in its vicinity are as follows: On each side of the canal there are delicate, elongate eminences of the encephalon, called *gloutia* (little buttocks) [the corpora quadrigemina]. You would best compare their mutual relation to that of the human thighs when they are in contact. There are those who liken them to the testicles and prefer to call them *didymia* (little testicles) rather than *gloutia*. Some call *didymia* the bodies
[I, 492] [the superior colliculi] associated with the pineal body, and *gloutia* the bodies [the inferior colliculi] that come next after these. The left and right walls of the canal [76] are formed by these bodies; it is

[74] Kühn omits *δυνάμει τε καὶ ἀξιώματι*.

[75] Reading with Helmreich *ἐπίφυσις* for the *ἀπόφυσις* of Kühn's text.

[76] From the description which Galen proceeds to give here, it is finally evident that this canal connecting the third and fourth ventricles cannot be the aqueduct of Sylvius. For it is roofed over by only a thin membrane; it leaves the third ventricle just below the pineal body; it leads down the median sulcus of the corpora quadrigemina; and it enters the fourth ventricle through the space normally occupied by the anterior medullary velum, which was probably torn in dissection, but which is supposed to be drawn up out of the way by the vermis. It is "closed" by the vermis, which, guided by the brachia conjunctiva, rolls forward and presses upon it, and it is "opened" when the vermis, carrying the anterior medullary velum, rolls back and frees it. In *De anat. admin.*, IX (Kühn, II, *727*, *728*; Galen [1956, *235*, *236*; 1906, II, *1–2*; 1962, *1*]), Galen gives directions for following it with a probe from the third ventricle and says he has often done so, but it is certain that he missed the real channel deep within the brain stem. Daremberg (in Galen [1854, I, *566*]) and Simon (in Galen [1906, II, *243*]) have each an

covered above by a thin, though certainly not weak, membrane [the arachnoid], attached on both sides to the *gloutia*. The membrane [the partially disrupted anterior medullary velum] that extends to the posterior [fourth] ventricle is the lower end of the vermiform epiphysis, which is not in the least like the *didymia* and *gloutia*, for the epiphysis is variously joined together, whereas the *didymia* and *gloutia* are homogeneous throughout and certainly do not have a composite structure at all. Besides its being variously joined together and seeming to be composed of many parts fastened to one another with thin membranes, the vermiform epiphysis is remarkable in this further respect also: the extremity of it at the posterior [fourth] ventricle is convex and thin where I have said it ends in the membrane [the anterior medullary velum] lying upon it. But as it leaves this place, it gradually grows larger and flattens out, so that its dorsum is nearly as wide as the distance between the *gloutia*, and thus, when it extends down the length of the canal, it blocks it off entirely. When it bends back to the rear, however, it draws along with it the membrane adnate to its convex parts and so opens as large a portion of the whole canal as will correspond to the extent of its backward turn. In fact, as it bends back, it rounds up and contracts upon itself, so that it gains in width as much as it loses in length. [I, 493] Hence it is reasonable that when it bends back a little and so becomes a little broader, the narrowest parts at the bottom of the canal are the only ones its lowest extremities cannot enter. When it bends back more and its breadth consequently increases, a larger part of the canal is opened, always as much of it as corresponds each time to the diminishing convexity [of the epiphysis] entering it.

None of these things would happen as they should, if Nature had made the epiphysis even a little thicker or thinner than it actually is. For the canal would never be completely closed by a thicker epiphysis, the thinnest portions of which would be incapable of reaching into the narrowest part of the canal; a thinner epiphysis would fail not only to close the canal completely, but also to open it properly. In fact, when it was closed, pneuma would filter through

---

excellent note on this point. In the passages in *De anatomicis administrationibus* cited above, Singer and Duckworth, ignoring this description in *De usu partium* and the notes of Daremberg and Simon, erroneously identify Galen's canal as the aqueduct of Sylvius. See also Meyer-Steineg (1911, *203*).

to some extent because the whole width of the canal would not be occupied by the thin epiphysis, and when it was being opened, the epiphysis would first have to bend back a great deal, or else the convex extremities would not be raised up and withdrawn from their base in the canal. Moreover, if the canal would be opened and closed irregularly and improperly by a vermiform epiphysis a little
[I, 494] too thick or thin, what must we suppose would happen if the change from what it is now was very great? Would not the whole existing arrangement of these bodies be thrown into utter confusion and destroyed? Certainly you could not point out a construction excellent for the perfect performance of the work, which would be more brilliantly conceived than one that is so accurate that if any detail in the arrangement is altered, the whole will be destroyed. For in instances where it is possible for a work of art to retain its usefulness though many attributes are added or subtracted, the artist does not need extraordinary skill, and the test of accurate workmanship lies in those works in which the omission of some small detail brings with it the ruin of the whole.

But if an error only in the mass of the epiphysis would destroy the value of the work, while the rest of its structure remained unspoiled and incapable of either aiding or hindering to any great extent, perhaps some would assign the cause to chance no less than to art. Since, however, this which is true of the size of the vermiform epiphysis is true of all the other parts as well (for whatever you change you harm the action, as I have just shown), how could one fail to be ridiculous in depriving Nature of her skill? For the *gloutia* are enough higher than the canal for the epiphysis to be carried upon them as it rolls up;[77] the canal as a whole is long, for no reason other than that the motion of the epiphysis may have a wide range,
[I, 495] and structures that are dense and made up of many small parts [like the vermiform epiphysis] offer the same usefulness. In fact, in order that its motion may differ a great deal in respect to the more and the less, Nature has made the epiphysis capable of bending and folding to a great extent. Since for all these reasons it would tend to be easily moved in various ways and there was [thus] danger that as it was carried upon the convex backs of the *gloutia* it would roll off to one side and abandon the canal, Nature contrived for it some ligaments

[77] Reading with Helmreich ἀνακυλιομένην for the ἀνακεκλιμένην of Kühn's text.

[*brachia conjunctiva*] leading to the *gloutia* and called tendons by those versed in anatomy; bound in and held fast by these on both sides, the epiphysis is prevented from going astray. Moreover, she also made it hard in order that it might be resistant to injury, though certainly not so hard, of course, as to be no longer a part of the encephalon; with a perfectly accurate estimate in this case too of its usefulness, she increased its hardness to the point where it could be hard and still remain the encephalon.[78] Yet if with all that she has done for the epiphysis Nature had made the folds composing it oblique or vertical instead of transverse, as they actually are, these [other] provisions would be of no avail. For it would not be rounded up in the way I have described if she had not given it a backward motion by rolling it into transverse folds, nor would it be able gradually to open and close the canal, as I have shown that it does. On the contrary, if this one thing had been neglected, it would have been of no use to construct so many wonderful parts around the canal. [I, 496]

It is now clear, at least to those who have been attentive to my discourse, that if any of the other arrangements I have mentioned were altered, the result in many cases would be merely an impairment of the action, but that there would be other instances in which the action would be utterly ruined. Hence I cannot conceive how anyone could undertake to show that these are not works displaying the most perfect skill.

[78] Reading with Helmreich ἐγκέφαλον for the ἐγκεφάλου of Kühn's text.

[II, 1]

THE NINTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Encephalon, Cranial Nerves, and Cranium]

1. Since I have been explaining all the parts of the encephalon and have been forced in many instances to include in my discourse parts in the vicinity of it because of the natural consecution which is found in them, it would be proper to speak in this book of the usefulness of the remaining parts of the head and to begin again at the point where I left off in the last book.

The particular one among the works of Nature that has always been of the greatest concern to her is the evacuation of the residues of the nutriment from all parts of the body and especially from important parts like the encephalon. Now some of the juice that constantly flows to the parts is so useful that it is assimilated by the body to be nourished, and this is the real nutriment; all the rest that reaches the member along with the useful juice and is separated from it when the useful juice is presented[1] requires canals suitable for excreting it, and if it finds none, it accumulates there on the spot and first becomes like a heavy burden. Later, by pre-empting their
[II, 2] passageways, it acts as an impediment to the next juices that keep flowing in, so that it does not permit the member to be nourished. These are slight disadvantages, but there are two others more serious, instruments of the diseases which are the inevitable consequence of impure bodies. In one of these, the parts, lacking their proper nutriment, behave like famished animals; for just as such animals

[1] In Galen's theory there are three stages in the nutrition of a part. In the first the nutriment arrives and is *presented* to the part; then it *adheres;* and finally it is *assimilated.* See *De nat. fac.*, I, 11; III, 13 (Kühn, II, *24–26, 198–201;* Galen [1928, *38–43, 306–311*]).

devour filth or anything of the sort, so the parts are driven by their natural desire to draw in some of the unwholesome juices. In the other, the residues accumulated in the course of time putrefy and so give rise, as they become more acrid and warmer, to inflammations, erysipelas, herpes, carbuncles, fevers, and an unnumbered host of other diseases. Hence, to prevent anything of the sort from happening, especially in the important parts, Nature gave a great deal of thought to the elimination of the residues.

Since there are two kinds of these residues, one vaporous and fuliginous, tending naturally to pass upward, the other watery and slimy, so to speak, which sinks down of its own weight, she cut two kinds of channels for their elimination, leading upward to the highest point the ones that evacuate the light residues and causing the ones for the evacuation of the heavy, sinking residues to slope steeply downward.[2] Moreover, the latter she made not only steeply sloping, but also exceedingly broad, since they were meant to be [II, 3] conduits, as it were, for large quantities of thick liquid. For the former she bored, so to speak, certain fine apertures [the sutures] corresponding to the fineness of the residues, but the canals of the encephalon that slope downward through the palate into the mouth and through the substance of the nostrils discharge thick, visible residues from large, visible orifices [the foramina of the palatine bone and perforations of the ethmoid].

It is not always possible to see clearly the elimination of the

[2] According to Galen there are two pairs of these channels for the elimination of the thicker residues from the encephalon. The first pair, which ends at the nostrils, he has described in chapter 6 of Book VIII; the second he will describe presently. Its two members begin, one from the anterior, the other from the posterior end of the third ventricle and lead toward one another along its floor to meet at the infundibulum. Thence they descend together into and through the hypophysis, below which they separate again and, passing down through the sphenoid bone and the vertical part of the palatine bone on each side, empty into the mouth at the greater and lesser palatine foramina. See Hyrtl (1880, *107–108*). This second pair of channels is the main route, adequate under normal conditions; the first pair is used only when there is too great a quantity of the residues to be carried off by the second, for example, when one has a cold. It is improbable that Galen in describing his second pair was thinking of the craniopharyngeal canal, for he insists on the large size of the openings, which are in the mouth, not in the nasopharynx. See Ellenberger and Baum (1926, *64*) and note 7 of this Book.

vaporous residues either in the body as a whole or through the head, for it sometimes escapes the sight because they are so thin. Indeed, in the soft, moist parts of the body, no special pathway has been set aside for any such evacuation, since all soft, moist bodies naturally yield readily and make way for substances passing through them rather swiftly and with a rush. When, however, these substances have gone by, soft bodies come together again and coalesce immediately to recover their original unity. But when bodies are hard, nothing can pass through unless a passage has been prepared beforehand. Therefore, definite channels in the encephalon itself, the meninges, and the skin of the head were unnecessary for evacuating the vapors, and if there were any, they would not be perceptible by our senses, for they would be swift to collapse as soon as the evacuation had taken place. In the cranium, however—for that is the name of
[II, 4] the bone enclosing the encephalon—Nature has cut for these vaporous, fuliginous residues passages [the sutures] that are perceptible, not only for the reason I have given which holds true for all the parts, but also for a special, additional reason which applies to this part because of its position. For the head lies above all the members of the body, like the roof of a warm house, and so, since it receives all the fuliginous, vaporous residues that rise from the subjacent parts, it needs a more copious evacuation.

Now the encephalon had to be protected by a strong enclosure and Nature consequently did not merely entrust its defense to skin, as she did for the parts in the abdomen, but first, before the skin was put on, she invested it with bone like a helmet. Hence it would not have been provided even with moderate elimination, let alone an elimination more copious than that of the other parts, if she had not constructed many vents for it by making the bone of the head porous and variously articulated by means of the so-called sutures. Anyone who has seen what these are like understands the whole matter already; those who have not seen them may comprehend it from the following description. Each of the bones joined together to form a suture has alternating prominences inserted into the concavities [of the other bone].[8] The prominences are shaped
[II, 5] very much like fingernails and the concavities are accurate recep-

[8] Reading *ἐγκειμένην* and *κοιλότητι* with Helmreich for the *κειμένην* and *κοιλότητος* of Kühn's text.

tacles for such a shape. Since each bone receives in its concavities the prominences of the other, the shape of the whole articulation becomes very much like that of two saws set against one another with their teeth fitting accurately together. And it is clear that the bones have acquired this mode of articulation for safety's sake, in order that they may not separate during vigorous motion. So too, master craftsmen frequently put together machines with many wedge-shaped bolts and thus make for them joints that will be separated only with difficulty, and this would be a second example for you of the way in which the bones are joined together, to be added to the first figure of the saws set against one another. Indeed, you would not be wrong in comparing this combination to clothes sewed together from many patches, and this is the reason, I suppose, why the Ancients called these combinations sutures (*ῥαφαί*, primary meaning, seams), a name still applied to them even now.

Why, then, did not Nature bore fine foramina like holes in the bone of the head, as she did in the bone of the palate? And why was she not content just with the spongelike cavities in it? The reasons are that these cavities had to be bounded on each side by a smooth, dense lamina of bone, for they must be adjacent internally to the meninges and externally to the membrane called the pericranium, and that the bone of the head had to be divided into several parts for another reason, as I have shown in the preceding book. Since, then, the rugged, spongelike cavities would, if left uncovered,[4] scrape and pierce the adjacent parts; since it would be useless [for Nature] to [II, 6] bore through the lamina on their outer side; and since in any case she must divide the bone of the head into many parts, she properly employed the sutures for transpiration as well. For it is better, as I have pointed out many times, that more numerous actions and uses should be accomplished by fewer instruments than that fewer actions and uses should be accomplished by more instruments.

In the preceding book I showed that the pericranial membrane must be attached to the thick membrane [the dura mater] and that this was the reason why sutures had to be formed. In this present book I am explaining a second usefulness for them, and there might also be a third, which has to do with the slender, emerging vessels, for which [Nature] would have made suitable foramina as she did

[4] Accepting Renehan's restoration (1965, 69) of *ἄν*, bracketed by Helmreich.

for the stout vessels, if she had not known that it was necessary to form the sutures and so used these for this purpose too. The thicker portion of the fuliginous residues is evacuated only through the sutures; the thinner portion can also pass through the cranium itself, which on account of its spongelike cavities would have been pervious to the thicker residues too, if it were not that both surfaces of it must be made smooth, as I have said.

2. Now perhaps someone may think that it was idle to make the cranium full of spongelike cavities, because the sutures are so numerous and large that they need no help from anything else in effecting transpiration. Here again it must be shown that the cranium needed to be made such as it is for another reason (χρεία, [II, 7] usefulness), although I was in haste to pass on now to the excretory canals for the thick residues lest this present book be lengthened by insertions at every turn. So I shall add only this one thing more and then return again to my proposed theme. If Nature had made the whole upper bone dense and thin at the same time, the parts lying beneath it would not thus be rendered more secure, because anything piercing it could penetrate easily on account of the shortness of the path. If she had made it dense and at the same time thick, it would be a burden to the whole animal, just as if a person had bound upon his head a weight which he could never remove. There remained the third possibility, namely, to make the bone neither thin nor dense, but thick, loose-textured, and full of spongelike cavities; for so it would neither be a burden, nor afford a short path into the encephalon for anything piercing it. The bone, then, has been made such as it is for the reasons I have just given and, to some extent, for the sake of transpiration as well.

3. Now let our discussion return again to the other kind of the canals that purify the encephalon, and explain the skill of Nature in dealing with them. In the preceding book I made clear the facts concerning the two canals that reach the nostrils. Of the other two that extend down to the palate, one [in the floor of the third ventricle anterior to the infundibulum] arises at the fundus of the middle [third] ventricle of the encephalon and passes steeply down; the other [in the floor of the third ventricle posterior to the infundibulum] begins at the canal[5] joining the encephalon to the *paren-* [II, 8] *cephalis* and slants down toward the first one. When they first come

[5] Not the aqueduct; see note 76 of Book VIII.

together, they are both received in a common, hollow, steeply sloping space [the infundibulum], the upper rim of which is a perfect circle. Thence, becoming continually narrower, it grows down into a gland [the hypophysis] below, which resembles a flattened sphere and also has a perceptible cavity.[6] The gland is succeeded by a bone[7] like a colander, that terminates at the palate, and this is the route of the thick residues.

The usefulness of each of the instruments along it is already clear even if I do not mention them, but I will do so because I do not want to leave anything undiscussed. The upper part of the cavity [the infundibulum] which receives the channels and which is called πυέλος (basin, pelvis) by some from its shape, and χοάνη (funnel) by others from its usefulness, serves the purpose of a cistern, so to speak. Its lower part, just as its name indicates, acts as a funnel; for it is pierced by a perceptible canal leading down as far as the cavity in the gland. Since it must be attached to the encephalon above and inserted into the gland below, it had to be made membranous, and since a thin membrane, the choroid meninx [the pia mater], also surrounds the encephalon itself, there was no reason to demand anything else to bind the pelvis [the infundibulum] to the encephalon, and so a portion of this membrane is properly extended to constitute the body of the pelvis.

As for the usefulness of the gland that comes next after the pelvis, very evidently it filters the residues, a great truth entirely unknown to anatomists, who pass over in silence the reason why the residues do not fall from the infundibulum directly into the perforations at [II, 9]

[6] The hypophysis does have a perceptible cavity in the beef and pig, which, however, does not communicate with the recessus infundibuli, as Galen says a few lines farther on that it does. See Ellenberger and Baum (1926, 779–780).

[7] The sella turcica of the sphenoid bone is pierced by foramina for blood vessels, and Galen may have thought that the residues descended through these into the body of the sphenoid. For him the sphenoid and palatine evidently constituted one bone (cf. *De ossibus ad tirones*, cap. 1 [Kühn, II, 743]) through the substance of which the residues passed down on each side to issue from the foramina maiora and minora in the horizontal portion of the palatine bone. It should be noted that whereas in man the foramen maius lies at the edge of the palatine and is also bounded by the maxilla, in the beef it is entirely within the palatine, in the pig entirely within the maxilla. See Ellenberger and Baum (1926, 72).

the palate (though it is a subject worthy of investigation), just as they also neglect this question in connection with the colanderlike bones [*os ethmoidale*] at the nostrils. For they do not tell that for the sake of which these bones have been formed, but consider it sufficient to say only that they filter the residues, and they pass over in complete silence the fact that it is better for the residues to be filtered rather than to escape directly. But I have demonstrated earlier this very thing and I have also shown that it is better to call these [ethmoid] bones spongelike, not colanderlike, and that that is the comparison Hippocrates made.[8] Now since injury [to the encephalon] could be more easily inflicted at the nostrils, great, bony defenses stretching beside them for a very long way were made in that region, but since the perforations at the palate ended within the mouth and were covered on the inside by a thick membrane besides, there was no need of great protection, and these three things, the gland, the bone, and the membrane, were enough. Even if I do not say so, I suppose it is already clear that this gland [the hypophysis] is outside the thick membrane [the dura mater] and that the interval between the bone of the palate [the sphenoid below the sella turcia together with the palatine] and the meninx equals the depth of the gland. It would be reasonable to tell now what bodies Nature has
[II, 10] established in this space; for it is clear that this is the safest place in the whole body of the animal. The entire encephalon and the cranium lie above it and the bone of the palate and the mouth lie below, so that an animal could die many times over, if such a thing were possible, before any injury from the blows of an external object penetrated to these parts.

4. The plexus called retiform [*rete mirabile*][9] by anatomists, is the most wonderful of the bodies located in this region. It encircles the gland [the hypophysis] itself and extends far to the rear; for

[8] See chapter 7 and note 55 of Book VIII.

[9] The *rete mirabile* is a highly complex arterial network absent in man but conspicuous in ungulates, where it occupies the same region as the circle of Willis in man. Its chief source is the internal carotid. In ruminants it also receives branches from the vertebral and condyloid arteries; in the pig, however, there is no connection with these two posterior arteries, and since Galen both here and elsewhere fails to mention any source other than the internal carotid, it is probable that he studied this structure in the pig. See Ellenberger and Baum (1926, *626, 663*); and cf. Galen's *De plac. Hipp. et Plat.*, VII, 3 (Kühn, V, *607–609*), and chapter 12 of Book XVI of this present work.

nearly the whole base of the encephalon has this plexus lying beneath it. It is not a simple network but [looks] as if you had taken several fisherman's nets and superimposed them. It is characteristic of this net of Nature's, however, that the meshes of one layer are always attached to those of another, and it is impossible to remove any one of them alone; for, one after another, the rest follow the one you are removing, because they are all attached to one another successively. But of course, on account of the delicacy of the members composing it and the closeness of its contexture, you could not compare this network to any man-made nets, nor has it been formed from any chance material. Rather, Nature appropriated as the material for this wonderful network the greatest part [*a. carotis interna*] [II, 11] of the ateries ascending from the heart to the head. Small branches are given off by these arteries to the neck, the face, and the external parts of the head. All the rest of them, as straight as they were formed in the beginning, pass up through the thorax and neck to the head and are received there comfortably by a part of the cranium, which is pierced through [by the carotid canal] and admits them with no trouble into the interior of the head. The thick meninx [the dura mater] too was about to receive them and had already been pierced through along the line of their invasion, and all these things gave the impression that the arteries were making haste to reach the encephalon. But this was not the case. For when they have passed beyond the cranium, in the space between it and the thick meninx they are first divided into many very small, slender arteries, and then they are interwoven and pass through one another, some toward the front of the head, some toward the back, and others to the left and right, giving the other, opposite impression, namely, that they have forgotten the route to the encephalon. However, this is not true either; for, as roots combine to form a trunk, so from these many arteries there arises another pair of arteries [*aa. carotides cerebrales*], equal to the pair that passed upward in the beginning, and so these now enter the encephalon through the perforations in the thick meninx.

Well, what is this wonderful thing, and for what purpose has it been made by a Nature who does nothing in vain? If you remember [II, 12] what I said and demonstrated when I was explaining the teachings of Hippocrates and Plato,[10] you will derive from it no small assurance

[10] *De plac. Hipp. et Plat.*, VII, 3 (Kühn, V, *607–609*).

in answering these questions, and you will easily find the usefulness of this plexus. For wherever Nature wishes material to be completely elaborated, she arranges for it to spend a long time in the instruments concocting it. Now I have already pointed this out in several other places,[11] but for our present needs it will be enough for me to cite one example of the arrangement in question by reminding you of the varicose convolutions [12] in which blood and pneuma are rendered suitable to form the semen. For the veins and arteries there are intricately coiled and in the first part of the coils contain pure blood; in the last part, however, near the testes, the humor contained in them is no longer perfectly red but is already whitish and needs little to complete the change into the substance of the semen, a change which is added by the testes themselves. But the retiform plexus is as much more intricately coiled than the varicose plexus as the elaboration needed by the psychic pneuma in the encephalon is more perfect than that needed by the semen. I was right, then, when I showed in those commentaries [*On the Teachings of Hippocrates and Plato*] that the vital pneuma passing up through the arteries is
[II, 13] used as the proper material for the generation of psychic pneuma in the encephalon. And I shall now say again what I said at the beginning of the whole work, namely, that it is impossible for anyone to find the correct usefulness of any part unless he is perfectly acquainted long before with the action of the whole instrument.

In those commentaries I have given the demonstrations proving that the rational soul is lodged in the encephalon; that this is the part with which we reason; that a very large quantity of psychic pneuma is contained in it; and that this pneuma acquires its own special quality from elaboration in the encephalon. Here we see that both the retiform plexus and other features of its construction are in wonderful harmony with those correct demonstrations. For the whole encephalon is interwoven with these intricately divided arteries, many of whose branches end in its ventricles, just as many of the veins do that descend from the crown of the head. Coming from the opposite direction, they encounter the arteries and are distributed as

[11] *Vide supra*, pp. 226–227, 381; and cf. *De semine*, I, 12–14 (Kühn, IV, *555–563*), and chapters 10 of Book XIV and 10 of Book XVI of this present work.

[12] Of the spermatic veins and arteries.

the arteries are into all parts of the encephalon, both into the ventricles themselves and the other parts as well. Now just as very many arteries and veins extend to the stomach and intestines and pour out bile, phlegm, and other such humors into the free space outside themselves,[13] while retaining within themselves the blood and vital pneuma, so in the same way the veins expel residues into the ventricles of the encephalon while retaining the blood; but the [II, 14] arteries most of all breathe forth the [vital] pneuma. For they come up from the parts below, whereas the veins descend into the encephalon from the crown of the head, Nature having marvellously made this provision too, in order that the substances escaping from their orifices may penetrate the whole encephalon. As long as they are contained in the vessels themselves, these substances travel with them into all parts of the body, but when they have once escaped from the vessels, each moves according to its own proper weight, the thin, light material passing up and the thick, heavy material down.

Now since the arteries that end in the abdominal parts slant steeply downward, no pneuma escapes from them into the free space that receives them [the cavities of the intestinal tract], except what is forced out by the very action [the pulsation] of the vessels, but since the arteries ending in the encephalon slant steeply upward, as much pneuma, well elaborated in the retiform plexus, always flows out of them in a given length of time as the arteries in the plexus send forward. For indeed it cannot pass rapidly through them, but is held back, wandering in every direction, up, down, and to the sides, in the many intricate turns and windings. Hence, remaining for a very long time in the arteries, the pneuma is elaborated, but when its elaboration is complete, it falls at once into the ventricles of the encephalon; for it ought not to be delayed longer, nor should it escape before it has been elaborated. And it was not expedient that [II, 15] this should happen only in the ventricles and not in the encephalon as a whole; rather it should happen to the same degree in the encephalon as well. The parts of it in contact with the membrane encircling it draw their proper nutriment directly from the vessels in the membrane; the parts happening to lie farther away are aided by the natural momentum of the materials. For all parts of the body

[13] That is, into the cavities of the stomach and intestines.

have the faculty of attracting material appropriate to them, but they cannot do so from afar, over a great distance, unless they have some extra, outside help. Accordingly, Nature has provided such help, particularly in the encephalon, first because it is the most important of all the parts, then because the distances between its vessels are very great, and thirdly because it can attract with less force on account of its softness and its only moderate warmth; for bodies that attract need greater tension and heat.

5. It would be good at this point if I paused briefly in my discourse in order to mention how all the veins and arteries of the body are inserted into all the parts needing both kinds of vessels. They are near one another and frequently so close together that those inserted into the stomach, jejunum, the whole small intestine, and the colon are actually in contact. Let us mention these vessels
[II, 16] first and next the ones inserted into the liver, lung, kidneys, bladder, uterus, spleen, and the heart itself; then there are those inserted into the shoulder blades, the thorax, and the arms and legs, and we should note that in none of these parts does the vein come to its insertion from below and the artery from above,[14] nor one vessel from the right and the other from the left, nor one from in front and the other from the rear; nor, though coming from the same direction are they widely separated. No, in all these parts they lie so close together that they are even in contact, and the vein always lies along the artery, whereas we should remember that in the case of the encephalon it was better for the vessels to come to their insertion into it from different regions, or rather, from regions lying directly opposite one another.

Shall we not, then, marvel at the foresight of the Creator who conducted the veins along with the arteries from the heart up through the thorax and the whole neck as far as the head itself and then conducted the arteries to the retiform plexus but the veins to the crown of the head [via the transverse sinus], and who did so in

[14] It is the difference between the modes of insertion of the veins and arteries into the encephalon and into the other parts to which attention is being called here, and we should therefore expect that "in none of these parts does the vein come to its insertion from above and the artery from below [as they do in the encephalon]." There is no indication, however, of any variation in the manuscripts, so that we are left wondering how the transposition came to be made.

no haphazard fashion, but with much care for their safety, since the veins are of great importance to the animal? For it is by the worth of the parts being nourished that we judge the importance of the veins that nourish them. If, then, the Creator had conducted these veins as far as the crown of the head outside the cranium and covered only by the skin, he would seem not to have recognized their importance; yet if he had carried them inside the cranium but had made them pass at once through the thick membrane [the dura mater], their route would thus certainly have been safe so far as injuries from [II, 17] without are concerned, but in another way it would not have been safe. For if, without being attached to it, the veins merely rested on the encephalon itself with its round shape and soft consistency, they could not possibly pass upward uninjured, nor would the thin membrane [the pia mater] be a sufficient bond for such large veins. Moreover, he ought not—and this is the third and last possibility—to introduce them within the cranium and conduct them to the crown of the head through the space between the bone and the thick membrane; for if he did, either they would suffer by striking against the cranium as they moved, or it would be necessary here too to prepare a hard tunic in the space between the veins and the cranium, a tunic such as is also seen in all the perforations of the bones.

No doubt, if Nature had not found a more ingenious means of safety for the veins, she would have adopted this one, as is indicated by the ones she contrived in the passageways through the bones. For the greatest evidence that a creator is skillful lies, as I have already said many times before, in his use of what has been formed for one thing to fulfill other uses as well, instead of seeking to make a special part for each use. Since, then, the thick membrane was right there, Nature did not think it necessary to construct another tunic, because this one could be doubled [to form the tentorium cerebelli] and receive the veins into its midst. Now is this the only clever thing she [II, 18] has contrived? Or is it not still more clever for her to have made this same fold useful not for this one thing alone, but, since the encephalon [the cerebrum] must be separated from the *parencephalis*, as I have shown in the preceding book, to locate the fold in this very region, where it may make a safe pathway for the vessels and at the same time surround the encephalon on one side and the *parencephalis* on the other? Would you not, then, be glad to hear of still a third clever use which our Creator has found in addition for this

fold? Well, since the thick membrane had to be attached to the cranium, as I have also shown in the preceding book, it was far better for the safety of the membrane itself and of the parts lying beneath it that the ligaments should grow out of it where it becomes thicker because it is folded. Since these must grow out by way of the sutures (I have shown this, too), it was reasonable for Nature to establish in this region the so-called lambdoidal suture.

6. When these things had been done, Nature made numerous openings along the passage for the blood in the thick membrane and caused to grow out from them veins, some large and some small, which passed upward into the diploë of the cranium and the membrane of the pericranium there, and downward into the underlying thin membrane. This she did not for this one usefulness alone, but in
[II, 19] order that the veins might both nourish (which of course is the special, proper work of all veins) and serve as ligaments to bind all the bodies in the vicinity to the hard membrane. The folds [*sinus transversi*] of the membrane that conduct the blood come together at the crown of the head into a common [15] space like a cistern, which Herophilus was accustomed for this very reason to call the wine vat [*torcular Herophili;* confluence of sinuses]. From this point, as from an acropolis,[16] they [the sinuses] send out conduits to all the parts lying beneath. It is impossible to tell the number of the outlets, because the multitude of the parts to be nourished cannot be numbered. Some conduits lead off from the central space [*torcular Herophili*] itself into the whole *parencephalis* [via the occipital sinus], ramifying and dividing in a way very like the conduits in a garden; others [*sinus sagittalis superior, sinus sagittalis inferior*] [17] lead off from the part [*sinus rectus*] which receives the torcular and passes forward, you would say, as a sanguineous aqueduct and which has been ingeniously constructed from the thick membrane. For when the parts [*sinus transversi*] conducting the blood had been joined together at the torcular and a branch [*sinus occipitalis*] sent down thence to the parts beneath, [Nature] still did not entrust the

[15] Reading *κοινὴν* with Helmreich for the *κενὴν* of Kühn's text.

[16] That is, from a storehouse or reservoir, because the Athenian treasury was on the Acropolis.

[17] The identifications here are tentative. If they are correct, Galen's description slights the superior sagittal sinus. Daremberg too (in Galen [1854, I, *581*]) is uncertain how this passage should be interpreted.

remainder [of the blood] to a single vein, but fashioned in addition this aqueduct [*sinus rectus*] by means of the parts of the thick membrane that extend anteriorly, and not till then did she make many outlets that flow out from it along its entire course.

7. After these, since the aqueduct was already getting near the middle [third] ventricle and there had to be produced from it the large veins [*v. cerebri magna, vv. cerebri internae;* veins of Galen] to be distributed to the choroid plexuses, [Nature] did not yet entrust the attachment of such veins to the thin membrane [the pia mater] alone but fashioned a gland [the pineal body] to help it. [II, 20] Establishing this gland in the middle of the descending veins, she thus surrounded it with the thin membrane and set around it in a circle the veins, held together by the membrane, in order that as long as their course was suspended, the gland might accompany them, and that when they had been inserted into the encephalon, the gland too might support its circular base on the back of the encephalon. The veins, dividing in this way around the gland, pass through the middle [third] ventricle to the anterior [lateral] ventricles, where they are interwoven with arteries coming up from below and form the choroid plexuses. The remainder of the thick membrane [*sinus sagittalis inferior*], which I have said is a sort of sanguineous aqueduct, passes straight forward longitudinally, as it began, giving off many veins which are distributed to the whole encephalon. Such is the skill Nature has used to provide a pathway for the veins.

The thick membrane itself, however, which was made into this aqueduct for the blood, was not to be extended so far for the sake of just this one thing; for Nature placed upon it another suture [the sagittal suture], passing from the crown of the head straight along the mid-line to the forehead. Moreover, since the encephalon had to be double, as I have said before, she made use of the thick membrane for this purpose also, by extending a part [*falx cerebri*] of it as far as [II, 21] the forehead to divide the encephalon. But before that, the part of it [*tentorium cerebelli*] between the gland [the pineal body] and the torcular lies perpendicular both to the canal[18] connecting the encephalon with the *parencephalis*, and to the vermiform epiphysis [*vermis cerebelli*] lying upon the canal, so that by lifting up the adjacent bodies toward itself it prevents them from bearing down heavily on the epiphysis of the canal. And what an advantage this is,

[18] See note 76 of Book VIII.

it needs no new proof to establish, if we remember what has been said in the preceding book about the action of the epiphysis. So too, the membrane at the lambdoidal suture elevates the bodies lying upon the posterior [fourth] ventricle. And the third suture, the one we call coronal, passing transversely along the middle of the anterior [lateral] ventricles and raising up the very large part of the encephalon that lies between [the suture and the ventricles], removes the pressure from them, for they would be quite compressed, weighed down, and straitened, if the suture had not been placed in this part of the head. Indeed, although the ventricles of the heart, thanks to the hardness of its substance, remain uncompressed, needing no outside help to keep them so, the ventricles of the encephalon cannot without extra assistance escape being compressed, because the encephalon is exceedingly soft. But whatever is still left to be explained about the sutures will be given in the following books.[19]

8. I must now return once more to the encephalon and tell about
[II, 22] the rest of its outgrowths.[20] Let us first review briefly the ones I have mentioned earlier. The largest are those leading to the nose [the ol-

[19] But the discussion comes chiefly in chapters 17 and 18 of this Book. There are shorter treatments of them in chapters 18 and 20 of Book XI.

[20] It will be helpful to place here at the beginning of the discussion of the cranial nerves the usual chart showing Galen's numbering of them compared to the modern system:

Modern	*Galenic*	*Modern*	*Galenic*
I. Olfactory	not nerves at all	VI. Abducens	probably combined with II
II. Optic	I		
III. Oculomotor	II		
IV. Trochlear	unmentioned	VII. Facial, VIII. Auditory	V
V. Trigeminal			
sensory root	III	IX. Glossopharyngeal, X. Vagus	VI
motor root	IV	XI. Spinal accessory	
		XII. Hypoglossal	VII

For excellent summaries of Galen's treatment of the cranial nerves, see Daremberg (1841) and Beck (1909). Galen (*De anat. admin.*, IX [1906, II, *8–9*; 1962, *9–10*]) says that he followed the system of the anatomist Marinus. See my Introduction, pp. 31–32. Dr. Goss's translation (1966) of Galen's *De nervorum dissectione* has very acute and interesting comments on this table. See note 39 of this Book.

factory lobes];[21] beside these are the channels [*nn. optici*] to the eyes,[22] and nearby are the outgrowths that move the muscles of the eyes.[23] The channels come together into the same place [the optic chiasma] before they pierce the thick membrane [the dura mater], and they separate again in the same way. Behind the place where they unite is the pelvis [the infundibulum] with the arteries [*aa. carotides cerebrales*] touching it on either side. All this is within[24] the hard membrane. The parts on which the membrane and the encephalon in this region rest are the gland [the hypophysis], the retiform plexus [*rete mirabile*], and the perforation leading to the palate.[25]

It becomes clear, then, though always not so clear to those who hear as to those who see, that there is no room left either at the anterior part of the head or at its base for sensory nerves [*nn. linguales* from the mandibular division of the trigeminal nerves] for the tongue to grow out; for at the anterior part there are the outgrowths to the nose and eyes, and at the base are the gland [the hypophysis] and the retiform plexus. Accordingly, since in front the encephalon itself was already divided[26] into outgrowths and the path downward was not available, a third route was necessary for the nerves of taste. Now such nerves could not possibly be engendered from the posterior parts of the encephalon, which are hard, and the anterior parts should not put forth nerves leading to the tongue any more than they should to any other part. For I have [II, 23] shown on countless occasions how careful Nature has been to provide for safety, particularly that of important parts, but when they would be easily injured by anything at all because they are so soft, then indeed she is even more careful to hide such parts away and protect them on all sides. But if she had caused the nerves for the tongue to grow off from the lateral parts of the encephalon in the region of the eyes, even so the route would not be as safe for them as the route of those growing off from the base. Since it was better for

[21] See note 20 of Book VIII. [22] See note 42 of Book VIII.
[23] See note 31 of this Book.
[24] Reading ἐντὸς with Helmreich for the ἐν τοῖς of Kühn's text.
[25] See notes 2 and 7 of this Book.
[26] Reading κατατετμῆσθαι with Helmreich for the κατατετρῆσθαι of Kühn's text.

the nerves to grow off from the base both for safety's sake and because the tongue happened to be situated in this region, and since all the anterior part of the base was already occupied by the bodies I have mentioned, it was necessary to make them grow out from the remaining parts in the rear [origin of the trigeminal nerves on the pons].[27] And so it was done in this way because only thus could it be done properly and only here could the source of the sensory nerves of the tongue be made double. For this sensory instrument, like the others, is double, with the parts on the right equaling exactly those on the left, but since the tongue must assist in chewing and swallowing and must be an instrument of speech, its parts have grown together and have become a single[28] instrument with a double nature. [Nature] therefore properly caused a nerve that is separate right from the start to grow out to each of the parts.

[II, 24] Now since it was better that all parts of the mouth too should be given a share of the sense of taste from the same places, Nature has made for them outgrowths of nerves [other branches of the maxillary and mandibular nerves from the trigeminal], which she bound all together, those on the right side in a separate bundle at the right side of the base and those on the left separately at the left side of the base, and so led them forward. She caused the choroid membrane [the pia mater] to grow off along with them because it could nourish and at the same time protect them, and she bored through and hollowed out the thick membrane to receive them. She did not pierce this with holes straight through it, but dilated and prolonged it like a tube as far as the bones in front through which it was convenient for the nerves to escape, and there she pierced the bones [at the foramina ovale and orbitorotundum][29] and both membranes and inserted some of the nerves into the tongue itself, others into the upper jaw, and still others into the lower jaw. But before she distributed them to the parts, she caused an accessory nerve, so to

[27] Or even farther back in the case of the beef. See Ellenberger and Baum (1926, *830*).

[28] Reading ἐν ἀπειργάσατο with Helmreich for the ἐναπειργάσατο of Kühn's text.

[29] In the beef and pig the foramen rotundum and orbital fissure fuse to form the large foramen orbitorotundum. See Ellenberger and Baum (1926, *65*). For comparable descriptions of the intracranial course of the trigeminal nerve, see *De anat. admin.*, IX, XIV (Galen [1906, II, *7–8, 173–174*; 1962, *8–9, 189–190*]).

speak [*n. temporalis profundus* from the mandibular division of the trigeminal], to grow off from the pathway; she then compressed it, making it denser and harder than those that end in the mouth, and inserted it into the temporal muscle. For this nerve was required to produce motion, and those of the mouth, the sensation of taste.

That the nerves inserted into the lower jaw and the tongue properly pursue steeply sloping courses is clear from the very position of the parts receiving them, whereas for those proceeding to the upper jaw Nature has cut another suitable path. First she carried them across toward the front and brought them near the region of [II, 25] the eyes. Here she used again one [the foramen orbitorotundum] of the perforations in this region by way of which she had inserted the nerves into the muscles of the eyes. Indeed, no better route can possibly be conceived either in the orbits of the eyes or outside; for the parts beyond the small corners of the eyes were guarded by the temporal muscles, and in addition, this would be a long, unsafe, circuitous route; and the large, inner corners were occupied by the nasal canals. Since there were already two perforations [the optic foramen and foramen orbitorotundum] in the orbits of the eyes themselves and there would have to be a third [the foramen sphenopalatinum][30] at the large corner, as I shall show in the course of my narrative, to make another, fourth one besides these would have been the culpable act of a Creator who was careless about making the bones resistant to injury. For as the number of thickly studded perforations increased, so to the same degree all the intervening parts of the bones would on account of their [increasing] slenderness become more liable to be injured. Hence for these reasons our Creator avoided cutting through the bone at any other point, and since he was reduced to choosing between the perforations already made, he settled on the route of those nerves that are more resistant to injury and caused the nerves for the upper jaw to pass through along it.

[30] It is apparent from this passage and from chapter 16 of this Book that Galen considered the pterygopalatine fossa leading to the foramen sphenopalatinum to be a part of, or an extension of, the orbit, a conception understandable enough if he was dissecting the beef or pig. See Ellenberger and Baum (1926, *71–72, 96, 100, 108*). From chapter 11 of Book X, however, it is evident that he confused the foramen sphenopalatinum with the lacrimal canal, which carries no nerve.

Now not only are the sensory nerves of the eyes much softer than the nerves of motion, but also their importance exceeds that of the motor nerves by an even greater degree of difference. For the eyes as a whole were made for the sake of the sensory nerves, and in them is lodged the whole principle of vision; moreover, the perforations
[II, 26] [the optic foramina] for these nerves are proportionately large. With good reason, then, Nature kept away from the optic nerves, which pass through perforations already large and which are far more important and softer, and made the nerves for the jaw pass through in company with the harder, less important nerves that traverse the narrower perforations. For she saw that association with these nerves would be painless and that the size of the foramen [orbitorotundum] would not become larger than that for the sensory [optic] nerves, since indeed it is elongate, and not perfectly round like the [optic] foramen. Perhaps someone may think that its length is greater than the diameter of the optic foramen, but if as a whole it is compared with the optic foramen as a whole, it will not appear any larger, or certainly not much larger. It was necessarily made elongate rather than round like that for the sensory [optic] nerves because it was meant to contain not a single nerve but two placed side by side. Indeed, to speak truly, each of these nerves is multiple,[21] and I shall tell about the nature of all the nerves more precisely a little farther on. For the present, to make my teaching clear, there is nothing to prevent my calling that which is divided among the muscles of the eye one nerve and that extending to the upper jaw another, which issues along with the first [through the foramen orbitorotundum].

When, however, the one extending to the upper jaw has arrived in the orbit of the eye, it is led directly to the parts called the cheek, where again the bone [the maxilla] lying below the eye is pierced

[21] This is one of the statements on which the conclusion is based that Galen has combined the abducent and oculomotor nerves. He also says (*De plac. Hipp. et Plat.*, VI, 3 [Kühn, V, *530*]) that Pelops, one of his teachers (for whom see Sarton [1927, I, *281*], Singer [1957, *46*], and my Introduction, p. 35), agreed that *two* cranial nerves are distributed to the muscles of the eye. The abducent nerve is thought to be the second member of the pair rather than the opthalmic or trochlear because of its close association with the oculomotor in the foramen orbitorotundum. See Daremberg (1841, *50–51*).

[by the infraorbital foramen] [82] to furnish a passageway for it. For certainly it should pass by without touching or injuring the muscles or being injured by them, and it was better for the motion of the [II, 27] muscles to be kept unimpaired and for the nerve to pass by undisturbed, without any share in an alien motion unbecoming to it. Providing, then, for these things, the Creator placed immediately below the eye another perforation [the infraorbital foramen] following after that first one [the foramen orbitorotundum] which is common to both nerves and which leads to the encephalon itself. But there [near the encephalon?] the nerves and their channel are covered by a thin lamina of bone, whereas in the parts called the cheeks, which are elevated, the nerve is covered thickly with bone and is carried through the depths in contact with it, as if the bone were made for the sake of something other than the nerve.[83] Indeed, Nature has not neglected to surround all vessels issuing from bones with hard tunics and to make the channels in the bones themselves smooth and loose-textured, especially when the parts of the bones that are pierced have a hard substance.

Now perhaps this guarding [84] of all the nerves, arteries, and veins so carefully that there is no failure at any point may seem a slight thing to those who have listened negligently and indifferently, or rather who have misunderstood, but for anyone paying more careful attention and testing it by actual dissection, it alone will be sufficient to show forth the providence and marvelous skill of the Creator. The way in which these nerves that lead below the eyes to the bones [II, 28] of the cheeks [the maxilla], as well as those I spoke of earlier [85] that issue from the skull lower down [branches of the mandibular division of the trigeminal], are interwoven in the tongue, the mouth, and all parts of the face will be made clear in the book following this discussion, when I shall explain the construction of the parts of the mouth and face.[86] For in this present book I propose to tell the

[82] That is, in the animals Galen was dissecting, by the foramen maxillare opening from the pterygopalatine fossa, which he thought of as part of the orbit. See Ellenberger and Baum (1926, 71).

[83] It should be borne in mind that in the animals Galen was dissecting the infraorbital canal is much longer than in man.

[84] Reading τοῦτ' with Helmreich for the οὗτ' of Kühn's text.

[85] Omitting with Helmreich the καί of Kühn's text.

[86] But this is not done until Book XI.

usefulness only of the actual outgrowths of the encephalon as these are bounded by the bone surrounding it. Hence, observing carefully this limit, when my account has traced a nerve beyond it, I shall turn back again to the encephalon, in order not to omit any of its outgrowths within the cranium or spend too much time on those outside it.

9. If I am to observe this limit, let me add to the foregoing discussion[87] the fact that an offshoot [*n. temporalis superficialis* from the mandibular division of the trigeminal?][88] from these nerves goes to the temporal muscles, issuing through the bones at the temples, and then let us pass on to another outgrowth of the encephalon. Accurate anatomists count this as the fourth pair, of course not counting in along with the others the pair that leads to the nose, because this does not have nerves growing out from it and does not issue from the bones as the others do. For anatomists reckon the soft nerves [*nn. optici*] of the eyes as the first outgrowth; the second is the motor nerves [*nn. oculomotorius* and *abducens*] for the muscles of the eyes; the third [*nn. trigemini*], which I have just finished
[II, 29] discussing, begins where the anterior part of the encephalon is attached to the posterior, passes forward through the thick membrane, and then divides into two parts [maxillary and mandibular divisions] and is distributed in the way I have described. The fourth pair[89] is placed a little farther back, arising more from the actual base than the preceding ones, though the outgrowths lie close together. It mingles at once with the nerves of the third pair, running with them for a long distance and then separating from them to be inserted into the whole tunic of the palate. These nerves are exceedingly small and slightly harder than those of the third pair, because the tunic itself that lines the mouth is harder not only than the tongue but also than nearly all the other parts of the face as well. For

[87] Helmreich brackets the καί of Kühn's text.

[88] The equivalent in the beef of the auriculotemporal nerve in man. See Ellenberger and Baum (1926, *857*). The "bones at the temples" are the great wings of the sphenoid, and the foramen is the foramen ovale.

[89] Evidently the motor root of the trigeminal nerve, erroneously thought to be continuous with the palatine nerve arising from the maxillary division of the trigeminal. But see Goss (in Galen [1966, *329*]), who suggests that the fourth pair is rather "the trochlear, abducens, and cavernous sympathetic fusing with the ophthalmic division of the trigeminal and continued as the pterygopalatine nerves."

this reason, then, these nerves grow out from slightly harder parts of the encephalon than those from which the nerves of the third pair arise. For always, the farther back we go, the harder we find the encephalon becoming, and moreover, the parts at its base are harder than the other parts. Hence it is with good reason that the fourth pair of nerves, in order to be less soft than the third, arises not only from posterior parts but also more from the base of the encephalon than the third pair does.

10. After these come the outgrowths from the sides of the head to the petrous bones; this is the fifth pair of nerves and they are not as yet hard. Just as they are passing through the bones [in the internal auditory meatus], they are divided into two parts, one of which [*n. vestibulocochlearis*] enters the channel to the ear, and the other [*n. facialis*], the so-called blind perforation [the facial canal ending at the stylomastoid foramen]. Of course this is not really blind, as it is said to be, but I suppose that when the first men to give it that name [40] passed down it a straw or pig's bristle which could not be made to go through, they assumed that the canal came to an end at some point. But the reason why the bristle did not pass through was not that the channel ends blindly, but that it is crooked, and if you cut the whole bone away little by little and expose the nerve, the bends in the channel will be detected and the nerve will be seen to emerge beside the ear [at the stylomastoid foramen]. But I have spoken earlier about the nature of the acoustic nerves, and I shall speak of those issuing by way of the blind perforation when I tell about the parts outside the cranium. [II, 30]

11. Now, however, it is time to undertake an account of another offshoot [*nn. glossopharyngeus, vagus, accessorius*] [41] of the nerves

[40] Herophilus and his followers, according to Galen in *De anat. admin.*, IX (Galen [1906, II, *8;* 1962, *9*]).

[41] The evidence that Galen included the glossopharyngeal and spinal accessory nerves along with the vagus in the sixth pair is found in two passages in *De anat. admin.*, IX, XIV (Galen [1906, II, *9, 179–180;* 1962, *10, 197–198*]). In the first of these he says, "In regard to the sixth pair of nerves, neither one of its two units consists of a single nerve springing from either side of the brain, but each of the two consists of three nerves which come off from three roots [*glosso-pharyngeal, vagus, and accessory nerves*]. We treat it, however, as we did the fifth pair and reckon it as a single pair, corresponding to the conception of Marinus. For to count these nerves as forming a single pair seems more reasonable

that arise from the encephalon. Counting those already enumerated, this is the sixth pair of nerves given off from the base of the encephalon, and whereas these too are not perfectly hard, they are as much harder than all those previously discussed as they are nearer to the spinal medulla. For of course the spinal medulla is the source of the hard nerves, because it has itself been made much harder than the encephalon. It is very easy for anyone to determine the cause of this,
[II, 31] if he remembers what I said in the preceding book, namely, that a softer outgrowth of the encephalon is necessary for accurate perception of sensation and a harder one for strong motion, that for this very reason some parts of the encephalon have been made harder and some softer, and that beginning at its anterior end where it is soft, the encephalon becomes increasingly hard [toward the rear]. The hardest parts of all are those where it is joined to the spinal medulla, and here the spinal medulla is also softer than all its other parts; for it too becomes gradually harder as it passes downward. In fact, it was formed to offer this usefulness to the animal, that is, to be the source of the hard nerves in the body, since the encephalon cannot receive such hardness for the reason given above.

Particularly in this pair of nerves of which I now intend to speak, Nature has shown clearly that perfect sensation cannot be produced through hard nerves and that hard nerves cannot grow off from the encephalon nor soft ones from the spinal medulla. For these nerves descend as far as the broad bone and are distributed to nearly all the intestines and viscera, although most of these lie along the spine, the lower end of which is called the sacrum by some and the broad bone by others; it is here that I have said the nerves end. Had it been
[II, 32] possible, it would have been better for them to come from the spinal medulla by a short route and be distributed very safely to the parts in this region, but of course the spinal medulla, being hard itself, could not possibly give rise to soft nerves, any more than the encephalon, which is exceedingly soft, could give rise to the very

---

and more convincing than to reckon the nerves of the fifth pair as a single pair. For its three component nerves make their way through a single one only of the foramina of the skull, and, in the dura mater, all these nerves are wrapped up together just as if they were a single nerve" (translation by Duckworth). See also p. 697 *infra*, where the glossopharyngeal nerve is said to be part of the sixth pair, and *De nervorum dissectione*, cap. 7 (Kühn, II, *839–841*; Galen [*1966, 330–331*]).

hard nerves that proceed to the limbs. Now that the limbs, subserving strong, vigorous actions, need very hard nerves is at once evident, and it is no less evident [42] that the viscera need softer ones, but I must speak about it to avoid any gap in my discourse.

First, then, since none of the viscera is endowed with motion performed at the will of the animal, and since they need nerves only for sensation, it was better to send them sensory nerves. It was better in the second place because the substance of the viscera, being of a soft consistency, would more easily be united with soft nerves and receive them to be completely interwoven with it. And in the third place the stomach must have very accurate perception of the need for food and drink. Hence most of these nerves seem to be distributed particularly to the first portions of this viscus in the region of its so-called [cardiac] orifice and afterwards to all the other portions of it as far as its lower end. But when nerves had once been brought down from the encephalon for the sake of the stomach, it was all the more convenient to distribute them to all the other parts in the [II, 33] vicinity as well, even though nerves would not be of any great service to them.

The stomach had special need of an appetitive faculty for food and drink, and this faculty was necessarily preceded by a faculty perceptive of the lack of them. Some physicians have thought that the other parts in the vicinity also share in accurate sensation to the same extent and so say that these are no less appetitive than the stomach. It seems to me, however, that although the parts do have perception in common to a slight degree, most of it falls to the share of the stomach and its [cardiac] orifice, where, indeed, most of these nerves are obviously inserted. For this reason that part of the stomach is the most sensitive; when we are very hungry, it is there especially that we feel contraction, as if it were convulsed and violently irritated, and it would not be so sensitive if it did not have its share of soft nerves. It is thus clear from what I have said that all the parts in the abdomen, but particularly the stomach, need nerves from the encephalon, and one can readily see from dissections what great provision Nature has made for their safety all along the route leading down from above; for she foresaw that they would be very

[42] Accepting Helmreich's emendation, *ἀσαφές*, for the *ἀσφαλές* of Kühn's text.

easily injured because they are soft and pass downward over a long distance.

Accordingly, she surrounded them with strong membranes and attached them to the various adjacent bodies which they happen to
[II, 34] encounter as they descend. At many points the attachment is of considerable advantage to these bodies, as it is to the seventh pair of nerves to emerge [*n. hypoglossus*]. Bringing these and the nerves of the sixth pair together as soon as they had passed through the bone of the head, she surrounded them with strong membranes and protected them on all sides, thus devising a common good for them both. For just as single, slender threads are perfectly easy to break, whereas those composed of many strands acquire strength to resist in proportion to the number of strands that have been combined, so nerves that have been gathered together, interwoven, and fastened with common bonds become much less liable to be injured than single nerves. Hence, when many nerves must pass to several adjacent parts of the body, Nature conducts them side by side and joined together for the whole distance till they reach the parts that are to receive them. Those, indeed, who look at such nerves too carelessly think they are all a single nerve, but they are not single; from the very beginning there are as many of them as there are parts into which they are to be inserted, and they seem to be one only because they are all interwoven and bound close together by the membranes surrounding them. This is what I promised a little while ago to say about the nature of the nerves. Later on, however, I shall complete my whole discourse on how they are combined, explaining
[II, 35] it separately and not as a subordinate topic as I have been doing now.

First let us finish the subject of the nerves [*nn. vagi*] which lead to the [cardiac] orifice of the stomach and whose path I had begun to describe. Since, after they had proceeded a short distance, the nerves of the seventh pair [*nn. hypoglossi*] leading to the tongue had to draw away from them, [Nature] in due order brought them together with the carotid arteries near by, and having joined them to the arteries with common membranes, she conducted them in their company through the whole [length of the] neck. In the thorax, however, where the arteries were assigned to the left ventricle of the heart, she once more detached the nerves and fastened them anew, one on each side, to the esophagus. When first she was about to make them branch into the stomach, she passed the one on the right

side around to the left and the one on the left around to the right, because she thought it necessary first to make them oblique, and then, when they had become so, to divide them. For so they were far less likely to be injured than if the division had been made when they were going in a straight line. Moreover, when she produced all their branches, she provided these too with membranes and supported them on adjacent bodies, thus remedying their vulnerable softness by outside aids at every point and preserving them. But I have already spoken earlier to some extent about their distribution and I shall say more about it later on.[48]

12. I should now speak of the seventh pair of nerves [*nn. hypoglossi*] arising from the encephalon. I mentioned just now that it is immediately connected with the preceding pair and that Nature contrived this connection in providing for the common safety of both outgrowths, but I must also tell whence this pair arises and where it is inserted; for this still remains to be explained. These nerves arise where the encephalon comes to an end and the spinal medulla begins; they proceed for some distance together with the nerves of the sixth pair and then, as they separate from these again, sometimes a very small part of them [*ramus thyrohyoideus*] twines about the straight muscles [*thyrohyoideus*] of the larynx, but the larger part is always inserted into the muscles of the tongue. These are the first nerves to be perfectly hard; for all those I have mentioned earlier are more or less soft, and none of them is hard like these, although the ones inserted into muscles are clearly harder than the others. [II, 36]

13. The muscles of the face are those moving the eyes, those moving the lower jaw, and, in addition, those moving the nasal alae, the lips, and the cheeks. Although the eye muscles are very small, the nerves [*nn. oculomotorius* and *abducens*] inserted into them are seen to be large in proportion to the mass of their substance for the very reason that they have a softer consistency than is proper for motor nerves. Hence Nature makes up by their size for what they lack in consistency on account of their softness, and she does the same sort of thing in the case of the temporal muscles. For she inserts in each of them three nerves [*n. temporalis profundus* from the mandibular division of the trigeminal nerve, *temporalis superficialis* also from the mandibular, *rami temporales* of the facial nerve]; two [II, 37]

[48] In Book XVI.

of these, concerning which I have already spoken, come from the third pair, and there is a third, harder nerve, of which I shall speak a little later, so that here the muscles acquire the strength for their action because they have a number of nerves. The muscles of the cheeks, nose, and lips receive outgrowths of nerves that are of moderate size [44] and are also moderately hard, for a nerve passing for a considerable distance through bone becomes hard from the length of its journey. Indeed, if the soft source is nearby, Nature cannot produce a hard nerve, but when she gradually produces and extends a nerve, especially when the route leads through bone, she makes it hard as time goes on and it gets farther away. In the same way she makes the spinal medulla and for that matter the encephalon itself grow harder not all at once but little by little.

If these things are so, it is now clear to everyone that the motor nerves [*nn. hypoglossi*] for the tongue could not grow off more conveniently from any other place or make use of a better route than the one they now follow. At the anterior parts [of the encephalon] there was no longer any unoccupied space, and this was the very reason, of course, why Nature caused the third and fourth pairs to grow off from the posterior parts. Again, she could not also make
[II, 38] other large nerves grow off from these same places and even if she could have done so, no route was available for them. For if she had made them traverse the hard membrane and had mingled them with those of the third and fourth pairs, they would have remained as soft as those nerves are. Moreover, although she could have conducted them through the bones of the head [45] and made them moderately hard by means of such a route, this would have been superfluous if they could be brought from some other place more conveniently, and there was no room left in the cranium near the root of the tongue, because many perforations had already been formed in this region. Necessarily, then, she produced this pair of nerves from the place where the spinal medulla begins to grow out, where the encephalon is harder, and, making them harder still along the whole way, she then distributed them all through the tongue.

You should not, however, listen lightly to the statement that they are distributed to every part of the tongue, since it will offer

[44] Or perhaps, "that are of a size proportionate to the size [of the muscles]."

[45] As she did for the facial nerves.

sufficient proof of the truth of what I have been saying and will show the greatest skill on the part of the Creator. As soon as the sensory nerves [for the tongue] arise, they flatten out and are interlaced in its outer tunic without touching the underlying muscles, whereas these motor nerves of the seventh pair are resolved into many fibers and are interwoven to fill all the muscles. And properly so, for the sensory nerves would be of no use in the depths of the tongue, which is to be associated with flavors [only] on its outer surface, and the motor nerves would be useless to the outer parts, which would be unable to distinguish differences of flavor because these nerves are hard. Thus Nature has done none of these things idly or without good reason. She made the motor nerves of the tongue more slender than the oculomotor nerves, which are stouter even though they move smaller muscles. The former are hard enough to give them strength, but if the large size of the latter had not come to their aid, they would be altogether incapable of producing motion, because they are so soft. [II, 39]

Certainly the nerves [*nn. temporalis profundus*, and *temporalis superficialis*] extending from the third [trigeminal] pair to the temporal muscles would be even less capable of moving them, for these muscles are large and hold most of the whole lower jaw, into which they are inserted by large tendons. Accordingly, on each side of them Nature sent out a third, hard nerve [*rami temporales* of the facial nerve] from the fifth pair, so that what the eye muscles gained from the size of their nerves was secured to the temporal muscles by the large number of theirs. This [third] nerve is more conspicuous in those animals in which the temporal muscles are large.[46] This is the proper time to tell whence this hard nerve comes to the muscles, since I have already finished describing the origins of all the outgrowths of the encephalon. I have said that a fifth pair of nerves [*nn. vestibulocochlearis* and *facialis*] is given off from the lateral parts of the head and enters the petrous bones; that [on each side] as it divides it is received by two unequal perforations; that by way of the broader one the larger part of the nerve is conducted directly to the ear; that the rest of it enters the other, narrower perforation, also called the blind perforation [the facial canal], and passes through an opening [the stylomastoid foramen] near the ears; and that the whole passage between the beginning of the nerve on the inside and [II, 40]

[46] The herbivora and carnivora; *vide infra*, pp. 698–699.

the point where it ends on the outside is variously involved like a labyrinth. Now Nature was not acting idly when she made this labyrinth, but in her care for the temporal muscles was sending out a hard nerve, and she did it just as much for the sake of the buccal muscles. Having in this region an unused, particularly hard bone without perforations, she used it to produce a hard nerve. Indeed, if the greater the distance of a nerve from its source the harder it can be made, Nature has obviously been most ingenious in preparing a pathway for this nerve in the petrous bone, for the length of the path and the dryness of the region would easily make it hard. Certainly where a nerve is moistened with a great deal of fluid, it will not be helped by a longer journey, but where it passes through a dry, arid region, it will be very easily dried out and hardened. In addition, the nerve gains security, thanks to the advantageous location of this petrous bone. Nature, in fact, seems to have combined in this one coil [the facial canal] everything of which the nerve stands in need, that is, security, a long path, and a dry region.

[II, 41] The largest part of this nerve opens the broad muscle [*platysma*] [47] of the cheek, but a small portion of it [*rami temporales*] goes to help the nerves from the third [trigeminal] pair which extend to the temporal muscle; for whatever strength of motion these lack because they are not as hard as they should be, is supplied to them by this nerve, especially in those animals in which the temporal muscles are large. Now why did Nature provide them with their strength from three small nerves instead of from a single large one? And why did she provide it for the muscles of the eyes from one large nerve?[48] The answer is that it would have been most

[47] Daremberg (in Galen [1854, I, *596*] identifies this broad muscle "opening" the cheeks as masseter, but masseter is innervated by the masseteric nerve from the mandibular division of the trigeminal, and it is platysma which receives the cervical branch of the facial nerve. That Galen really means platysma here can be established still more firmly by comparison with other passages farther on. See chapters 4, *ad fin.*, and 16, *ad fin.*, of Book XI and particularly pp. 699–700 of chapter 6 of Book XVI. Galen not only was the discoverer of this muscle, but also in *De musc. diss.* (Kühn, XVIII, pt. 2, *929–930;* Galen [1963, *478*]) gave it the name which has persisted to the present. See also his *De anat. admin.*, IV, 2 (Kühn, II, *423–429;* Galen [1956, *95–97*]), and Simon (in Galen [1906, II, *xi–xii, 274–275*]).

[48] Which, however, has previously been said to be composite.

unreasonable to make many perforations instead of one in the orbits of the eyes. For I have shown before that there was good reason not to make another perforation [there] for the nerves extending to the upper jaw, but to use again the one [(the foramen orbitorotundum) made] for the nerves extending to the [oculomotor] muscles. But in the temporal bones [the great wings of the sphenoid], which are much larger than those of the eyes and do not even have perforations few and far between, not to mention having them thickly studded as the orbits of the eyes do, it was better for Nature to make narrow openings [the foramen ovale] and detach nerves from the third pair [*nn. temporalis profundus* and *temporalis superficialis* from the mandibular division of the trigeminal], since of course the outlet [the facial canal] in the petrous bone could not be made broad. For it is clear that the convoluted character of this outlet would be destroyed if the bone were all used up beforehand with broad openings. If, then, the hard nerve could not be made thick and a greater number of soft [40] ones could not grow off to be distributed into the many other parts of the muscles, it is clear that Nature had [II, 42] good reason not to be content with only one kind of nerve. Moreover, having several sources of motion would be the only way to manage so that if ever one source should be injured, she would at least have the others to be of service.

14. At this point let me interrupt for a moment the continuity of my narrative to say something about the terms I have already been using and shall continue to use in all the rest of my discourse. Think, if you please, of two nerves, one the hardest of all the nerves in the body, the other the softest; again, think of a third nerve midway between the two [in consistency], being equally remote from both extremes. Call all the nerves hard that lie in the interval between the middle nerve and the hardest, and all the remaining ones soft until you get to the softest. Consider that the hard nerves have been constructed so as to be best for motion and naturally most unsuited for sensation, and that conversely the soft nerves are well constituted to perceive sensation accurately and are poor at producing vigorous motion. Moreover, you should consider that perfectly soft nerves are not motor nerves at all, and that those less soft and already

[40] Reading ἀπαλῶν with Helmreich for the ἁπλῶν of Kühn's text; another excellent example of the improvement in the text made possible by the use of the manuscript Urbinas 69.

approaching [the consistency of] the nerve in the middle are motor as well, but fall far short of the action of hard nerves. Then you should think that the spinal medulla is the source of all the hard nerves and the lower end of it gives rise to the hardest; that the encephalon is the source of all the soft nerves and the median part of its anterior portion is set aside for the softest; and that the region
[II, 43] where the encephalon and spinal medulla join is the source of the substance of the intermediate nerves.

Now when a nerve grows off from the encephalon in a soft condition, it cannot be a motor nerve right at first, but if it is dried out and becomes harder as it grows longer and advances, it will then be entirely motor. Since at their very beginning, however, some nerves are more soft and others less so, and since as they advance some are dried out quickly and others more slowly, some necessarily become motor nerves when they have proceeded a short distance from their source and others [only] after proceeding farther. Some nerves, indeed, seem to maintain for a very long distance the same character they had at the beginning; for example, those [*nn. vagi*] leading to the stomach continue throughout their journey to be the same sort of nerves they were when they grew out, for these must always remain sensory. Of the nerves extending to the mouth from the third pair [*nn. trigemini*], the ones [*nn. linguales*] that are inserted directly into the tongue are so soft that they have not as yet become motor nerves, but the nerves [*nn. alveolares inferiores* from the mandibular division of the trigeminal] which are inserted into the bones of the lower jaw and pass by the large teeth [through the mandibular canals] are dried out and hardened along the way; they come out [by way of the mental foramina] opposite the teeth called canine and are distributed to the muscles of the lips. In the same way the [maxillary] nerves passing through the orbits of the eyes to the bones of the cheeks [through the infraorbital canals] grow so much harder along this route that even though they are small, they move the muscles of the upper jaw and the alae of the nose.

All these facts are in agreement with my preceding discussion and
[II, 44] in harmony with one another. They make it plain that hard nerves are strong and soft nerves weak, and they demonstrate that the former are useful for acting and the latter for being acted upon; that there is good reason why both kinds grow from the parts of the encephalon I have indicated; that none of them anywhere grows out

without a purpose but each for the sake of some instrument; and that each has the size and character proper to the nature of the part that is to receive it. Also in this discussion I have already practically demonstrated that no part of the head or face is without its share of nerves; for I have spoken of the eyes, ears, tongue, the membrane lining the whole mouth, and all the parts in the region of the lips and upper jaw. If any detail has been omitted that needs to be explained more clearly, it will be set forth in the following discussion.

15. The flesh around the teeth which is called the gums, all the teeth themselves, all the skin of the face, and the membrane lining the inside of the nose receive branches of nerves from the third [trigeminal] pair. By the route through the jaw which I explained just above, the molars receive large, distinct branches; some of the gums receive more branches and some less, but they all—and the long teeth [the canines] too—receive slender ones that are hard to see. By the route of the [maxillary] nerves leading to the cheeks [through the foramen orbitorotundum and the infraorbital foramen or canal] nearly all parts of the upper jaw, the so-called molars, and [II, 45] the gums around them receive branches; the offshoots to the molars are large and distinct, but those to the gums and the rest of the teeth are small and hard to see. The eyelids, all the region of the eyebrows, and the entire forehead are innervated from the nerves [*nn. frontales* from the ophthalmic division of the trigeminal] that pass up to the temporal muscles from the orbits of the eyes. From the nerves [*nn. faciales*] issuing from the blind foramina [the facial canal ending in the stylomastoid foramen] and sending indistinct ramifications [*rami temporales*] to the temples, branches proceed to the [parotid] glands and other parts in the vicinity of the ears and to the thin parts of the cheeks. The greatest portion of this nerve causes the lateral movement of the cheeks by means of the broad muscle [*platysma*],[50] of which I shall speak later on.

The skin itself, where it is covered with hair, is only for the sake of sensation, like the skin of all the rest of the body, and so it receives from all the nerves lying below[51] it a few thin, slender branches that are hard to see, like the threads of a cobweb. The skin of the forehead, however, having a share in voluntary motion,

[50] See note 47 of this Book. Daremberg again says masseter.

[51] Reading *ὑποκειμένων* with Kühn for the *ὑπερκειμένων* of Helmreich's text.

properly has perceptible nerve fibers, plain to be seen [*rami temporales* of facial]. For stretched beneath it is a thin, musclelike substance [*m. frontalis*] which receives many nerve fibers; the skin cannot be stripped off here as in the rest of the body but is closely united [with the musclelike substance], and both skin and substance have a single motion, capable of lifting the eyebrows. The skin is even more marvelously joined to the muscles of the lips. For you
[II, 46] could not say that here the muscles are stretched underneath and the skin grows above them, as on the forehead, on both jaws in many places, and even on the inner sides [palms and soles] of the hands and feet [palmar and plantar aponeuroses], since in these places one can separate them and set definite limits where the muscle ends and the skin begins. Throughout the lips, however, a blending has occurred, the muscles and the skin being so lost in one another and so intermingled that you cannot call the product of the two either muscle or skin, and you cannot separate the whole into its parts but must in justice call the lips of animals either skinlike muscle or musclelike skin. And this strange, incredible combination has been made with good reason, in view of the unique action of the lips. For it is useful for them to be closed accurately, opened widely, and moved in every direction, and none of these actions would be performed vigorously or properly, as they are now, if the substance of the lips had not been made such as it is.

16. Since I have said that the tunic lining the inside of the nostrils receives a share of that part of the nerves which goes to the orbit of the eye and yet have not described their route, it would be logical to add an account of this now, in order to avoid any gap in my discourse. In the large corner of each eye it can be observed that the bone [*ossa sphenoidale* and *palatinum*] common to the eye and the nose has been pierced through [by the foramen sphenopalatinum] into the cavity of the nostril, and that passing through each perforation is a nerve of considerable size [*n. nasopalatinus*], which
[II, 47] branches off from the orbit of the eye when the nerve of the third pair first arrives there.[52] This nerve seems not only to be distributed to the nasal membrane but also to proceed as far as the palate; for this one tunic is common to both the nose and mouth, acquiring this association and continuity by way of the passages [the choanae]

[52] See note 30 of this Book.

which lead into the mouth and by which we breathe. In fact, this tunic takes origin from the thick membrane [the dura mater], which gives off membranous outgrowths to the nostrils by way of the perforations in the ethmoid bones and to the mouth by way of the perforations [53] near the gland [the hypothysis] at the infundibulum, so that in these regions too the thick membrane is attached to the bone of the head, just as it is by the membranes which, as I have told earlier, pass up at the sutures and form the pericranium.

Perhaps it would be a good time now to speak of the remaining ligaments of the thick membrane and to show why it is connected with the cranium, strongly in many places, weakly in some others, in some with moderate force, and in many not at all. I shall show here too what I have pointed out hundreds of times already, that Nature omits nothing, nor does she undertake anything superfluous. For she obviously binds the thick membrane to the bones very strongly indeed by the lambdoidal suture and by the one that runs in a straight line longitudinally [the sagittal suture], and not so strongly at the coronal suture. Now she also inserts many other slender [II, 48] ligaments like fibers into the upper and lateral parts of the cranium, and by all these ligaments as well as by the vessels passing through, the thick membrane is stretched upward and brought close to the bones and in contact with them. At the anterior and posterior parts no membrane grows off that is comparable to the pericranium given off from the upper parts, but they do have as outgrowths to the nostrils and palate some small, weak ligaments.[54] With good reason, then, [the thick membrane] in this region has those slender ligaments and many stronger ones as well, in order that they may compensate for the lack [of the pericranium]. But, again,[55] at the base its ligaments are least numerous and are weak, so that in many places there seem to be none at all. Here, in fact, since the membrane always sinks downward because of its weight, it was superfluous to attach it to the bones with strong ligaments. In all the other places, however, in order to provide a generous space for the expansion and contraction of the encephalon, it is properly separated as far as possible from the encephalon and stretched upward toward the cranium. Properly, too, its lower part was made thicker, in order

[53] See note 7 of this Book.

[54] Helmreich brackets the τούτους of Kühn's text.

[55] Reading αὖ τὴν with Helmreich for the αὐτὴν τὴν of Kühn's text.

that the hard bones below it may cause no pain and be entirely unnoticed by the encephalon, which must evidently be supported upon it. Moreover, in the region of the retiform plexus [*rete mirabile*], [Nature] has made it harder too as well as thicker, in order that it may be like a bone placed under the encephalon, which is
[II, 49] largest in this area, and may not be weighed down at any point or narrow the space for the arteries there and compress them. And further, I have come near forgetting and have neglected to say that the hard membrane [the dura mater] has put forth an outgrowth and spread it beneath the retiform plexus, which also must not be pressed against the bones below; this fact too should now be added as no small proof of the foresight of the Creator.

17. In the same way let us once more take up the subject of the sutures, add whatever is still lacking in the earlier discussion, and so bring this book to a fitting close. I have said above that the sutures were constructed to be of service in the transpiration of the fuliginous residues, for the attachment of the thick membrane to the bone of the head, for the transference of vessels, some passing inward and some outward, and for the formation of the pericranium. Now, however, I shall add what is still to be said about their usefulness and then tell about their situation and the number of them. It is useful for the cranium to be composed of many bones for this additional reason, namely, that if it should be struck and fractured at any point (and many such accidents occur), the breaks would not extend through the whole cranium, but would be checked and stopped where the bone that was struck came to an end. Such, then, are the uses of the sutures.

If I remind you of what I have said before, no long discourse will
[II, 50] be needed for me to show that there is good reason why one suture that is straight along the middle of the head [the sagittal suture] and two that are transverse [the lambdoidal and coronal sutures] have been made. For since the head is an elongated ball, so to speak, it was reasonable for one straight suture to be extended along the middle of the head from back to front and for two that are transverse to receive this and make the shape of the three of them very like the letter Eta (H). Since the head as a whole is longer in this direction [from front to back] and as if compressed at the two ears, it was proper for the number of longitudinal and transverse sutures to be unequal, for otherwise Hippocrates would have been wrong to call

just [56] a Nature who distributed equals to unequals. But it is not so. For, being most just, she made a single, straight suture extending lengthwise of the head, since thus the parts on both sides of it, on the right and left, would be moderately wide. She made the transverse sutures two in number, however, one at the back, as I have said before, called lambdoidal, the other at the front, called coronal, in such a way that the bone of the head included between these two sutures was equal to the bones on either side of [57] the middle section of the head.

But the greatest example of the justice of Nature lies in the sutures of peaked heads. There are in all three forms of these peaked heads; one is the exact opposite of the normal shape of which I have just been speaking, [and this occurs] when the head has lost both its prominences, that at the occiput and that at the forehead, and is equal on all sides like a perfect sphere. There are two other shapes, [II, 51] in one of which the head lacks only the prominence at the forehead, and in the other, only the prominence at the occiput. The sutures in the spherical head are like the letter Chi (X); for there are only two intersecting sutures, one transverse from ear to ear and the other extending straight along the middle of the crown of the head to the mid-point of the forehead. For just as it was right that the longer dimension should have more sutures when one dimension of the head was in excess, being longer than the other, so when they had been made equal, Nature gave them an equal number of sutures. When the head lacks the bulk of the occiput, the straight [sagittal] and coronal sutures remain, but the lambdoidal is lost, since this is the one near the lost prominence. Hence the two sutures make a figure very like the letter Tau (T); similarly, indeed, when the prominence of the head at the forehead is lost, the coronal suture is also lost along with it. There is left only the longitudinal [sagittal] suture together with the lambdoidal, and this again makes the shape of the two combined like the letter Tau (T).

One can imagine a fourth form of the peaked head, though it cannot occur, that is, the head might be made more prominent at the two ears than it is at the forehead and occiput. If this form could be produced, this and not the spherical shape would be said to be the opposite of the normal one, because its whole length would have [II, 52]

[56] For example, twice in *De fracturis*, cap. 1 (Littré, III, *412–415*).

[57] That is, in front of and behind.

been changed into breadth. In reality, however, such a perversion of the natural form could not occur. For it would produce not just a peaked head but actually a monster incapable of life, and the reason is clear, at least to those who have not listened with complete indifference to what I have said before Since the *epencranis*[58] is added at the rear and the outgrowths to eyes [the optic chiasma and nerves] and nose [the olfactory lobes] in front, the normal head has properly been made very like a lengthened ball and it could lose either the anterior or posterior prominence or both at once, but the loss could not increase to the point where part of the encephalon itself would also be destroyed. Certainly the distance between the ears could not exceed the length unless this happened, and since this cannot happen, such a shape for the head is also impossible. For this reason Hippocrates[59] has plainly described four shapes in all and the sutures for each one in the same way I have just described them, without mentioning anywhere in his writings a fifth shape for the head. These are the only sutures of the head, and Nature has assigned them justly in respect to their position and number for each of the shapes.

18. These are not the only places where bones are combined; there are certain others, which neither Hippocrates nor any one of the other careful observers of the nature of the body has thought should be called sutures. These run longitudinally, parallel to the
[II, 53] mid-line of the head, being situated one near each ear, and I think they may rightly be called squamous agglutinations [the squamosal and sphenoparietal sutures], because the apposed bones have been gradually fined down to thin plates without depth, because the bone coming down from above is placed on the inside and the bone coming up from below lies upon it on the outside, and because they do not in this region fit into each other as sutures do. The combination of the bones [*ossa sphenoidale* and *frontale*] at the temples is also a suture, but Hippocrates, so it seems to me, considers it to be part of the coronal suture and so does not mention it separately. The remaining juxtapositions, those of the upper jaw, though not exactly like those of the head, are nevertheless sutures, and anatomists are wont to call them so. I shall speak of them when I discuss the upper jaw, but the squamosal sutures I shall explain in this book.

[58] Erasistratus' name for the cerebellum; see chapter 13 of Book VIII.
[59] *De capitis vulneribus*, cap. 1 (Littré, III, *182–185*).

Now since the part of the cranium that surrounds the thick membrane above and at the sides must be loose-textured and porous, and all the rest must be so very hard and dense, especially the so-called temporal bones, the extremities of these bones have therefore been made squamous. The upper one [*os parietale*] coming down from the head has been placed on the inside in order to be associated for a long distance with the thick membrane, and I shall tell the usefulness of this almost at once. The other hard bone [*os temporale*] coming up from below has been made as a rampart for it. All the ligaments of the thick membrane extending to the [II, 54] cranium end in the porous cavities of the cranium, so that if all of it were hard and dense like the lower bone, the ligaments could not be inserted into it any more than they are into the lower part. There was no reason (χρεία) why there should be such ligaments in that region, as I said a little earlier, but in the upper and lateral regions, where there was a reason for their presence, the bone was properly made spongy and porous, and it was of course quite impossible for such a bone to be united with a hard, dense one. I shall tell more in detail hereafter[60] about such a way of combining the bones. This is the reason (αἰτία) for the formation of the squamous bones, but the other sutures, by which the head is joined to the upper jaw, and the sutures belonging to the upper jaw itself will be discussed in the following book.[61] Now, however, I shall bring to a close this present book, which is already long enough.

[60] See chapters 18 and 19 of Book XI.

[61] This is done, however, not in Book X, but in Book XI.

CORNELL PUBLICATIONS IN THE HISTORY OF SCIENCE

GALEN

ON THE USEFULNESS OF THE PARTS OF THE BODY

II



The eyeball (folio 118 of MS Urbinas 69); reproduced by permission of La Biblioteca Apostolica Vaticana

GALEN

ON THE USEFULNESS OF THE PARTS OF THE BODY

Περὶ χρείας μορίων

De usu partium

Translated from the Greek with an Introduction and Commentary by

MARGARET TALLMADGE MAY

II

CORNELL UNIVERSITY PRESS

ITHACA, NEW YORK

Copyright © 1968 by Cornell University

All rights reserved. Except for brief quotations in a review, this book, or parts thereof, must not be reproduced in any form without permission in writing from the publisher. For information address Cornell University Press, 124 Roberts Place, Ithaca, New York 14850.

First published 1968

THIS BOOK HAS BEEN PUBLISHED WITH THE AID OF A GRANT FROM THE HULL MEMORIAL PUBLICATION FUND OF CORNELL UNIVERSITY.

Library of Congress Catalog Card Number: 68–13220

PRINTED IN THE UNITED STATES OF AMERICA
BY KINGSPORT PRESS, INC.

Table of Contents

VOLUME I

Introduction

I	The Text of *De usu partium*	3
II	Analysis of the Treatise	9
III	Anatomy before Galen	13
IV	Galen's Contribution to Anatomy	39
V	Galen's System of Physiology	44

The Books of Galen on the Usefulness of the Parts

First	The Hand	67
Second	The Wrist and Arm	113
Third	The Foot and Leg	154
Fourth	The Instruments of Nutrition	204
Fifth	The Instruments of Nutrition, continued	244
Sixth	The Instruments of the Pneuma	278
Seventh	The Instruments of the Pneuma, continued	335
Eighth	The Neck, Head, Encephalon, and Senses	384
Ninth	The Encephalon, Cranial Nerves, and Cranium	424

VOLUME II

Tenth	The Eyes	463
Eleventh	The Face	504

Twelfth	The Head and Spine	550
Thirteenth	The Spine and Shoulder	585
Fourteenth	The Reproductive Tract	620
Fifteenth	The Reproductive Tract, the Fetus, and the Hip Joint	655
Sixteenth	The Nerves, Arteries, and Veins	681
Seventeenth	"Epode"	724
	Literature Cited	737
	Index	753

List of Illustrations

VOLUME I

The paths of visual rays (folio 123 of MS Urbinas 69) *frontispiece*
The glossocomion *page* 365

VOLUME II

The eyeball (folio 118 of MS Urbinas 69) *frontispiece*
Galen's optics *page* 494

GALEN

ON THE USEFULNESS OF THE PARTS OF THE BODY

II

THE TENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Eyes]

1. I have said earlier that it was better for the eyes to have an elevated position and to be protected on all sides. It is not hard to understand that it was better too that they should be placed in the anterior part of the body [looking] in the direction in which it moves and that there should be two eyes rather than a single one; for I have spoken before and shall continue to speak in what follows of [II, 55] the need for all the sense instruments to be double and paired.[1] Certainly, if all these factors—safety, an elevated, anterior position, and duality—must be kept in mind, you could not place the eyes anywhere else to better advantage. If you think it objectionable for eyes not to have been formed from the posterior parts as well, you have forgotten what I have demonstrated earlier, namely, that all the sense instruments need soft nerves; that such nerves could not possibly grow out from the *epencranis;*[2] and that, moreover, to each eye there extends from the encephalon an outgrowth [*n. opticus*], which is compressed where it passes through the bones in order to make it resistant to injury, but which upon reaching the eyes themselves is resolved again, flattens out, embraces the vitreous humor like a tunic, and is inserted into the crystalline humor [the lens]. I have said these things before and I have also said that the crystalline humor itself is the principal instrument of vision, a fact clearly proved by what physicians call cataracts, which lie between the crystalline humor and the cornea and interfere with vision until they

[1] Reading διττὰ καὶ διφυῆ πάντα with Helmreich for the διφυῆ καὶ συμφυῆ of Kühn's text.

[2] Erasistratus' name for the cerebellum; see chapter 13 of book VIII.

are couched.[3] Now the crystalline humor, being clear, radiant,
[II, 56] gleaming, and pure—and only if it were so would it be altered by colors—could not possibly be nourished directly from the blood itself, since the qualities of blood are so very different. It needs rather to be fed with something more appropriate, and so Nature formed and prepared as nutriment suitable for it the vitreous humor, which falls as far short of the moistness and brilliance of the crystalline humor as it is itself thicker and clearer than the blood.[4] For the crystalline is absolutely clear and moderately hard, but the vitreous is moist like fused glass and [only] as clear as you would expect a substance to be if a little black were mixed with a large, clear body and the perfection of its clearness were impaired throughout. There is no vein whatever in either of these humors. Hence it is clear that

[3] According to Garrison (1929, *349*) the true nature of cataract was not understood until the work of Brisseau (1706) and Maître-Jan (1707). Maître-Jan is said to have proved in an autopsy that opacity of the lens *is* cataract. Now Galen (see chapter 6 of this Book) knew the clouding of the lens, calling it *glaucosis*, but seems never to have thought that it was this condition that was treated by couching. What was moved down in this operation, according to him, was not the lens itself but a mass of humors that had seeped into the space in front of the lens and solidified there. *Vide infra* and see also *De plac. Hipp. et Plat.*, VII, 6 (Kühn, V, *635*), and *Introductio seu medicus*, capp. 16, 19 (Kühn, XIV, *775*, *784*); the latter work is listed by Kühn (I, *xviii*) among those of suspected origin.

[4] Fabricius ab Aquapendente (1600, *86–87*) objects for several reason to such a use for the vitreous humor. First, it is not in direct contact with the crystalline humor, as Galen assumes, but is separated from it by a tunic, the *aranea* (apparently the lens capsule, which Fabricius interprets as an extension of the retina); secondly, if bones, membranes, and other very white parts remote from the nature of blood can still be nourished by blood, there is nothing to prevent the crystalline humor too from being nourished in the same way; thirdly, the vitreous humor is not a mean between the perfect clarity of the crystalline and the opacity of the blood, as Galen says it is, but is itself exquisitely pure, pellucid, and clear; and fourthly, the volume of the vitreous is four times that of the crystalline, a ratio quite unnecessary if its sole use was to nourish the crystalline. In the opinion of Caspar Hofmann (1625, *221*), one of the most eminent of Fabricius' pupils, this is a solid refutation, unless love for his teacher has deceived him (*Qua in re consentiunt illi* [*Galeno*] *pene omnes: solus D. Aquapendens . . . solide refutat, nisi amor me decipit*).

the crystalline is nourished from the vitreous by *diadosis*,[5] and that the vitreous is nourished from the body [the retina] that surrounds it and that was formed from the portion of the encephalon coming down from above and broadening out.

2. And there are some who with no[6] justification call this body the retiform tunic. Now it does have a netlike configuration, but it is in no wise a tunic, either in its usefulness[7] or in its substance. On the contrary, if you strip it off and just put it down in a heap in one place, you will undoubtedly think you are looking at a detached portion of the encephalon. Its principal and greatest usefulness, that for the sake of which it was brought down from above, is to perceive the alterations of the crystalline humor and in addition to convey and transmit nutriment to the vitreous humor. For it does indeed appear to be full of arteries and veins far larger and more numerous than its own mass requires. Now along with every nerve leaving the encephalon a portion of the choroid membrane [the pia mater] grows off, carrying with it an artery and vein, but none of the other nerves is accompanied by such large vessels, since [in this case] provident Nature is preparing nutriment not only for the nerves but also for the humors of the eye. Moreover, extending into this netlike body from[8] the choroid tunic surrounding it are slender processes like cobwebs, which are formed as ligaments and at the same time convey nutriment to it.[9] [II, 57]

[5] *Diadosis* (διάδοσις) means for Galen the assumption by the tissues of the nutriment delivered to them by the veins. See *De nat. fac.*, I, 2, II, 6 (Kühn, II, 7, *104*; Galen [1928, *12*, *13*, *162*, *163*]). Here the assumption of the nutriment must take place directly, without benefit of veins.

[6] The necessary negative found in most of the manuscripts and in Helmreich's text has been omitted in the manuscripts and editions on which Kühn's text particularly depends.

[7] Reading χρείαν with Helmreich for the χροιάν of Kühn's text.

[8] Here Helmreich has inserted ἐκ, which is lacking in the manuscripts and in Kühn's text.

[9] A little farther on, Galen refers again to these processes, calling them slender vessels. What he saw here or thought he saw is problematical. In the first place, he undoubtedly failed to distinguish the pigment layer of the retina, which had remained adherent to the choroid when he stripped off the retina; it was not until after the middle of the nineteenth century that the pigment layer was properly assigned to the retina (see Adelmann [1966, III, *1253–1298*, *passim*]). Hence the connec-

For of course all parts of this choroid tunic manifestly have very many vessels, a fact which is indicated by its name, because such a comparison would not have been made or such a name given if it were not a bond of union for a large number of vessels, just as the chorion is. This [choroid] tunic has too the same usefulness and is besides really a tunic, covering and clothing the bodies lying beneath. It takes origin from the thin membrane [the pia mater] which surrounds the encephalon and which, as I said just now, [II, 58] grows off together with all the nerves and carries with it an artery and vein. In this instance too we must admire the wisdom of the Creator; for although nowhere else does he separate any nerve from the membranes that grow off along with it but conducts them in company with each nerve in order to nourish and protect it on all sides, here in this one place, where the nerve is first inserted into the eye, he separates it from both membranes and makes them as thick and hard as the thick membrane surrounding the encephalon itself, or even thicker and harder.

Here we must observe with no little care how his provision for this netlike body [the retina] resembles the provision he has made for the encephalon and in what respects it is different. That it is

---

tion he mentions was between the pigment layer and the rest of the retina, not between the retina and choroid, and the pigment layer is nonvascular. Moreover, in the higher vertebrates the vascular systems of the retina and choroid are regularly separate and independent, the former being supplied with blood by the branches of the central artery of the retina and the latter by the ciliary arteries. Polyak (1957, *600*), however, mentions a most interesting possibility. "A double retinal blood supply," he says, "is a feature characteristic of all Primates. . . . However, it appears that in the Simians the two systems are not so completely separated as in Man, as the following observation indicates. In Man pressure on the eyeball, by which the central blood vessels in the cribriform lamina are strangulated, produces in a short time an ischemic edema of the retina, resulting in blindness. In the Macaque Monkey this type of visual loss could not be induced experimentally . . . , indicating an incomplete separation of the ciliary and the central retinal systems." If, then, a macroscopic vascular connection between the two coats could actually be observed in the rhesus monkey, for example, which we know Galen used, it could then be said that he took his description of this feature from this animal and was not merely seeing what he wished to see. But until such observations are reported, judgment must be suspended.

quite contrary to provisions for the other outgrowths is already evident, for he does not separate or divide any of them from either of the meninges, whereas in the eyes he makes the meninges part company with one another and also with the outgrowth coming down from above [*n. opticus* and retina]. Now the portion of the encephalon located in the eyes is treated like the encephalon itself insofar as it is all interwoven with arteries and veins and insofar as the hard membrane [the dura mater, the sclera] is very well separated from it and always touches the bones and is bound to them; but the treatment is no longer similar when the thin, soft membrane [the pia mater, the choroid] either abandons it or brings along an artery and vein [*aa ciliares breves* and *vv. vorticosae*] different from those [in the retina]. [II, 59]

Let what is to be seen itself show you the usefulness of the separation. Where the soft membrane [the choroid coat] first withdraws, it is entirely devoid of vessels. A little farther on it appears just as much like a chorion as the soft membrane of the encephalon, for it has received a great many insertions of vessels [*aa. ciliares breves* and *vv. vorticosae*] from all the regions above. You would think that it had, as it were, gone to market for nutriment and before returning had sent back a little by those slender vessels I mentioned a short while ago, as if by servants, but had carried all the rest along with it. For it does return, bringing with it a very large number of slender vessels lying close together and is inserted anew along with all of them into the offshoot from above [the retina] in such a way that their insertions [*orbiculus ciliaris* and ciliary processes] resemble the hairs of the eyelids, a comparison made not inappropriately, I think, by those who concern themselves with inquiring into Nature.

Where it is first inserted, the outgrowth from above checks its advance and comes to a halt; for the purpose for which it was sent down has now been accomplished, and it is inserted into the crystalline body [the lens], the changes in which it can faithfully report to the encephalon. The junction of these parts [the retina and lens] naturally forms a perfect circle, because, when this insertion is made from all sides into the middle [equator] of the crystalline body, which is round, a circle necessarily results. This, indeed, is the largest circle [10] on the crystalline body and divides it into two parts; [II, 60]

[10] Galen's description in the following pages of the relations of the coats of the eye, the lens, vitreous body, ciliary body, and iris shows

for of all junctions with a spherical body, that made at the largest circle on the body is the most secure, since it is the one uniting by the most numerous points of attachment the members to be joined. It was reasonable too to keep the vitreous humor from passing forward at this same circle, so that thanks to it the crystalline humor rests in the midst of the vitreous like a sphere cut in half in water. Thus, for safety's sake this one circle, which I have said is the largest one on the crystalline humor, joins them together on one side (the inner side that resembles a hemisphere of the crystalline) and becomes a common boundary and ligament for them both, for the netlike body [the retina] as well, and for the choroid tunic as a fourth member. Now this [choroid] tunic is the strongest one of these bodies and the most capable of supporting and protecting them. But although it is strong [enough] to protect them, it is too weak to protect itself and incapable of enduring the hardness of the surrounding bones without injury. Accordingly, just as in the encephalon, so here too it is surrounded by a tunic [the sclera] from the thick membrane [the dura mater], and this tunic, everywhere separated from it and joined only by the prolongations of the vessels, is [yet] united with it at that circle I have mentioned on the crystalline humor. Moreover, a fifth junction made at this one place in addition
[II, 61] to the four already mentioned is no inconsiderable help to the underlying bodies to prevent their suffering from the bones around them and being broken away from one another in very violent movements.

Thus the hard membrane [the sclera] is joined securely to the

---

clearly how imperfect his understanding was. It has been impossible to identify the various parts of the ciliary body or to distinguish it from the zonule of Zinn, the "insertion of the retina" on the lens. It will be noted that Galen's iris is not equivalent to the structure now called the iris. It is rather a "section through the ciliary region," as Liddell and Scott define it, and Galen himself (*Methodus medendi*, XIV, 19 [Kühn, X, *1020*]) defines it as the place where all the tunics are united [in the "seven circles"] and says that it is also called the crown. The "seven circles" to be described are: (1) crystalline body, or lens; (2) vitreous body; (3) retina; (4) choroid; (5) sclera; (6) expansion of tendons of eye muscles; (7) fascia bulbi and conjunctiva. See also Daremberg (in Galen [1854, I, *612–613, 614*]); Hyrtl (1880, *588–591*); and Simon (in Galen [1906, II, *xii–xiii, 258–259*]), who calls attention to the fact that before Galen's time the term iris was used as we use it today.

choroid, the choroid in turn is joined to the netlike body, and this to the vitreous and crystalline humors, to the vitreous over its whole surface, and to the crystalline only at the *iris*,[11] so that by means of the intervening bodies the vitreous humor is united with the outermost of all the tunics, that is, the softest body is united with the hardest, and this Nature has contrived through her most opportune interposition [of the other members]. Close upon this same circle [the sclera] comes a sixth, outer tunic, inserted into the hard tunic, the aponeuroses of the muscles moving the eyes, and besides these there is another, the seventh, which is the insertion of a periosteal tunic [the fascia bulbi and conjunctiva], attaching the eye as a whole to the bones and also covering the muscles moving it. You can see this membrane even before dissection; it is white, just as it appears to be, and comes to an end where all the other circles lie beneath it, where it joins the white to the black. This place [the ciliary region] is called *iris* by those skilled in such matters; some call it the wreath, and if you go about the dissection of the circles in [II, 62] the right way and make your examination without obliterating them, you will see the seven lying one upon another in this region and differing in thickness and color, so that even if you wished you could not give the place any name other than *iris*.

3. These works, however, are not the only ones that show forth the wisdom of the Creator; those of which I am about to speak are far greater still. For in my discourse I have brought as far as the middle region of the crystalline humor the seven circles that lie upon one another and are joined together there. You will most particularly admire what comes next if, before you hear it from me, you try to observe by yourself the skill displayed in it. Now what was the better thing to do in order that the crystalline humor might have accurate perception of its proper objects and at the same time be kept safe and quite unharmed by anything from outside? Should it be left perfectly bare without any covering? If it were, it would not persist for a single moment but would perish instantly and be completely destroyed, being unable because of its inherent softness to withstand anything from outside that might come in contact with it. Or should one set before it some dense barrier capable of keeping it

[11] κατὰ τὴν ἶριν. I have used the cognate word, italicizing it to indicate that it not what is now called the iris. Galen's explanation of the term follows almost at once.

safe? But then there would be the risk that by any such barrier it would be hidden away, veiled in total darkness, and made completely insensitive. If, then, a construction maintaining its accuracy
[II, 63] of sensation laid it open to injury and one that gave it resistance destroyed its accuracy, the construction of the instruments of sight had reached an impasse.

Nature, however, would not be at a loss even in this situation, as we should have been, but would first search out and foresee what was the better thing and then construct it with the utmost skill. She realized that since a thick, hard covering would hinder the eyes in performing their own proper work and a soft, thin one would be altogether liable to injury, it would be better to form one that was hard, but exceedingly thin, if it were also made clear. But when she turned to the creation of this, she was absolutely obliged to make it grow off from one of the seven circles at the *iris* [the ciliary region]. Now a hard tunic could not possibly be made to grow off from the four soft circles [the vitreous body, lens, retina, and choroid]. The three outer circles are left, and of these the last one of all, the circle of the periosteum [the fascia bulbi and conjunctiva], although much harder than the four inner circles, is even more unfit to be useful as a covering.[12] The second circle, the one underneath this that comes from the muscles, itself needed other coverings, so there remained the hard tunic [the sclera] coming from the meninx [the dura mater] and surrounding the choroid, and from this it was possible to form a covering.

Observe in this instance too Nature's combined forethought and skill: since this tunic was exceedingly thick and not as dense as was needful, she began by making it grow thinner and at the same time
[II, 64] denser, and, gradually bringing it forward, she ended by making the very middle of it extremely thin and dense.[13] You will think it wonderfully like horn that has been cut thin. Hence those skilled in anatomy, thinking the name hornlike [tunic] appropriate, have called it this, and the name has always remained to this day. For this hornlike tunic, being made thin, hard, and dense, must straightway become clear also, so as to be most suitable for transmitting light, just as horn is, that has been carfeully thinned down and polished.

Now although we cannot[14] take thought beforehand for such

[12] Note that Galen was unaware of the corneal part of the conjunctiva.
[13] To form the cornea, the "hornlike tunic."
[14] The μὴ of Helmreich's text is omitted by Kühn.

things, as Nature can, are we at least able to have [correct] afterthoughts and criticize [justly] any one of the things she has made because it would have been better to construct it otherwise? For my part, I think that most of us at any rate cannot do even this. Indeed, most people do not set forth the skill of Nature, for if they did, they would wholly admire her, nor do they have the sense not to censure her even if they do not admire her.[15] But it would be only fair for them either to point out some better construction than the one actually existing, or, if unable to do this, to admire what actually exists. O thou reviler of Nature, show us any other of the seven circles at the *iris* that would be better suited to give rise to the hornlike tunic [the cornea], or, if you cannot do so and if you think that it was not good for it to grow off from the hardest circle of all, then point out what better you would have done about the production of this tunic if you had stood in the place of Prometheus! Would you not have made it thin and clear, so that it would not hinder the transmission of the visual rays, and hard, so as to keep the crystalline humor safe? You could not say it should be made different from what it has already actually been made,[16] though it would be far easier to find something that had been overlooked, censure it, and make changes than it would be to construct a tunic perfect in every respect in the first place.[17] [II, 65]

But now, returning once more to wisdom, let us observe what else Nature has done. This hornlike tunic, having been made thin and dense, is a barrier for the instrument of vision very well suited to keeping it unharmed by outer objects without obstructing the visual rays,[18] but it has three disadvantages which necessarily attend such a construction and which you, O most clever accuser, if you were endowed with the authority of Prometheus, would perhaps have overlooked. Not so Prometheus himself, however. Knowing how to exercise forethought, he saw clearly first that this hornlike tunic would lack nourishment, for it could not attract over such a long distance and could not receive veins because it is dense, hard, and

[15] The text is corrupt here.

[16] The words *οὐδὲ νῦν ἐπ' ἤδη γεγενημένου*, found in Helmreich's text, are omitted by Kühn. In the myth, Prometheus, whose name means "forethought," was entrusted with the creation of man.

[17] The *αὐτὸν* of Helmreich's text is omitted by Kühn.

[18] The words *μηδὲν μᾶτ' ἐμποδίζεσθαι*, found in Helmreich's text, are omitted by Kühn.

thin; second, that although it would be sufficient protection for the crystalline humor against injury by outer objects, it would itself by reason of its hardness cause no less pain than they would; and third that over and above these things it would scatter and disperse the
[II, 66] visual faculty sent into the eyes from above. Now since you would be ignorant that the essence of this faculty is of the nature of light, and ignorant too that it is destroyed when it is dispersed by abrupt association with a brighter, stronger light, you would not have known that in placing such a brilliant tunic around it you would be surrounding it with a domestic evil. But the Creator of animals was not unaware of these things. On the contrary, he foresaw how to bring it about first that the hornlike tunic should be nourished; second that it should not touch the crystalline humor at any point; and third that it should not disperse its light, and he corrected all these difficulties with a single clever device.

Perhaps I would tell you now what this is, O most clever accuser of Nature, if I did not realize very clearly indeed that you will deny my theory of vision.[19] Well, let us suppose that you have not heard

[19] There were two theories of vision in classical times, propounded by Plato and Aristotle respectively. Plato (*Timaeus*, 45 [1920, II, *26*]), following Empedocles, says that fire, not the kind that burns but the kind that gives a gentle light, is enclosed within the body and flows out through the eyes. When daylight encounters this visual stream, the two coalesce wherever the inner light strikes an external object, and the resulting motions of what is touched are communicated by the visual stream to the whole body until they arrive at the soul, where sight is produced.

Aristotle (*De sensu et sensili*, cap. 2, 437b9–438a5 and 438a25–438b5) quotes the fragment of Empedocles containing the seed of Plato's theory, with which he cannot agree. It is beyond the bounds of reason, he contends, to think that anything issuing from the eye could possibly reach objects at a distance, a star, for instance. Rather, the eye is affected by the motion of the external medium, whether this is air or light.

Galen, whose clearest exposition is in *De plac. Hipp. et Plat.*, VII, 5 (Kühn, V, *618–620*), follows Plato, as he so often does. If sight were caused by something proceeding from the object to the eyes, he says, it would be impossible to judge the size of what we see, for an image of the same size as the object would have to be formed, and this, in the case of a mountain for example, would be utterly unreasonable. Accordingly, he thinks, the visual faculty, "which is of the nature of light," is delivered to the eyes in generous quantities through the channels in the

this theory and that I did not say just now that the essence of the visual faculty is of the nature of light. Assuming that nothing has been said about it and it is unknown, learn, if you will, or rather recall, this very fact, demonstrated by its effects, namely, how our vision is hindered by a sudden, strong light. Now perhaps you do not know how greatly the soldiers of Xenophon suffered as they made their way through deep snow;[20] for I should not be surprised if you have overlooked his writings too. And I dare say you have never heard that Dionysius, tyrant of Sicily, built a chamber above his prison, a chamber that was completely covered with shining chalk and very bright in other respects too; that he brought his prisoners up into this chamber after a protracted stay below; and [II, 67] that they, coming into bright light from deep, long-continued gloom would of course gladly look up to the light and as they did so, would be blinded, unable to endure the sudden, instantaneous onslaught of brilliance.[21] Leaving these things, I shall try to remind you of what we see in our daily life, and first of painters and how, especially when they are working on white parchment, their eyes tire easily, if entirely unassisted. So, to provide for this they place near by gray or dark-colored objects, to which they keep looking away, thus resting their eyes. Moreover, light is a test for those suffering from ophthalmia, for it hurts them, whereas looking at gray or dark-colored objects is painless. Also, if anyone wishes to see something at a distance in bright light, he places either his hands or something larger and more confining above his eyes right at his eyebrows, and in great[22] eclipses of the sun the stars appear for the same reason, just as Thucydides[23] has written that they did in his day. The stars are visible too from the bottom of a well, especially when the sun is not directly overhead.[24] Indeed, if anyone wished to

---

optic nerves (see note 42 of Book VIII). This faculty then issues from the eyes, using the air surrounding the illuminated object to be perceived as the brain uses its sensory nerves; the crystalline lenses are altered by the sensations reported by the air acting as a nerve; and these alterations are in turn faithfully reported to the brain by the retinas, which are themselves practically extensions of the brain.

[20] *Anabasis*, IV, 5 (Xenophon [1922, *48*, *49*]).

[21] There seems to be no other source for this story.

[22] That is to say, in total eclipses.

[23] In Book II, 28 (Thucydides [1951, *99*]).

[24] Cf. Aristotle, *De gen. an.*, V, 1, 780b18–22.

gaze full at the sun without blinking, he would quickly destroy his
[II, 68] sight, and at the time of an eclipse many who wish to gain a more accurate understanding of the phenomenon and so look intently at the sun have blinded themselves completely without realizing what they were doing. And how bad for the eyes it is to walk through the snow you may learn by trying it yourself, if you do not believe Xenophon. If, however, you are waiting to hear something simpler, place a lighted lamp or some other flame in bright sunlight and you will see it instantly grow dim, and moreover, if near any large flame whatever you place a lamp or some other smaller flame, it is instantly quenched, the lesser light always being overcome and dispersed by the greater.

Nature would not, therefore, disperse the light of the crystalline humor right in the eyes themselves; rather, in order carefully to keep this light and along with it that of the vitreous humor confined and held together on all sides, she provided the choroid tunic that grows off from the thin membrane [the pia mater], making many parts of it black but many other parts gray or blue. This she brought forward from the *iris* [the ciliary region] along with the hornlike tunic [the cornea] to be useful in the three ways I have mentioned [25] to nourish the hornlike tunic by being close to it; to keep it from striking against the crystalline humor (for the hornlike tunic is hard); [26] and to furnish for tired eyes a corrective object to look at. This is the reason, I suppose, why all of us when we are
[II, 69] distressed by bright lights naturally and instantly close our eyelids, hastily seeking the natural remedy. For my part, I marvel at the blue color spread out over this tunic [the iris]; for since this is found nowhere in the body except in this one place, and obviously no other place except this has need of it, what I have been demonstrating throughout this discourse is now clear, namely, that Nature makes nothing defective and nothing without a purpose.

4. I marvel just as much at the roughnesses on the inner side of the tunic [the iris] that surrounds the crystalline humor.[27] For these are

[25] This prolongation of the choroid coat is evidently the iris of modern terminology.

[26] Helmreich has added the statement in parentheses from Oribasius; it is lacking in the manuscripts.

[27] Helmreich's and Kühn's texts both read ὑαλοειδὲς—the *vitreous* humor—and Helmreich records no variant reading in any manuscript. I feel, nevertheless, that the thought absolutely demands κρυσταλλοειδὲς,

moist and soft like a sponge, and where they touch the crystalline humor they render painless the association of the whole tunic with it. And even more than this I marvel at the density of its outer side where it is associated with the hard hornlike tunic [the cornea]; for not only must the crystalline humor be free from any pain caused by this blue tunic [the iris] but the tunic itself must also not suffer in any way from the hornlike tunic. A still greater marvel is the perforation of it at the pupil, because everything that had previously been well worked out would be utterly ruined if just this perforation were overlooked; but Nature would not overlook this any more than she would anything else. Here she pierced the blue, grapelike [28] tunic [the iris]—for that is what they call it, likening its outer smoothness and inner roughness, I suppose, to one of the grapes in a bunch. Only at this perforation is there no intermediate tunic be- [II, 70]
tween the hornlike tunic and the crystalline humor, and only here the association and mingling of the inner and outer light occurs as if through very thin, clear horn. Accordingly, our Creator has provided a means by which the hornlike tunic may always be prevented from touching the crystalline humor even at this perforation and has done so by bringing the portion of the hornlike tunic [the cornea] in this region farther out, by pouring around the crystalline humor a thin, pure liquid [the aqueous humor] like that in eggs, and thirdly, in addition to these devices, by filling the whole space at the pupil with an etherial pneuma of the nature of light. This is the true state of affairs, but the assertion still needs to be demonstrated, particularly because of those people who do not wish any action or usefulness to be discovered, but are anxious for everything to be obscure and completely unknown. Well, then, where this hornlike tunic [the cornea] grows off from the *iris* [the ciliary region], it will seem to you to be very close to the crystalline humor, since all the humors and tunics of the eye are united in this region, but as it gets farther toward the outside, it withdraws more and more, its greatest possible separation being at the pupil, as one can learn from dissection and from couching cataracts. For since cataracts arise in the space be-

---

and I have so emended. For it is obvious from the context that it is the iris that is under discussion, and to call the iris a tunic surrounding the vitreous body is meaningless.

[28] Grapelike = ῥαγοειδῆ, Latin, *uveam*, our uvea, a term used by Galen for the iris only, not for the whole choroid coat.

[II, 71] tween the hornlike tunic and the crystalline humor, the instrument that is introduced to draw them aside, when moved around through the large, free space, up, down, to the sides, and in short, circularly in all directions, does not touch either of the bodies in question [the lens and cornea] because the distance between them is very great.

5. That the space between the crystalline humor and the grapelike tunic [the iris] contains a thin liquid [the aqueous humor] and that the region around the pupil is full of pneuma you may best learn from the following: first, in living animals you see that the eye is exactly extended, every part being filled, and that no part of it is shriveled or lax, whereas if you care to dissect a dead animal, you will see even before you do so that the eye is already somehow more shriveled than it is in its natural state. As you dissect the hornlike tunic [the cornea], the thin liquid will at once come pouring out, and also when cataracts are couched, this frequently flows off through the wound. Immediately the whole eye may become shriveled, contracted, and lax, and if you stretch the tunics and separate them from the crystalline humor, the large space between is seen to be empty. If, then, earlier, when the animal was alive, this space was full and distended the tunics, and if after death it is empty and the surrounding tunics become lax, it is clear that the space was filled with some pneuma, or liquid, or both. Moreover, if we close one eye
[II, 72] and keep the other open, we see that the pupil becomes dilated and expanded, as if it were inflated. Now reason makes evident that it is in this condition because it is full of pneuma, and you may also make trial of this by artificial means and test reason by what is actually to be plainly seen; for if you inflate the grapelike tunic [the iris] from within, you will see the aperture dilate. And so it is clear from the experiment that the pupil enlarges because it is full of pneuma. However, reason says simply that when the grapelike tunic is filled from within, it is greatly extended and expanded and that in this way the aperture too becomes larger, just as happens with all other thin, membranous, collapsible bodies in which there are holes and perforations. In the same way the membranes of sieves must be stretched if their holes are not to collapse. If, then, while the animal is still alive, it is possible to see that both membranes [the iris and cornea] are stretched and that when one eye is closed, the pupil of the other is enlarged, and if, when the animal is dead, you can see that the membranes are already lax even before the thin humor is emptied

out and that they become extremely lax after it is emptied, it is clear that while the animal was living they were filled with both humor and pneuma. Now one of these [the pneuma], being thinner and less substantial, is easily evacuated before dissection, but the humor still remains because it needs an evacuation that is perceptible.

Moreover, in very old persons the hornlike tunic [the cornea] frequently becomes so shriveled that some of them have no sight at all, and others still see, but poorly and with difficulty. For when the [II, 73] wrinkles fall one upon another and as a result the tunic is doubled and acquires added thickness, and when there is also less pneuma coming down into the pupil from above, the sight is hindered proportionately. But of course this lessened influx of pneuma from its source [the encephalon] is itself the greatest cause of the shriveling at the pupil. From all this it is evident that all the space next to the crystalline humor is always filled with both pneuma and a thin liquid, and that the liquid is in the other parts, but most of the pneuma is right in the pupil itself. Thus the wrinkled condition of the hornlike tunic itself in old persons is proper to old age [29] because of weakness and the lack of pneuma coming down from above. The affection called *phthisis* [of the eye] is a shrinking of the pupil itself without any separate involvement of the hornlike tunic. Hence in most cases it occurs in [only] one of the eyes so that it is readily recognized and does not escape the notice of any physician; for the healthy eye beside it indicates the failure of the one affected. In the aged, however, the symptom, being common to both eyes, does escape most physicians because there is not only a wrinkling of the hornlike tunic but also a narrowing of the pupil. Sometimes too the condition occurs when the grapelike tunic [the iris] is too greatly relaxed because there is not enough of the thin liquid, but this affection is one we need not discuss at present. The affection resulting from the lack of *pneuma* that comes with a stoppage of the [II, 74]

[29] Reading τῷ γήρᾳ with Helmreich for the τοῦ γήρατος of Kühn's text. The word *phthisis* in the following sentence probably does not mean tuberculosis, and I have therefore italicized it to point the difference. See chapter 13 of Book VI, p. 310, where phthisis (tuberculosis) of the eye is said to involve the coats of the eye, as this *phthisis* does not, and see also *Definitiones medicae*, CCCXLI (Kühn, XIX, *435*), where the definition is similar to the one here. Kühn (I, *clix*) considers these definitions spurious but very valuable as a collection taken from ancient sources, perhaps by Galen himself.

passages leading down from above [80] and with senile weakness indicates that the pupil is [normally] full of pneuma, and this is also indicated by the enlargement of the pupil of one eye when the other eye is closed.

6. Is it only for the purpose of keeping the crystalline humor and hornlike tunic far apart and never in contact that this thin liquid and the pneuma at the pupil are useful, or are they important for other reasons as well? In the case of the pneuma, I have demonstrated in my treatise *On Vision* [81] that it is of the nature of light and brings in the faculty most important for the action of the eyes. As for the liquid, you may learn from what follows that it is most necessary not only for filling up the empty space but also for preventing the crystalline humor itself and the inner portion of the grapelike tunic from drying out. First you should know that the sight is injured when too much liquid escapes in couching [cataracts], and that the affection called *glaucosis* [82] by physicians is excessive dryness and solidifying of the crystalline humor, causing blindness more than any other disease of the eyes. Then you should observe and consider the nature of the grapelike tunic [the iris]; for the part of it touching the crystalline humor is very like a soaked sponge, and all bodies of this sort become hard when they dry out. Sponges show
[II, 75] this to be true and so do grapes and the tongues of animals. If this part of the grapelike tunic should become dry, it would lose the entire usefulness for the sake of which it was made such as it is, and so it must always be kept wet in order to be soft.

Now all these things are indications of a certain wonderful forethought and skill and so to no less a degree is the natural coating [the capsule] of the crystalline humor. For the hornlike tunic [the cornea] has been formed as a barrier or embankment for it, to receive the force of whatever strikes against it from without, whereas its own proper tunic is not only "like the skin stripped down from a dried onion," [83] but is also even thinner and clearer than thin cobwebs, and what is more remarkable, it does not extend around all of

[80] The supposed channels of the optic nerves. See note 42 of Book VIII.

[81] A lost work already referred to in Book VIII.

[82] See note 3 of this Book.

[83] Cf. Homer, *Odyssey*, XIX, 232–233, where the same simile is used to describe Odysseus' tunic.

the crystalline humor, which is completely without protection and bare of a tunic in the part where it is united[84] with the vitreous humor; for it was better for the humors to be united in this region. All of the part, however, that looks to the outside and is in contact with the grapelike tunic [the iris] puts on this thin, brilliant tunic. Moreover, the image of the pupil takes shape in this as in a sort of mirror; for it is smoother and more glistening than any mirror.

Thus Nature has ordered well the instrument of vision [the lens] in every way, in the proper degree of softness, in its suitable position, in brilliancy of color, and in the excellence of its coverings. For its natural covering [the capsule] is smooth, clear, and glistening like [II, 76] a mirror. The covering [the iris] next to this is full of veins, soft, dark, and perforated; it is full of veins so that it may abundantly nourish the hornlike tunic; soft, in order not to cause pain when it touches the crystalline humor; dark, in order to collect the light and pass it on to the pupil; and perforated, in order to send out to the outside the light which it[85] has passed on. The outermost covering of all [the cornea] is a sheltering barrier that is thin, clear, and hard like horn; it is thin and clear in order to transmit the light readily, and hard so as to be a sure protection.

Well, are these the only things to be justly praised, or should we also praise the shape of the crystalline humor? For it is not a perfect sphere, evenly rounded on all sides, although for the reasons I have often mentioned this is the shape most favored by Nature and most agreeable to her. It was not safe, however, to make the crystalline humor perfectly spherical; for it would not have received the circles applied and united to it in the region of the *iris* [the ciliary region] as it does now, and there would be danger that whenever the eye was moved suddenly and violently or struck, the crystalline humor would be rolled out from the vitreous humor. In fact, unions or attachments between perfectly spherical bodies are more insecure than those between flatter bodies, because the former rest upon convex surfaces, from which it would consequently be easy for them to roll off, and this is the very reason for the shape of the crystalline humor.

[84] Reading *ἐνούμενον* with Helmreich for the *ἐνοχούμενον* of Kühn's text. Evidently Galen overlooked the posterior part of the capsule, perhaps because it is thinner than the anterior.

[85] Omitting with Helmreich the *ὁ ἐγκέφαλος* of Kühn's text.

And now all parts of the eye seem to be established in safety with the exception of the hornlike tunic itself [the cornea] that covers
[II, 77] them; for since this was made from the membrane [36] from above [the dura mater], it lies in front of everything else, alone exposed to all injuries and receiving the assaults of smoke, dust, cold, heat, and objects that would crush or cut into it. For this reason, although of necessity our Creator placed it in front of the other structures because he had nothing more suitable, nevertheless, realizing its excellence, he protected it in every way with eyelids and eyelashes and with bones and skin round about it. He set the eyelashes in front like a palisade, so that small bodies, warded off by these hairs, might not readily fall into the open eyes,[37] and he established the eyelids themselves to be folded together and close the eyes if a larger body is encountered. For protection against still larger masses he has set the eyebrows above and the cheeks below. At the large corner [of the eye] there is the nose and at the small corner, the outgrowth of the zygomatic arch. Placed within the circle of all these parts that receive first the assaults of larger bodies, the eye itself suffers nothing, and to its protection against injury the movement of the skin also contributes to no small degree. For the skin, contracting from every side, presses the eye inward, drawing it together into the least possible space. If anything gets past the curvature of the bones and is borne inward upon the eye, the skin together with the eyelids becomes much wrinkled in this region and is the first to receive the
[II, 78] impact, the first to suffer, to brave the danger, and to be destroyed. Next below the skin the eyelids are crushed, shattered, and made to suffer in various ways; for they are set in front of the hornlike tunic like a shield. Now from what substance was it sensible to make these shields? Should it be from something exceedingly soft and fleshy? But if so, they would be more easily injured than the hornlike tunic and they would be anything but a protection. Or should it be from something perfectly hard and bony? But [then] they would not move easily or touch the hornlike tunic without causing pain. Hence

[36] Omitting with Helmreich the *παχείας* of Kühn's text.

[37] Galen's treatment of the eyelashes and eyebrows is an amplified version of Aristotle's (*De part. an.*, II, 15, 658b14–18), and Aristotle in turn took his from Xenophon's *Memorabilia*, I, iv, 6 (Xenophon [1923, 56–57]). See chapter 7 of this Book and chapter 14 of Book XI for further references to this subject.

it was sensible to make the eyelids from a substance that is indeed very hard, but capable of moving easily and being close to the hornlike tunic without injuring it.

7. Moreover, it was better for the eyelids to be joined to the bones and also to the eyes themselves. Therefore, since in constructing them this must be borne in mind, and more than this, their ease of movement, resistance to injury, and painless association with the hornlike tunic, it is at once just to admire Nature, who has done all these things so accurately that a still better construction is inconceivable. For, producing the membrane called the periosteum, she brought it forward from the rim of the brows as far as the eyelids had to extend and brought it back again by way of the lower [inner] parts of the lids.[88] She did not, as some think, place it in contact with itself like a two-layered shield, nor did she bring it back as far as the place from which it had grown off, but, joining it to the underlying muscles that surround the eye and producing it [II, 79] thence as far as the *iris* [the ciliary region], she inserted it into the hornlike tunic at that point. Viscous, fatty substances together with certain membranes extending from the muscles occupy the space between the two parts of the periosteum, and it is here too that the so-called hydatids [sties?] come to be formed when sometimes these fatty bodies, made by Nature to oil and soften the eyelid, become abnormally large. The lower eyelids also are analogously constructed from the periosteum at the cheek bones, which extends for some distance and then turns back to the hornlike tunic.

At the point where the periosteum begins to run back, a certain substance harder than membrane is stretched upon it. This has been called tarsus, and it encloses, surrounds, and holds together the convexity resulting from the folding, being formed for this very usefulness and for two others besides, one of which, the greater and more cleverly devised, I shall explain a little farther on; the lesser, however, I shall discuss now. This tarsus is pierced with fine holes, from which the hairs of the eyelids emerge, the hard tarsus furnish-

[88] The lower (inner) part of this "periosteum" is obviously the conjunctiva. It is possible that the upper part is the orbital septum, or, since the two layers are said not to be in contact, it may be the sheet of muscle fibers of orbicularis oculi. In the latter case the "certain membranes" which together with "viscous, fatty substances" (the tarsal glands?) occupy the intervening space may be the orbital septum.

ing the foundation for them and keeping them set upright. For just as it was better for the hairs of the eyebrows to fall one upon another, so it was better for these hairs to be kept always erect and stiff. Now the usefulness for which they were formed was in each case best served when they were constructed as they actually are;
[II, 80] for the hairs in the eyebrows receive everything that runs down from the forehead and head before it can fall into the eyes, whereas those of the eyelids, without themselves harming the eyes in any way, prevent sand, dust, and little flying animals from entering. Moreover, in these matters one might most particularly admire this feature in Nature's work, namely, that she has not made the hairs of the eyelids turn up toward the brows or toward the cheeks, and neither has she turned them inward upon the eyes themselves. In the first case they would lose the usefulness for which they were formed and in the second, they would actually harm the eyes by interrupting our view of the things we look at. What more shall I say? Is not the exactly suitable interval between them marvelous? For if they had been placed farther apart, many things would get into the eyes which are now kept out, and if they touched one another, they would to some extend darken the eyes. And certainly they ought not to darken them or lose the usefulness for which they themselves were created.

8. Now that I have treated of the eyelids and finished my discussion of the eye as a whole, it is time to tell from what source we provide it with motion; for to leave it completely at rest would be the act of a creator who either did not know the causes of vision or took no thought for what is better in every instance. But to be ignorant or careless is not characteristic of the one who has dis-
[II, 81] played such wisdom and forethought in the whole formation of the animal. What then do we say are the causes of vision that he must know, and in what way must he provide for what is the better? The eyes cannot see everything from every position in the way that the ears can hear everything irrespective of their position; for we cannot see anything beside or behind us or above or below, or, in short, anything at all except what is in a straight line with the pupil. If, then, the eyes had been made entirely without motion, looking only in a straight line, we should see very little indeed. It is certainly for this reason that [our Creator] has made them capable of turning through a very wide angle and has made the whole neck free to

move in concert with them. It is for this reason in particular that two eyes were made and separated from one another by a considerable interval. Persons blind in one eye do not see objects in front of that eye, even if they are brought close to it. If, then, the eyes must have voluntary motion and all such motion is accomplished by muscles, it is clear that it was the Creator's task to set muscles around the eyes, and my task not simply to tell their usefulness but also to tell how many there are, how large they are, and how they are placed.

Well then, since there are four movements of the eyes, one directing them in toward the nose, another out toward the small corner, one raising them up toward the brows, and another drawing them down toward the cheeks, it was reasonable that the same [II, 82] number of muscles should be formed to control the movements. And so two were formed at the sides (one at each corner) [*recti, medialis* and *lateralis*], and one of the other two above [*rectus superior*] and the other below [*rectus inferior*], but they all become tendinous to make one broad, circular tendon that ends at the *iris* [the ciliary region]. Since it was better that the eye should also rotate, Nature made two other muscles [*obliqui, superior* and *inferior*] that are placed obliquely, one at each eyelid, extending from above and below toward the small corner of the eye, so that by means of them we turn and roll our eyes just as readily in every direction. There is also another large muscle [*retractor bulbi*] [89] that surrounds the root of the eye and holds close and protects the insertion of the soft [optic] nerve. This raises upward, elevates, and at the same time turns the eye a little; for, shaken violently in hard falls on the head, that soft nerve would easily be broken off unless it was anchored on all sides, held fast, and in every way protected. And if you ever see a person with one eye as a whole more prominent, you may know that if he can still see and the condition is not the result of a blow, that soft nerve has been stretched because of the paralysis of the muscle which is no longer able to hold, control, or bind it. And if he cannot

[89] Lacking in man, but present in the horse, beef, pig, and other animals. Especially in the carnivora, according to Ellenberger and Baum (1926, *917*), four divisions of it can be detected, corresponding to the four recti muscles and surrounding the posterior part of the eyeball and the entrance of the optic nerve. Cf. *De anat. admin.*, X (Galen [1906, II, *28*; 1962, *31*]).

see any longer, the nerve too is already affected. If the eye has become prominent as the result of a hard blow and the person can still see, the muscle itself is the only thing that has been ruptured; if
[II, 83] he cannot, the nerve too has been broken off. This muscle, then, which has been made for this usefulness and which surrounds circularly the whole root of the eye, has been thought by some anatomists to be triple, whereas others think it is double, dividing it thus according to certain layers or partitions of the fibers. But whether or not you like to say that this is one muscle composed of several elements or that there are two muscles, or three, there is a single usefulness for them all, and that is the one I have just told.

9. These are the many great works of Nature in her construction of the eye, but there is left still to be discussed something that you will admire no less than all I have told hitherto. It was of course entirely necessary that the eyelids too should be moved at the bidding of our will; for otherwise they would be of no advantage [to us]. As instruments for all voluntary movements Nature has prepared muscles which move the parts by means of tendons inserted into them. I have shown in my book *On the Movement of the Muscles*[40] that every part moved by the will needs at least two muscles set to oppose one another and capable the one of extending, the other of flexing it, and I have also shown that no muscle can perform both movements, because it always draws toward it the part to be moved and, being but single itself, has only one position.

If this is so, how will the eyelids be moved? The lower one, indeed, is entirely without motion; the upper one is obviously
[II, 84] moved, but some of the sophists, not finding the muscles that move it or the way in which it is moved, have had the effrontery and impudence to agree that the motion of the eyelids is not under the control of our will, but natural,[41] just as the movements of the stomach, intestines, arteries, heart, and many other instruments are involuntary and not under the control of the will. For they think it better to deceive than to confess their ignorance. Now a liar about

[40] *De motu musculorum, passim;* see in particular I, 4–6 (Kühn, IV, *384–396*).

[41] At least one of the targets here may be Aristotle, who makes this statemeent in *De part. an.*, II, 13, 657a37–657b2. If so, it is easy to see why, in view of the tone of what follows, the name was omitted; for though Galen often disagrees with Aristotle, he is always respectful.

some subjects would go undetected by most men, but if he says that there is no light and that it isn't daytime at all, when everybody can see the sun above the earth, he will be thought crazy. Then what about the man who says that when we walk we use our legs one after the other not in obedience to our will, but involuntarily and naturally? To me this man will seem no less crazy than the first. For when we can move them faster or slower and closer together or farther apart, and can stop altogether and again set them in motion, how can one avoid being foolish if he says that the action is natural and not under the control of our will? Well, if it is impossible for us when we close our eyes to keep them so as long as we wish and open them again when we choose, and similarly if we cannot then close them again and do both these things one after the other as long as we please, then the movement of the eyelids is no work of ours. But if we can do these things freely at our pleasure for as long as we wish, it is clear that, provided the eyelids are in a normal condition, the movement of the upper eyelids takes place under the control of our will. Moreover, it would have been idle for Nature to give them to us if, when some outer object which would strike and injure the eyes was directed against them, we wanted to close them and could not. [II, 85]

It is not at all remarkable, however, for the sophists to say such things, for they care not for truth but only for glory. Indeed, this piece of impudence on their part yields no inconsiderable proof of the skill of Nature's handiwork. For since the motion of the upper eyelids is clearly to be seen but we cannot tell how it happens or find the muscles causing it, what would we have done if, like Prometheus in the myth, we ourselves were shaping animals? It is quite clear, I believe, that we would have left the upper eyelid without any motion at all. But perhaps they will say that they would have produced muscles from the brow and inserted them into the entire tarsus of the eyelid. But if you had, O cleverest of men, the whole eyelid would have been everted, turned inside out, and bent back toward the brow. Well, let us concede this point and let the eyelid be properly opened; you must tell us next how it is to be closed. Now you cannot produce another muscle from the lower eyelid and insert it into the tarsus [of the upper eyelid], for this would be a great absurdity, and neither can you produce one from the inner parts underneath the upper eyelid. For the first result of such an

arrangement would be that the eyelid would not close but, when tensed by such a muscle, would be turned in, folded under, and
[II, 86] doubled. Then, too, the muscle itself would have a most abnormal position, pressing upon the whole eye and being compressed by it, and restricted and hampered in its movement. Justly then, in my opinion, it is something to wonder at that the sophists, who have not as yet been able to discover or explain the works of Nature, still accuse her of a lack of skill. For I think they should be expected to show that it was better that the eyes should not be provided with lids, or that if they were, the lids should be without motion, or that if the lids did move, the motion should be involuntary, or that if it was voluntary, the muscles should be arranged thus and so. But they have reached such heights of cleverness that although the eyelids obviously move, they do not understand how it happens and do not discover any other movement! And they are so senseless as not yet to admit that the One forming and framing so many wonderful parts is a Craftsman. Furthermore, if there should be a discussion among artisans as to how best a house, a door, a little couch, or something of the sort should be constructed to serve the usefulness for which it was formed, and if, while the others were at a loss, there was one who knew how, he would justly be admired and considered a clever craftsman. And shall not we who, not to mention being incapable of planning the works of Nature, are not even able to understand them when we see them already formed—shall not we admire them more than man-made creations?

[II, 87] But now let us leave these sophists and, after we have first explained what has been perceived by the best of our predecessors, let us see for ourselves what is this wonderful story about the movement of the upper eyelids. I have already said earlier somewhere that underneath the skin covering the eyelid there are thin membranes, and I shall begin my present discussion with this remark. Now these very membranes conceal the muscles themselves that move the eyelid, muscles that are exceedingly small and are tensed by tendons (aponeuroses) inserted into the tarsus. I have said before that the tarsus is cartilaginous, applied like a ligament to the membranous body forming the eyelid, but I have not as yet said precisely that it receives the flattened and thinned outgrowths of those little muscles. So learn this now, and learn too that one of the muscles

[medial half of upper part of *orbicularis oculi* with lacrimal part?] is transverse, is placed at the large corner of the eye near the nose, and extends to the half of the tarsus on that side, and that the other muscle [lateral half of upper part of *orbicularis oculi?*] is also placed obliquely [42] but lies beside the small corner of the eye and is inserted into the other half of the tarsus on that side. Hence, when the first muscle acts, it draws down the part of the eyelid continuous with it, the part near the nose, and when the other acts, it draws the rest of the eyelid up. For since the head of the first muscle is placed at the large corner of the eye and the head of the second at the brow, and since the pull of every muscle is exerted toward its [II, 88] own beginning, necessarily the motion of the one part of the eyelid near the nose is downward and that of the other at the small corner of the eye is upward. Hence, if both muscles together [43] should draw on the eyelid at the same time, the part of it near the small corner would be drawn up and that at the large corner would be pulled down, so that the eye would be no more open than closed. This is the so-called crooked eyelid of Hippocrates,[44] which he gives as a very bad sign in diseases, and he calls this twisting of the eyelid Ὄλωσις (distortion).[45] That is to say, this affection is found when both muscles are convulsed and draw toward themselves the parts of the tarsus connected with them. But if one muscle acts and draws the eyelid toward itself while the other is completely at rest, the whole eyelid as a result is then opened or closed; for the part of the tarsus being moved always draws the rest along with it. The reason for this is the hardness of the tarsus, and if it were membranous, fleshy, or soft in any other way, the part moved would not be followed by the other part. Indeed, it was this very thing that Nature foresaw when she added to the eyelid the hard, cartilaginous tarsus and fastened to this the extremities of both muscles. For just as all of a crooked stick follows along when you grasp it by either end and pull, so in the same way the whole tarsus follows [II, 89]

[42] Reading λοξὸς μὲν καὶ αὐτός with Helmreich for the ὅλος καὶ αὐτὸς πλάγιος of Kühn's text.

[43] Reading ὁμοῦ with Helmreich for the ὁμοίως of Kühn's text.

[44] *Praenotiones*, cap. 2 (Littré, II, *116–119*); *Aphorismi*, sectio IV, 49 (Littré, IV, *520, 521*).

[45] In *Praedicta*, I, 69 (Littré, V, *526, 527*).

either of the muscles when it is tensed. This is the third and most important reason for the formation of the tarsus, the reason I put off discussing a little while ago. And this is the state of affairs as regards the upper eyelid.

10. Why does not the lower eyelid also have its share of motion, when it was formed for the same usefulness and has a place no less suitable for the muscles? For Nature would seem to be unjust here if, when it was possible to assign half of all the motion to each eyelid, she bestowed the whole of it on one of them; and unjust not in this respect alone, for she would also appear no less wrong in making the lower eyelid much smaller, since seemingly it would be necessary for the eyelids to have equal shares of size and motion, just as the ears, lips, and alae of the nose do. But their situation is the reason for the difference. If the lower eyelid had been made larger than it actually is, it would not be so well established, but would droop down upon itself and fall in wrinkes. Also it would loosen and separate from the eye, and worse than all this, rheum, tears, and everything of that sort would accumulate in the eye in quantities hard to excrete. Hence it was better to make the lower eyelid small, for, being made so, it always holds the eye firmly, molding itself to
[II, 90] it, surrounding it accurately, and easily squeezing out all the residues. Again, having been made small, the lower eyelid very clearly no longer needs to move at all.

Certainly the skill of Nature in her dealing with the eyelids, as I have described it here, seems to have been discovered and beautifully explained by the best anatomists, and I would now trust them entirely if I could be sure that I had precisely distinguished the muscle at the large corner of the eye. As it is, however, never up to this time have I seen it clearly in any subject, and in operations for ulcer that whole region is not only cut away but even burned out so as sometimes to remove laminae from the bones beneath, without at all impairing the movement of the eyelid. Hence I think I need to make further observations. If ever I can persuade myself that I have discovered the whole truth of the matter, I will reveal it in the book *On Movements Difficult to Explain* which I intend to write.[46] At

[46] If Galen ever wrote such a work, it has not survived. He had not done so when he was writing *De anatomicis administrationibus* (see note 12 of Book II of this present work), for he refers to his intention again in Book IV, chapter 5 of that work (Kühn, II, *443;* Galen [1956,

present it is enough for me to say just this, that Nature's skill reaches such heights of wisdom that it has never been entirely found out even though sought after for such a long time by such great men.

11. Next I should investigate matters having to do with the corners of the eyes. If the fleshy body [*caruncula lacrimalis*] lying at the large corner is useful, Nature would seem to be doing the small corner an injury in depriving it of a useful covering. If it is useless, however, she would again be wrong in burdening the larger corner with something superfluous. Then what is this thing? And how is it that she is unjust to neither corner? She has placed the fleshy body at [II, 91] the large corner as a covering for the passage to the nose [the lacrimal canal]. That opening serves a double purpose for the animal, one that I discussed earlier when I was on the subject of the nerves from the encephalon and another that it is now the proper time to mention.[47] Through these passages all the residues of the eyes flow into the nostrils, and in many cases, shortly after the eyes have been anointed with drugs, these are frequently spit up by some and discharged from the nose by others. For this channel from the corner of the eye is bored through into the nostril at the point where the nostril itself is also bored through into the mouth [the pharynx], and so what flows out issues through the nose when we blow it or through the mouth when we cough. It is certainly to prevent the residues from flowing out of the corners of the eyes and to keep us from shedding tears continuously that these fleshy bodies have been made to grow upon the channels, to direct the evacuation of the residues of the eyes away from the corners and into the proper channels.

The best proof of what I have said lies in the frequent errors of

---

104]). In the meantime, however, he had indeed made further observations and had found levator palpebrae superioris, unmentioned here, of which he gives a good description in Book X of *De anat. admin.* (Galen [1906, II, *42–46;* 1962, *46–50*]). In *De libris propriis*, cap. 2 (Kühn, XIX, *20*), he tells again of his dissatisfaction with the current explanation of the muscles moving the upper eyelid and his successful search for the muscle really responsible for it. Our respect for Galen and his achievements can only be raised to new levels by this example of his skill, persistence, and intellectual honesty.

[47] But the lacrimal canal carries no nerve; it has been confused here with the sphenopalatine foramen, which, of course, conducts no tears. *Vide supra*, pp. 441, 456.

those physicians who call themselves oculists. Some of them, while dissolving out with acrid drugs the so-called pterygia, serious trachoma, figlike ulcers, and lumps on the eyelids, have unwittingly also dissolved out along with them this sinewy bit of flesh at the large corner. Others in operating for tumors of the large corner have cut away more than they should and so have permitted the residues to flow out there. They call this affection a flux, and why
[II, 92] should I need to speak of the absurdity of this? But [for proper evacuation of the residues] Nature has made sufficient provision in these fleshy bodies and besides these in the exceedingly fine perforations [*puncta lacrimalia*] found slightly lateral to the large corners of the eyelids; for they penetrate to the nose and by turns both deliver and retain the thin moisture. It is of no inconsiderable advantage (χρεία) to deliver it on the one hand when it is in excess, and on the other to retain it when it is deficient, in order to preserve the natural balance calculated to make the eyelids move easily. Excessive dryness, of course, tends to make it difficult for them to bend and move, because they are hard; an undue amount of moisture, however, tends to make them soft and weak; and only a condition halfway between the two is best for all their natural actions. To give ease and lightness of movement, two glands [the lacrimal glands] were also formed in each eye, one in the lower and the other in the upper part and these pour forth moisture into the eyes from perceptible openings, just as the glands at the root of the tongue draw off saliva into the mouth. It is likewise for no other reason that Nature has prepared the fat that surrounds the eyes, as its hardness makes evident; for thanks to this hardness it does not easily dissolve, but always moistens[48] them because it is oily.

12. I have explained nearly everything pertaining to the eyes with the exception of one point which I had intended to omit lest many of my readers be annoyed with the obscurity of the explanations and
[II, 93] the length of the treatment. For since it necessarily involves the theory of geometry and most people pretending to some education not only are ignorant of this but also avoid those who do understand it and are annoyed with them, I thought it better to omit the matter altogether. But afterward I dreamed[49] that I was being cen-

[48] Reading τέγγει with Helmreich for the στέγει of Kühn's text.

[49] For the many occasions on which Galen was influenced by admonitions reaching him in dreams, see Walsh (1934, 7). For Galen's devo-

sured because I was unjust to the most godlike of the instruments and was behaving impiously toward the Creator in leaving unexplained a great work of his providence for animals, and so I felt impelled to take up again what I had omitted and add it to the end of this book.

Now as regards the sensory nerves [*nn. optici*] that descend from the encephalon to the eyes and that Herophilus indeed even calls channels because only in them are the pathways for the pneuma clearly perceptible,[50] this very fact is contrary to expectation, setting them apart from the rest of the nerves, and so likewise is the fact that they grow out from different places, are united [in the optic chiasma] as they pass forward, and then divide and separate again. What was the reason, then, why Nature did not make their outgrowth from above begin at a single place,[51] and why, when she had caused one to grow off from the right side and the other from the left, did she not produce them straight to the region of the eyes instead of first bending them inward, joining them together, uniting their channels, and afterward again producing them each to the eye that is in a straight line with the outgrowth from above? For certainly she did not interchange them, bringing the one from the right side to the left eye and the one from the left side to the right eye; yet the shape of these nerves does greatly resemble the letter Chi (X), and some one whose dissection was not accurate might [II, 94] think, perhaps, that they are interchanged and do cross one another. But this is not the case; for after they have met inside the cranium and their channels have united, they at once draw apart again, showing clearly that there was no other reason for them to approach one another save the joining of their channels.

Well then, since I am under the orders of some divinity, in obedience to him I shall tell what is the use of this arrangement and how great an advantage (χρεία) it offers the instruments of vision. First I shall call on those of my readers who, being properly edu-

---

tion to mathematics, the prevalent aversion to it in his day, and the inability of many supposedly educated persons to use it, see chapter 14 of this Book and *De plac. Hipp. et Plat.*, II, 3 (Kühn, V, 223). In the latter passage Galen mentions the custom of employing professional computers to determine interest on loans or investments.

[50] See note 42 of Book VIII.

[51] Literally, "from the same place."

cated in geometry and other disciplines, know what circles, cones, axes, and other things of the sort are, to wait a little and allow me to explain as briefly as possible what is signified by these terms for the benefit of those far more numerous readers who do not know. For the discussion will not be altogether without profit even for those who know, and if they pay attention, they will learn how clearly one must instruct the ignorant in such matters. And I have determined to join the discussion of vision directly to these definitions so as to accomplish my purpose more quickly.

Let there be a circle (and I call a circle that which is everywhere equidistant from its middle), a circle seen by one of the eyes while the other remains closed; from the mid-point of the circle (which is
[II, 95] also called its center) think of a straight path to the pupil of the eye that is seeing it, a path not bending in any direction or deviating from its straight course; think rather of that straight line as you would of a thin hair or the filament of a cobweb accurately stretched from the pupil to the center of the circle. Again, from the pupil to the line which bounds the circle and is also called its circumference imagine a series of very many other lines extending like thin cobwebs. Call the figure bounded by all these straight lines and by the circle a cone, and think of the pupil as its apex and the circle as its base. Let the straight line that extends from the pupil to the center of the circle and is in the middle of all the other straight lines and of the whole cone be called its axis. Since a piece of ground is called and conceived of as convex or concave, I presume you could doubtless conceive of one midway between the two as level, having nowhere either convexity or concavity. Call the upper limit of such an area a plane surface.

Next imagine this: that on the cone's axis extending through the air from the pupil to the center of the circle there is suspended a
[II, 96] grain of millet or some other small object of the sort. Of course it will obstruct the view of the center of the circle and prevent the pupil from seeing it. If now you have understood this, it will be very easy for you next to comprehend that any body whatever placed between the external object that is being seen and the eye that is seeing it will obstruct the view and prevent the object before the eye from being still perceived, but that when this body is taken away altogether or moved aside, it will come to pass that the object is once

more visible. If you have now understood this also, it is time for you to conclude that whatever is to be seen must be unobscured, with nothing interposed in the straight line that extends from the eye to the object. And if you have now understood this also, you will think those mathematicians not unreasonable who declare that objects seen are seen in straight lines. Then call these straight lines visual rays; call those thin filaments extending from the pupil to the circumference of the circle no longer filaments but visual rays, and say that the circumference of the circle is seen by means of those rays, its center through the other ray placed at the axis of the cone and the whole plane of the circle through the large number of rays arriving at it.[52] Call all those rays equidistant from the axis and lying in the same plane rays of the same order.[53] Now you have at some time, I suppose, seen the rays of the sun escaping through a narrow opening, advancing without being deflected or bending at any point, and pursuing a path that was perfectly straight and undeviating. Consider, please, the path of the visual rays to be like that too. [II, 97]

After you have clearly understood these things, if indeed you do understand them, or if you do not, after you have repeated them at any rate over and over, pass on whenever you have learned them to what I have written next and learn in addition[54] first and foremost that each object seen appears not alone or isolated but always accompanied by something else, because the visual rays surrounding it fall sometimes on objects beyond the body at which one is looking and sometimes on objects near it. Learn as the second fact that a thing seen by the right eye alone appears somehow to lie more to the left side when it is close by, and more to the right side when it is farther off; that if it is seen by the left eye alone, it will appear to lie more to the right when it is nearer and to the left when it is farther away; and that if it is seen by both eyes, it will appear to lie in the space between. In addition to these two things learn thirdly that if

[52] It should be borne in mind that, according to Galen, these visual rays are the paths for the pneuma which issues from the pupil and uses them as it uses the nerves in the body. See note 19 of this Book.

[53] Omitting with Helmreich *ὅσαι δ' ἄλλως ἀνομοιοταγεῖς*, found in Kühn's text.

[54] Reading *προσμανθάνειν* with Helmreich for the *προμάνθανε* of Kühn's text.

the pupil of one of the eyes is pressed at the side or displaced either upward or down, objects hitherto seen to be single appear to be double.

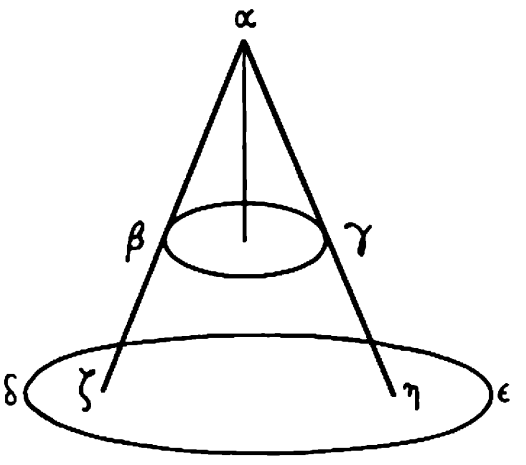


Fig. 1

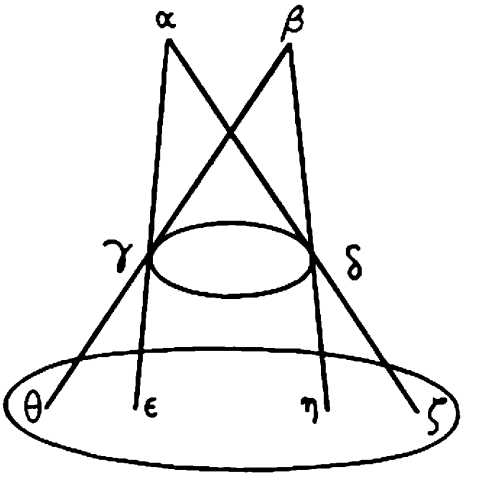


Fig. 2

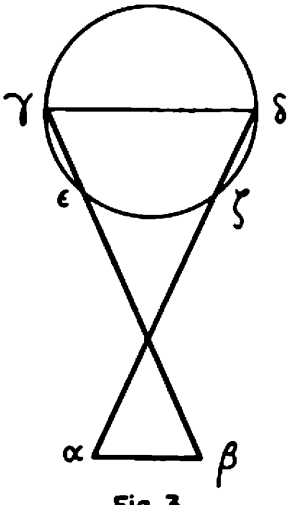


Fig. 3

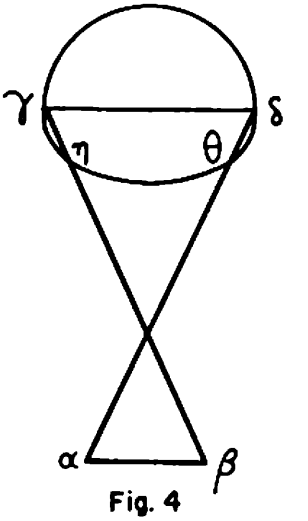


Fig. 4

Galen's optics

[II, 98] Again I hope that the mathematicians who know these very things will allow me for the sake of the many [who do not] to explain briefly each of these statements; and first let us speak[55] of the first one, [which states] that everything at the side of an object is visible.[56] Think of the pupil [as located] at α. Let the magnitude

[55] Reading λέγωμεν with Helmreich for the λέγομεν of Kühn's text.

[56] See figure 1, this page. The excellence of Galen's geometrical analyses here and in chapter 15 of this Book goes far to disprove Simon's contention (in Galen [1906, II, *vii-viii*]) that he was a poor mathematician.

seen be $\beta\gamma$. Let visual rays from the pupil α fall on β and on γ. Let a magnitude $\delta\epsilon$ lie beyond $\beta\gamma$ and let the visual rays $\alpha\beta$ and $\alpha\gamma$ be produced and fall on the magnitude $\delta\epsilon$ at ζ and η. Then it is clear that the magnitude $\beta\gamma$ will be seen over against $\zeta\eta$.[57] Therefore, $\zeta\eta$ will be hidden so as not to be seen at all, but the magnitudes $\delta\zeta$ and $\eta\epsilon$ on either side of it will appear, being seen at the sides of $\beta\gamma$, and in another manner of speaking we shall say that $\beta\gamma$ is seen beside each of them. This is the discussion of the first proposition. Concerning the second, which states that an object is not seen in the same place by one eye as it is by the other, nor in the same place by both eyes together as it is by either one of them but is seen in one place by the right eye, in another by the left, and in still another [II, 99] by both eyes, this is what I must now say: [58] Let the right pupil be at α, the left at β. Let the magnitude seen be $\gamma\delta$ and let visual rays from each pupil fall on γ and on δ, and when they have so fallen, let them be produced. By the right pupil the magnitude $\gamma\delta$ will be seen directly over against the magnitude $\epsilon\zeta$, by the left pupil it will be seen directly over against the magnitude $\eta\theta$, but by both directly over against $\eta\epsilon$. Hence neither pupil will see the object in the place where the other sees it, and both together will not see it where either sees it separately.

If anyone does not follow these demonstrations by means of lines, he will be clearly convinced when he tests the reasoning by trying it on himself. For if he stands near a pillar and then closes each eye in turn, some of the things seen by the right eye on the right side of the pillar will not be visible to the other eye; again, some of the things seen by the left eye on the other, left side of the pillar will not be visible to the right eye; but when he opens both eyes together, he will see both sides. For more parts are concealed from the vision of one eye than are concealed from the vision of both eyes together, and the whole object that is seen appears to lie directly over against the parts which it entirely conceals,[59] so that all that appears beyond [II, 100] it seems to be situated either to the right of it or to the left. Therefore, only what is not seen will lie in a straight line with the object seen. But there are some things seen by the right eye and some by the left, and hence the position of the magnitude seen will

[57] Reading κατὰ with Helmreich for the καὶ οὐ of Kühn's text.

[58] See page 494, figure 2.

[59] Reading ὧν with Helmreich for the ὃ of Kühn's text.

appear to be a property dependent on each of the eyes. Whatever neither eye sees will be entirely invisible [60] to both eyes together, and on this account the object seen by both eyes at once will conceal less than if the eye observing it were alone, whichever eye it is.

Now if you care to stand a little farther away from the pillar and open and close each eye in turn while gazing steadily at it, it will seem to jump suddenly from one place to another; if it is the right eye you close, the pillar jumps to that side, and if it is the left, it jumps to the other side. Moreover, if you open the right eye, the pillar will seem to jump to the left, and if you open the left one, it will seem to jump to the right; for to the right eye it seems to lie farther to the left, and to left eye, farther to the right. If you look with both eyes at once, it seems to occupy a place midway between the places it appears to occupy to each eye used separately. And if you care to look at one of the stars in the same way or at the moon, especially when it is full and equal on all sides, it will seem to jump suddenly to
[II, 101] the right when you open the left eye and close the right, and to the left when you do the opposite. That this is what appears to happen is clear to everyone who has tried it, and I have demonstrated a little earlier by means of the lines what the cause [of the phenomenon] is and why it must needs be produced.

You may also test by trying it yourself the fact that if you turn one of your eyes in a different direction, the object appears low down to that eye if the pupil happens to be moved downward and the opposite if it is moved upward, but without the preceding discussions you cannot learn the cause of these things.[61] For unless the axes of the visual cones are established in one plane, the object absolutely must appear to one eye to be higher and to the other to be lower, since if any cone's axis is more elevated [than that of another cone], the whole cone itself is also more elevated. In a cone extending to objects from the lower eye all the visual rays of the same order are lower, and the opposite is true of the cone extending from the upper eye. Since what is seen by the higher visual rays appears to be higher and what is seen by the lower rays appears to be lower, it is reasonable that an object will appear higher when it is seen by the higher cone and lower when seen by the lower cone. You will have clear proof of what I have said if you care to press one eye at the

[60] Reading *ἀόρατα* with Helmreich for the *ὁρατὰ* of Kühn's text.

[61] Here begins the discussion of the third proposition.

side, then close it and look with the other eye at the object that has falsely been appearing double. For one image of the object's position, the one the eye now closed had when it was open is lost entirely,[62] and the other remains unchanged, preserving its original position. Yet when you have been looking [63] at the object before you with both eyes in their normal state and close one eye, the image of its position immediately changes and the object seems to jump to another place, and when you open the eye again, the image of the position changes once more and never remains in the same place, no matter which eye you open or close. When you move the pupil up or down by pressure at the side, however, one image of the position is lost entirely and the other remains unchanged when you shut the other eye. [II, 102]

Hence not every displacement of the pupil makes the object appear double, but [only] one that moves it higher or lower than it is normally. Those moving it laterally toward the large or small corner of the eye make the object appear to the left or right, but do not double it; for the axes of the cones remain in one plane. Furthermore, when the eyes are distorted either right at the beginning in the embryo or later on, if neither pupil is made higher [than the other] and the eyes are defective only in having one turned toward or away from the nose, the person will not err in his perception of objects. But those in whom one pupil has moved higher or lower will suffer terribly in turning them and making them level in order to see accurately. That an object is indeed seen in its own place is proved when touch, guided by vision, does not go astray and miss the mark. For the rest, both persons with one eye defective and those who see with both eyes easily divide threads with the finest needles,[64] and this could never be done without accurate perception of objects. But since, as I have said, every object is seen beside something else, it is now reasonable that when compared with things in its vicinity the object will appear to lie sometimes on the right, sometimes on the left, and sometimes in a straight line, and thus these statements do [II, 103]

[62] Both Helmreich's and Kühn's texts read ἀποτελεῖται with nothing to indicate variant readings in the manuscripts. I suggest that since "is produced entirely" makes no sense, ἀποτελεῖται should be emended to ἀπόλλυται, as in the similar sentence a few lines farther on.

[63] Accepting Helmreich's emendation, ἰωρᾶτο, for the ἐν ἑώρα of Kühn's text and the manuscripts.

[64] Or perhaps, "thread the finest needles."

not disagree. There are countless other proofs of optical propositions, of which it is not possible to speak here. For indeed, as I have said, I have not written these things of my own accord, but at the bidding of a divinity, and whether I have in these discussions attained a goal in keeping with the present work, he himself may be the judge.

13. Let me now put the capstone on this discussion by reminding you that the axes of the visual cones must be situated in one and the same plane if single objects are not to appear double. These axes of ours have as their beginning the channels from the encephalon.
[II, 104] Hence the channels had to be established on one certain plane surface while the animal was still an embryo being formed in the uterus. Then what would this plane, horizontal surface be, on which Nature laid down the channels while she was forming animals? Would it be some hard membrane, a tunic, a cartilage, or a bone? For a soft instrument that yields to whatever touches it would not remain firm and unbending. Also, where would she then establish it and how would she spread it safe and undistorted beneath both the channels? For all who busy themselves with dissection know very well that these things are not easy of accomplishment in that region. I do not say this now because Nature would not have found some clever device so to generate and locate the plane that it would neither injure other things in the vicinity nor be injured itself, if it had been absolutely necessary to create it and if the two channels could not have been provided with a position in one plane very easily and conveniently in another way.

What, then, is this very easy and convenient way, which it has from the very beginning been my intention to explain? It is the bringing together of the channels [in the optic chiasma]. For if two straight lines meet at a certain, common point as their apex, they are evidently in one plane, even if they happen to be produced from that point an infinite distance in different direcions. And [other] straight lines that join at any point these two straight lines when they have been produced indefinitely lie in the same plane with the two, because every triangle lies entirely in one plane. Now if there is
[II, 105] anyone who does not understand what I have said, he clearly does not know even the elements of geometry. It would be a long task if I were to write demonstrations of such things, and indeed a person would not understand these either unless he had studied a great deal

beforehand. In the eleventh book of his *Elements*, Euclid[65] has certainly demonstrated the very thing of which I have just been speaking; it is the second theorem in that book and the proposition is stated as follows: "If two straight lines intersect one another, they are in one plane, and every triangle is in one plane." You must, then, learn the demonstration from Euclid and when you have learned it, come back to me and I will show you in an animal these two straight lines, the channels from the encephalon. Again, each of them [arriving] at the eye on its own side curves round it, as I have said before, circularly like a net [the retina] as far as the crystalline humor [the lens] and surrounds and holds within it the vitreous humor, so that the pupil lies in a straight line with the whole root of the eye where the nerve begins to be resolved. And thirdly, in addition to these things, [I will show you] the meeting of the optic nerves in the anterior part of the encephalon, from which they begin to pass forward in one plane to generate the eyes as a whole in their proper position and to bring it about that neither pupil of the eye is higher [than the other]. This is the reason why it was better that the nerves providing the eyes with the sensation of sight should start from a single source.

14. Next I must tell why Nature did not make for them both a single source above, directly from the encephalon itself, and why [II, 106] instead she caused one to grow off from the right side of it and the other from the left, brought them thus together, and fused them in a central space. From this region it was impossible to form an outgrowth—I will not say of such large nerves as both these are, but even of much smaller ones; for the pelvis [the infundibulum], which has been explained in the preceding book and which contains the canal cleansing the encephalon, is located here, and it could not be better placed anywhere else, since it has to discharge into the palate all the residues. By the same reasoning the channels extending from the encephalon to the nose[66] could not be placed elsewhere nor could they begin to grow out from any other part of the encephalon; for since the nose is in the middle of the face, of course the channels leading to it had to occupy the middle of the anterior region of the encephalon. If, then, it was better not to place elsewhere these channels or the pelvis either, and if it was impossible

[65] 1952, *303*.

[66] See note 44 of Book VIII.

while these were where they actually are for the [optic] nerves to grow out from the middle region, the rest is now clear, namely, that it was better for the nerves to grow off one from each side, pass forward a little, and arrive at the same point. But in regard to the outgrowth of these nerves you will learn another, more marvelous
[II, 107] work of Nature, which I think it better to explain in the sixteenth book when I am describing the anatomy of the nerves.[67] I have surely fufilled the command of the divinity, and not in vain, as I think;[68] on the contrary, the discussion will have some usefulness whenever men actually lay aside the indifference to the most beautiful things that holds them fast.

Now perhaps I may as well tell what the older [anatomists] have said about the union of the [optic] nerves. Some of them say that it is in order to avoid the injury which these nerves would suffer if they were straight that they have been turned first inward and then out again; others say that it is in order that they may share their affections with one another and divide between both of them an evil afflicting one; and there are those who say that the sources of all sensations must be attached above to a single source.

If these last had said only that sight must be attached above to a single source and had showed how great would be the harm if this had not been done, it is clear that they would then be speaking the truth and that the preceding argument would not be my own discovery. As it is, however, when they say that the principal perceptive part receiving all the sensations must be one (and they are right to say this) but then believe that it is for this reason that these soft nerves come together, there they surely make a very great mistake. For the part receiving all the sensations is of course the encephalon, since if it is not, the nerves of the ears, the tongue, and all the other parts of the animal as well will evidently not be brought up to one source.

[II, 108] Similarly, those who believe that the nerves come together in order to share their affections say this in contradiction of the providence of Nature, whose contrivances have the opposite aim, as I have already pointed out on many occasions; for it is better if possible for one part not to suffer along with another. If, however, this argument seems reasonable to anyone, he may use it, just as for

[67] See chapter 3 of Book XVI.

[68] Accepting Helmreich's interpolation of οἶμαι.

that matter the one may also be used that says the nerves would be easily broken if they extended in a straight line, but this does not please me either. For the nerves [*nn. vagi*] that arrive at the stomach would really often be broken off, borne down by its weight, if they were not first twined around the esophagus, but the channels that reach the eyes would suffer nothing of the sort, since no such weight is added to the eyes as there is to the stomach when it is filled with food and drink, and since their position does not change and they are not separated very far from their source. Even if one of these conditions did exist, the muscles that surround the nerves and even more than these the outgrowth of the thick membrane [the dura mater], which is never so thick and hard over any other nerve, would nevertheless suffice to protect them. And before they issue from the cranium, the nerves would not suffer harm any more than the encephalon itself would, though it is in constant motion to and fro, or any more than the outgrowths to the nostrils would, though they are very thin, soft, and long.

These arguments, as I have said, anyone who wishes to may use, but I for my part, having no confidence at all in them and being [II, 109] persuaded that Nature does nothing in vain, have long sought the reason for such a position of the nerves and I think I have found it, all the more because a god has considered it worthy of being written down. For before I received his order (a person calling the gods themselves to witness must speak the truth), I did not intend to discuss this, not wishing to be hated by the many who would choose to suffer any ill you please rather than to have anything to do with geometry. I had decided to mention the three arguments of which I have told you, to commend as most plausible the one stating that the channels were made oblique to avoid rupture, and myself to add this truth, that it was better if ever one eye was closed or totally incapacitated for the pneuma coming from the encephalon to both eyes to go wholly into the remaining one. And indeed, its visual faculty being thus doubled, it would see better. Moreover, this obviously does happen; for if you care to place longitudinally on your nose between your eyes a small piece of wood, your own hand, or anything else that can prevent external objects lying before them from being seen by both eyes, you will see dimly with each eye, but much more clearly if you close one eye, as if the faculty hitherto divided between the two were now coming to the other eye. I was [II, 110]

going to tell only this one use for the joining of the channels, since this too is a true use, but just as I have already shown times without number that Nature does some things for a principal reason and others out of her abundance, so here too the first and most necessary use is to keep us from seeing external objects double, and the one I have just been telling is secondary.

A god, as I have said, commanded me to tell the first use also, and he himself knows that I have shrunk from its obscurity. He knows too that not only here but also in many other places in these commentaries, if it depended on me, I would omit demonstrations requiring astronomy, geometry, music, or any other logical discipline, lest my books should be held in utter detestation by physicians. For truly on countless occasions throughout my life I have had this experience: persons for a time talk pleasantly with me because of my work among the sick, in which they think me very well trained, but when they learn later on that I am also trained in mathematics, they avoid me for the most part and are no longer at all glad to be with me. Accordingly, I am always wary of touching on such subjects, and in this case it is only in obedience to the command of a divinity, as I have said, that I have used the theorems of geometry.

15. Perhaps someone will interrupt me to ask how, if I have
[II, 111] intentionally omitted many things, this can be a complete treatise not omitting the usefulness of any part and for some of them telling not just a single usefulness but several. There is a prompt answer to this and one too that draws support from what the objector has put forward. Since our Creator is so skillful that each part he has made has not only one usefulness but two or three, or frequently four, it is thus very easy to omit for the ordinary man some of those that are less obvious. For example, earlier in this book I wrote of a certain usefulness for the shape of the crystalline lens, but in that place I omitted the principal, most important usefulness, because lines were necessary to demonstrate it. So let it be told now; for when once I have been compelled to say something about optical principles, any [further] discussion of the sort should no longer be obscure.

Since the objects of vision are seen in straight lines and since the aperture [the pupil] in the grapelike tunic [the iris] through which the crystalline humor must communicate with the object to be perceived lies in front of it, it is now quite clear, at least to anyone

remembering what has been said before, that a perfect sphere will have fewer points communicating with the objects to be perceived, and a flat surface will have more. If you still do not understand, however, I will explain this too with lines.[69] Let the diameter of the perfectly circular pupil be $\alpha\beta$, the diameter of the crystalline humor be $\gamma\delta$, and the part of it facing the pupil be $\gamma\epsilon\zeta\delta$. Let $\beta\epsilon$ and $\alpha\zeta$ be [II, 112] drawn from the pupil to touch the crystalline humor. It is then clear that the part of it $\epsilon\zeta$ will have communication with the objects to be perceived, and that the parts $\gamma\epsilon$ and $\delta\zeta$ on either side will not come into communication at any point with anything visible. But certainly if the crystalline humor were less convex, a greater part of it would be in such communication, because the straight lines touching a body will embrace a smaller part of it if it is very convex and a larger part if it has been flattened.[70] Let the part of the flattened crystalline humor turned toward the pupil be $\gamma\delta\eta\theta$ [71] and again let there be drawn from the extremities of the pupil the lines $\beta\eta$ and $\alpha\theta$ to touch it. Then $\eta\theta$ will be the part of it to be associated with the objects to be perceived, and the part which is cut off on each side of the lines touching it and which is without communication is very small. Now if the crystalline humor were a perfect plane, the whole of it would thus be in communication, but as it is, since I have shown that it must be rounded in order to be resistant to injury, this too is a marvelous work of Nature's, to have made it round and at the same time capable of communicating over most of [II, 113] its parts with the objects to be perceived. This is the way in which matters pertaining to the eyes are arranged. I shall explain next all the other parts of the whole face.

[69] See page 494, figure 3.
[70] See page 494, figure 4.
[71] We should prefer the order $\gamma\delta\theta\eta$ or $\gamma\eta\theta\delta$.

THE ELEVENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Face]

1. All the remaining parts of the head that still need to be explained will be discussed in this book. There are left, so it seems, nearly the whole face and several upper parts, such as the muscles called temporal and the external outgrowth [1] of the ears. Now I have spoken earlier of the inner base itself of the ears, where perception of the sound first takes place, and I have also spoken of the temporal muscles, to the extent at least of saying that one on each side is inserted into the elongate coronoid process of the lower jaw, and that because its usefulness is so necessary, each muscle has several sources for its nerves, in order that if anything should ever happen to one or two of the sources, the remaining one at any rate might [still] provide the lower jaw with motion.

2. It is now the proper time to tell why Nature has concealed these muscles almost wholly within the bones of the head, carving
[II, 114] very deeply into those over which they pass and raising very high those that surround them, whereas she simply places other muscles upon the bones like a covering of felt.

Similarly [I must tell] why she has created the mass of nearly all the other muscles to correspond to the size of the animal and has failed to do so only in the case of the temporal muscles; for in their large or small size these are very much out of proportion to the body as a whole in the various kinds of animals. For example, in man they are very small and not at all sinewy, but in the lion, wolf, dog, and, in general, all animals called saw-toothed,[2] they are very large

[1] Reading ἔκφυσις with Helmreich for the φύσις of Kühn's text.

[2] The carnivora; see note 8 of Book VIII. Presently they will also be called cleft-footed, an Aristotelian term. See *De part. an.*, I, 3, 643b30–644a11.

and very sinewy. As regards other animals, they are very large in the pig and ass, but certainly not equally sinewy; next in order is the beef and then comes the horse. In the ape, lynx,[8] and long-tailed monkey they are weak and small, as in man, and after these come the goat, sheep, and deer. Of the apes themselves, those most resembling man have their temporal muscles most like [those in man]. In apes that begin to resemble the form of the dog-headed ape, these muscles are larger and more robust, just as they are in the dog-headed ape itself; for this animal has a nature half way between those of an ape and a dog, so that the temporal muscles in it are as much larger and more robust than those in the ape, as they are smaller and weaker than those in the dog. The ape that most resembles man is the one that has a very round face, small canine teeth, a flat sternum, and [II, 115] longer clavicles, and that has the least hair and stands well erect so that it can walk properly and run swiftly. In this ape, therefore, as in man, the temporal muscle occupies a small portion of the hairy part of the head, whereas in others, as in the dog-headed ape, it stretches very far up the head. In all saw-toothed animals it passes beyond the ears, extending to the rear along the entire head, and so in these animals the temporal muscle is not only very large, as due proportion to the size of the body requires, but also more robust. In the ass, beef, and pig, and generally speaking, in animals with a large jaw, it is only very large, being in proportion to the size of the jaw, but it is by no means robust, as it is in brave animals.

In fact, Nature makes the temporal muscles large for the sake of these two things, the strong action of the lower jaw in biting, and the size of it; for, being made for the sake of the jaw, they are properly in accord with both its action and construction. Since, then, the strength of saw-toothed animals lies in their bite, in them the muscle has been made both very large and very robust; in the ass, beef, pig, however, and any other animal which has a large lower jaw but does not defend itself by biting, it is only very large, but certainly not sinewy, tense, or vigorous in its action; for of course it was better for [II, 116] a large jaw to be moved by a large muscle. In man, on the other hand,

[8] This cannot be the common, carnivorous lynx. In *De anat. admin.*, IV, 3 (Kühn, II, *430;* Galen [1956, *97*]), and XI (Galen [1906, II, *66;* 1962, *72*]), it is mentioned again along with the ape as belonging in the group of animals resembling man most closely. Duckworth or his editors, Lyons and Tower, suggest that it may be a variety of cynocephalous ape.

who has a small jaw and teeth suited only for eating, the temporal muscle has properly been made small; for excessive size was unnecessary in a muscle that was not meant to carry a large jaw or perform the vigorous actions of lions and dogs. Indeed, man's courage does not stem from his ability to bite, and he surpasses other animals not in this respect, but, as I showed in the beginning, because of his reason and his hands. Wherefore, one should admire the skill of Nature (as Hippocrates [4] does when in admiration he calls her always just) because she chooses what is adequate not according to ordinary [5] appearance, but in respect to faculty and usefulness, and this, I think, is a work of divine justice to find out what is needful, to distribute to each animal what is in accordance with its worth, and, of those things that are fitting, to make none that is superfluous and none deficient. It would be superfluous, I think, if the temporal muscle was made large when it must move a small jaw, and deficient if it was not made large when it moves a large one. But no animal has a jaw [comparatively] smaller than man's or larger than that of the ass or horse. Necessarily, then, the muscles moving the jaw are smallest in man and largest in those animals.

Why the lower jaw was made largest of all in the pig, ass, beef, and horse, smallest in man, the ape, long-tailed monkey, and lynx, and intermediate in size in other animals I have told earlier, when I
[II, 117] was demonstrating that animals having hands, like man, or hands of a sort, like the ape, do not need to take their food with their mouths, stooping, whereas those that do not have hands, like the horse, have a larger neck and for the same reason a longer jaw. [I said also] that this is the reason why in long-legged birds the neck grows long and the beak is elongated, because they must use these parts in place of hands to secure their food easily. But since in the classes of animals Nature has been wont to withdraw from extremes gradually, as Aristotle [6] also points out correctly, first after man there is the ape, which has a somewhat longer jaw; for I have already shown many times before that the ape is a laughable imitation of man. Then come the second and third classes, and thereafter all the others in proper order, so that with good reason the animals that are intermediate between those having hands and those that have no hands at all, like

[4] *De fracturis*, cap. 1 (Littré, III, *412–415*).
[5] Reading πρόχειρον with Helmreich for the πρωτέραν of Kühn's text.
[6] *Hist. an.*, VIII, 1, 588b4–23; cf. *De part. an.*, IV, 5, 681a9–15.

the ones called saw-toothed and cleft-footed, are also midway between the extremes in respect to the length of the instruments of the neck and jaws; for when these [the carnivora] eat, they use their feet somewhat like hands. For these reasons man has the smallest temporal muscle of all the animals, because in him the jaw moved by this muscle is the smallest and also has a weak action.

3. Now why is this muscle the only one buried in the bones of the head, some of which receive it, while others embrace it circularly, so that [only] a small part of it projects at the end of the forehead? Or [II, 118] is this true not only of this muscle, but also of the muscles of the eyes, and is there a common reason for this? [7] Of all the muscles, these in particular, when something is the matter with them, bring on spasams, fevers, torpor, and delirium, and so Nature has surrounded both [8] of them with circles of hard bone as a rampart to prevent their being injured by things striking against them that would crush or cut them. And why do these in particular cause trouble when there is something the matter with them? The reason is that they are very near the source of the nerves, and only a single bone keeps them from touching the encephalon itself. Indeed, the temporal muscles can do more damage to the encephalon than the muscles of the eyes, both because they are larger and because a single source of nerves [9] is implanted into the eye muscles and several sources [*n. temporalis profundus* from the mandibular division of the trigeminal nerve, *temporalis superficialis* also from the mandibular, *rami temporales* of the facial nerve] into the temporal muscles. Now if, as Hippocrates [10] said, parts that are near [to affected parts], that are closely associated with them, and that are primary are the ones to suffer most, and if there is no muscle nearer the encephalon than the temporal muscles or more closely associated with it through more nerves, it is reasonable that the source feels their affections as quickly as is possible. Hence it is for this reason that Hippocrates [11] was right

[7] Reading *οἱ τῶν ὀφθαλμῶν, καὶ ἡ χρεία* with Helmreich for the *ἢ τῶν ὀφθαλμῶν χρεία* of Kühn's text.

[8] That is, both sets of them, the temporal muscles and the muscles of the orbits.

[9] But Galen has previously said that the nerve supplying the muscles of the eye is multiple. See note 31 of Book IX.

[10] *De humoribus*, cap. 4 (Littré, V, *482*, *483*); cf. *De articulis*, cap. 53 (Littré, IV, *236*, *237*).

[11] *De articulis*, cap. 30 (Littré, IV, *142*, *143*).

when he said that blows on the temple are serious and cause stupor.

Even before Hippocrates, Nature recognized that she would be doing animals a very great wrong if she neglected the safety of the temporal muscles. She therefore created as secure a place as she
[II, 119] possibly could, principally by constructing a hollow [the temporal fossa] like a cave to receive them, making the surfaces of the bones lying on the inner side of them concave like a receptacle and adding to the upper extremities of the bones ridges [the temporal lines] turned back toward the muscles in order that the latter may be protected on all sides as much as possible and [only] a very small part of them may project above the enclosing wall of the bones. She did not leave even this part entirely without covering, but from the upper bone of the head [*os temporale*] and the one at the extremities of the brows [*os zygomaticum*] she made to put around it on each side a long, bony outgrowth [the zygomatic process of the temporal and temporal process of the zygomatic bones], convex on the outside but concave where it faces the muscle. Moreover, the bone coming from the upper parts she brought downward toward the brows, and the one coming from the lower part she stretched far enough upward, and then she joined these together in the middle, thus establishing a sort of bony vault [the zygomatic arch] in front of each muscle in order that this might be the first to be wounded, crushed, or suffer in various ways if anything hard from without should strike violently against the muscles. Indeed, this arch (for that is what anatomists call it) is not just ordinary bone but has no marrow and is dense and hard as rock; for Nature has contrived to establish in front of these muscles a rampart as insensitive as possible.

4. Such is the provision for the safety of the temporal muscles. Each one, ending in a single large tendon, is inserted on the coronoid
[II, 120] process of the lower jaw, which it draws upward when it is tensed, and in so doing it closes the animal's mouth. Accordingly, there must be some muscles pulling in the opposite direction to open the mouth, and these must be placed in the parts below the jaw, if, that is, I was correct in my demonstration that every muscle draws toward itself the part into which it is inserted. Then what are these muscles, how many are there, where do they grow out, and what is their source of movement? There are two of them [*digastrici*], just as there are two of the temporal muscles, and each is placed on one side of the lower jaw in opposition to one of the temporal muscles. They

take their rise from the posterior parts of the head [from the mastoid notch of the temporal bone] where the styloid processes are; for that is what anatomists are wont to call the slender offshoots of the cranial bones in this region. If you wish, you may call them graphoid (styloid) or belonoid (needle-shaped). The muscles are inserted into the lower jaw beyond its bend [the angle], one on each side being produced along its inner part straight to the region of the chin, and if they are tensed, they open the mouth, just as the temporal muscles close it.

Certain others have been made by Nature for the rotary motion of the jaw in chewing, and these are the two muscles [*masseteres*] which also form the fleshy portion of the cheeks. Some think that these are not one muscle on each side, but three, because they have as their sources three aponeuroses, tendons, or insertions into the jaws. For some speak of them in one way and others in the other, each group striving to explain clearly the form of these muscles, which differs from that of all others; but they give the impression [II, 121] that they disagree about the muscles themselves, when one says that each muscle has three sources, and another that each has three extremities, or heads, or aponeuroses, or tendons, or insertions. In this instance, however, the controversy among the anatomists is not over the facts, but over the way of presenting them. For each muscle is a sort of triangle, having its apex, as it were, at the so-called cheekbone.[12] Thence one side of the triangle extends to the end of the zygomatic arch, and another to the lower jaw. The remaining, third side, like a base joining both these sides to all the first [13] parts of the lower jaw, extends along the length of it. This muscle is most sinewy in the region below the cheekbone where its apex, so to speak, is situated. It moves and rotates the jaw, acting sometimes with some of its fibres and insertions and sometimes with others; for Nature cleverly managed this too,[14] in order that as the motions succeed one another, the complex action of chewing may be pro-

[12] The "cheekbone" seems here to be the zygomatic process of the maxilla.

[13] That is, to the posterior parts; reading *πρώτοις* with Helmreich for the *εἰρημένοις* of Kühn's text.

[14] Reading *ἄλλοτ' ἄλλαις τῶν ἰνῶν τε καὶ καταφύσεων ἐνεργῶν, εὐμηχάνως καὶ τοῦτο τῆς φύσεως ἐργασαμένης* with Helmreich for the *ἄλλο τ' ἄλλων τῶν ἰνῶν τε καὶ καταφύσεως ἐργασαμένης ἀπὸ τῆς φύσεως* of Kühn's text.

duced. Properly, then, they call these muscles masseters (chewers), even though the temporal muscles also have the greatest possible claim to this appellation. For the latter perform only this one work in chew-
[II, 122] ing, namely, to bring the teeth vigorously together, and then it follows that if there is anything between them, it is broken up, but to triturate the nutriment with the molar millstones, so to speak, is the work of the masseteric muscles. These are the ones, too, that move the food about and that, as they are tensed and contract, bring what has escaped the teeth back upon them again; for the temporal muscles contribute nothing further [15] to this. Now the tongue plays no small part in this action, moving the nutriment about like a hand and turning it in the mouth so that every part of it may be equally broken up, and on the outside this masseteric muscle, one on each side, has been prepared as a second hand to help the tongue. The greatest assistance it receives in this action, however, is rendered by the lower extremities of the cheeks, the skinlike portions near the lips, to which extend the thin, broad muscles that, one [*platysma*] on each side, enclose the whole neck. For the cheeks and the lips too are moved by these, even though the jaw is not being moved at all, and somehow all the muscles that do move it have each a character peculiar to it which no other muscle possesses. I have finished my discussion of the masseteric muscles.

5. The temporal muscles and those [*digastrici*] below that are set opposite them and open the mouth differ in still another way from all the other muscles. From the middle of the temporal muscle a
[II, 123] tendon grows out which I have said is inserted into the coronoid process of the lower jaw as it extends upward, and in no other muscle, indeed, would you find a tendon growing out in such a way. Moreover, when each of the opposing muscles [*diagastrici*] that grow out from the posterior parts of the head reaches the part called a tonsil and the bend [the angle] of the lower jaw, it is no longer a muscle, but becomes a perfect tendon, bare of all fleshy substance. Of course, it is characteristic of other muscles also to end in tendons, but I will tell you of a special feature that is peculiar to this one, not

[15] The ἔτι of Helmreich's text is omitted by Kühn. The reader has probably noted the omission of the buccinators from this description. The only reason that comes to mind is the highly specialized form of these muscles in the ape, where they form the buccal pouch, a feature obviously not found in man.

being found in any of the others. When each of these tendons has proceeded a little farther, it is no longer a tendon, but becomes muscular again and is inserted into the lower jaw, as I said before. Hence it is clear that the fleshy parts of these muscles are at their beginnings and ends and the sinewy parts are in the middle, a condition not found in a single one of the others, just as one does not find a tendon growing out from the middle of any muscle other than the temporal.

What, then, is the cause of these things? For Nature does nothing without a reason. You must be reminded of some things I have said earlier, and you must in addition now learn others; you must be reminded of what I have said[16] of muscles in general, as to why some end in tendons and some do not; and you must now learn in addition whatever is necessary for you to hear about these [particular muscles]. Now the reason why each temporal muscle, ending in a single large tendon, must be inserted by it into the coronoid process of the jaw, which extends upward and is slender, [II, 124] hard by nature, and elongate, you can easily discover for yourself without my help, if you have not listened altogether idly to those discussions of mine. Nevertheless, I shall remind you briefly that if the jaw were not raised by such large tendons, in the first place it would be broken off times without number, because such a heavy weight had been suspended by weak bodies. Then too, it would not be moved at all easily; for neither a smaller tendon nor a fleshy substance would be able draw it up. I shall tell also the reason why this tendon grows out from the middle of the muscle, after I have given you here too a little reminder of what I have already demonstrated at the beginning of this book.

The main point of this was that the temporal muscles, needing a high degree of safety, are rimmed all around with bones, so that only a small part of them projects above the concavity. If you remember this and are familiar with the parts of the head, you are now in a position to conclude that if Nature had placed these muscles so as to pass for a long distance longitudinally along the head directly to the coronoid processes, she would not have found any protection to be contrived for them, and besides, she would have made an extraordinary mass in that region and left empty and completely collapsed the

[16] In *De motu musculorum*, I, 3, (Kühn, IV, *377–382*).

places where they now are. For she could not put any other part
[II, 125] there very conveniently, not the eyes, certainly, nor the nose, nor the ears, and I have told earlier the reason for the location of these parts. What arch, such as the one they now have she would have placed before them if she had extended them lengthwise of the head, and what bony brows she would have raised up it is impossible to say. If, then a longitudinal location for the muscles would make them prominent and deprive them of protection, if it would produce unjustifiable eminences and concavities in the whole head, and if on the other hand placing them where they now are would result in safety for the muscles themselves and a regular shape for the whole head, it would not be more convenient to place them elsewhere. Then if this is so, it is clear that the middle of them came to lie in a straight line with the coronoid process that was to be moved, so that the tendon had to grow out from that place.

The arrangement of the muscles [*digastrici*] that are opposed to these and have their tendons in their central portions displays a far greater skill. We should pay particular attention to situations in which we see that a part is contrary to what we expect, not perfectly normal, and unlike others of its kind. For in its case either Nature has forgotten analogy, or, having devised something very clever, she has exchanged its common characteristics for other things. Certainly, I think I have shown throughout this work that she nowhere departs very far from analogy without good reason, but has instead either made a part different from others for some special usefulness, or abandoned the original, most important con-
[II, 126] struction and had recourse to another, secondary one from great necessity, as, indeed, she has done in the case of these muscles.

Now the appropriate place for them to grow out was not from the rear, as they actually do, but from the anterior parts of the neck; for so each would best draw down the jaw in a straight line with its own source. But if they had been placed there, it is clear that in growing out from the cervical vertebrae they would first and most particularly be very much cramped for space themselves, and they would also narrow the space available for the other parts located in this region. For there is practically no other place in the body where one can see so many instruments in such a small space and there was not one of them that would have been better placed elsewhere, neither the esophagus, rough artery [the trachea], and larynx, nor

still less by far the muscles surrounding them and the veins, arteries, glands, and nerves. Some of these had to pass up from below and others down from above, since if they did not, the head would not have its share of arteries and veins, or the lower parts their share of nerves and muscles. It is clear that the food, drink, and pneuma must follow this route too and that expired air and the voice must come back up again, [furnishing many advantages for animals].[17] Moreover, it is also perfectly clear to everyone, I suppose, that the arteries and veins must necessarily be divided here and distributed to both jaws, the tongue, the mouth, the posterior and anterior parts of the head, and all the parts of the neck, together with the spinal medulla included in it. It was no less necessary than these things I have [II, 127] mentioned for glands to lie upon the branchings of the vessels so that these may not be unsupported and suffer harm. Futhermore, for the sake of the rough artery itself Nature has created in this region certain other glands [salivary, thyroid, thymus] of which I have spoken earlier.

Hence such a large number of instruments, which cannot be transferred to any other place without the greatest damage to the animal, has already completely occupied this region that there was good reason for the muscles opening the lower jaw to grow out not from the bones of the neck, but from the place of which I have told you, and for each of them to be thinned down into a tendon bare of flesh in the place most filled with many instruments in the neighborhood of the tonsils. If they were thicker, they could not pass through for want of room, and if they were made thinner than they actually are, they would be very weak muscles.[18] Therefore, since they had to be made both resistant to injury and narrow, Nature properly removed all their flesh in this region, and, bringing forward only the bare tendons, as soon as she got them beyond the narrow place, she caused flesh gradually to form around them and made them muscles again.

And so Nature has created these three kinds of muscles to move the mouth, those that open it [*digastrici*], those that close it [*temporales*], and those that give it various motions of rotation [*masseteres*], and [II, 128]

[17] *εἰς πολλὰ τῶν ζώων χρησιμῶς* is bracketed by Helmreich.

[18] Reading *ἰσχνότεροι δ' ἦσαν οἷον νῦν εἰσι γενόμενοι μῦες* with Helmreich for the *ἰσχνοὶ δ' εἶσαν, ὥσπερ καὶ νῦν εἰσι, γενόμενοι μῦες ἔτ' ἦσαν* of Kühn's text.

in neither their positions, nor forms, nor the convenience of their insertions has she overlooked anything. For each one is obviously inserted into the particular part of the jaw which is most easily laid hold on and is best suited to the motion for the sake of which the muscle was formed.

6. If you care to observe the difference in the size of the muscles and the source of the nerves moving them, you will discover here too the wonderful justice of Nature, that is, if it is reasonable that those muscles that raise and support the whole jaw hanging suspended, as it were, from them should be made the largest in the series, the ones set opposite these that move it downward in the direction in which its whole weight also naturally inclines it should be by far the smallest, and that the others should be intermediate in size between the two, just as they also hold an intermediate position. Two other muscles [*pterygoidei interni*], situated on the inner sides of the lower jaw where it is most concave, and extending to the bone of the head, have been granted to the temporal muscles as assistants, and these too are capable of drawing up the jaw. And the assistance from the inner muscles [has been granted to the temporal muscles] for the same reason that several sources have been made for the nerves moving them.

7. The third pair of nerves [*nn. trigemini*] from the encephalon is the source of the nerves for all the muscles of the face and, more-
[II, 129] over, for nearly all the other parts of it as well. For these nerves have been distributed to the temporal and masseteric muscles, to those inner muscles [*pterygoidei interni*] in the mouth itself, to all the teeth, to the lips and nose, and to all the skin of the face, the bones being pierced for them and offering a passage in whatever direction each of the offshoots starts to lead. They lead always to a part needing either sensation or motion, and they do so in such a way that each part's share of nerves is neither too little nor too great, but always exactly right in view of the mass and usefulness of the part.

Now I suppose that if all such things had been done without regard to skill, such hard bone would most probably not have to be pierced at all with many thickly studded perforations, and even if there were a perforation, this would necessarily be found to have been made at random,[19] with no instrument passing out through it.

[19] Helmreich omits *μάταιον* found here in Kühn's text.

Necessarily, moreover, no nerve at all would go to certain inner parts of the mouth and external parts of the face, whereas to others not one but several nerves would be distributed; for such are the works of chance. But I do not see how intelligent men can attribute to the working of chance the fact that nerves are sent to all parts and that the size of each is as great as the part needs, since if this were so, what would be left to be made with forethought and skill? For it would be altogether contrary to what [20] is done by chance. Hence in the first place every nerve would have to pass either inside through [II, 130] the mouth or outside of the bone of the face where obviously in the former case it would be injured by hard foods and in the latter by outer objects striking against it. In the second place, necessarily the roots of some of the teeth would have nerves and others would not; the roots of the molars, because they are large, would have small nerves, and the roots of the other teeth, because they are small would have large ones; part of the masseteric muscle would be made without its share of nerves (for what necessity is there for all its fibers to be moved?); and some of the skin would have insertions of nerves and some would not (for again all the skin would not have to be made sensitive). Obviously, all such things as these we shall call works of skill and wisdom, that is, if their opposites are works of chance, and the proverb [21] about rivers running up hill will now come true, if we are to think that disorderly, unreasonable, unjust things are works of skill and the opposite are works of chance. Now I care nothing about names, and if you wish to give the name of chance to that which forms all the parts of animals so justly and to understand and agree on this one thing, that you are using [22] pure invention in these names, you can, when you see the sun above the earth, call such a state of affairs night and the sun itself not light but darkness, if this pleases you. You need never desist from such cleverness, just as we need never cease being so stupid that when we find the parts all justly endowed with a construction proper for them, we declare the cause to be not chance but skill.

[20] Reading *τῷ* with Helmreich for the *τὸ* of Kühn's text.

[21] A very common Greek proverb, found in the works of Zenobius, Diogenianus, Gregorius Cyprius, and others. See Leutsch and Schneidewin (1958, I, *47*, *185*, *219* n.; II, *96*, *747*).

[22] Reading [*δικαίως*] *ἐμπέπλασαι* with Helmreich for the *οὐ δικαίως ἐμπέπλασο* of Kühn's text.

[II, 131] Oh, by the gods! (for it is the part of the gods to pity madness) [23] why is it that when the bones are pierced, offshoots from the superior nerves are inserted into all parts of the face, but none of these nerves goes off to be inserted into the parts [*digastrici*] that open the mouth, although they are near at hand? But neither does any branch from these nerves [for *digastrici*] ascend to the temporal muscles nor any branch from the latter's nerves descend to these muscles. And why has the skin been completely divided to form the mouth? For it is now time for me to pass on to this subject. How is it that we do not find the cleft in the back or in the head or some other part of the body? For these would be the works of chance. If it was heat not to be confined or pneuma that broke open the skin of the mouth (for such is the nonsense they talk),[24] how is it that this did not happen at the crown of the head, that the break-through and the expiration did not occur at this point, seeing that both heat and pneuma naturally rush upward? Then, too, if our bodies were created by the rebounding and interweaving of atoms, how is it that they did not rather break through the head or another part of the body so as to form the mouth there? And if the mouth was broken through by chance, how did it forthwith contain the teeth and tongue? Or how did the channels of the nose open directly into the same place, or the channels at the palate that cleanse the encephalon? For teeth do not necessarily grow under parts of the body where
[II, 132] clefts have been made; indeed at the anus and the pudendum, particularly of women, there are clefts no less [than at the mouth], but there is not a tooth in them and no underlying bone at all, however small.

8. Will you have it that these things too have happened by good fortune through the agency of atoms? Why do we have thirty-two teeth in all, sixteen placed in a single row on each jaw? Those in

[23] Or perhaps, "for the madness of these people is pitiable."

[24] This particular doctrine, I suspect, stems from Asclepiades, who in turn may have been influenced by Epicurus' idea (1926, *39*) that the soul consists of fine particles like pneuma with a mixture of heat. There is also the description of generation in the Hippocratic treatise, *De natura pueri*, cap. 12 (Littré, VII, *486–489*), where the mixture of the semens from both parents is said to become heated, swell, and acquire pneuma, which forces a way out, thus forming the *umbilicus*. This mechanical explanation, by the way, is never censured by Galen—but of course the Hippocratic writer could do no wrong.

front, called incisors, are sharp and wide, suited for cutting when they bite. Next come the canine teeth, broad at the base and sharp at the upper end, and capable of crushing whatever is not cut by the incisors because it is hard. Following these are the molars, also called the millstones, which are rough, broad, hard, and large, being suited for comminuting perfectly what has been cut off by the incisors or crushed by the canines.

If in your thinking you change any one of their qualities, you will see their usefulness straightway ruined. If they were made perfectly smooth, they would not be well fitted for their work, since everything is comminuted better by irregular, rough bodies. It is for this very reason that when millstones upon which grain is ground are worn down in time and become smooth, they are cut and roughened anew. If the molars were rough but not hard, what good would they be? For they would be worn down instead of comminuting the food. Certainly if they had been made rough and hard but were not flat, there would be no advantage here either, that is, if material to be comminuted has to be supported on a flat base. This is the reason [II, 133] why nothing can be comminuted upon the incisors and canines because they are narrow. But what if the molars had all these qualities but were small? Would not failure in this one respect entail the loss of the usefulness of the other qualities too, since we should need an extremely long time to comminute our food? So also in the case of the incisors and the sharp teeth [the canines] that come next after them—if in your thinking you change any one of their qualities, you will find their usefulness destroyed.

Let us grant, however, that all these things have also been done thus wisely by some good fortune. Change merely the position of the teeth and see what happens. Just imagine that the molars lie toward the outside and the incisors and the sharp [canines] toward the inside,[25] and consider what usefulness these teeth or the flat molars either would still have. Would not all their other qualities be made of no avail, even though very beautifully foreseen by the most provident atoms if these erred only in arranging them? Now if a man arranged a chorus of thirty-two members in good order, we would praise him for being skillful, and shall we not then praise Nature when she has arranged the chorus of the teeth so beauti-

[25] That is, the molars at the front (outside) and the incisors and canines at the back (inside).

fully? If you desire it, let us attribute this also to atomic chance, so that we assume that it is by good fortune and without any skill not only that some teeth were made sharp and others dull, some smooth and others rough, and some small and others large, but also that their
[II, 134] position was so arranged. Let this too be granted.

And what shall we say about the roots, about the fact that the small teeth have one, the larger have two, and the largest three or four? Here again the concourse of the atoms has by some chance marvelously produced a work of skill, precisely as if some most just Creator had been in charge of them. Moreover, is it not marvelously done by the atoms to have made the molars in the middle the largest and the ones on either side of them smaller? For it was not necessary, I suppose, that the space on the inside [at the back] of the mouth, being narrower like the space at the front of it too, should have teeth as large as the middle portion near the cheeks, which is very broad. Indeed, it would be wrong to put large teeth in narrow parts of the mouth and small teeth in the broad parts, and since the tongue had to be broader at its root, as I have shown,[26] it was not better for large teeth to lie beside it in that region.

Likewise, to have made those slender outgrowths of the bones of each jaw which are called *phatnia* (φατνία [the alveoli]) from their resemblance to the mangers (φάτναι) used for cattle, is this too not a work of marvelous good fortune? At each tooth these grow around it, binding and holding it fast, so that it is not easily shaken free. To have made suitable places for the roots, large places for large roots and small places for small ones, also seems to me a work
[II, 135] of some marvelous justice. Indeed, no human artisan either among those who fit timbers together with bolts or among the workers in stone has made for the prominences on the things which he is fastening together concavities to receive them that are so exactly equal to them as those which the most fortunate movement of the atoms has prepared for the roots of the teeth. For it knew, I suppose, though it had no mind, that cavities too broad would cause a loose junction with the bones, whereas cavities too narrow would not permit the roots of the teeth to reach the bottom. Moreover, would not one also marvel that the teeth are bound to the *phatnia* with strong ligaments [the periosteum], especially at the roots

[26] The perfect tense is used, but the subject is discussed farther on, in chapter 10.

where the nerves are inserted, and marvel the more if this is the work of chance, not skill?

But the thing a person would marvel at most of all and which, even granting all the aforesaid good fortune of the Epicurean atoms and the particles of Asclepiades, he would not allow them, balking and saying that it was the work of a just Governor and not of fortunate motion—this thing is the equality of the teeth. Indeed, the fact that the lower teeth are made exactly equal to the upper, even though the two jaws are not so, is a display of justice of the highest order. And the making of the teeth on the right side equal to those on the left, and the *phatnia*, roots, nerves, ligaments, arteries, and veins [of one side] equal to the *phatnia*, roots, nerves, ligaments, arteries, and veins [of the other]—how can I still believe that this is [II, 136] the work of chance and not of skill? Is it not a display of a certain justice that there is an equal number of each of these on the right and on the left sides of each jaw? Nevertheless, let us grant even this to the most fortunate atoms, which those men say move without reason, but which are in more danger of doing everything according to reason than are Epicurus and Asclepiades.

Now the other works of the atoms are wonderful, and so is this one, namely, that they have put the molars in the inner parts and the incisors in the outer parts not only in man but in other animals as well. It is possible that they would have been moved [thus] fortunately in one kind of animal, but for the same thing to be true of all kinds requires prudence and reason. I cannot make out how it can be the work of unreasoning motion to prepare many sharp, strong teeth for fierce animals; for if you have ever seen the teeth of the sheep and the lion, you know, I suppose, that they are not alike. Is it not also a marvel that the goat has teeth like the sheep's, and that the teeth of the leopard and dog are made like those of the lion? It is a still greater marvel than the claws too correspond, that fierce animals have sharp, strong claws, like natural swords, whereas they are not made so in any of the timid animals. Perhaps one might attribute to the wonderful good fortune of the atoms the fact that adjacent, [II, 137] neighboring parts are justly formed, but to refrain from giving any one animal strong claws but weak teeth is the work of Creator who is perfectly mindful of the usefulness of each part. To make shorter necks for animals that have their limbs divided into toes, because food can be conveyed to the mouth by the toes, and longer necks

for animals having either solid or cloven hoofs so that they may stoop and graze—is not this too the work of some Creator mindful of the usefulness of the parts? Is it not a marvel that because cranes and storks have longer legs they also have a large bill and longer neck, whereas fish, lacking legs, have no neck at all? Why, indeed, did fish need feet or a neck when they do not need to walk or make sounds? But when the fish tribe is so numerous, for the atoms not to forget and make feet or a neck in a single one of them is the work of an accurate memory! Perhaps one might believe in the fortunate motion of the atoms for man alone, or for a single kind of animal, but that they should have similar good fortune in all animals is incredible, unless atoms also have intelligence.

9. I may explain the other animals at some future time. In man—for we must return to him—a single canine tooth has been
[II, 138] produced on each side [of each jaw], whereas the lion, wolf, and dog have many of them on both sides. Here, also, Nature understood clearly that she was forming a civilized, social animal, whose strength lay not in the might of his body, but in wisdom. Hence whatever was necessary to crush sufficiently any harder bodies would be done by the two [canine teeth], so that she has with good reason doubled the number of incisors, because they have a wider usefulness, and she has made the molars still more numerous, because they have the widest usefulness. There is no fixed number of such teeth as these [the molars]; in some individuals having longer jaws, five are formed on each side, and in others with smaller jaws, there are four. In most cases, however, there are five, and there are never four on the left side and five on the right, or again, five on the left and four on the right, or four below and five above; and yet once in a while, at least, atoms would be bound to lose sight of equality of number!

For my part, though I have made uncounted allowances for the atoms, how could I grant them works involving memory? For not even their authors dare endow them with intelligence and reason. And how could memory of equality or analogy be made in such a thing? [27] How is it that man has a small mouth when the lion, the wolf, and, in general all animals called saw-toothed [the carnivora]
[II, 139] have mouths very widely divided, unless here too our Creator was

[27] Reading *ἐγγίγνοιτο* with Helmreich for the *ἐδείκνυτο* of Kühn's text.

mindful of the usefulness of the parts? In fact, it was logical for the size of the mouth to be in accordance with the nails and with the strength of the teeth. For what would be the use of these things if the mouth were small? And why would a man be better off if he had many molars and his mouth had a very wide gape? What I said not long ago about the masseteric muscles is enough to show how greatly the part of them near the cleft of the mouth contributes to perfect comminution. Hence if the mouth gaped more widely in man, as it does in the wolf, he would not comminute his food perfectly and he would gain no advantage in defense from its size, since he does not have many sharp [canine] teeth. On the other hand again, if it were drawn together into a small compass in that animal, as it is in man, the action of its sharp teeth would be spoiled. In general, then, if you examine all animals, you will find that those whose strength lies in biting have the mouth very large and full of such teeth, whereas in those whose teeth are useful for chewing and perfectly comminuting the food, the mouth is drawn together into a small compass and has within it many molars and either no sharp teeth at all or a single one on each side of the jaw. Just as these parts have been constructed in a fashion analogous to one another, so too the nails have been accurately constructed in the same way. In domesticated, timid animals they are broad, soft, and blunt, but in wild, fierce animals they are large, sharp, strong, and curved. For I [II, 140] suppose the atoms must not overlook this either, but must make the nails of fierce animals suitable for cutting and holding.

10. Furthermore, the mass of the tongue is nicely adapted to the mouth, for it easily reaches every part, as it could not if it were smaller, and it is nowhere hampered by the want of room from which it might very easily suffer, I suppose, if its size were excessive. Is it not marvelous that it is readily moved in every direction? And is it not also marvelous that it is moved according to the will of the animal and not involuntarily, like the arteries? For if its movements were not in accordance with our impulses, how could we perform the act of chewing? Or swallowing? Or conversing? Since it was better for these motions to be performed in accordance with the animal's impulses, is it not praiseworthy too that the tongue is therefore moved by muscles? Is it not marvelous that since it must be moved up toward the roof of the mouth, moved down,[28] and

[28] Kühn omits *καὶ κάτω καταφέρεσθαι*.

turned to the sides, it therefore has many muscles, one providing one movement and another another? Now if the tongue is double, like all the other sense instruments—for I have already spoken of them—the muscles on each side are properly equal in number and size. Thus it also has two arteries [*aa. linguales*] inserted into it, one on each side,
[II, 141] and similarly two veins [*vv. linguales*] and two pairs of nerves. One of these [*nn. linguales* from mandibular division of the trigeminal] is soft and one hard [*nn. hypoglossi*], the first distributed into its outer tunic, and the second scattered into the muscles, because by the one it must perceive flavors and by the other it must be moved according to the will, as I have also said earlier at some point, where I was explaining the outgrowths of nerves from the encephalon.

In certain animals, indeed, such as the snake, the tongue too [29] is divided, but in man, since it was not better that it should be, for either eating or speaking, the parts of it are properly united and come together to form one part. It is clearly double in man, however, since no muscle, vein, artery, or nerve passes across either from the right side to the left or from left to right.[30] It is made large and strong at its base to establish it firmly, and slender at the tip so that it may move quickly, and this also seems to me a work of no common foresight. Since some of the muscles must move the tongue upward toward the palate, and others must move it down, and still others turn it to the sides, is it not a work of marvelous forethought that some of them [*glossopalatini*] [31] are therefore inserted into it from the parts above, others [*genioglossi* and *hyoglossi*] from the parts below, and still others [*styloglossi*] from the sides? For I have shown in my book *On the Movement of the Muscles* [32] that every muscle draws the part toward its own source. Hence the muscles inserted from above would necessarily move the tongue up, those
[II, 142] whose sources are below would move it down, and in the same way the lateral muscles would perform the movements to the sides.

Since the tongue becomes hard to move when it is dried out, as

[29] As well as the other sense instruments.

[30] Not strictly true, in spite of the tongue's median fibrous septum, which may account for the error. Galen would not, however, have been pleased to see the decussation of the fibers of the genioglossi, for example.

[31] Daremberg (in Galen [1854, I, *674*]) says mylohyoideus, surely a slip or oversight on his part.

[32] *De motu musculorum*, I, 4–5 (Kühn, IV, *382–391*).

one sees clearly in persons who are excessively thirsty and in those who have had all the moisture of the mouth dried up in burning fevers, Nature has made marvelous provision to keep the tongue from being easily affected by such a trouble. Now I have said earlier in speaking of the larynx that there are glands like sponges placed beside it, one on each side, to serve this purpose. The same thing has been done in the case of the tongue, and channels from these glands pour forth through the lateral and lower parts of it a phlegmlike humor, moistening the tongue itself and the lower parts, the sides, and the whole circuit of the mouth. The upper parts have the channels leading down from the encephalon, and I have spoken about these earlier.

Thus everything having to do with the tongue has been prepared most fully and perfectly by Nature, and both the other arrangements and also the ligament [*frenulum linguae*] below the tongue display no little foresight of hers. For since every muscle naturally exerts traction toward its own source, it was of course necessary that when the muscles inserted into the tongue at its root pulled on it, it would contract upon itself and, being tensed by them, it would round up like a ball, so that it would not reach to the front teeth and to the lips as it did before, and, in addition, it would not be securely seated, because it would be free on all sides. To meet all these needs [II, 143] Nature has marvelously prepared a ligament of the size that would be most suitable. It was made neither simply nor at haphazard, but with a marvelous, due proportion; if it extended farther out along the tongue or came to an end sooner than it should, it would certainly not be as good for the articulation of the voice and it would also be a hindrance to the motion in chewing. In fact, it conduces to both these things for the base of the tongue to be firmly seated and for the tip to reach nimbly in every direction. Surely if this ligament came only a little way forward, the tongue would be inconvenienced less, indeed, than it would have been if the ligament had not been made at all, but nearly as much; on the other hand, if it came very far out, it would keep the tongue from being extended to the roof of the mouth, to the upper teeth, and to many other parts of the mouth. Hence the connection is so accurately measured that if you either add to it or subtract from it a little, the action of the whole instrument will be hampered.

The greatest possible admiration is due Nature when in such

delicate matters she always does right and error is rare. And yet, how frequently in the fathers that beget and the mothers that bear us it must be[83] not error that is rare but right-doing. For drunkards consort with drunkards, and men that do not know their own
[II, 144] whereabouts from repletion with women in the same state.[84] Hence in this way the very beginning of our procreation is faulty, and then come the unspeakable errors of the pregnant woman, her indifference to proper exercise, her gluttony, passions, drunkenness, bathing, and untimely indulgence in love. Nevertheless, to such outrages Nature opposes many acts and performs them successfully. This is not the way in which farmers sow wheat or barley, or plant grapevines or olive trees; for first they see to it in advance that the soil to which they entrust their seeds shall be in good condition, and then they take no little care that the seed shall not be deluged with too much water and rot, or withered by droughts, or killed by frost. No one, however, takes such great care in implanting a human being or in nourishing a human embryo; on the contrary, just as all men take little heed to themselves in all the other affairs of life, some being overcome by insatiate, greedy pleasures and some devoting all their abilities to gaining riches, power, and rule, so in the same way they are careless of their first generation itself. But now let us leave them alone and pass on to what comes next.

11. I have previously told all that Nature has contrived for the epiglottis, the larynx, and, in general, for swallowing and for producing the voice. If anyone remembers those things, I think he will marvel at the conformity of the usefulness of the parts and will
[II, 145] clearly be persuaded that it was not heat or a moving pneuma that broke open the mouth by chance; for certainly some one of the parts within it would have been found to be defective, or superfluous, or wholly lacking in usefulness. When all of them, however, are found to be so constructed that we may eat, swallow, produce our voice, and breathe, and when not one is idle or defective, or capable of being better if it was made differently, I think there is sufficient evidence that the mouth itself and everything in it have been con-

[83] Reading ἐχρῆν with Helmreich for the εὑρεῖν of Kühn's text.

[84] [ἑτέραις] οὕτω διακείμενοι, Helmreich; ἑτέραις οὕτω διακειμέναις, Kühn. In this instance I have rejected Helmreich's emendation and adopted Kühn's text. After the decision was made, it was good to discover that Renehan (1965, 69) has come to the same conclusion.

structed with skill. Moreover, concerning the tunic lining all the parts, I have also said earlier that it receives no small share [*n. palatinus*[35]] of the soft nerves from the encephalon, in order, I suppose, that it too may be able to perceive flavors, as the tongue does. I have said too that it has a moderate degree of softness or hardness in order not to become insensitive, or sensitive only with difficulty, [as it would] if it were more dried out and hardened like bone, and in order not to be readily injured or bruised by hard, acrid foods.

Concerning the uvula I have said in my book *On the Voice*[36] that it contributes to the volume and beauty of the voice in two ways,[37] namely, that the incoming air is first divided by it, and the violent rush of the air and hence its coldness are broken up; that not only has the voice clearly been impaired in some individuals who have had the uvula cut off at the base, but these have also felt the inspired air to be too cold; furthermore, that many such people die when [II, 146] their lung and thorax become chilled; and that the uvula must be cut off not regardlessly or at random, but so as to leave a part of it at the base. Hence I need say no more of these matters; for it is enough here just to mention the main points.

I have also written in what precedes about the apertures of the nose, how marvelously they come next after the spongelike (ethmoid) bone placed before the cavities [the extension of the lateral ventricles into the olfactory lobes in some animals] of the encephalon, and how the connection was cut through into the mouth at the palate in order that inspiration may not begin in a straight line with the rough artery [the trachea] and that the air entering it may first be bent and convoluted, so to speak. For I think this should be doubly advantageous: the parts of the lung will never be chilled when oftentimes the air surrounding us is very cold, and the particles of dust, ashes, or anything else of the sort very frequently mixed with the air will not penetrate as far as the [rough] artery. For the air can pass on its way in this winding path, but such particles are held back, encountering first the bodies [the mucous membrane] which surround the bends and which are soft and moist, contain a sticky substance, and are capable for all these reasons of retaining

[35] See note 39 of Book IX. [36] See note 3 of Book VI.

[37] Reading *καθ' ἑκάτερον λόγον* with Helmreich for the *καθ' ἑκάτερον δὲ ἄλογον* of Kühn's text.

what falls upon them. But if anything does penetrate as far as the mouth, it will be separated [from the air] there at the palate and the
[II, 147] "column"; for that is what the uvula is called. The best proof of this is what happens every day both to those who wrestle in clouds of dust and to those who travel a very dusty road; for they presently blow their noses and cough up and spit out the dust. If, however, the channels in the nose did not first pass straight up toward the head and then turn obliquely back toward the palate, and if they did not find the uvula there to receive them, it is clear that nothing would keep all such materials from falling into the [rough] artery; for this is what happens if a person breathes through his mouth. Indeed, I myself have seen many athletes [88] overcome by precisely this thing, who were in danger of strangling when they breathed the dust in through their mouths, and of course they ran this risk because they needed great quantities of inspired air all at once. Only at such times do animals, those in normal health at least, breathe through the mouth; for when there is inflammation or induration, or when some other condition stops up their nasal passages, they are then compelled to breathe through their mouths, but this is because the nasal passages are not normal. When these are healthy, there is no need of the mouth at all [for breathing], unless the individual should suffer from a long, severe attack of asthma. Hence what I have already said earlier is clear, namely, that the nose is first of the respiratory instruments in order; that unless the animal is constrained by some difficulty, the mouth is not an instrument of respiration at all; but
[II, 148] that at the times of which I have now been speaking, it is to some extent a help to the animal in breathing. It is also evident that the column [the uvula] contributes greatly toward keeping dust or any other such substance from falling into the larynx; for in addition to the two uses already mentioned for this part, there is this third one which you should also know.

It is now established that not one of the parts of the mouth has been formed defectively or in vain, but that in the bulk of their substance, in composition, conformation, and situation all have been excellently constructed. If there is any one of them that I have not explained, the explanation will be clear from what has been said, and so it is enough to mention in the case of one or two parts the

[88] Especially in the performance of his duties as surgeon for the athletes at Pergamon.

usefulness of everything pertaining to them, as I have done for the tongue. For example, what I have said about the tongue when I was praising the proper proportion of its size, you can, if you look, discover to be true of all the parts alike. Thus none of them is so small that its service is defective, and none is so excessively large as to crowd any of the others or be itself straitened by them. The apertures of the nose are large enough for inspiration; the size of the column [the uvula] is quite sufficient for its three uses; and the epiglottis is just the size of the part it is to close. So it is too with the channels of the larynx and the esophagus: the one is just large enough for respiration and the voice, the other for the passage of food. Similarly every tooth and all the other parts display marvelous [II, 149] proportion and harmony with one another, showing clearly what I said at the beginning of the whole work, namely, that our Creator was looking to the consummation of a single work when he constructed all these parts.

12. I began with the temporal muscles, intending to speak thereafter of the forehead and ears, because these parts of the head still remained to be discussed. After the temporal muscles, however, influenced by the consecution of things I discoursed next about the other muscles of the lower jaw, and then I explained the mouth and its parts. So now I shall return to what is left to be said about the ears and the wings (alae) of the nose—for that is what the mobile lower extremities of the nose are called—making the instruction include them both, and joining to it a special treatment of the things not yet told.

Well, then, I have already said earlier that all prominent, uncovered parts which are exposed to outer objects striking them need to be made of a substance not easily crushed or broken, and this is certainly another proper occasion for making the statement; for I suppose it is necessary to make a common statement about a common usefulness of the parts. The ears are seen to be easily folded over and not to be harmed in the process at all, and they obviously [II, 150] do not suffer in any way from the pressure when the head is enclosed in a close-fitting cap or a helmet. In fact, being moderately soft and hence yielding readily to objects striking against them, they weaken the force of the blows. If they were perfectly hard like bone or soft like flesh, either parts of them would easily break off, or they would all be crushed together, one or the other. This is the reason

why they were made cartilaginous, and I shall now tell why they are wholly exposed.

Nature contrives a covering for all the sense instruments, for some of them in order that the encephalon nearby may not be injured, and for others in order that they themselves may be kept safe. I have shown that this is the character of the bone placed before the instrument of smell, the bone they call colanderlike [*os ethmoidale*]. Moreover, the whole nose is also such a means of protection. In the case of the eyes I have shown that the eyelids, the nose, the so-called cheek[s], the brows, and the motion of the surrounding skin itself were made to protect them. I think I need say nothing about the tongue, which is shut away in the mouth as if in a cave. Then there remains the sense instrument of hearing, in which Nature first constructed the coiling channel in the petrous bone so that no outer object might strike and injure it, and this too I have sufficiently explained to you in an earlier book. Secondly, just as she placed the
[II, 151] hairs of the eyebrows above the eyes to be the first to receive anything flowing down to them from the head, so in the same way she has wished to place something in front of the ears too. Now for the eyes, which need to be situated high up (for this has also been demonstrated), it was better not to make a rampart so large that it would darken them. For the sense of hearing, however, the opposite is true: what was placed in front not only would not hinder the impact of sound, but would even increase its resonance.

The Roman consul Arrian [39] has furnished excellent evidence for the truth of this idea; for after he had become hard of hearing, he used to place his hollowed hands inclined from back to front beside his ears in order to hear better. So also Aristotle [40] has said that the horse, ass, dog, and other animals having large ears move them about

[39] This was Flavius Arrianus, the historian, who was consul about A.D. 130. I have not found any other source for the information that he was troubled with deafness. Here is one more striking instance in which Helmreich's text (reading Ἀρριανὸς as an emendation for Ἀριανὸς, the form found in MS Urbinas 69 and one other) is superior to Kühn's text, which has Ἀδριανὸς, the reading of the other manuscripts and the editions. The commentators have naturally been distressed at their inability to identify a consul of that name living in Galen's time or earlier. See Hofmann (*1625, 255–257*) and Daremberg (in Galen [*1854, I, 681–682*]).

[40] *De part. an.*, II, 11, 657a12–17; *De gen. an.*, V, 2, 781b13–16.

and always turn them toward the noise or the voices, because they have been taught by Nature the usefulness of the parts. But in man such a size would be inconvenient when he covers his head with a close-fitting cap, a helmet, or some other such thing, as he must frequently do. As a matter of fact, although the ears of the war horse are much smaller than asses', their size is also inconvenient when it is necessary to cover its head. [In man], however, it was better for the ears to extend upward and project in front of the channels as much as they actually do; for so they cause resonance and cover the channels without at the same time being a hindrance [II, 152] when the whole head is covered. Hence there is good reason for man's ears either not to move at all, or to have [only] a little, weak motion; for since they are small, there would certainly be little or no advantage for us if we could turn them around. They are convex on the outside and concave on the inside in order that nothing may fall into the channels and that the ears themselves may not readily suffer harm. For I have already said many times that the rounded shape is most resistant to injury. Moreover, they were both made much convoluted for the same reason (*χρεία*, usefulness), since they could thus be more folded over and doubled upon themselves than if they were simple and uniform.

13. You can also see how [Nature] has provided for the beauty of the ears, leaving no part rough, unfinished, or ill-proportioned; for out of her abundance she characteristically does this also. Just as in making shields or bars for doors,[41] very frequently in making sword hilts, and sometimes even in making bowls, good workmen give an extra proof of their skill by modeling some ornament or device for the work beyond what is useful, such as ivy, or the tendrils of grapevine, or a spray of cypress, or some other such thing, so Nature out of her abundance ornaments all the members, especially in man. In many parts there is manifest ornamentation, though at times this is [II, 153] obscured by the brilliance of their usefulness. The ears show obvious ornamentation, and so, I suppose, does the skin called the prepuce at the end of the penis and the flesh of the buttocks; for if you look at an ape, you will clearly recognize the ugly shape of this part when it

[41] Accepting Helmreich's emendation, *κλείθρων*, for the *ἐπικλείθρων* of Kühn's text. Renehan (1965, 63) suggests *ἐπικλίντρων*. The following discussion of the relation of beauty to usefulness may be compared with that in chapter 9 of Book I.

is uncovered. On the other hand, although the eye is a far more beautiful part than any of these, its beauty is disregarded because its usefulness is so greatly admired. Beauty is disregarded too in the nose, lips, and other parts, because [in them] the beauty of their usefulness far surpasses the pleasure aroused by their appearance. But if a little bit of the lip or the alae of the nose were cut off, it is not easy to express how ugly it would make the whole face. All these things, however, as I have said, were made not in accordance with Nature's first principle, but incidentally, so to speak, and in sport. The things that concern her most and that she keeps constantly in view are those pertaining to actions and usefulness. I have told earlier wherein action differs from usefulness, and I have said that the action of a part is prior to its construction and generation, and that usefulness comes first in importance and action second. I have also showed that true beauty is referable to the perfection of usefulness, and that it is usefulness which is the first goal in the construction of all the parts.

14. Since I have nowhere mentioned earlier in my discourse that
[II, 154] out of her abundance Nature sometimes also aims at beauty of form and that this too must be recognized by those studying Nature, I have thought it most proper to speak of it now. Well, then, the hair of the beard not only protects the cheeks but also serves to ornament them; for a man seems more stately, especially as he grows older, if he has everywhere a good covering of hair. This is also the reason why Nature has left the so-called cheekbones and the nose smooth and bare of hair; for so [if they were hairy] the whole countenance would become savage and bestial, by no means suitable for a civilized, social animal. The very thickness of the bone, however, serves as a covering for the cheekbone, and the warmth of expiration for the nose, so that these parts are not completely without protection. Moreover, you can touch your eyes, especially in cold weather, and you will then feel most keenly how warm they are. For not even the eyes are completely bare and unguarded against the cold, because they have a suitable protection in the innate heat, which needs no outer covering whatever. On the other hand, for woman, the rest of whose body is always soft and hairless like a child's, the bareness of the face would not be inappropriate, and besides, this animal does not have an august character as the male has and so does not need an august form. For I have already

shown many times, indeed throughout the work, that Nature makes [II, 155]
for the body a form appropriate to the character of the soul. And the female sex does not need any special covering as protection against the cold, since for the most part women stay within doors, yet they do need long hair on their heads for both protection and ornament, and this need they share with men. Really, however, there is another reason (χρεία, usefulness) that makes it necessary for us to have hair on both our chins and heads. For since the exhalation from the humors rises to the head, Nature makes use of its thicker residues in particular to nourish the hair, and since men have as much more of these residues as they are warmer than women, she has devised for men two ways to evacuate them, from the hair of the head and from the hair on the chin. Let this be enough to say of these matters.

Next comes the discussion of the reasons why the forehead does not have hair as the rest of the head does, and why it is only here that the skin is moved according to the will of the animal. Of course, the forehead is covered by the hair of the head as much as we wish it to be, so that there is no need for it to have hair of its own on that account. If the forehead did produce hair, we should constantly have to have it cut, because the forehead overhangs the eyes. I have shown elsewhere and especially in connection with the instruments of nutrition that Nature has made sufficient provision to keep man from being greatly troubled about his body and from being a perpetual slave to its necessary services. For I think it fitting for a wise, civilized animal to have moderate care for his body and not to be like the many who, when a friend is in need of someone [II, 156]
to come to his aid, say they haven't the time and run away, and who then in private pluck their hair with plasters of pitch, adorn themselves, and spend their whole lives in unnecessary attention to their bodies, not understanding at all that they have something better than the body. These people should be pitied, but we for our part should study what we have set before ourselves and show that there was good reason why the skin of the forehead not only was made hairless for the sake of the eyes but was also endowed with voluntary motion for their sake too. For when we attempt to see many external objects at once, the eyes must be opened very widely, and again, whenever we have occasion to fear that something will strike them, they must be drawn together and held tightly, being

closed by all the parts accurately surrounding them. So for both these reasons (χρείας, usefulnesses) Nature has made all the skin around them move in obedience to the will, both the skin of the forehead above them and that of the cheeks below, in order that, being alternately stretched and folded again upon itself, it may be able to open and close the eyes.

Moreover, she has not been unmindful of the hairs of the eyebrows either but has managed it so that these, together with the hairs of the eyelids, are the only ones that preserve always the same length, whereas she has caused the hair of the head and chin to grow
[II, 157] very long. For on the head and chin it serves two uses, one that has to do with the covering of the parts, the other with consuming the thicker residues, and the first is an extremely varied usefulness, since we do not need the same covering at [different] times of life, seasons of the year, or places, or in [different] bodily conditions. Indeed, the same amount of hair is not suitable for a man, a child, an elderly person, and a woman, nor is the same amount suitable in both summer and winter, or in both a hot and a cold place, or for persons suffering from ophthalmia or headache and those who are perfectly well. Hence it was better for us to accommodate ourselves to changing conditions and have the length of our hair different at different times. As regards the eyelashes and eyebrows, however, if you either added or subtracted anything, you would destroy their usefulness. For the former are set like a palisade before the open eyes so that no small bodies may fall into them, and the latter must provide shelter like a wall and be the first to receive all that flows down from the head. If, then, you made them shorter or thinner than they should be, you would to that extent impair their usefulness; for whatever they formerly kept out would be allowed by the eyelashes to fall into the eyes and by the eyebrows to flow into them. But again, if you made them longer or thicker, they would no longer be a palisade and a wall for the eyes, but coverings very like a prison,
[II, 158] hiding and darkening the pupils, which ought least of all instruments to be obscured.

Has, then, our Creator commanded only these hairs to preserve always the same length, and do the hairs preserve it as they have been ordered either because they fear the injunction of their Lord, or reverence the God who commands it, or themselves believe it better to do so? Is this the way in which Moses reasons about Nature

(and it is a better way than Epicurus')? Yet it is best for us to adopt neither, but, continuing to derive the principle of generation from the Creator in all things generable, as Moses does, to add to this the material principle. For our Creator has made these hairs feel the necessity of preserving always an even length for the reason that this was the better thing. And since he had decided that it was necessary to make them so, he spread beneath some of them [the eyelashes] a hard body like cartilage [the tarsus] and under the others [the eyebrows] a hard skin united to cartilage by means of the brows. Now it was not enough merely to will that they should be so; for even if he wished to make a rock into a man all of a sudden, it would be impossible. And this is the point at which my teaching and that of Plato and the other Greeks who have treated correctly of natural principles differs from that of Moses. For him it suffices for God to have willed material to be arranged and straightway it was arranged, because Moses believed everything to be possible to God, even if he should wish to make a horse or beef out of ashes. We, however, do not feel this to be true, saying rather that some things are naturally [II, 159] impossible and that God does not attempt these at all but chooses from among the possible what is best to be done.[42]

Accordingly, when it was better that the length and number of the hairs of the eyelids should be always the same, we do not say that

[42] Walzer (1949, *18–37*) shows that the fundamental cleavage revealed here between Aristotelian and Platonic philosophy on the one hand and the Judaeo-Christian point of view on the other had long been recognized; that it existed within Greek philosophy itself even before the Book of Genesis entered the discussion, since the Stoics maintained the absolute omnipotence of God, which was limited as Galen would limit it by the other sects; and that the intrusion of the material cause into the creative act was also a denial of the *creatio ex nihilo* upheld by later Jews, Mohammedans, and Christians. This passage is one of the six which Walzer has gathered together from all Galen's works and discussed to show his attitude toward Jews and Christians, which was one of uncompromising insistence on demonstration as the basis of all belief and refusal to accept anything on faith; he was, however, an admirer of Christian virtues. These passages are (1) an Arabic quotation from a lost treatise, *De Hippocratis anatome;* (2) this present criticism of Mosaic cosmogony; (3) and (4) two statements from *De pulsuum differentiis,* II, 4, and III, 3 (Kühn, VIII, *579, 657*); (5) an Arabic quotation from a lost attack on Aristotelian theology; and (6) an Arabic quotation from his lost work on Plato's *Republic.*

he willed it and straightway they were made so; for though he willed it times without number, they would never become such as they are if they grew out from soft skin. As for the other requirement, they could not possibly stand erect unless they were implanted in something hard. We say, then, that God is the cause of two things, namely, the choice of the better in what is being made and the selection of material. Since the hairs of the eyelids must stand erect and at the same time remain always of the same length and number, he implanted them firmly in a cartilaginous body. If he had implanted them in a soft, fleshy substance, he would be worse than either Moses or some wretched general who planted his wall or palisade in a swamp. That the hairs of the eyebrows too are kept always the same depends on the same selection of material. For just as grass and plants coming up from damp, rich soil grow very tall, whereas those that come from dry, rocky soil remain without increase, small and hard, so in the same way, I suppose, the hair
[II, 160] coming from soft, moist parts has a very good growth, like the hair of the head, armpits, and pudenda, whereas that from the hard, dry parts does not grow and remains short.[48] Thus, like herbs and plants, hair has a twofold generation, stemming in part from the providence of the Creator and in part from the nature of the place.

One can often see a field in which wheat or barley is growing up as yet like tender, short grass, and another spot similarly thick with vegetation and full of real grass. The rich growth in the latter has been produced by natural moisture, but the farmer's providence has produced it in the field. For those unable to distinguish from the other grass the form of the seeds just sprouted from the earth, the orderly arrangement of their growth will be sufficient indication. For the evenness of their germination and the fact that the edges of the field have been established in straight lines will be enough to show that this spot has been filled with vegetation by the skill and providence of the farmer. With the growth that has sprung up by itself the contrary is true in both respects; the germination is uneven and is not marked out in straight lines. This is the nature of the hair

[48] An excellent note by Daremberg (in Galen [1854, I, *687–688*]) points out many of the glaring deficiencies of Galen's treatment of this subject. For instance, the hair of the head according to his theory should grow no longer than the eyebrows, since it too is implanted in a place by no means soft and moist.

in the armpit and on the other members; for it is not bounded by definite lines like the hair of the eyebrows, eyelids, and head,[44] but has irregular boundaries and is scattered indiscriminately, without order. It has sprung from the moisture of the locations and is not a work of the Creator's providence, and therefore much of it is produced in warm natures and very little or none at all when the [II, 161] nature is cold. The hair for which the Creator himself provides, however, as the farmer does for his field, is produced in all natures, warm, cold, dry, and wet, unless they have an excessively unbalanced, bad temperament, like rocky or sandy soil.

Now just as all soil, except that which is very poor, is the object of the farmer's skill, so too every healthful temperament of the body admits the skill of the Creator of animals; it takes a very considerable affection of the part to make the hair of the eyelids or eyebrows fall out, and so too, I suppose, it is an affection that makes the hair of the head fall out, though not so great a one. In fact, though it is difficult to grow plants in hard, dry soil and they need a great deal of provident care, it is not easy to destroy them; for they are strongly rooted and are seized and held fast on all sides. In the same way the Ethiopians have short hair on their heads that does not grow long because of the dryness of the skin, but they do not readily become bald.

With his foreknowledge of these things, then, the Creator, knowing that it was better to make the hairs of the eyelids and eyebrows short and incapable of growth but also permanent, implanted their roots in hard, cartilaginous skin, as if in clay or rocky soil. Of course, the beginning of a plant could not possibly be inserted into actual rock, just as the root of a hair could not be inserted into a bone, and so on the head, already a well-tempered spot, he made, as it were, a cultivated field of hair, partly to absorb [II, 162] the moisture flowing there lest it harm the underlying parts, and partly to form a covering for the head itself. Now hair has also been produced of necessity around the pudenda—for these regions are warm and moist—and makes a covering and an ornament for the parts there, as the buttocks do for the anus and the prepuce for the

[44] Note that here the hair of the head is classed with the eyelashes and eyebrows, as that which is subject to regulation, whereas a few lines above it is classed with the hair of the other locations, which grows only from soft, moist parts and without regulation.

pudendum. For in many places our Creator, all-knowing and most clever in choosing and creating what is better, uses for needful purposes the parts which are generated of necessity.

15. Hence, while he was decorating all the parts in this way, he neglected neither the brows nor any other part, but, as I have said just now, first placed beneath each of the parts to be made the material suitable to it and then from this made what was necessary. I have told why it was better for the skin of the forehead to be moved, and the Creator, understanding that no part can have voluntary motion unless it has muscle, stretched beneath it a thin, muscular substance [*m. frontalis*]; for he always makes the mass of the muscle proportional to the size of the part to be moved. Only here is the skin united with the muscular substance, just as it is adherent in the palm of the hand and sole of the foot to tendons [palmar and plantar aponeuroses]. That I was not quibbling over names but
[II, 163] wished to show the difference between the parts when I said that the skin of the forehead was *united* and that of the hands and feet was *adherent*, you will see clearly, if you are willing to dissect the parts carefully. For, as I have said in my discussions of them, the tendons coming down from the muscles [*palmaris longus* and *plantaris*[46]] above them into the skin of the inner side of the hand and the sole of the foot, make it more sensitive, bare of hair, and harder to fold over than the skin elsewhere. On the forehead, however, the uppermost portion of the underlying muscular substance itself becomes skin. There is a third class of skin, that of the whole body of the animal, where the skin is attached to the underlying parts, but not adherent to them, and there is a fourth class, the skin of the lips, where the muscles lose themselves, as one might say, and are completely mingled with the skin.

No one of these classes was made idly or without a purpose. Some of them I have explained above, showing that they could not possibly be better arranged otherwise. Concerning all the skin around the eyes, I was about to speak in this present discussion, showing that it is not stripped off from the underlying flesh and that the same is true of the inner side of the hands and the bottom of the feet. But in neither of the latter places is it loose, as it is on the forehead, nor does it have perceptible motion, since it was not made as it is for the

[46] In man the tendon of plantaris is inserted into the calcaneus and does not continue into the sole of the foot to become the plantar aponeurosis, as it does in the ape. See note 56 of Book III.

same usefulness. For here [on the forehead] if it was not loose, it could not be moved voluntarily. So I shall certainly tell how it gets this attribute. It is everywhere united to the underlying muscular [II, 164] substance of which it constitutes the superficial part, but it is free from the bones beneath, being kept from contact with them by the periosteal membrane, which is itself all loose and laid upon the bones, not united with them nor adherent, but attached by certain slender fibers. Nowhere else has skin of such a nature been formed, because nowhere else does it have this usefulness.

In the parts of the cheeks near the eyes you would find no muscular substance placed beneath [the skin], but, as in the rest of the skin, a loose membrane, which also has the periosteum stretched below it.[46] Because the lower part of this skin is adherent to the jaws and its upper is united with the muscular substance that underlies the forehead, it can be moved along with these parts. Yet if you wish, this may be counted as a fifth kind of skin in addition to the four of which I have spoken, though its own proper form differs in no respect from that of the animal's skin as a whole. Since it is surrounded only by the two skins that move,[47] being united and adherent to them, it has a share in voluntary motion, and in this respect it too is different from the animal's skin as a whole. Through the same wisdom of the Creator only the substance of the lips has been made such that it can justly be called either skinlike muscle or musclelike skin. Moreover, it had to be moved with voluntary motion and be made much harder than the other muscles, and this was the reason [II, 165] why he composed it of skin and muscle blended.

16. There are four sources for the muscles arriving at the lips, and these are clear and distinct before they are mingled with the skin, but when they have been blended with it, they are extremely indistinct and inseparable from the substance of the lips. In fact, as I have said, the lips of animals are formed by the blending of all the skinlike substance with all the muscular substance. I shall now explain why the muscles inserted into the lips are four in number, and why two of them [*triangulares*] [48] arise from the lower edge of the lower jaw,

[46] Reading *ὑποτεταμένον ἔχονθ' ὑμένα* with Helmreich for the *περιτεταμένον ὑμένα* of Kühn's text.

[47] That is, with the skin of the forehead and jaws.

[48] It is evident that here Galen is describing conditions in the ape, where the zygomatic and quadrate muscles are not distinct from one

while the other two [*zygomatici*] arise a little below the cheekbones, and I shall explain too that they should be made neither more nor less numerous and neither larger nor smaller, and that they should not arise from any other sources. There are four of them because the lips must have four sources of movement, two for each lip, one of which draws it around to the left, the other to the right. The size of the instruments to be moved is proportional to the size of the muscles. The heads of the upper ones[49] [*zygomatici*] are hung up on the cheekbones; for they must control the oblique movements of each part of the lip. Again, the whole position of the lower muscles [*triangulares*] is oblique and their motions are oblique.

Here too is displayed the same wisdom of the Creator which I have already demonstrated times without number. For by means of four muscles he produces eight movements; four of these, two for each lip, are oblique and four others in addition to these are straight.
[II, 166] Two of the four are perfectly straight and these occur either when the lips are moved far apart, one being pulled upward toward the nose, and the other drawn down toward the chin, or when they are brought together, the upper lip being drawn down and the lower lip up. Just as I have showed that in the wrist and arm straight movements result from oblique ones, so we find the same thing happening in the lips too. For in either lip if a single muscle acts, the motion is lateral, but if both are tensed, the whole lip will then be drawn upward by the upper muscles or down by the lower ones. Moreover, when the outer fibers are tensed, the lips are turned out, but they are turned in and folded under by the inner fibers, so that if these two movements are reckoned in along with those that are perfectly straight, that will make four for good measure, and there will be eight in all, since there are four oblique. Of these extra movements which I have just mentioned and which are added to the oblique, the first occurs when the lips are separated, the second when they are brought together, the third when they are turned outward, and the fourth when they are folded under.

In order that not only these movements but also along with them those of the jaws may be most vigorously performed, Nature has

---

another and triangularis is very prominent. And it is also evident that the "substance of the lips" is orbicularis oris. See Huber (1933, *178–183*).

[49] Reading *τῶν* with Helmreich for the *τοῖς* of Kühn's text.

stretched on the outside a broad, thin muscle [*platysma*], one on each side, extending as far as the spine of the neck.[50] Some of its fibers pass straight up to the lower lip from the sternum and the [II, 167] parts of the clavicles contiguous to the sternum, and others pass up, already obliquely, to the sides of the lips from the remaining parts of the clavicles. Still more oblique than these are the fibers going up from the shoulder blades to the sides of the lips and the parts of the cheeks adjoining them. As for the rest of the cheeks, certain other fibers draw them all back toward the ears. This muscle has been unknown to anatomists, although it receives a very large number of nerves from nearly all the vertebrae of the neck, but its motion will become clear to you if you care to close your jaws exactly and then draw away your lips and cheeks as far as you can in each of the directions of which I have been speaking. When you have discovered the action of this muscle, immediately its usefulness will also be evident, namely that it is of very great assistance in talking and chewing. I suppose it is evident too that it was better to bring nerves [*n. mentalis* from *n. trigeminus; ramus marginalis mandibulae* from *n. facialis*] into the lower lip from those passing through the lower jaw, and into the other lip from those [*rami labiales superiores* from *n. trigeminus; rami buccales* from *n. facialis*] passing through the upper jaw. So also it was far better to derive the arteries and veins for each lip from those [*aa. labiales, inferior* and *superior; vv. faciales, anterior* and *posterior*] in the vicinity rather than to try to bring them from some place more remote. But I shall write about the just distribution of the arteries, veins, and nerves to all the members later in my discourse.[51]

17. Earlier I have told in part why the alae of the nose must be [II, 168] cartilaginous and must at the same time be movable at the will of the animal, and I shall now mention it again. The motion of the alae is of no little help in more sudden inspiration and similarly in blowing out the breath vigorously. This is the reason, then, why they were made movable, but they were made cartilaginous because this substance is hard to crush or break. If anyone cannot now reason out for himself that they move in obedience to the animal's will because this is better than if the movement were independent of the will, as it is in the

[50] For the nuchal portion of platysma in the ape and its degeneration in man, see Huber (1933, *177–179*).

[51] In Book XVI.

arteries, he has been paying but scant attention to all my previous discussions. Moreover, that muscles must of necessity be inserted into them if they are to have that kind of motion, anyone ought to understand who has heard times without number about the nature and movement of muscles. Now perhaps there are some who expect to learn from me what these muscles are that reach the alae of the nose, how large they are, how they lie, and whence they take origin; for these are no longer matters of reason but the findings of anatomy. Well, then, let us learn first that the muscles[52] grow out beneath the cheekbones near the origins of the muscles [*zygomatici*] extending to the lips, and next that, as regards their position, after accompanying these muscles for a little way they withdraw from them, always more obliquely toward the nose. Of course they are small, to correspond with the parts they move, though surely I need not say this to the readers of these books about the providence of the
[II, 169] Creator, for they are already convinced of it. Indeed, it would also be superfluous to say that small offshoots of the nerves going through the upper jaw are brought to these [muscles]; nevertheless, let this also be said in order not to leave anything out of my discourse.

Similarly, perhaps I need say nothing to the reader who has a good memory about the tunic lining the channels of the nose, but let us also say that this has been formed for a twofold usefulness to the animal: first [that it may be a lining] like the tunic that lines the larynx and the whole rough artery [the trachea], and second in order that the whole instrument may have a share in sensation, since neither the bone of the nose nor the cartilage is capable of being sensitive. I need say nothing further, however, about the nerves[53] inserted into this tunic; for I have explained them sufficiently before, when I was describing the paired outgrowths from the encephalon. Moreover, earlier, when I was explaining the other parts of the eyes, I told about the perforations [the lacrimal canals] of the nose which it has in common with the eyes and which penetrate, one on each side, to the large corners of the eyes. You should not wish now to hear over again what I have already told previously, and you should

[52] Perhaps part of levator labii superioris proprius in the ape. See Huber (1933, *184*). In man this would be the angular head of levator labii superioris. See Gray (1966, *387*).

[53] The nasopalatine nerves; see note 30 of Book IX.

consider that my omission of any small details has been intentional, because they can readily be comprehended by those who have read carefully what I have written. For since I have already explained times without number things analogous to these, I think that whatever I have omitted will be very easy to discover.

18. So I shall return again as briefly as possible to the parts of the [II, 170] head still remaining in need of explanation, and I shall begin anew with the number and position of its bones. The man who is unwilling to leave off with any one of Nature's works unknown (and certainly he alone will rightly be called a natural philosopher) must properly understand why there are seven bones of the head itself, nine belonging to the upper jaw, and two to the lower. Here also it will be necessary to remind you of what I have said earlier about the junctions of bones in general. Bones have been joined together for the sake of either movement, transpiration, a passageway, diversity of the parts, safety, or resistance to injury; for movement, in the fingers, wrists, elbows, shoulders, hips, knees, ankles, ribs, vertebrae, and, generally speaking, in all the movable joints (diarthroses); and for transpiration, as I have said in discussing the sutures, for the generation of the pericranium, and for the passage of certain vessels that extend both from within outward and from without inward, I have shown that the sutures of the head were formed. Moreover, I have demonstrated in my discussion of the sutures of the head and no less in discussing the hands that all parts composed of many members have a certain resistance to injury and a degree of safety. And I have also said that the junctions in the squamous bones were made for the sake of the difference in the bony parts. The heads of the members, called epiphyses and condyles, were made for the same [II, 171] reason. Now when a bone has marrow, it is possible in most cases to see a head growing at each end of it like a lid.

I think that this very statement has introduced what I have in mind to say. [My discussion] will show first why the lower jaw has marrow and the upper jaw has no share in any such substance at all; and secondly why, although the lower jaw has marrow, there is no epiphysis at either end of it as there is at the ends of the humerus, ulna, radius, femur, tibia, fibula, and bones generally that have marrow. And right along with these things I shall demonstrate also the reason why the upper jaw has no marrow, just as the lower jaw has none in certain kinds of animals, and when I have demonstrated this,

then finally I shall return to discuss also the number and position of the bones.

We must begin, then, with what is to be seen most clearly in all animals, namely, that none of the small bones has marrow,[54] because they do not have a single, significant, large cavity, but only sponge-like pores, and these are few and narrow. For if in addition to being small a bone was also made hollow, it would be very weak indeed, just as one of the large bones, if it were solid and dense, would be extremely heavy and hard to move. Since, even as it is, the tibia, femur, humerus, and all other such bones need very large muscles to move them, what must we think [it would be like] if they did not
[II, 172] have such large cavities and had not been made rather loose-textured in consistency? The best proof of this is the fact that in all weak animals the bones have been made more porous and their cavities are larger, whereas in stronger animals they have been made denser and more nearly solid, Nature, I suppose, being careful not to suspend great weights from instruments that are too weak. Thus in the dog, wolf, leopard, and all animals having tense muscles and sinews, the bony substance is much denser and harder than it is in the pig, sheep, and goat, and the most vigorous and tensest animal of them all, the lion, is believed to have no marrow at all in its bones.[55] In truth, the bones in all its other parts are very evidently of such a substance, but in the femur and other, comparable members you will see an indistinct, narrow cavity extending through the midst of them.

Hence, if anything is clear, this is of the clearest, namely, that Nature had regard for the weakness and strength of muscles and made the weight of the bones to correspond. Indeed, since she had two goals in all her construction of bone, hardness for the sake of its own safety, and lightness for the movements of the animal, and since it was not easy to combine both these advantages in the same structure—for the first would be produced from denseness and hardness, and the second from the opposite qualities—it is clear that it was better to choose the more useful one of the two. Motion is the
[II, 173] more useful for animals, because it is proper to their true nature; for an animal, qua animal, is not absolutely resistant to injury, but it does move of itself. Nevertheless, in all animals for which it was possible to provide both advantages because the muscles were so tense and

[54] See note 33 of Book I.

[55] This statement is a reflection of Aristotle, *Hist. an.*, III, 7, 516b7–9.

the whole body was so strong, [Nature] made the bones dense and hard like stones, and she is so careful about this with all animals that not only no creature that walks the earth but also none that flies in the air or lives in the water is otherwise [than it should be]. Thus in the eagle the constitution of the bones is very dense and hard; next after it come the fierce falcons, such as the kirkos,[56] the dove-killer,[57] and the like; and then in other birds, the cock, duck, and goose, the structure of the bones is porous, hollow, and light. Hence, if man is not comparable with the lion in the strength of his muscles or of his whole body, his largest bones have with good reason been made not only hollow but porous.

And yet, if there was good reason for them to be hollow and if in the earlier part of my work I have already shown times without number that Nature rightly uses everything formed for a purpose for something else too, she ought not to leave these bones empty when she could store in them a provision of suitable nutriment. I have shown in my commentaries *On the Natural Faculties*[58] that marrow is the proper nutriment of the bones; that in bones having no cavities a substance of this sort is contained in their spongelike pores; and, moreover, that it is no wonder if marrow is thicker than the juice in the spongelike pores, even though it was formed for the same usefulness. This is the reason why all hollow bones have marrow. All that have marrow, however, do not forthwith acquire epiphyses at their heads; for the lower jaw has marrow within it, but no epiphysis, being too dense to need one. Now when porosity and hollowness are both present together in the same bone, you may see at once that there is a head growing upon the end of it because it needs a lid and because this must be dense and solid, particularly when the bone ends at a movable joint; for bones that articulate need to be hard since they have to be continually in motion and to rub against one another. I must mention again one of the uses of the junctions of bones such as I was speaking of a little while ago; for it is not possible in any of these uses to unite properly parts that have [II, 174]

[56] An unidentified species; see Aristotle, *Hist. an.*, IX, 36, 620a18, where Thompson (1910) renders it circus.

[57] See Aristotle, *Hist. an.*, IX, 12, 615b7, and IX, 36, 620a18. Thompson (1910) renders it dove-killer in one place and pigeon-hawk in the other.

[58] *De nat. fac.*, III, 15 (Kühn, II, *212;* Galen [1928, *327*]).

contrary natures. How, indeed could a dense and a loose-textured part attain an amicable union, hard to dissolve, or a porous part attain such a union with one that was hard? In this regard I have said that Nature was most clever when she devised the squamous bones of the head that join the porous bones of the bregma [*ossa parietalia*] with their spongelike cavities to the dense, hard temporal bones. But for the sake of a like usefulness the heads of the members have in all cases been made dense and hard, though they grow upon porous, loose-textured bones. How, then, does Nature operate here? She scorned to unite opposites, but contrived an amicable, painless asso-
[II, 175] ciation for them by the way in which she joined them, smearing cartilage over both of them like glue which filled up the porosity of the bones and smoothed out the spongelike pores and the roughnesses at the ends. When it was poured around outside the hard part, it bound them together and, with itself as the medium, joined them so beautifully that unless you boiled or dried them out, you would not notice the junction. On the other hand, where there was not much difference in the bones and the end closing off the cavity was a little denser than the bone surrounding it, Nature had no need to use an epiphysis. Thus she needed none for the bone of the lower jaw. For this bone, being not just a little denser than the humerus, femur, and other bones of the sort, but differing widely and completely from them, became able of itself to close off the marrow without any epiphysis on the outside. The reason for its being made much harder than those bones and hence for its having a small cavity is its nakedness. In fact, since it is so prominent and lies bare and exposed, it would be easily crushed or shattered if it had not acquired a resistance to injury from its own substance. The reason why it has any cavity at all when it needs to be hard is found in the temporal muscles, which are not so strong in us as they are in the lion, where they must hold up without pain a bone that is dense, hard, and solid.
[II, 176] Moreover, since the lion's strength is exerted above all in biting, he needs a strong jaw. And surely Nature would not implant strong teeth in it unless she had first made it strong too. Thus she also made his whole neck robust, joining the vertebrae in that region together with strong ligaments. Man, however, being a social, civilized animal, did not need such a stout jaw, but since he required rather one that was more resistant to injury than the humerus and femur and at the same time light on account of the temporal muscles, he has

obtained a jaw exactly adapted to both uses. Thanks to this same forethought, the upper jaw is wholly without marrow, because it has no motion whatever. For since one of the two uses had been excluded, it was constructed only for resistance to injury, and this has been shown to result from the solidity of the bones.

19. Now I have shown that since bones of different qualities could not well be united, it was better to mark them off from one another with sharp lines, and this is especially true of the upper jaw; for it is composed of bones dissimilar in substance because their usefulness is different. The cheekbones [the maxillae] are very thick, the bones of the nose are very thin, and the others are very hard. The cheekbones are made resistant to injury by their thickness, and the others by their hardness, but the nose was made weaker because the animal would not be [as] greatly harmed [if the nose were injured] as [it would be] if any of the other parts of the upper jaw were affected. In fact, when these other parts are affected, it necessarily ends in an injury either to the nerves passing through the jaw or to the masseteric muscles, and sometimes even parts of the [II, 177] head itself are involved, if it is the bones near them that are affected. The affections least harmful to the animal, then, are those of the nasal bones, and for this reason these are not as hard or thick as the more important bones. Because of this difference the cheekbones [the maxillae] with good reason have a special boundary, those of the nose another special boundary, and so do the others, both those [*ossa zygomatica*] above the cheeks, that at the point of the jaw,[59] and those at the openings from the nose into the mouth.[60]

The longitudinal suture in each jaw has been formed because the body is double, with a right and a left side. I have often spoken of the usefulness of this, but the suture is not apparent in the densest bones, such as the occipital and frontal bones, the bone of the palate [*ossa sphenoidale* and *palatina*] and that at the point of the jaw [the premaxilla]. This is the source, I think, of the controversy among anatomists over these bones, some declaring them to be completely devoid of sutures and others saying that on account of the exactness and density of their junction the sutures are not apparent, but that

[59] The premaxilla, present in the ape. See Sullivan (1933, *45–51*).

[60] The various components of the boundaries of the choanae (the different parts of the sphenoid, and the vomer and palatine bones) are not distinguished.

when the bones are boiled and dried out for a long time, they become distinct. I have spoken in greater detail about these disagreements in other works of mine.[61] What both sides agree on, however, is sufficient for this present discussion, namely, that each of these bones is exceedingly hard. If, then, we find the usefulness of this, it
[II, 178] will no longer be at all difficult to find the reason for the number of bones.

They are very hard because, lying exposed in front of everything, they were constructed for resistance to injury and because they are exempt from the cause which operated when the bones at the top of the head were made loose-textured and full of spongelike pores. For

[61] See *De ossibus ad tirones*, cap. 6 (Kühn, II, 754); *De anat. admin.*, IV, 4 (Kühn, II, *439–440;* Galen [1956, *102*]), X (Galen [1906, II, *49–50;* 1962, *54–55*]). There are other references to the dual nature of the lower jaw in chapters 18 and 20 of this Book. Perhaps the "controversy" was also discussed in the lost treatise *On All Disagreement in Dissection.* The Galenic view, that the lower jaw is composed of two bones joined so closely together that the suture becomes visible only after long boiling, persisted until the time of Vesalius, who (1543, *44*) declared, "In man, however, [the lower jaw] is formed from a single bone, and at the point of the chin it is broad, not sharp as in other animals. In fact, no part of the jaw is more difficult to cut through than this. Furthermore, I have not yet observed that it is separated by cooking or by decay underground. And although particularly in the Cemetery of the Innocents at Paris but elsewhere as well . . . I have inspected large numbers of lower jaws, I have never found one divided into two parts" (*Homini autem, unico conformatur osse, ac in summo mente lata, neque ut in caeteris animalibus, acuta cernitur. Nulla enim parte maxilla difficilius quam hic discinditur. Praeterea coctione, aut carie in terra illam dissolvi, nondum animadverti. & quamquam cum alibi, tum praecipue Parisijs in Innocentum cemiterio maximam inferiorum maxillarum . . . frequentiam conspexerim, nullam tamen unquam in duas bipartitam partes adinveni*).

This assertion was one of those challenged by Sylvius (1555, *82–83*), who maintained that the suture, though concealed by excrescences of the bones, is nevertheless present. For an excellent review of the history of the whole controversy, see Artelt (1955).

Galen's position was of course to some extent defensible, for he had in all probability seen the mandibular symphysis unossified either in ruminants or in the young of other animals (see Ellenberger and Baum [1926, *76*]), and if he ever had the opportunity to examine a late human abortus or a stillborn infant, his opinion could only be strengthened. See also Singer (in Galen [1956, *246*]).

most of the vapors from the whole body pass up to these bones which lie in the highest position, and therefore, as I have shown before, Nature has used them to procure a varied evacuation. The bones placed laterally, besides being relieved of such a cause, must also often be in trouble when we fall, are struck, or are hurt in some other way [and thus should be thicker]. For it is not easy for a person to fall on the crown of his head, nor is he readily struck in this region,[63] whereas all the other bones—the occipital, frontal, and the bones at the ears—are continually receiving blows and often suffer in falls. Thus when the former were not apt to be struck in this way and needed [to be used for] evacuation, while the latter were apt to be continually receiving blows and did not need [to be used for] evacuation, there was good reason for the former to be made loose-textured and full of spongelike pores and the latter dense and hard.

Again, the bone of the palate [*ossa sphenoidale* and *palatina*] lies like a wedge between the head and the upper jaw and also contains the openings[64] of the canals purifying the encephalon; besides, it lies underneath at the base of the whole head, as the part of the bone of the occiput that is continuous with it does too. For all these reasons it was made dense and hard, and perhaps there was good reason to [II, 179] have made it so for its own sake[64] as well. For because it is one of the bones at the base of the head which need to be hard and because, if it had been made porous, it would easily putrefy and become gangrenous at certain times when the residues from above were flowing down through it, it has therefore been made hard and dense; and this in addition to the fact that it lies between the upper jaw and the head and so needs to be strong. The outgrowths from it of the bones like wings [the pterygoid processes] were made to provide a base

[63] "Galen," says Daremberg (in Galen [1854, I, 703]) in his comment on this passage, "prefers to deny the frequency of blows on the top of the head rather than to let it be supposed that there is any want of foresight on the part of Nature, but perhaps that Nature of his, though so wise, did not foresee the blows of either a sabre or a bludgeon! Galen would no doubt answer that it is our barbarity that is to blame, but that Nature could not foresee the wickedness of men, since *natural* blows on the top of the head are rare."

[64] See notes 2 and 7 of Book IX.

[64] Reading δι' ἑαυτὸ with Helmreich for the δι' ἓν αὐτῶν of Kühn's text.

and protection for the muscles [*pterygoidei*] at the sides of the mouth; for the heads of these muscles are attached to the concavities bounded by those wings. Since this is the state of affairs, irrespective of whether these parts of the bones are really without sutures or the sutures are invisible because of the accuracy of the junctions, I have at least shown clearly the necessity for them to be hard and dense. For this reason they should not be closely united with the loose-textured bones lying next them, and so their junctions with these were made distinct; and besides, in many places these fulfill other uses of which I have spoken before, being made for the sake of the instruments [blood vessels and nerves] passing through them, of a close connection, of the transpiration of the residues, or of resistance to injury.

20. There are two bones [*ossa parietalia*] called the bones of the bregma; these are porous, lie at the top of the head, and are everywhere surrounded by hard, dense bones. From the bone of the occiput at the rear, the bone of the forehead at the front, and the temporal bones at the sides, they are with very good reason marked
[II, 180] off by lines [the sutures]. In addition to these there is a seventh bone, that of the palate [*ossa sphenoidale* and *palatina*], which some consider a bone of the upper jaw, while others consider it a bone of the head, since it lies between them like a wedge. The number of the other bones of the upper jaw is nine in all: the two bones of the nose;[65] a third in front of these [the premaxilla], which I have said[66] contains the incisors; the two cheekbones [the maxillae], one on each side, in which lie all the rest of the teeth; above these the two [*ossa zygomatica*] at the anterior outgrowths of the arches and below the sockets of the eyes; and the remaining two at the openings from the nose into the mouth. Since I have spoken before in my anatomical commentaries[67] about the lines bounding each of these bones, I need say nothing further; for I have planned the whole course of my narrative for those who already know what is to be seen in dissection.

The bone of the lower jaw has only one division in it, and that not at all clear, at the point of the chin, a division which I have said was

[65] The nasal bones, of course, but the other components forming the nasal cavities are not distinguished.

[66] In *De ossibus ad tirones*, cap. 4 (Kühn, II, 750).

[67] *De ossibus ad tirones*, capp. 1–4 (Kühn, II, 739–752).

made there because the body is double. All the rest of it on either side has no line of division, Nature being careful, I suppose, not to break up the lower jaw into many bones, in order to prevent its coming apart easily and being shattered in more vigorous movements. Of course the movements of this jaw in biting and in breaking up hard substances must be great and strong, and for this reason Nature has also provided very carefully for its articulations. Around [II, 181] one of them, the so-called corone [the coronoid process], she has placed the zygomatic arch and has inserted into it the very large tendon of the temporal muscle; around the other [the condyle] she has placed as a defense the outgrowths of the head called mastoid, so that in violent movements it may never slip away from the adjacent cavity. And there is good reason why this bone has its articulation at the rear and the corone extends straight up. For the corone together with the temporal muscle, which pulls the whole jaw up, is the means whereby the mouth is closed, whereas it is opened by the articulation [of the condyle with the temporal bone] behind at the mastoid outgrowths and by the muscles [*digastrici*] moving this, which I have said are placed in opposition to the temporal muscles. Of course the diarthrosis itself is surrounded by certain strong ligaments, and there is also a great deal of cartilage poured around it; you who have once heard the things that are common to all articulations should remind yourselves of them in each particular instance.

I suppose I ought to guard against talking about the same things over and over, but certainly my readers ought not to shrink, any more than Nature does, from reflecting on them. For in her works and in her cogitations it is fitting that nothing should be omitted, but in explanations once is enough to make a general statement. Accordingly, having already told how many things Nature has devised for all the diarthroses and intending, as I do, to speak of them in the [II, 182] following book, I consider it just to omit them for the time being. It would be fitting for you, however, to scrutinize each joint in the dissection itself to see whether it appears to have all the things I have said it needs. For you will admire Nature most if you leave not one of her works unexamined.

THE TWELFTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Head and Spine]

1. Since I have spoken of all the parts belonging especially to the head, I ought to tell next about those it has in common with the neck. The parts that are common to the neck and head are those by which we incline and raise the head and move it from side to side. Now no such movements are possible without a diarthrosis, ligaments, and muscles. But a diarthrosis is a junction of bones that has been made for the sake of voluntary motion, and it is evident that there must absolutely be no less than two bones being joined together, and that each of the ligaments and each of the muscles growing out from one of them must be inserted into the other. From this it is also evident that every diarthrosis, every ligament, and every muscle are concerned in the joining of the members together, and that they are properly reckoned to be common parts.

[II, 183] 2. Well, then, I have often shown that no movement of bones can take place unless they are articulated and joined together with muscles, if it is true that there must necessarily be one member that moves and another that is moved, the first of these being a muscle and the other the junction of the bones. In what precedes I have already said that the ligament is not without a use (for even if it is not necessary for the production of the movement itself, it is at least useful in making the movement correct), but I shall mention it now as a main point in my discourse; that is to say, if the articulating bones were not strengthened by ligaments, there would be nothing to keep them from being displaced from their proper situation in every movement and turned now to one side and now to the other. To prevent anything of the sort from happening, Nature surrounds every diarthrosis of bones on all sides with ligaments which are

strong, indeed, but which also permit a considerable degree of relaxation.

So one would certainly admire this first work of hers, particularly because she has invented a substance [for them] that is suitable for widely different uses. For in order that the articulating bones may be bound and held together accurately and may not be easily torn away from one another in vigorous movements, the ligament must be made as hard and resistant to injury as possible, but again, in order that it may readily follow the motions of the bones when the muscles pull on them, it must be soft and consequently weak. And of course strength and weakness are opposites, and so are hardness and [II, 184] softness. Hence from dissection itself you can learn how skillful in these matters Nature was when she invented a substance which has both advantages to a sufficient degree and also escapes injury. For you will see that every ligament is hard enough to bind [the bones] securely together without hindering their movement and soft enough not to be easily crushed or broken off. Now here is something you hear Hippocrates[1] saying "Whenever a person has too much nourishing moisture soaking the bodies around his joints, the heads of the members are easily dislocated." I suppose, too, that you are not unaware of those persons who are bent over because these bodies are so hard, since you see daily how they are hindered in their movements. In the normal state, however, the elements around the joints and particularly the tendons and ligaments are exactly proportioned for ease of movement and protection against injury.

Now everybody knows that we must admire the perfect skill displayed in those works in which the balance is so fine that if you add or subtract the least detail you ruin the whole thing. A work in the creation of which there is enough latitude is attempted even by the unskilled, but one that is very close, with no latitude, needs no chance cleverness and no little experience. Hence when Hippo- [II, 185] crates[2] had said that the medical art[3] itself is long, he added, "The time is short," because, if it were not short but had sufficient

[1] *De articulis*, cap. 8 (Littré, IV, *94–97*). Galen gives only a loose paraphrase, not a direct quotation of Hippocrates, who merely says that there are many persons of such a moist constitution that they can dislocate and restore their own joints easily and without pain.

[2] *Aphorismi*, sectio I, 1 (Littré, IV, *458*, *459*).

[3] Kühn's text omits τέχνη.

latitude, he would not have said that the art was long. So too in every creative art, the fineness of the balance is an indication of accuracy, and one can see this accuracy [4] in the bodies of animals not only in the ligaments but in all the other parts as well. There are three of these simple substances needed in the present discussion, cartilage, ligament, and nerve, the cartilage being harder, the nerve softer, and the ligament midway between the two [in consistency]. Nature has made marvelous use of each one in all the parts of the animal, never putting nerve or ligament in the place of cartilage, or cartilage or nerve in the place of ligament, or ligament or cartilage in the place of nerve. For I have shown earlier that hardness is not suitable for sensation, nor softness for motion.

3. It is not through nerves alone, then, that a part is moved, nor through cartilages or ligaments alone. Cartilage serves the purpose of a grease for the joints, but if it were attached to instruments of motion, its weight would be a superfluous burden, just as if a stone had been suspended from them. A nerve is sensitive in proportion to its softness, but it is too weak to move or transport the whole member. And a ligament, being midway between the two, is capable of binding the members safely together without preventing their
[II, 186] movements, but it certainly cannot itself be an instrument of motion, because it takes its rise not from the source moving the animal, as the nerves do, but from bone. Now I have shown that the mass of such a source must be soft, but nothing perfectly hard can grow from a soft body, and nothing soft from a hard one.

Constrained by these necessities, Nature could not use ligaments alone for voluntary motion because, not being attached to the place that contains the directing principle of the soul, they have no share in either sensation or motion; and neither could she use nerves alone because their softness makes them incapable of transporting such great weights. Properly, then, wherever a member needs only to be attached, there is only a ligament; wherever it needs only sensation, there is only a nerve; and in members useful for voluntary motion there are both, the nerve conveying the command of the reasoning power and contributing the principle of motion, and the ligament providing the nerve with the strength to raise the members to be moved. Thus it was necessary to create an instrument of motion that

[4] Or perhaps, "this fineness of balance"; the Greek admits either interpretation.

should be blended of both, that should certainly be harder than a nerve and softer than a ligament, that should have less sensation than a nerve and more than a ligament, and that should occupy a middle ground between strength and weakness, and the other opposites which are found in ligaments and nerves, because it shares in the nature of each of the two materials producing it and does not have perfectly either nature alone and unmixed but is blended of both. [II, 187]

Of course one thing cannot be completely blended with another unless it is first broken into small pieces. Hence both [nerve and ligament] had to be divided into slender fibers and then these had to be joined with one another in order to produce a substance midway between their own, the substance of an instrument of motion. But if [Nature] did only this without filling the spaces between them with a soft substance like a cushion to serve as a safe foundation for the fibers, it would not be possible even for a short time to keep them unbruised and unbroken. Accordingly, Nature, wise in all things, has placed this cushioning, which is itself not without its uses, all around the fibers as a protection from the cold and heat, and a covering very like felt,[5] and in addition she has provided [in it] wonderful bedding and wrapping for the arteries and veins. I told you about this in the very first book, saying that we give the name of flesh to that which renders these services to animals and that it is a remedy for heat and cold, even though these are opposites. And again in my book *On the Movement of the Muscles*[6] I have already told how the nerves and ligaments are resolved into fibers, how simple flesh is mingled with them, and how, when the fibers come together again and are blended, the thing that results from their sum becomes a tendon and everything taken together becomes the muscle. I have just now spoken too of the usefulness of producing a tendon and a muscle; for [II, 188] a tendon is the principal instrument itself of motion. The muscle is formed for the sake of producing it and provides the uses of composite flesh, which becomes soft bedding for the animal when it falls or lies down in some other way, a covering very like felt when it is struck, a protection when it is wounded, warmth when it is cold, and coolness when it is warm. Indeed what else is there besides flesh which lies in front of all the important parts and is exposed to every

[5] An echo of Plato; see chapter 13 of Book I.

[6] *De motu musculorum*, I, 1–2 (Kühn, IV, *368–376*), and see also note 36 of Book I.

injury? Thus Nature derives benefit from everything and adorns and protects the animal.

These general statements about the usefulness of ligaments, tendons, and muscles have been written as prefatory matter in this particular book of the whole discourse, because I have given in preceding books sufficient explanations of the nature of the nerves and their source and usefulness. Moreover, the discussion I have just completed applies to the most important joint of all,[1] and so let no one complain this time because I made a general statement about this matter. I have already said many times that I make a common explanation completely in one place once for all and remind you of it in particular instances in order that I may finish the whole work as quickly as possible. So too I have earlier explained sufficiently that some muscles end in one large tendon whereas others arrive at the
[II, 189] members as fleshy parts, moving them of course by many small tendons, and in this I not only made a common, general statement, but also added particular examples.

4. Well, then, bringing the discussion back to the joint of the head, which was the subject proposed in the beginning, let us observe the skill of Nature displayed in it; for it was proper, I suppose, for this also, like all the other parts, to be ordered according to its worth. This joint is so important for the animal that it is the only one of them all that cannot endure for a moment even a chance displacement, not to mention a serious dislocation. In fact, the animal is instantly deprived of all respiration, voice, motion, and sensation, because the root itself of the nerves has been affected. Now the source of the nerves is the encephalon, the rational soul being sowed in it as in a fertile field. The outgrowth from it of the spinal medulla, like a trunk stretching up into a great tree, a trunk that extends the whole length of the spine, gives off a very large number of nerves like branches dividing into countless offshoots, and so the whole body receives through these first and foremost its share of motion and afterward its share of sensation. How the nerves are distributed
[II, 190] will be explained in a later book.

The joint of the head, containing within it, as it does, the root of all the nerves moving the lower part of the animal, has properly the safest construction of all. This safety comes from the thickness of

[1] That is, the articulation of the vertebral column with the cranium.

the ligaments, the large number of muscles, and the very accuracy with which the bones are joined. They are bound together by three very strong ligaments, the first of which, the largest, is flat and surrounds circularly the whole diarthrosis.[8] The other two are moderately rounded like nerves; one of them joins the extremity of the elongate outgrowth [the odontoid process] of the second vertebra [epistropheus] to the [occipital] bone of the head, and the other, cutting across the first at right angles, extends transversely from the right side of the first vertebra [atlas] to the left.[9] On the posterior parts alone lie eight muscles[10] which both protect and move the diarthrosis. The form of the bones themselves and the accuracy with which they are joined are marvelous, even if you are only looking at them; but if besides looking you consider the usefulness of each of their parts, you will both marvel at the skill of our Creator and sing the praises of his foresight.

Since the whole head had to have two kinds of movements, one inclining and raising it, the other turning it from side to side, it was necessary either to make the diarthrosis double or to produce one straight movement by combining two simple, oblique ones, as I showed when I was discussing the hands, wrists, and many other parts. That for those parts it was better so[11] I have shown earlier, but I shall tell in this book that it was not better in the case of the head and remind you here once more that there are movements of some parts where it was not desirable to make a straight movement from [two] oblique. Indeed, it is proper to explain those works of Nature in particular in which she seems mindful of the similarity of uses. For when she appears never to construct differently parts needing the same sort of motion but always makes them in the same [II, 191]

[8] The two articular capsules and the atlantoöccipital membranes, not distinguished from one another. See Daremberg's note (in Galen [1856, II, 9]) on this passage, and see also Ellenberger and Baum (1926, 59).

[9] The first of the rounded ligaments is the apical odontoid ligament, perhaps reinforced by the superior crus of the transverse ligament of atlas, and the other is the transverse ligament itself. It may be noted that the description is probably not based on conditions in the rhesus monkey, where a strong apical ligament is lacking. See Sullivan (1933, 60–61).

[10] To be discussed in chapter 8.

[11] That is to say, it was better for them if their straight movements were the resultants of pairs of oblique movements.

way, it is clear that she has provided carefully for both analogy and justice. So when is it better to make one straight movement from two oblique? When there is little difference between the oblique ones and the straight. And when is it not better? When it is necessary to turn the part farther in each direction; for then it is better for the straight movement to be strong. Thus, if it were possible, Nature would always make straight movements from oblique, because of course she wishes to provide the largest number of actions for the animal by means of the smallest number of instruments. But two oblique movements cannot make a straight movement vigorous if they are [greatly] inclined away from it. Hence in the case of the head it was not better to construct the straight movements from oblique; it was, in fact, preferable to make separate muscles and diarthroses for each kind. Accordingly, two diarthroses were pro-
[II, 192] duced, and the muscles moving them are of two kinds, each kind being composed of two classes. I say that there are two kinds of movements, straight and oblique, and two classes in each kind, extension and flexion for the straight movements and rotation to the left and to the right for the oblique. As a result, there had to be four classes of muscles moving the head, in order that [12] some might raise and others incline it, and that some might rotate it to the right and others to the left.[13]

5. Let us, then, beginning with the diarthroses, tell now how marvelously Nature has constructed all these things. In the first vertebra [atlas] she has placed two concavities [the superior articular facets] corresponding exactly to the convexities [the condyles of the occipital bone] of the head found in that region. One of them lies on the right side, the other on the left, just as the prominences on the head itself do too. Hence it is immediately clear that Nature has prepared these concavities and protuberances for lateral movements in both directions.[14] For if she had created them for the sake of the

[12] Kühn omits the *ἵν'* found here in Helmreich's text and keeps the verbs that follow in the indicative mode.

[13] It will be increasingly evident to the reader as he goes on that the neat theory of the movements of the head fails to fit the facts. The actions ascribed to the articulations and the various muscles are either wrong or, as Daremberg puts it, "exaggerated or incompletely described." See Daremberg (in Galen [1856, II, *11* note *1*, *22* note *1*]).

[14] Galen is wrong. Though slight lateral movement is permitted in this joint, its chief movement occurs in the nodding of the head.

straight movements, she certainly would have placed one of them in front and the other behind. Though there was only one kind of diarthrosis and motion still remaining, this could not be made at the same vertebra to which the lateral movements had already been entrusted. For just as I have shown that in the case of the ulna and radius a double diarthrosis was made at the elbow for the sake of two kinds of motion because there too it was better for the oblique [II, 193] movement to be very far removed from the straight, so we find the same situation here. Pay closer attention to my discourse and you will learn the whole matter thoroughly.

When it is better for the oblique movements to be very far removed from the straight, one of two things becomes necessary: either there must be two diarthroses, or there must be a single one that is sufficiently loose and is rounded on all sides. For the joint to rotate easily in every direction it must be formed alike on all sides, because, if one part has more than its just share of eminence or concavity, it will check and destroy some one of the movements of one kind. Thus the joints at the shoulder and hip have been made both perfectly round and also loose, and for this reason the upper arm and leg can be moved around in all directions by the muscles surrounding the diarthroses, though this is true of the arm to a greater degree than of the leg. For the hand is produced at the end of the former member and the foot at the end of the latter, the one an instrument of prehension and the other of walking, so that diversity of motion is more characteristic of one and safety in walking of the other. Hence not only has the shoulder joint been made looser than the hip joint and surrounded by weaker muscles and slenderer ligaments; it also has a shallow concavity, whereas that at the hip joint is deep. For the same reason Nature has made in the hip joint a very strong, rounded ligament [*ligamentum teres*] ex- [II, 194] tending from the head of the femur to the middle of the acetabulum, but she has not done so in the shoulder joint, which she has constructed rather for ease and great diversity of movement. This is the reason why of all the joints the one at the shoulder most frequently suffers dislocation; it is not that Nature failed to recognize this, but that, as I have already said earlier, times without number, when safety of construction and diversity of movement are in conflict, she chooses what is the more useful for each joint. For the arm a construction permitting easy movement is the more useful, but the

joint of the head does not tolerate being dislocated, because it is a most important joint and [if dislocated] kills the animal instantly. Otherwise, Nature would certainly not have grudged it diversity of movement, for of course it would not be a bad thing if the head turned far enough in both directions so that we could see things not only beside but behind us. Such easy motion, however, could not be produced unless the diarthrosis was very loose, and accordingly Nature chose to bestow a little safe motion on the head rather than varied motion that was not safe. Hence she created a joint that was not simple and loose but double and tight.

6. Since this is the state of things and I have shown that the joint of the head must be made double, it is now time for you to see whether it was better for the head to move laterally at the first vertebra and straight at the second, as it actually does, or for these
[II, 195] [joints] to be constructed the other way, so that the head would be extended and flexed at the first vertebra and moved laterally at the second. At this point I should like to have reasoning with me one of the clever accusers of Nature who, when they are asked if they can conceive of any better construction for a part, are unable in most cases to think up anything clever even in a small detail and who, when sometimes they do attempt to speak, become utterly ridiculous. I should like one of them to talk with me, in order that when I interrogate him now, he may in the same way make some answer about this proposed choice. For perhaps I, being a devoted friend of Nature's, might seem to be neglecting some better construction, and to test her I should use not myself, but those who are waging implacable war on her. Since, however, I cannot make them answer in the book, my readers can lay it aside, inquire of them what they say, and learn to which of the two vertebrae it was better to entrust the diarthrosis of the head and its lateral movement. As for me, I shall show that the first vertebra is preferable, and with reasons that are not specious like the ones used by those inveighing against Nature, but scientific and all but geometrical I shall compel even those who are unwilling to praise her to change their ideas now for
[II, 196] the better, that is, if their souls as well as their faces [15] are human and they have minds, however small. Indeed, no auditor distresses me so

[15] Reading *πρόσωπον* with Helmreich for the *σῶμα* of Kühn's text. The order of the sentence also varies slightly in the two versions.

much as the one who does not follow what I say, since of those who do understand I do not know of one who has ever gone away accusing Nature of any lack of skill.

Well then, just as in the discourses of the mysteries the uninitiated are bidden to close the portals of their ears,[16] so I too, who am inducting not into human ordinances, but into the veriest mysteries of the truth itself, bid those not initiated in the methods of demonstration to close the portals of their ears; for asses would learn the lyre sooner than those people would comprehend the truth of what is said here. And though I realize that very few indeed will follow my discourse, still, for the sake of those few, I have not hesitated to deliver even to the uninitiated my mystic sayings. The book will not judge or determine the worth of the one who reads it and will not escape from the stupid and place itself in the hands of the learned.[17] Even our Creator, though knowing perfectly the ingratitude of such men as these, has yet created them.[18] The sun makes the seasons of the year and perfects the fruits without paying any heed, I suppose, to Diagoras,[19] Anaxagoras, Epicurus, or the others blaspheming against it.[20] No beneficent being bears malice over anything, but naturally aids and adorns all. So too, though I am not unaware that [II, 197] times without number this book will be treated spitefully and abused by foolish and ignorant men, like an orphan fallen into the hands of drunkards, I am nevertheless undertaking to write it for the sake of

[16] See Daremberg's note (in Galen [1856, II, *14–15*]) on this passage, explaining the allusion and defending the text against the charge of corruption. For another allusion to initiation into the mysteries, see chapter 14 of Book VII.

[17] Reading *οὐ γὰρ δὴ κρινεῖ γε τὸ βιβλίον οὐδὲ διαγνώσεται τὸν ἀναγνωσόμενον οὐδὲ τὸν μὲν σκαιὸν διαδράσεται*, etc., with Helmreich for the *οὐ γὰρ διακρινεῖ γε τὸ βιβλίον, οὐδὲ διαγνώσεται τῶν σκαιῶν οὐδείς, καὶ εἰ διαδράσεται*, etc., of Kühn's text.

[18] Daremberg (in Galen [1856, II, *15*]) unkindly remarks, "Galen with his habitual modesty is comparing himself to the Creator."

[19] Presumably Diagoras of Melos, the Greek sophist called the Atheist, who flourished in the late fifth century B.C. See Diels (1956, I, *385*; II, *86*, *257*, *261*). Daremberg suggests that Galen doubtless wrote "Protagoras" rather than "Anaxagoras"; for Anaxagoras acknowledged a Creative Spirit and Protagoras did not. See Diels (1956, II, *37–40*, *265*).

[20] "For he maketh his sun to rise on the evil and on the good, and sendeth rain on the just and on the unjust" (Matt. 5:45).

those few who are capable of reading and understanding it correctly and judging what is said.[21]

7. Certainly it is to these men I am speaking now as I take up my discourse again and say that since each vertebra surrounds circularly the spinal medulla, which has that great and wonderful power of which I have often spoken, the diarthroses of the head with the first vertebrae and of the other vertebrae with one another cannot possibly be made loose. Hence here you must not look for huge, perfectly rounded concavities, spherical heads, slender ligaments, weak muscles, and a simple diarthrosis. Now if the diarthrosis must be double—for it is at this point that my discourse digressed—I was right when I said that in the first vertebra Nature made two concavities [the superior articular facets of atlas], one on each side,[22] embracing the convexities [the occipital condyles] of the head, and an elongate outgrowth [the odontoid process, dens] extending up from the second vertebra and attached to the head by a very strong ligament [the apical ligament (with the superior crus of the transverse ligament?)]. By means of this outgrowth the head is meant to be inclined and raised, and by the joints at the first vertebra it is to be moved laterally. Here you must become a natural philosopher and an anatomist, and when you have seen the diarthroses of which I
[II, 198] have spoken, you must ponder in your own mind the question whether it is possible for the whole head to be rotated laterally if the eminences of the head and the concavities lying beneath them do not touch one another; for if this is impossible and if it is absolutely essential in these diarthroses for the bone of the head to be in contact with those lying beneath it, it follows of necessity that it is the first vertebra with which the contact must be made.

How, then, will the second diarthrosis that controls the straight movements be given a construction no less safe than this one? How else, indeed, than as it actually is? For the second vertebra [epistropheus] has a long, strong outgrowth [the odontoid process, dens] stretching up toward the head, but bound to it by a strong.

[21] In Kühn's text the break between chapters 6 and 7 comes after *αὖθ* : *τὸν λόγον* in the first sentence of chapter 7 of Helmreich's text.

[22] Again Helmreich's recension has solved an awkward passage, which in Kühn's text demanded the interpretation that Galen described two odontoid processes, "one on each side" of epistropheus. Cf. Daremberg's note (in Galen [1856, II, *16–17*]).

round ligament before it could touch it. The outgrowth is called *pyrenoid* (like a fruit stone) by the younger physicians; the Ancients and Hippocrates [23] too called it the tooth (dens). The upper end of it goes up along the inner side of the anterior parts of the first vertebra, and so, since it would touch the spinal medulla at this point and compress and bruise it, especially in movements, Nature has devised a twofold remedy to prevent any such injury: she hollowed out the part of the first vertebra in this region, placed the dens upon it, and around the dens on the outside she placed a strong, transverse ligament, which separates it from the spinal medula and holds it in the cavity of the first vertebra. And if you suppose this ligament to [II, 199] be destroyed, you will not find for the spinal medulla any other protection that is better. The cavity of the first vertebra alone is not capable of holding the dens within itself in all movements if it is unaided by the encircling ligament, but even if this should be granted as a premise, the compression and bruising of the spinal medulla would not [thus] be avoided. For as things are, the intervening ligament deadens the force exerted by the *pyrenoid* outgrowth and becomes a bulwark for the spinal medulla, but in the other case,[24] there would be nothing to prevent the spinal medulla from being completely crushed when the uncovered bone, constantly liable to slip, would fall upon it. Surely it is just to praise the arrangement whereby the dens grows off from the anterior parts of the second vertebra and goes up along the inner side of the anterior parts of the first vertebra; for this place is safer than the posterior region and so the spinal medulla is less liable to be disturbed.

It is clear, then, from these things not only that the first vertebra had to be joined to the bone of the head by a diarthrosis but that the second vertebra must also be joined to the first. Manifestly, if they had grown together, they would of course hinder one another in their movements, the one at rest always resisting and holding back the one that was acting. As it is, however, each in turn is able to perform its own movement while the other remains in place. Since, then, it was better for the first [two] vertebrae to be joined by a separate diarthrosis, Nature has given them what is certainly the most suitable form of articulation. Well, what form is the most [II, 200]

[23] *De morbis vulgaribus*, II, sectio II, 24 (Littré, V, *96*, *97*).

[24] That is, if there were no transverse ligament.

suitable? To me it seems that not even a lunatic would mention any other than the one they now have. Beneath the concavities [the superior articular facets] which are situated on the upper side of the first vertebra and by which it receives the eminences of the head [the occipital condyles], lie other concavities [the inferior articular facets] on the lower side that are very similar [in the ape] and that enclose the convexities of the second vertebra [the superior articular facets of epistropheus]. Thanks to these concavities, the connection of the second vertebra with the head, the work of which is to incline and raise the head, is not interfered with at all by the first vertebra, although this connection is situated in the midst of the first vertebra, and neither is the other, lateral movement, which is accomplished by the diarthrosis of the first vertebra [with the head] hindered by the second vertebra.

Perhaps it might not seem marvelous that four concavities were made in the first vertebra or that two were placed on the upper side of it and two on the lower. Perhaps there might be someone who would not marvel that they were placed on both sides, some on the right and others on the left, though all these were useful things to have done. And perhaps he would not marvel that the concavities are exactly as large as the eminences and would say that this was not a mark of skill, being done accidentally and not as a result of the providence of the Creator. Yet if the concavities were larger, they would at once make the joint loose and liable to slip, and if they had been made smaller, they would make it hard to move, because it would be straitened. Moreover, that the upper concavities are far-
[II, 201] ther apart and the lower ones not so far, and that the distance between each pair is exactly as great as that between the convexities which they receive—let this too, if you will, be the work of chance! The outer [lateral] rims of the concavities have been made higher and turned toward the space within the concavities, whereas the inner [medial] rims are lower and have an outlet, as it were, toward the space outside,[25] a state of affairs which I for my part would never grant had been so marvelously produced just by chance. For it is clear that when Nature was providing for the conformation of the parts, she contrived a form such as this for the concavities, so that in more vigorous movements the convexities entering them may not

[25] Reading ἐκτος with Helmreich for the ἐντος of Kühn's text.

escape toward the outer sides even if they should sometimes slip aside a little, and so that the whole diarthrosis may be very safe.

As for the odontoid process and the space in the first vertebra that receives it, how could anyone suspect that these were made accidentally? But even granted that they were, at least I think that nobody in his senses considers the ligaments—either the [apical] one joining the end of the ascending outgrowth [the dens] to the head or the [transverse] one binding the dens and protecting the spinal medulla—to be the work of chance rather than skill. And as for the facts that although there are twenty-four vertebrae in the whole spine, no such ligaments have been made in any of the others, and that even in this one they were made nowhere except in the place where they are useful, I do not suppose that anyone would dare say that these were accidental. What shall I say of the outgrowths of all the vertebrae and their foramina? To me, indeed, these seem the [II, 202] result not only of skill, but of a marvelous providence. This is not the proper time, however, to explain them; for I have undertaken not just to speak of the spine and vertebrae, but to teach you the movements of the head, and these have been found to be performed by the diarthroses at the first and second vertebrae. Hence these are the only ones I must explain now, and if there is proof of greater wisdom in the entire construction of these vertebrae and of the spine as a whole, I should put it off until the following book.

8. So let us go back to the matter in hand. I shall mention first my having told you that because of the excellence of the ligaments, the accuracy of the joints, and the strength of the large number of muscles moving them, the movements of the head are so wonderfully performed that nothing better or safer can be imagined, and I shall remind you also that two of my propositions have been demonstrated. For having spoken of the ligaments and the joints of the head, I shall now pass on to the third and last proposition and show Nature's skill in dealing with the muscles moving it. Then let us not omit here any part of their structure but explain what position each of them has, how large and strong it is, and how many of them there are in all; and let us show that here too there is nothing fruitless or defective, and in short that if anything were different, it could not [II, 203] possibly be better than it actually is. It would be best if the demonstration and explanations were made when the things to be seen were right before us, for no words can form an image of them as accurate

as can be gained by touch and sight. Since the materials for a demonstration are not at hand, the discourse will thus be more difficult, but I must try to make a beginning at some point and be as clear as I can.

There are more than twenty [26] muscles moving the head, and they are placed around it in a circle like a chorus, one having one action entrusted to it, and another, another. Eight of them are anterior, fourteen posterior, and they are diametrically opposite to one another. There are other muscles on each side, two on the right and two on the left, and these are also opposed to one another; their first and foremost action is to draw toward themselves the neck and along with it the whole head too. For I have already pointed out on countless occasions that Nature, who forms other things justly, has opposed to every muscle producing a movement another that performs a motion contrary to the first; in fact, if she did not do this, the movement would be defective or completely destroyed, because each muscle has a single action, a contraction upon itself. To begin
[II, 204] with, eight of the muscles inclining and raising the head are small and are placed around the joint at the rear; others larger than these are extended along the whole neck and by their first fibers subserve the movements of the head alone, which are made at the first and second vertebrae, the fibers that come next moving the remaining five vertebrae of the neck. Four [*recti capitis posteriores, majores* and *minores*] of the eight small muscles control a straight movement; they grow out from the the bone of the occiput a little above the diarthrosis and are inserted [*majores*] into the posterior outgrowth [the spinous process] of the second vertebra and [*minores*] into the adjacent part of the first vertebra.[27] Two [*obliqui capitis superiores*] of the remaining four grow out in the same way as those just mentioned from the bone of the occiput; they pass obliquely outward

[26] Reading εἴκοσι πλείους with Helmreich for the εἴκοσιν ὀκτὼ ἢ πλείους of Kühn's text.

[27] Note the reversal of the origins and insertions. The recti muscles are now said to *arise* from the vertebrae and be *inserted* into the occipital bone. The distinguishing of the smaller posterior recti muscles from the larger is one of Galen's achievements testifying to his great skill in dissection. Cf. *De anat. admin.*, IV, 7 (Kühn, II, *454–456;* Galen [1956, *110*]), and see Milne (1914, *396–397*).

[laterally], are inserted into the lateral outgrowths [the transverse processes] of the first vertebra, and produce the oblique movement of the whole head.[28] The other two [*obliqui capitis inferiores*], which connect the first vertebra with the second, are oblique and have a position opposite to that of the two previously mentioned and a contrary motion; for when the former [*obliqui capitis superiores*] hold the head in an oblique position against the first vertebra, in addition to the head [29] they also draw the second vertebra against it too, whereas the latter [*obliqui capitis inferiores*] return the head to its former, natural position, as its inclination becomes straight. Indeed, their situation is such that the two pairs of muscles which I said earlier are joined at the top, form a triangle [30] on either side. The three pairs of large muscles [31] (they may also be reckoned as four or two because of their interweaving, which I have set forth in my [II, 205] *Manual of Dissection*) [32] have the same motion as the so-called spinal muscles,[33] a motion which I shall explain a little farther on. By their first fibers, which are inserted into the first and second vertebrae, they move the head alone, but by their remaining fibers they move the other five vertebrae of the neck, and the head along with them. All these muscles raise the head, drawing it back, and the oblique muscles cause motions that are slightly oblique.

[28] Note again both the reversal of the origins and insertions and the errors and omissions in the assigning of the actions.

[29] Reading αὐτῇ with Helmreich for the αὐτῷ of Kühn's text.

[30] The suboccipital triangle; the two muscles "joined at the top" are rectus capitis posterior major and obliquus capitis superior, the third side of the triangle being formed by obliquus capitis inferior.

[31] Probably splenius capitis and semispinalis capitis (complexus), and perhaps also longissimus cervicis (transversalis cervicis). But see chapter 12 of this Book, *ad fin.*, where longissimus thoracis and spinalis thoracis seem to be included.

[32] *De anat. admin.*, IV, 6 (Kühn, II, *452–453;* Galen [1956, *108–109*]). Singer seems to be in error when he suggests that Galen is referring here to the suboccipital triangle, which is dealt with in the following (seventh) chapter.

[33] Apparently a term used by the anatomist Lycus, of whom, as we have seen, Galen had no very high opinion. See my Introduction and cf. *De anat. admin.*, IV, 6 (Kühn, II, *451–452;* Galen [1956, *108*]). These muscles are probably longissimus thoracis, spinalis thoracis, and their derivatives. See chapter 12 of this Book, *ad fin.*

The anterior muscles [84] that lie beneath the esophagus incline only the head itself with their first fibers, which are inserted into the first and second vertebrae, and at the same time they turn it to the sides with the oblique fibers, which have the outline characteristic of small muscles. Since with their remaining fibers they bend the neck, they also compel the whole head to bend along with it. The other six muscles [*sternocleidomastoideus*] [85] do not cause an inclination that is straight, as these do, but one that is slightly oblique at the same time that they bring the head forward. For they grow from behind and below the ears and extend to the sternum and clavicle; they are continuous with one another, so that even if we should speak differently and say that this is one muscle compounded of three, we should not be wrong. I have discussed all these muscles not only in my *Manual of Dissection* [86] but also in one other book, and, as I said
[II, 206] in the beginning,[87] anyone seeking to follow accurately what I am saying here should properly be trained first in those. There are four other muscles, very strong and large, that are placed two on each side, on the right and on the left; they move the neck laterally with a slight inclination, the anterior pair bending it forward and the other pair back. The anterior pair [*scalenus longus*] [88] arises from the pierced outgrowth [the transverse process] of the second vertebra and the other pair [*atlantoscapularis anterior*] [89] from the lateral protuberance [the transverse process] of the first.

I have now clearly expounded to you how many muscles there are, how large they are, where they are situated, and how they

[84] Probably longus capitis, longus colli, rectus capitis anterior, and rectus capitis lateralis, not distinguished from one another.

[85] In the ape this group is composed of three distinct members, sternomastoideus, cleidomastoideus, and cleido-occipitalis. See Howell and Straus (1933, *97*).

[86] In Books IV and V, *passim*.

[87] The "other book" is doubtless *De musc. diss.* Kühn, XVIII, pt. 2, *941–949;* Galen [1963, *481–483*]). No such statement is found, however, near the beginning of *De usu partium*. The two works are mentioned together in the third chapter of Book II, but the reader is not told to familiarize himself with them.

[88] Of the ape; not identical with any of the scalene muscles in man. See Howell and Straus (1933, *97*).

[89] Not found in man, but present in the ape; see Howell and Straus (1933, *119–120*). I cannot be certain about the identification of these two muscles since no insertions are mentioned.

move. In fact, nobody is so ignorant of reckoning as not to realize that there are more than twenty of them. On the one hand, it has, I suppose, been clearly stated that some of them are larger and others smaller, and on the other, anyone having his wits about him will be capable of observing that this necessarily follows from what has been said. For a muscle growing down [from the head] into the clavicle or sternum cannot possibly be small, just as those that lie upon the back of the articulation cannot be large. Thus all their positions and their actions as well are evident if one knows their origins and terminations, since action depends, as I have already said times without number, on how the fibers are placed and directed. I have also said that all muscles have fibers extending for the most part longitudinally and that fibers transverse or oblique in respect to the length of the whole muscle are rarely found. Hence if I say nothing [II, 207] definite about the fibers when we are discussing the position of a muscle, it must be considered that they are arranged in the way all the others usually are. And so there is nothing still remaining to be said about the construction of the muscles around [that is, moving] the head; their number, position, size, and motion have all been sufficiently explained.

9. Next let me point out once more my purpose in saying all these things, [namely, to show] that for the muscles moving the head we cannot possibly conceive of any other construction that would be better. Since the diarthrosis had to be very safe, since at the same time it was better for it to be moved very freely in every direction, and since I have shown that these requirements are mutually incompatible and that a joint constructed for safety performs few movements and those slight, whereas ease and variety of movement demand a loose articulation, first we must sing Nature's praises for choosing what is the more necessary, and then, because she has not completely neglected either requirement but has reconciled them by many contrivances, we must stand amazed at this work of hers and not merely praise it. The safety of the joints of the head has been secured by those means of which I have spoken, and the curtailment of movement that would necessarily result from this has been corrected by the number and size of the muscles and by the various ways they are placed. It is indeed clear to everyone that there are many large muscles; moreover, the fact that they have been put around the head on all sides shows the manifest variety of their

[II, 208] positions. Hence the head is not deprived of any movement; for you can easily incline it in any direction you wish by the action of the muscle in that region.

Now I shall explain that there is good reason for the head to have muscles differing widely in size. The posterior muscles [*recti capitis posteriores* and *obliqui capitis*] that raise the head are the smallest of all because they alone accurately cover the diarthrosis; for what the others round about them gain from being large comes to these from their advantageous position. Only one other pair of muscles has a position equally advantageous and a contrary motion as well, and that is the first portion [*recti capitis anteriores* and *laterales*] of the muscles lying beneath the esophagus. Just as the posterior muscles covering the articulation raise only the head, so the first portion of these muscles is formed to incline it, but the rest of them [*longus capitis* and *longus colli*] proceed as far as the fifth thoracic vertebra and perform the straight flexion of all the vertebrae over which they are stretched and, along with these, they also bend the whole head. Since of the eight small, posterior muscles, those [*obliqui capitis, superiores* and *inferiores*] that incline the head to the sides raise it straight up when they act in pairs but obliquely when one of them acts alone, since, too, the larger muscles [*splenius capitis, semispinalis* (*complexus*), and perhaps *longissimus cervicis* (*transversalis cervicis*)] lying upon these and extending all along the neck behave in the same way, and since it was therefore necessary to place some anterior muscles in opposition to these in order to perform oblique flexion, the six muscles [*sternocleidomastoideus*] reaching to the

[II, 209] clavicle and sternum were created capable both of inclining the head and of drawing it forward and around. So too, if one of the four muscles [*scalenus longus* and *atlantoscapularis*] bending the neck laterally acts alone, the whole[40] neck is inclined in that direction, but if the anterior pair acts, it bends the neck forward slightly without inclining it to either side. If the posterior pair acts, it raises the neck a little, but does not incline it to either side, and if all four muscles act together, the neck remains perfectly steady without an inclination in any direction.

Here too Nature has obviously not lost sight of what I have already demonstrated on countless occasions, namely, the construc-

[40] Kühn omits the *σύμπας* found in Helmreich's text, and in the next clause inserts *σύμπασα* not found in Helmreich's text.

tion of many instruments to serve one action, either because the movement is vigorous, or because it provides the animal with an important usefulness. Well, why should I need to say in this book particularly that the movement of the head is most useful to animals? It is also clear that because of the size of the part, muscles with strong actions are necessary. Indeed, this arrangement is almost peculiar to the head and none such is found in any other articulating bones; for nowhere else is there to be seen such a preponderance of one bone over the other as there is in the head and the first vertebrae. Certainly you would not say that the head was [only] twice, thrice, or even four or five times as large [as the vertebrae]; and yet, even if this were so, I should think it a great preponderance. But actually this is not the true relation, for each individual bone of the [II, 210] head is many times larger than either vertebra. Futhermore, there are sixteen [41] of these bones in all, not counting the lower jaw, and if this is added (as it should be, since it is a part of the head as a whole), it is impossible to estimate how many times the bones of the head taken together repeat the measure of either of the first [two] vertebrae. Now when a very large bone articulates with very small ones, all its muscles cannot possibly be inserted into one or the other of the small bones, but there is every necessity for all the muscles to be attached to the head and for not all, but only those that can, to be inserted into the first vertebrae. This was possible, I suppose, for those supplying the head either with its perfectly straight movements or with one of the movements that are slightly oblique. Hence there was good reason why not all the muscles moving it have been inserted into the first vertebrae, but only the small, posterior ones [*recti capitis, majores* and *minores; obliqui capitis, superiores* and *inferiores*], anteriorly the first part of the muscles lying under the esophagus [*recti capitis anteriores*], and at the sides the small muscles [*recti capitis laterales*] attaching the first vertebra to the head.

10. I think, then, that no one remembering how many parts must be placed in the neck would consider it necessary for the first vertebrae to have been made larger than they actually are; for [if they were larger] these alone would occupy all the space in that region, so that no room would be left for the esophagus or the parts [II, 211] of the larynx and rough artery [the trachea]. In fact, there are very

[41] Reading ἑκκαίδεκα with Helmreich and the manuscripts for the ἑπτακαίδεκα of Kühn's text. Cf. chapter 20 of Book XI.

many of these parts, all of which I have earlier described in detail, and each has the location most essential to it, which cannot be changed. But this is not the only reason why it was impossible to make the first vertebrae larger; there are many other, strong reasons as well, and I shall now explain each one of them to you. For when they have all been demonstrated and all the nature and usefulness of the spine has been recognized, you will see very clearly that this [choice of the proper size for atlas and epistropheus], which alone remains still in need of explanation, is also one of Nature's marvelous constructions. There is this to notice, that although the spinal muscles extend straight along the length of the spine, their fibers are oblique, and that Nature rarely does such a thing and [only] for the sake of some special usefulness; for generally the fibers of a muscle are very long and have a position extended [longitudinally]. We must, then, begin our story again at this point.

Nature has made the spine for animals to be like the keel [42] of the body that is necessary for their life; for it is thanks to the spine that we can walk erect and each of the other animals can walk in the posture that is the better one for it, as I have shown in the third book. She has, however, wished the spine to be useful not only for this. Just as her custom is always to work artistically and employ one
[II, 212] construction of a part for many uses at once, so it is in this instance too; first she scooped out the interior of all the vertebrae, preparing thus a suitable pathway for the portion of the encephalon that was to descend along it, and, secondly, she did not make the whole spine from one simple, uncompounded bone. And yet this was better for a safe foundation, since it could never be dislocated, wholly or partially, or suffer any other affection of the sort, if it were not so variously jointed. Indeed, if she were looking only for resistance to injury and did not have another, prior, more valuable aim in constructing each of the instruments, she would not have fashioned a spine that was other than simple and quite uncompounded; for if one were making an animal of stone or wood, he would not fashion it any differently, since it would be better to have a single support extending along the whole spine than a great many that were small and separated by joints. Then, too, it would be much better, I suppose, if the limbs were also made in the same way in animals

[42] See note 10 of Book III.

constructed of stone or wood, and if the whole body of such statues came from one stone, it would be much more resistant to injury than if it was composed of many parts. For an animal that was meant to make use of its members, however, to walk with its feet, grasp with its hands, and bend and straighten its back, it was not better that there should be only one bone in [each of] its feet or hands, or in its whole spine, and in this respect, certainly, an animal that makes [II, 213] many, varied movements is better constructed than one that moves with greater difficulty.[48] For if motion fails in any part of an animal, it seems to be no different, so far as that part is concerned, from one made of stone and so it is no longer an animal. Hence, since motion in particular is an essential characteristic of an animal and there can be no motion without joints, it was better for the animal to be composed of many parts.

But consider here the limit fixed for their number. Though the leg needs many parts, it does not forthwith need a thousand. Nature has a secondary aim, which shows the proper number for each member, and this is the resistance to injury of the whole instrument. Thus, as you yourself look impartially at each aim in turn, when you consider reasonably how necessary it is for the animal to move its parts in many different ways, you will blame Nature for making such large bones in the thigh and upper arm. On the other hand, when you turn back again to regard safety alone, you will think that the spine ought to be made of a single bone instead of the twenty and more that actually compose it. Nature, however, considers the aims not in turn, but always both together; in value action comes first and safety next after it, but for lasting health safety leads and action follows. If you are willing to look at things in this light, I intend to show at this time for the vertebrae of the spine, as I did earlier for [II, 214] the arms and legs, that no juster or more accurate blend of action and resistance to injury could possibly be imagined.

11. It needs, then, no further discussion [to establish] that if the whole spine were a single bone, that part of the animal would be without motion, as if transfixed by a spit or nailed to a stake; for this would not have escaped even us, I think, if we were standing in the place of Prometheus. But I shall presently explain to you a thing which neither you, nor I, nor any other man would yet have under-

[48] Helmreich omits the *οὕτως* found in Kühn's text.

stood, though of course it would not have passed unnoticed by Prometheus, namely, the reason why not two, or three, or four, or, in short, only a few vertebrae were made in the spine, but vertebrae as numerous and as variously associated with one another as they actually are. I shall show, indeed, that the total number of them has been determined most justly, that all the outgrowths, the junctions of the joints, the unions, the ligaments, and all the foramina have been marvelously constructed for both action and resistance to injury, and that if you change even some little detail in them or imagine that something is either added from without or destroyed, some action will straightway become defective or the part will be weakened.

I must begin my explanation with the part of the spine that is most important of all, that is, with the part they call the spinal medulla. Now nobody could say that this need not have been formed or that it
[II, 215] would be better if it had a location other than that along the spine or that this other location would be safer than the one where it actually is. If it had not been formed at all, one of two things would happen: either all parts of the animal below the head would be perfectly motionless, or it would be absolutely necessary to bring down a special nerve from the encephalon to each of them. If they became perfectly motionless, the thing would happen that I mentioned a little while ago, that is, the animal would no longer be an animal but would be like a creation made of stone or clay. And to bring down a small nerve from the encephalon to each part would be the work of a Creator utterly careless of the safety of the nerves. For, not to mention that a slender nerve liable to be broken off and crushed could not safely be brought down a long distance, it would not be safe even if the instrument was a strong one, like a ligament, artery, or vein. Moreover these instruments,[44] like the spinal medulla, grow out each from its own source, like a great trunk from the earth,[45] and as they advance and draw near the members, they branch and supply all the parts with that which they are bringing from their sources. Hence it was better for the spinal medulla too, like a river flowing from the fount of the encephalon, to send out at each place it happens to pass

[44] With the looseness too frequently encountered in his thinking, Galen proceeds to make a statement about the three instruments he has mentioned which is applicable to only two of them.

[45] Reading ἐκ γῆς, ἐν with Helmreich for the ἔκτισε of Kühn's text.

a nerve like a conduit for sensation and motion; and so this is obviously what has been done, for invariably into each part in the [II, 216] vicinity a nerve growing off from the adjacent portion of the spinal medulla is inserted. I have spoken earlier about this too, and I do not know whether there is anyone so senseless as not to believe that it is far safer to send motion from the source of reason to all the parts below through the midst of the spinal medulla than to send it directly from the encephalon to each part through a slender nerve.

It is time now to consider the next point. Since the spinal medulla was formed to be like a second encephalon for the parts below the head, since, like the encephalon, it had to be protected by a hard enclosure resistant to injury, and since this enclosure had to be made and put somewhere, was it not better to scoop out the keel, so to speak, which underlies the body of the animal as a foundation and is of course entirely bony, and to make its center hollow so as to form a pathway and at the same time a safeguard for the spinal medulla? Here are the four uses of the spine for you: it serves first as a base or foundation stone for the instruments necessary to life; second, as a pathway for the spinal medulla; third, as a safeguard; and fourth, as an instrument of motion for the animal's back. There is a fifth use to be added for good measure, namely, the protection of the viscera lying in front of the spine. Now this one would be a necessary consequence, but the aims that Nature kept in view when she constructed the spine as a whole are the four of which I have just [II, 217] spoken, and a special quality has been given to it in accordance with each of them. For because it is like a keel and a foundation for the whole animal, it has been made of bones, and hard bones at that; because it is the pathway of the spinal medulla, there is a hollow within it; because it is like a city wall for the spinal medulla, it is fortified with many ramparts all around it, of which I shall speak a little farther on; and because it is an instrument of motion (for this is the first point I am hastening to reach in my discourse), it has been made of several bones united by joints.

12. I shall explain why the spine is composed not of two or three long bones, like the humerus and ulna in the arm and the tibia and femur in the leg, but of twenty-four bones in man, not counting the broad bone [*os sacrum*] at the end, and of a larger number in other animals, and here too I shall show the skill of Nature. I shall reduce my whole discourse to three heads: the first head and the one of

which I think there is most particular need to speak at this point is the necessity that the vertebrae of the spine should be very numerous and small; the second is the necessity that four grand divisions of it should be made, the neck, the back, the loins, and the bone called by some the sacrum and by others the broad bone; and the third is
[II, 218] that there had to be seven vertebrae in the neck, twelve in the back, five in the loins, and that it was better for the sacrum too to be composed of four bones.[46]

The first head, which I need most particularly for my present purpose and which states that the spine must be composed of many very small bones, is clearly demonstrated for us if we remember the nature of the spinal medulla and the troubles that come upon an animal when the vertebrae are unseated. For its nature closely resembles that of the encephalon and the symptoms that befall the animal are similar to those that occur when the encephalon is affected, namely the impairment of motion and sensation in all parts below the affected vertebra. Now everybody knows these things. The saying of Hippocrates,[47] on the other hand, that if many consecutive vertebrae are displaced it is less[48] dangerous, but that if any one of them escapes singly from its union with the others it is fatal, is not so well known to everyone, and it is this very statement of which we have particular need at this point. For Hippocrates himself in teaching us the cause of the trouble writes that if many vertebrae are

[46] Galen's treatment of the sacrum is inconsistent. In man it is composed of five fused vertebrae, in the sheep, goat, and pig, of four, and in carnivora and the ape, of three. See Ellenberger and Baum (1926, *36*) and Sullivan (1933, *59*). It should be noted that no mention is made of the coccyx here; in chapter 7 of Book XIII, however, where the number of components of the sacrum is not stated, the coccyx is described as a cartilaginous outgrowth of the sacrum, an indication, I suppose, that Galen had been working with young animals. Then in *De ossibus ad tirones*, cap. 11 (Kühn, II, *761–762*), the sacrum is said to be composed of three parts, to which a fourth *bone* called the coccyx is added. This confusion gave rise to volumes of comment and made of the sacrum a veritable bone of contention, the most famous antagonists being Jacobus Sylvius (*1555, 86–87*) and Vesalius (*1543, 81–85; 1555, 103–107*).

[47] *De articulis*, capp. 46–48 (Littré, IV, *196–215*).

[48] Kühn omits the ἧττον which is found in Helmreich's text and in one of the manuscripts and which accords better with what Hippocrates says.

displaced together, each one being changed a little, the distortion of the spinal medulla then becomes a curve, not a sharp angle. But if only one of the vertebrae gets out of place, he says, "The spinal medulla would suffer from making a sharp bend in a short space and the escaping vertebra would compress it, if not actually break it off." If these things are so, if the spinal medulla cannot be bent very much [II, 219] or very sharply, and if the spine cannot be moved painlessly by large, loose joints with a great deal of play, it was better that the whole should be assembled from many small members, each one contributing a little. For thus its bending would be performed not at an angle but along the circumference of a circle, and injury to the spinal medulla from being compressed, crushed, or broken off would be avoided. It has been clearly demonstrated, then, that it was better for the spine to be formed from many bones having small movements, and I said that I had need of this demonstration particularly for my present purpose.

Moreover, I should like to put off discussing the other two heads for the moment, for I am anxious now to explain the spinal muscles, and it is for this that I needed to say all these things, because in addition to being useful in themselves, they also serve to explain the construction of those muscles. Now if it has been demonstrated that there must be many vertebrae in the spine, it is of course reasonable that each should have its own proper motion, but if the two muscles [*longissimus* and *spinalis*] [49] stretched along them from the head to the broad bone [*os sacrum*] had long fibers extending longitudinally, each vertebra could not be moved separately, for the fibers would draw on them all alike. As it is, however, because the fibers are oblique at each vertebra, sometimes one part of the spine and sometimes another can be pulled around to the side, inclined, or raised. [II, 220] Furthermore, since we can move individual parts of it, we can also move the whole if [50] we make all the fibers act at once, but certainly its partial movements do not result from that construction which would move [only] the whole spine at once; for if the fibers of the muscles extended longitudinally along it, we should easily move the whole of it at once, but we should then be unable to move each

[49] Considered as one muscle on each side; this description seems to fit the ape. See Howell and Straus (1933, *121–124*).

[50] Reading εἰ . . . καταστήσαιμεν with Helmreich for the ἢ . . . καταστῆσαι of Kühn's text.

vertebra by itself. Now a construction capable of doing both things properly is better than that which can do only one. And if such a construction provided two other, additional movements into the bargain, would it not be many times better than the other? Well, there are additional movements. For now, because each fiber acts by itself, we can turn the vertebrae laterally in either direction, but then [with the less desirable construction] we could only incline and raise them. So I was right when I said earlier that by their upper parts which are attached to the head these muscles common to the whole spine move the joints at the first vertebrae. Certainly it was not possible to make their fibers straight all at once at the first vertebrae alone, since these had to preserve the same order throughout in the way they were placed. Nothing bad, however, would result from
[II, 221] such a position [as they now have], because the head must derive its straight movement from them and along with this the two other, lateral movements as well. This, then, is the reason for the way the fibers of the spinal muscles are placed.

13. I must pass on to what remains to be said about the vertebrae and in its proper order explain each of the things I earlier postponed. The first of them, I think, was to speak about the small size of the vertebrae that articulate with the head. I said not long ago that since a great many instruments necessarily had to be placed in that region, the first vertebrae could not be made large. Moreover, I think it is clear too that in view of the construction of the other vertebrae lying below, it was better for those at the top to be made smaller and smaller, that is, if what is carried by something ought to be smaller than the thing that carries it. This is the reason why in the spine Nature made the lowest bone [*os sacrum*] the largest of all, like a base placed beneath all the vertebrae. The next largest is the vertebra joined with this one; it is the twenty-fourth, counting from the first [atlas], and the fifth in the series of lumbar vertebrae. These in turn, being placed beneath the others, are properly very large, and the fifth is the largest of them, as I have just said. The farther each of the
[II, 222] others is from the position of this one, the smaller it is, the smallest of the whole five being the first lumbar vertebra. Again, the last of the dorsal [thoracic] vertebrae, which is joined with the first lumbar, is smaller than it is; the one above the last dorsal is in turn smaller; and this decrease continues up to the head, except that if at some point a vertebra is found slightly larger than its neighbors, this

is not without a great usefulness, as I shall show later on in my discourse. This is the reason why the first vertebrae were made small.

14. I must tell next why it is useful for them not to have other processes such as the rest have and why their bodies are slenderer than all the others and their inner cavities broader. Now if by this time there is any reader who does not believe that Nature does nothing in vain, what I have written up to this point has been written in vain.[51] However, it is not that I think the reader is still in doubt about Nature but that I think he is not yet perfectly the natural philosopher, being still unacquainted with some of her works. So let him press earnestly on toward what remains. Let him learn first her common aim in the construction of the cavities in all the vertebrae, and then from the common aim let him even without me reflect on the particular one for the cervical vertebrae. For anyone who has heard that Nature uses the cavity in the spine to accommodate the thickness of the spinal medulla will no longer be unable to account for the way it differs from vertebra to vertebra. Since, as I said a little while ago, Nature had no other purpose [II, 223] in thus hollowing out the vertebrae than to prepare this safe pathway for the spinal medulla, it is of course necessary for the width of their inner cavities to be as great as the thickness of the spinal medulla, and since this thickness is not the same in all the vertebrae and is largest in the first ones, there was good reason for making their cavities very much broader than the others. Certainly, if it was right to make these vertebrae broad because of the thickness of the spinal medulla in that region and light because they lie above all [the others], it is clear that they must be slender too. For how could they possibly still be light if they had been made both broad and thick? And so for this reason (χρεία, usefulness) the first vertebrae were made with broad inner cavities but with little bodily mass.

15. Now perhaps even without my help anybody ought already to have discovered the answers to such questions as this: For what purpose has Nature made the spinal medulla vary in thickness and grow ever slenderer as it descends? For in this situation also she has had in mind an absolutely correct mean and has made its thickness in each vertebra just what it ought to be. But let me add my own

[51] Kühn omits *εἰ μή τις ἤδη πέπεισται, μάτην* from his Greek text, but includes the translation of it in his Latin version.

opinion and remind you of the usefulness of the spinal medulla, because the purpose for which it was made in the first place is also the reason why it was better to make it as large in each vertebra as it actually is. Well, I have said that it was formed to distribute the
[II, 224] nerves which are to move all parts of the animal below the head. Hence for this too we must admire Nature, who has produced from the encephalon a medulla of the size necessary if it is to suffice for all the lower parts. At all events, the whole medulla is obviously used up in the outgrowths of the nerves, as the trunk of a tree is used up in its many branches. I suppose that if the animal were not formed with skill and if Nature in determining the thickness of the spinal medulla had not set herself the goal I have mentioned, the medulla would necessarily be found either not to be coextensive with the whole length of the spine or to have something left over after its distribution into all the parts. For if she had made its origin from the encephalon above smaller than the usefulness of the parts [demands], the end of the spine would, of course, straightway be found to be devoid of medulla, and straightway also the lower parts [of the body] would be deprived of motion and sensation. If, on the other hand, she had made it too large, there would be at the extremity of the spine a part of it that was superfluous, like a conduit forming a stagnant pool, at rest and useless. If, then, neither of these conditions is to be seen even in a single kind of animal, and if the medulla and spine always end just as they begin, together,[52] how could anyone fail to believe what I have said or fail to admire Nature? For when [I see that] the spinal medulla, which in man must be divided into fifty-eight nerves,[53] issues from the encephalon just large enough to be precisely adequate to the distribution, with

[52] The defects of this description are obvious. Galen has not seen the cervical and lumbar enlargements, the termination of the cord in the lumbar region, or the filum terminale in man, and I can find no animal in which conditions are such as he describes. The chances are negligible that he had in mind human abortuses of around three months, when the spinal medulla really is as long as the vertebral canal.

[53] That is, twenty-nine pairs, another error. This statement of Galen's does not mean that he had dissected the human body. He could have arrived at his (erroneous) conclusion from what he remembered of his study of the skeletons available during his student days in Alexandria. When he was writing *De usu partium*, Alexandria must have seemed far away and long ago.

nothing defective or superfluous, I cannot admire her as much as she deserves. Surely, if you also consider the place where each nerve first leaves the spinal medulla, the size of the nerve, and the part to which it passes, you will praise not only the skill but also the justice of Nature. The places where the nerves grow out are so safe that not a one of them anywhere is squeezed, crushed, broken off, or harmed in any way, even [54] in the many, great movements made by the spine, and the mass of each nerve is just what is needed by the part that receives it. Moreover, the whole path it follows from its first growing off to its outermost end has been admirably constructed for its safety. [II, 225]

Well, I shall write about all these things as my narrative proceeds. But [here] I shall explain only what remains of the construction of the spine—for it is of the spine that I proposed to speak in this book—and I shall begin again where I left off. Now since the spinal medulla is to be like a second encephalon for all the parts below the head, and since the spine has been prepared both as a flexible path [55] and as a safe protection for it, Nature has devised many other wonderful things for the vertebrae. She has caused the so-called *acantha* [56] to grow out from the middle of the posterior parts, placing this palisade, so to speak, before the whole spine in order that it may be the first to be crushed, shattered, or suffer in any way before the injury reaches any one of the vertebrae. As far as its posterior extremities [57] the *acantha* is bony, but there a great deal of cartilage lies round about it. For I have also shown earlier that a cartilaginous substance is most suitable for covering and protecting underlying instruments because it cannot be broken off and shattered like hard, brittle substances, or cut and bruised like soft, fleshy ones. Again, Nature has inserted on this cartilage sinewy, broad, strong, thick ligaments [*ligamentum supraspinale* and *ligamentum nuchae*] to protect and bind together the whole *acantha* so as to make one body, as it were, consisting of all the outgrowths [the spinous processes], though these stand at no little distance from one [II, 226]

[54] Kühn omits μηδ'.

[55] Reading εὐτρεπῆς with Helmreich for the εὐπρεπῆς of Kühn's text.

[56] The spinous processes of all the vertebrae taken together to form a sort of picket fence.

[57] That is, the free ends of the processes.

another. This sinewy band, however, is responsible not only for making all the outgrowths of the vertebrae like one, but also for their varied movements. For it is hard enough to be stretched easily by the flexed spine and soft enough not to be broken off or harmed in any way when it is stretched. Futhermore, suppose it to be made slightly harder; it would then oppose the movements and hold the vertebrae in their original position, being unable to follow them as they separated; but if it were softer, though it would not impair their movement, it would fail to protect the security of their union. As it is, however, its moderate hardness is very well adapted for both
[II, 227] uses. So too the ligament [58] binding together the anterior parts of the vertebrae has the exact degree of hardness suitable for those parts. I shall talk about these matters a little farther on.

Along with the things I have said were granted to the *acantha* for safety's sake, it has acquired in addition a most fitting shape for each of the outgrowths [the spinous processes]; for the upper ones incline downward and the lower ones upward, so that the form of the *acantha* becomes very like that of the structures called vaults, and I have said many times already that of all shapes this is the most resistant to injury. So it is no longer surprising if the vertebra at the mid-point of the spine is the only one in which the posterior outgrowth [the spinous process] forming the *acantha* does not incline in either direction, that is, neither toward the neck nor toward the loins, but extends straight back without bending.[59] And indeed, this is [another instance] of the same providence [of Nature]. How would she have made the whole *acantha* itself like a vault if she had not first, I suppose, directed all the outgrowths of the lower parts up and those of the upper parts down and had not, secondly, united them to some common boundary, straight and unbending, which would be like the summit of the vault?

[58] One thinks at once of the anterior longitudinal ligament, but from what is said farther on, in chapter 16 of this Book and chapter 8 of Book XIII, it is apparent that Galen has in mind the intervertebral fibrocartilages instead of, or at least in addition to, this ligament. See also Daremberg's note 2 (in Galen [1856, II, *46–47*]).

[59] Proof conclusive that Galen is describing the simian spine, in which the spinous process of the tenth thoracic vertebra is indeed horizontal, whereas all above it are directed obliquely downward and those below, upward. See Sullivan (1933, *58–59*). In man they still point slightly down even in the lumbar region and nowhere point up.

Moreover, all the outgrowths which I have said constitute the *acantha* are not of equal size in all the vertebrae, and Nature has done this with wonderful forethought. For in the places where another important part is closely associated [60] with the spinal medulla, it was not reasonable to be careless of the size of the out- [II, 228] growths. Where the spinal medulla was alone, it was unjust to make them very long, and neither was it just to make the *acantha* grow out long from the small vertebrae or short from the large ones. Nature had good reason, then, in the thoracic parts, where the heart is placed in front of the spine and the great artery [the aorta] lies upon it, to make the outgrowths forming the *acantha* longest, and shorter [61] in all the other parts. Now the other parts are the lumbar, sacral, and cervical; the lumbar and cervical adjoin the thoracic vertebrae on either side, but the sacrum is a very large bone situated below, which I have said Nature placed beneath the framework of the vertebrae like a base. In the lumbar region the mass of the vertebrae is noteworthy, [for] on their inner sides rest both the vena cava and the great artery. At the sacrum, however, their bodily mass is more considerable, but no important instrument lies beneath. There was good reason, then, why next after the thoracic vertebrae the posterior outgrowths [the spinous processes] of those in the lumbar region were made very large. The cervical vertebrae, being slenderest of all, could not have outgrowths that were long and at the same time safe, for these would easily be broken off on account of their slenderness. And so I was right to say just now that Nature was taking both the masses of the vertebrae and the differences in [II, 229] the instruments lying along the spine into consideration when she made unequal the spinous outgrowths forming the *acantha*.

16. We shall therefore no longer be at a loss to explain why the twelve dorsal [thoracic] vertebrae have outgrowths that are not equal each to each. For although they all belong most particularly to the thorax, the lower ones that are close to the diaphragm are not near the heart but already well away from it like the lumbar vertebrae. And certainly it is no longer hard to understand why I said that there are four grand divisions of the whole spine; for since the thorax lies in the middle, being bounded on either side by the neck

[60] Literally, "come into the same position with."

[61] Reading *βραχυτέρας* with Helmreich for the *βραχυτάτας* of Kühn's text.

above and the loins below, and since the broad bone [*os sacrum*] furnishes a common support for all these, four grand divisions of the whole spine are necessarily produced. But why one part is made up of seven vertebrae, another of twelve, another of five, and the [sacrum] of four parts (since I have promised to tell the usefulness of these things) you shall hear next, after I have first finished all the present discussion.

For immediately after what I have [already] said, I should explain why there are nine outgrowths in all from the lumbar vertebrae, eleven from the cervical vertebrae, from five of them, that is,[62] but seven from the first two, and seven also from all the thoracic vertebrae. Now just as each vertebra's posterior outgrowth [the
[II, 230] spinous process] that forms the *acantha* has been shown to offer the usefulness of a barrier, so too there are two other, transverse outgrowths [the transverse processes] from the vertebrae, and these both furnish a similar protection to the lateral parts of the vertebrae and at the same time are placed beneath the inner and outer muscles of the spine like a base. For the muscles lie upon all of them, and so do the arteries, nerves, and veins that pass to and along them. In the thoracic vertebrae they have another, third usefulness, to serve for the articulation of the ribs, a usefulness that is most necessary for the action of respiration. But I have spoken of this in greater detail in a separate treatise.[63] The ends of these outgrowths, like those of the whole *acantha*, are turned toward the mid-point of the spine, just as all the vertebrae, I suppose, have an inclination toward this region for the reason I have given earlier.

Now why do the thoracic vertebrae have thick transverse processes, whereas in the lumbar and sacral regions they are slender, and in the cervical both thick and forked? Is it not that in the thoracic region, since the ribs not only articulate with them but also lie along the whole length of them, it was reasonable to make them firm and strong, and that in the lumbar and sacral regions, since only vessels and muscles rest upon them, strength would be unnecessary and superfluous? In the cervical region, however, they were made both
[II, 231] forked and thick for a very good reason, and the larger of the two ends was turned downward as in the other vertebrae, but the other,

[62] Reading τοὺς γοῦν with Helmreich for the τοῖς δὲ κάτω of Kühn's text.

[63] Perhaps in the missing portion of *De causis respirationis*, the extant part of which is found in Kühn, IV, *465–469*.

smaller one upward. Only these vertebrae have this additional feature, because in them the posterior outgrowth [the spinous process] is smallest of all, as I said a little earlier, although the spinal medulla in them has its greatest power; for I have shown that its first parts are more important than the rest of it. Hence [Nature] has made the transverse processes of these vertebrae thick and at the same time forked, so that they may compensate for whatever safety the vertebrae of this region lack because the *acantha* is short.

Thus far all parts of the spine have obviously been justly ordered, but from here on you must pay closer attention to what is said about all the other outgrowths and their articulations as well. Since the vertebrae must make the spine like one body, firm and strong but at the same time adapted for movement, it is fitting first to admire Nature because she has most ingeniously made the spine well suited for both uses, even though these are contrary to one another. For all the vertebrae with the exception of the first two, being bound together safely at their anterior [ventral] parts and articulated posteriorly, gain firmness in their posterior figures from the way they are joined in front, and are not hindered in their movements because [II, 232] they are not united and because posteriorly they are divided by joints of considerable size. For this reason we can bend very far forward but not back, since, if we use force, we break the anterior ligament which brings the vertebrae so accurately together that they are not far from being united and which allows little play for the backward bending of the spine. The ligament could not be strong and at the same time stretch very much, although this too was admirably provided for as far as possible by Nature when she made this ligament mucous,[64] as Hippocrates calls it. But I shall tell about its substance as a whole in discussions that follow. Since it was better for the spine not to be flexed similarly in both directions—for if it were, it would be quite unstable and loose—and since Nature had to

[64] This is the first of the statements alluded to in note 58 of this Book, which indicate that Galen thinks of the intervertebral fibrocartilages as forming part, if not all, of the anterior longitudinal ligament. When he says it is mucous, he is undoubtedly referring to the nucleus pulposus, which is particularly large in the ape. See Sullivan (1933, *60*). This is also Hippocrates' treatment of the subject in *De articulis*, cap. 45 (Littré, IV, *190, 191*). Cf. Galen's comment on this passage of Hippocrates' (Kühn, XVIII, pt. 1, *526–528*).

choose the more useful direction, here too you may consider the usefulness, because in all the actions of our life it was better for the spine to bend forward and this was far less painful for the vessels, the great artery and vena cava, that lie along it in front. For they would be torn away if they were stretched very much, and they would be broken off by the bending of the whole spine backward. And so, because in this region [65] the spine must be tightly bound together at all the vertebrae, the joints were with good reason made at the back of it.

[II, 233] I shall now bring this book to a close at this point. Indeed, as there are a great many things still left to be explained about the whole spine and all of them cannot be told in this book—for if they were, its length would be disproportinate and excessive—and as they do not allow of any appropriate division, so that I could not properly treat of some of them in this book and postpone the others to the next, I have thought it better to keep all that is left for the following book.

[65] That is, at their ventral edges.

THE THIRTEENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Spine and Shoulder]

1. When the space at the back of the vertebrae is divided into three parts, one precisely at the back, where the *acantha* is, and two others on either side of this, which are bounded by the roots of the transverse processes, it is clear to everyone not only that it was not better for the articulations to be made at the part precisely in the middle, but also that it was impossible, since this space was already occupied by the *acantha*. If the vertebrae had been articulated with one another at one of the two remaining parts and bound securely together at the other, in the first place, Nature in assigning unequals to similar locations would have lost sight of justice; in the second, she would have made the whole spine lean to one side; and in the third, she would in doing so necessarily have prevented and destroyed half the movements belonging to it. For we should not be able to turn laterally in both directions alike a spine that was defective on one side, and when we bent over, the unjointed side, unable to follow the one that was jointed, would hinder its motion so that thus not just half but almost all the action would be lost. These are the reasons (χρεῖαι) why all the vertebrae are articulated with one another on both sides of the posterior part. [II, 234]

2. The reason why some vertebrae have long, double outgrowths and others simple, short ones is their inequality in size. Now a joint that is long and double is better for safety and at the same time for uniformity of movement, whereas a simple, short joint, besides slipping easily, also has a defective movement. If it had been possible for all the vertebrae to be put together with outgrowths that were both double and long, Nature would not have grudged us this, but the outgrowths of slender, little vertebrae could not be made double and

long, and at the same time resistant to injury; for because they had to be made so thin and narrow, like the vertebrae themselves, they would be easily shattered and broken. Now since each vertebra is associated with those on either side of it, above and below, there was good reason for making two outgrowths [the articular processes]
[II, 235] slanting upward and two others slanting down. These, however, are common to all the vertebrae and, as I have said,[1] the large ones have two additional outgrowths [the accessory processes] slanting downward. For since the articulations of the vertebrae are made by the outgrowths that slant downward and rest upon those that slant upward, Nature for the sake of safety has placed under the whole articulation a second outgrowth slanting downward, and, causing a strong ligament [the articular capsule] [2] to grow out from its end, she has stretched this under all the outgrowth slanting upward as well, so that when the animal has occasion to move vigorously, the joint may never be displaced from its proper seat. But if to the three outgrowths I have mentioned (the largest of all [the spinous process], which forms the *acantha,* and the two transverse) you add the two slanting upward and the four slanting downward, it is evident that there are nine in all.

Now obviously there are indeed precisely this number of outgrowths of just these kinds that do belong to the lumbar vertebrae, and there are also eleven belonging to the vertebrae of the neck, not counting the median outgrowth lying in front of [ventral to] the large one [the spinous process] that slants downward; for this is the body itself of the vertebra. Those that are clearly outgrowths are the one forming the *acantha,* the transverse, each forked, as I have said, and the four that serve for the joints. For good measure there are in addition two others, one on each side, lying close to the upper boundaries [of the bodies] of these vertebrae and helping to increase

[1] ὡς εἰρηται, but thus far nothing of the sort has been said. As the subject will be discussed, however, later on in this same chapter, perhaps εἰρηται should be emended to read εἰρήσεται, the future tense. Daremberg (in Galen [1856, II, *49*]) would like to say *nous le dirons.*

[2] Daremberg (in Galen [1856, II, *49–50*]) says, "In man the articular processes are supported on the outer side by irregular ligamentous fibers more numerous in the cervical and dorsal [thoracic] regions than in the lumbar, and on the inner side by the ligamenta flava. In animals, even in the ape (and Galen's description applies to them), a true fibrous capsule surrounds these processes, especially in the lumbar region."

the concavity receiving the downward-slanting body of each of the vertebrae.[3] One need only see these outgrowths for their usefulness to be evident at a glance. The reason why the lower parts of the [II, 236] cervical vertebrae were made long I shall tell a little later,[4] when I have finished the discussion in which I am now engaged.

Now seven outgrowths have been formed for each of the dorsal [thoracic] vertebrae, although these vertebrae do not all have the same shape. In the upper nine the posterior [spinous] outgrowth is very large, as I have already said; the transverse outgrowths are very thick; and those slanting upward and down [the articular processes] are short and broad, like those in the neck. The vertebra that comes next, the tenth, is similar in other respects, but its posterior outgrowth is not long, slender, and slanted downward, as in the others, and the four by which it articulates with the vertebrae on either side of it are not similar to those in the others either, for the two upper ones resemble those slanting upward in the nine vertebrae placed ahead of it, whereas the other two, that slant downward, resemble the downward-slanting outgrowths of the vertebrae below it. In fact, this is the only one of all the vertebrae having the exceptional characteristic that at both joints it [merely] rests upon the vertebrae with which it is associated, since in all the rest placed below it the outgrowths that slant upward are concave and the downward-slanting ones are convex. Hence with their convex outgrowths they rest upon the vertebrae below them and with their upward-slanting outgrowths they receive those above them. All the vertebrae of the back and neck above this [tenth] one receive and bestride with their [II, 237] downward-slanting outgrowths the upward-slanting ones that have been made slightly convex. But the tenth dorsal vertebra is, as I have said, the only one of them all to have both [pairs of] outgrowths moderately convex, so as to rest upon those on either side, which end in concavities with rims. The next two vertebrae have their outgrowths making up the *acantha* similar to [those of] the lumbar vertebrae, and this similarity extends to the upward- and downward-slanting outgrowths by which they articulate with one another. Moreover, the last two dorsal vertebrae also have the other two outgrowths [the accessory processes] which slant downward

[3] These additional "processes" are the rims of the concave cephalic surfaces of the bodies.

[4] Kühn omits *μικρὸν ὕστερον* but translates it in his Latin version.

from the lower parts and were placed underneath the joints to protect them, and from which I have said strong ligaments [the articular capsule] grow out. These are the only ones of all the vertebrae not to have the oblique outgrowth on each side which I called transverse before.[5]

Well, it would be next in order to tell the reason why they are dissimilar; for Nature does nothing in vain. I have shown that since the whole spine forms a rounded *acantha* like a vault,[6] the middle vertebra is the only one properly to have its posterior outgrowth straight and not inclined. But this middle vertebra is none other than the tenth dorsal, since Nature here has divided the whole spine into equal *masses* of vertebrae, not taking into account their *number;* for
[II, 238] the upper ones are much more numerous, but the lower are as much greater in mass as they are fewer. And we should admire Nature as perfectly just, because she has chosen an equality based not on ordinary appearance but on truth. With good reason, then, just as this vertebra has a special position and a special posterior outgrowth not shared with the others, so its articulations are special too; for in order that the whole spine might bend uniformly it was of course necessary for the middle vertebra to remain in place while all the others withdrew gradually from one another and from it, the upper ones retiring upward and the lower ones down. Thus, right at the outset Nature in making articulations suitable for this movement created in the vertebrae lying above the middle one upward-slanting outgrowths that were convex and downward-slanting ones that were slightly concave; conversely, in the vertebrae below the middle she made the upward-slanting outgrowths concave and the downward-slanting convex.

Now since, as I have shown earlier, the spine has acquired its straight movements from those that are slightly oblique, and since it is characteristic of movements thus slightly oblique that they are performed by concavities on each side rotating around convexities

[5] Daremberg (in Galen [1856, II, 52]) suggests that this error is more apparent than real, since in the ape the transverse processes of the eleventh and twelfth thoracic vertebrae resemble in form and direction the accessory processes of the lumbar vertebrae. But Sullivan (1933, 58) says that they *also* have accessory processes.

Galen repeats this statement at the end of this chapter, and it appears again in chapter 3.

[6] Reading τελευτώσης with Helmreich for the τελευτῶντ' of Kühn's text.

that remain fixed, it was reasonable for Nature to have made the middle vertebra immovable at both its articulations, all the other vertebrae placed below it immovable at their lower articulations, and all those lying above immovable at their upper articulations. For of course when the spine becomes convex, the vertebrae lying below [II, 239] must shift downward and those lying above move up. Moreover, when we lift our heads and straighten up, the vertebrae must reverse their motion, those lying above moving down and those placed below moving up. For the rule of each configuration is that when we bend over, the vertebrae withdraw as far as possible from one another as if the spine needed to become longer at that time, and when we lift our heads, they all come together again toward the same point, approaching the middle vertebra as if now the whole spine were obliged to become shorter.

If you recall the motion of the radius, the articulation it makes with the humerus, and the articulation of the wrist with the slender outgrowth of the ulna which some call styloid, I dare say you will need no third example to understand clearly[7] that when bones articulate with one another, concavities turning in both directions around convexities are most suitable for oblique movements. If you do, however, then recall also the articulation of the navicular with the talus and the latter with the tarsus, because in all these, concavities rotating in both directions around convexities that remain fixed produce oblique movements. One concavity turning about one prominence produces only lateral, oblique movements, but if two oblique movements are combined and draw a part toward [II, 240] both sides a little off center, it has been shown many times already that whenever both act at once, one straight movement compounded from them necessarily results. Moreover, it has also been shown earlier that in the case of the spine it was better to have the straight movements generated from oblique.

If you remember all these things taken together, I suppose you will have already admired the skill of Nature, who has devised for the vertebrae the best structure, the most suitable movement, the proper number and size of outgrowths, and, in short, every attribute in accord both with the other attributes and with all the uses of the spine. Now the last two of the dorsal [thoracic] vertebrae, those

[7] Accepting Helmreich's emendation, ἐνάργειαν, for the ἐνέργειαν of the manuscripts and Kühn's text.

below all the others, not without reason have instead of transverse outgrowths the downward-slanting [accessory] outgrowths that lie beneath the joints. For one of these vertebrae has resting upon it the last of the false ribs, which is very short and slender and moves only a little and weakly; the other has the diaphragm growing out from it. Hence they did not, like the other thoracic vertebrae, need strong transverse outgrowths supported by, and safely articulated with, the parts of the bones of the ribs in this region, but have instead of the transverse outgrowths those slanting downward, as in the neighboring lumbar vertebrae.

3. Well, then, has Nature, who has been perfectly just in all these
[II, 241] things, unjustly grudged a posterior [spinous] outgrowth to the first cervical vertebra alone? Or was it not also better to construct it so? I think that if you remember what I have written in the preceding book, you no longer need a more extensive demonstration. For I said in that book that the straight, short muscles [*recti capitis posteriores, majores* and *minores*] raising the whole head occupy the entire articulation. Necessarily, then, the outgrowth was not formed on the first vertebra, because in this region the muscles were already occupying it; for there was no good reason for depriving animals of such a movement, and if the movement was kept, a sharp, bony outgrowth could not possibly be set under the muscles. Not only would it dislodge them, but it would also obstruct them when they moved, bruising, pricking, wounding, and injuring them in every way. This is the reason why Nature did not make the posterior outgrowth for the first vertebra. And I expect you to pay most particular attention to those works of hers in which, though abandoning similar construction for similar instruments, she has not turned away at haphazard from the similarity or chosen in its place some random thing, but has chosen what only those parts that were being made ought to have. For it is not by accident or by chance that the tenth dorsal [thoracic] vertebra is the only one of them all to have a straight posterior outgrowth, whereas it is curved in all the others; and it was not done without a purpose when the two following vertebrae were
[II, 242] deprived of their transverse outgrowths and the first cervical vertebra of its posterior outgrowth.

No, Nature has obviously chosen to construct each of these things in this way because it was better to do so, just as she chose for the same reason to carve out the apertures (those by which the nerves

from the spinal medulla escape) not in the same way in the first vertebra as in all the other cervical vertebrae. For all the others have on their lateral parts where they fit together a long aperture like a semicircle, extending inward as far as the spinal medulla so that by both apertures a space is formed as broad as the thickness of the nerve issuing through it.[8] The first vertebra, however, has no such aperture either on the side where it articulates with the second and far less on the upper side toward the head; for here too, in all the nerves from the spinal medulla, the Art that fashions animals has been provident in foreseeing and guarding against the injury to the nerves themselves (and to the vertebrae besides) that would result if the nerves grew out at any other point.

Seeing the apertures, you can consider how much better it was for the vertebrae to be bored through only at this point and at the same time how very safe it was for the nerves. Indeed, since the apertures themselves and the nerves growing out through them lie under the roots of the outgrowths that slant upward and downward [the articular processes], they are protected on all sides and could not be better placed elsewhere. For if they were led off from behind the [II, 243] outgrowths,[9] it would not be safe for the nerves themselves, because they would have to travel a long way to the anterior parts of the animal and be unprotected by any safeguards; and if they were shifted farther forward [ventrally] than they are now, the vertebrae would be damaged by having deep holes carved out of them, their ligament [the anterior longitudinal ligament together with the intervertebral fibrocartilages] [10] would be weakened, and the instruments lying upon this side of the spine would be ruined—and none of these things is negligible or deserves to be slighted by a wise Creator. For damage to the nerves on their perilous journey would throw the anterior parts of the animal into disorder, since they must be supplied with sensation and motion; boring through the vertebrae where they are thickest and rest upon one another would necessarily destroy to some extent the safety of their union, just as if you should make many broad holes in the wall of a house; and the ligament which joins them together and needs to be very strong, as I have said

[8] The "apertures" are the vertebral notches of the pedicles, by the juxtaposition of which the intervertebral foramina are produced.

[9] That is, dorsal to the articular processes.

[10] See notes 58 and 64 of Book XII.

before and shall say later on, would be seriously weakened if it no longer preserved its continuity, but were pulled apart and eroded, so to speak, in many places, as it actually would be if something of this sort should happen to it. Moreover, the instruments that lie upon the front of the vertebrae in the dorsal [thoracic] region are certain
[II, 244] veins [*vv. azygos, hemiazygos, hemiazygos accessoria*] that nourish the thorax, the largest of all the arteries [the aorta], and the esophagus; in the lumbar region of the spine there are the lower part of this artery, the portion of the vena cava found there, and the very large muscles called psoas; and in the cervical there are the muscles [11] that incline the head, and the upper part of the esophagus. None of these parts I have mentioned as occupying the space in front of the spine could be shifted to any better place.

Properly, then, provident Nature made the nerves grow out from the spinal medulla right at the point where the lateral parts of the vertebrae come to an end, so that the nerves may not suffer in any way, or weaken the composition of the spine, or break through the continuity of the ligaments, or run the risk of being harmed by traversing a long, more dangerous path. In fact, the place now assigned to them is perfectly safe, because the outgrowths slanting up and down [the articular processes] are set before them like a palisade. In the lumbar region (for the discussion should begin here, because, having the largest vertebrae, it has also noteworthy outgrowths) if you look closely at the second [accessory pair] of downward-slanting outgrowths, which I have said earlier end in a strong ligament and are of no little assistance to the outgrowths that
[II, 245] slant upward and make the articulation, you will find it not only useful for this but also much more so in preparing the first exit for the nerves. For, being extended behind them, it is actually a wall and a bulwark against whatever strikes against them in any way; it is the very first to receive and ward off the blow; and if there must be a wound, fracture, or any other kind of injury whatever, this bears them all before the nerves suffer. Moreover, you can see that this outgrowth is large in the lumbar vertebrae, because these are the largest, and that it is also large in the last two thoracic vertebrae. In the remaining ten its usefulness for the nerves is provided by the lateral [transverse] outgrowths, on which the bones of the ribs rest and with which they articulate. Indeed, since these vertebrae had

[11] Rectus capitis anterior, etc.; see note 34 of Book XII.

already become smaller than the ones below them and needed to have this outgrowth of considerable size, and since they no longer had space for an additional downward-slanting outgrowth, it became necessary for Nature to make what she had constructed for one thing serve again for something else as well. Certainly this [transverse process] is large and strong and has a most advantageous position, as if it had been prepared for protecting the nerve.

The other, cervical vertebrae have the exit of the nerves safely sheltered and protected by the transverse outgrowths, which I have said are forked. In all these, with the exception of the first, the nerves issue on each side at their lateral edges, and, as I have said [II, 246] before, each of two adjoining cervical vertebrae contributes equally, insofar as this is possible, to the formation of the aperture transmitting the nerve. But in all the lumbar vertebrae the nerve merely rests against the edge of the upper vertebra; for the outgrowth protecting the nerve emerges in this region and the vertebrae themselves are large, so that each can unaided provide enough space for the nerve, whereas in the neck the vertebrae are too small for one alone to provide a path for it. It is for this very reason that Nature cut a notch like a semicircle in the edge of each [cervical vertebra], being careful not to bore through the vertebrae themselves, because if she had done this, she would have put a strain on them, slender as they are, and would have made them extremely weak. Likewise for this reason she made the bodies themselves elongate below, where they rest upon one another, and hollowed out the upper sides in order that the upward-slanting outgrowths [12] of the vertebra below, which create the concavity and embrace the elongate extremity of the vertebra ahead, may also themselves contribute somewhat to the production of the common aperture. For the semicircles, so to speak, are on the outer side of these, and behind them are the articulations of the vertebrae. Between these [13] the nerve emerges, sheltered by all the prominences that surround it and at the same time cutting a little notch in each vertebra, though if you separated the vertebrae and [II, 247] moved them quite apart from one another, you would think that there had been no notches cut at all and that their appearance was a necessary result of the outgrowths of each vertebra.

[12] That is, the rims of the bodies themselves, not the superior articular processes.

[13] Between the bodies and articular processes.

Thus Nature has provided very carefully for making all the vertebrae resistant to injury and particularly those in the neck because they are smallest, and she has used every means to avoid boring through the bodies themselves and weakening not only the vertebrae but also the entire composition of the spine, which is a sort of keel [14] and foundation for the structure of the whole animal. In the lumbar region, as I have said, one can clearly see the nerve resting against the sides of the lower parts of each vertebra; in the dorsal [thoracic] region too it rests against the edge of the vertebra ahead, though clearly no longer in the same way but as if seemingly it was also bound to the vertebra below; and in the vertebrae of the neck, because these are the smallest of all, each one has contributed equally to the passage for the nerve; for in the space between the outgrowths [15] Nature has made a sort of concavity so indistinct as to seem not to be notches cut out of them but to follow of necessity.

Now when Nature made the bodies of only the cervical vertebrae
[II, 248] elongate below and hollowed out above, was she thinking merely of forming these apertures or was she providing for something else more useful as well? And why did she make the surfaces that bound all the other vertebrae plain, smooth, circular, even on all sides, and perfectly flat, and why did she attach them to one another by these, failing only in the cervical vertebrae to use this same plan for joining them together? Isn't it that although the primary aim in the construction of all the vertebrae is twofold (firmness and safety for the whole spine because it is like a keel or foundation, and motion because it is part of an animal), for all the other vertebrae below the neck the greater usefulness is safety, whereas in the upper ones it is motion? If you consider that we need to incline the neck, raise it, and turn it to the sides in various ways, quickly, and for more actions and to a greater degree than we need to move the whole spine, you will, I think, praise Nature for choosing for each part of it the suitable thing, motion for the neck, and firmness for all the rest. But the lower vertebrae could not rest safely upon one another without a flat base and a ligament stretched tight, nor could the upper ones move easily without a long outgrowth and a lax ligament. Well, as I have shown, all joints having a varied movement end in rounded heads, and if Nature had given no thought at all to

[14] See note 10 of Book III.

[15] That is, between the rims of the bodies and the articular processes.

the firm security of the cervical vertebrae and had constructed them only [16] for facile movement, like the humerus and femur, she would [II, 249] have made them end like those members in rounded heads. However, she did not lose sight of their second usefulness, and so she made them just long enough to be suitable for moving not only easily, but safely. And there are other things contributing no little to safety, some of these common to all the vertebrae and others special and peculiar to the cervical vertebrae alone.

4. Certainly, all the ligaments surrounding them on all sides, those at the lateral outgrowths and to a much greater extent those at the rear are common to all the vertebrae,[17] but the strength of the muscles in this [cervical] region, their size and number are special things, peculiar to those in the neck; for there are many large, strong muscles surrounding these little vertebrae. Moreover, of course their extremities [rims], the sides that form the upper concavities [of the bodies of the vertebrae], do themselves hold fast the prominences of the vertebrae above that enter them. Thanks to all these things, the cervical vertebrae have been constructed for safety no less than the others, even if they are joined together very much more loosely. This, then, is how Nature has both ordered safely the other features of the whole spine and made the nerves issue in the way that was [II, 250] most needful.

In the first vertebra, however, which [we know] is very different from the others if we remember its articulations described in the preceding book, it was not safe for the nerve to grow out either from the upper parts, by which the vertebra articulates with the head, or from the lower, where it embraces the second vertebra, or even from the side, as it does in the others. For the movement of the first vertebra is strong and makes great changes in its position since sometimes it embraces accurately the prominences of the head [condyles of the occipital bone] or the convexities of the second vertebra, and sometimes it is far removed from them. Hence if the nerve were placed right at the articulations, it would be in danger either of being crushed whenever the first vertebra comes accurately together [with the head or second vertebra] or of being torn apart when it is far removed [from them], and besides, the first vertebra

[16] Accepting Helmreich's emendation, *μόνον*, for the *μόνους* of Kühn's text and the manuscripts.

[17] See note 2 of this Book.

itself could not be carved out because it is thin in this region. For this reason, then, since the nerves could not issue safely from the lateral parts, as they do in the other vertebrae, or from the region where the crown of the head embraces the second vertebra,[18] Nature has bored through the first vertebra itself with very fine holes[19] where it is thickest near the upper articulations, thus securing by every means in her power resistance to injury for both vertebra and nerve. As for the nerve, it will be clear to everyone that it would be safer if kept away from the joints, and as for the vertebra, it will be
[II, 251] perfectly clear that if it is pierced where it is thickest with extremely fine holes, nothing very bad will happen to it. Hence, even if someone should say that all the good things mentioned in this whole discussion have not come to belong to all the other vertebrae through a certain providence and skill but have been made by chance, I should think that to his other assertions he would not dare add that the apertures in the first vertebra were also made by chance. For it is plain to be seen that because it was better for the nerves not to grow out at its edges, the vertebra itself was therefore pierced, and that because it was dangerous to pierce a thin vertebra, the apertures were made very narrow and were placed where it was thickest. And indeed, Nature was not acting idly or at random when she made this very provision, namely that the first vertebra should

[18] "The crown of the head" is a term used elsewhere by Galen for the occipital condyles. See *De ossibus ad tirones*, cap. 8 (Kühn, II, *756*), and *De anat. admin.*, XV (Galen [1906, II, *209;* 1962, *229*]). But the condyles do not of course articulate with epistropheus, and they enter rather than "embrace" the concave superior articular facets of atlas. Daremberg (in Galen [1856, II, *62*]) wishes to read "first" for "second," an emendation which would not, of course, solve the second difficulty. In the ape the inferior articular facets of atlas are indeed slightly concave and "embrace" the superior articular processes of epistropheus, but I can see no reason why Galen should call them the crown of the head. Either he blundered here, or, as I suspect, there has been an early, grave damage to the text, though Helmreich in his critical apparatus records no significant variants in the extant manuscripts.

[19] The sulci in atlas which afford passage to the vertebral artery and first cervical nerve and which correspond to the superior vertebral notches of the other cervical vertebrae are converted in the ape (and sometimes in man) into a canal. See Gray (1948, *78*) and Sullivan (1933, *58*), and cf. *De anat. admin.*, XV (Galen [1906, II, *209;* 1962, *229–230*]).

be thickest in this region. She did so first in order that it might safely be pierced there, and secondly that on its lower side it might receive the convexities of the second vertebra and on its upper side the prominences of the head. For where it had to bear the greatest strain it was better to make it especially strong.

5. Then has Nature, who has created all these things in the right way, distributed each of the nerves that emerge [from the first vertebra] to parts where they are not needed? Or should we admire her in this too, because she has distributed them both to the muscles that lie upon or alongside the first vertebra? In fact, since these must be moved, there was good reason for them to receive nerves from [II, 252] the parts of the spinal medulla near by. And what about all the other muscles lying round about the neck and moving the head? Was it not better for them also to receive their nervous principles directly from the spinal medulla in the neck? Furthermore, since it was impossible to assign to the head any portion of the first pair because it is so slender, Nature has supplied it from the second pair [*n. occipitalis major*—medial branch of dorsal ramus of C_2]. Each nerve escapes through the overlying muscles [*semispinalis capitis* and *trapezius*], passing first obliquely up and posteriorly, and after this again obliquely up and anteriorly, and so is distributed to all the parts of the head in the vicinity of the ears and the back of it as far as the crown and the beginning of the bregma. Of these I shall speak again when I explain the nerves in the sixteenth book. The remainder of the second pair is distributed downward to the muscles near by [*splenius*, *longus capitis*, *semispinalis capitis*] by which the movements of the first vertebrae in respect to one another and to the head are executed.

These nerves do not issue from lateral apertures as the third pair and those thereafter do, or by an aperture bored in the second vertebra like that in the first. They could not issue from lateral apertures for the reason I gave in discussing the first vertebra, or from any other part either, because the first vertebra embraces the [II, 253] second. Accordingly, they issue in the only place they could, on either side of the *acantha*, where Nature made spaces [the superior vertebral notches] between the first and second vertebrae; through these the second pair of nerves comes forth quite uninjured by their motion.

The third pair of nerves from the spinal medulla emerges from the

apertures common to the second and third vertebrae and is distributed [the dorsal rami] both to the muscles [*platysma*] [20] moving the cheeks and to those [21] which tilt back the entire neck along with the whole head. The part of it that passes forward [the ventral rami] is mingled with both pairs, the second, mentioned earlier, and the fourth, still to be described, and the precise distribution that takes place from this union [the cervical plexus] to the anterior parts of the neck I shall describe in the sixteenth book. For the present, we need to know simply that the third and fourth pairs themselves supply nerves to the muscles common to the neck and head and to those moving the cheeks, just as, in fact, they do to all the parts behind the ears.

Next after these four comes the fifth pair, which emerges where the fourth and fifth vertebrae come together and is distributed as soon as it emerges, just as the ones I have already mentioned are. One part [the dorsal rami] of it passes back deeply into the muscles
[II, 254] common to the neck and head, and the other [the ventral rami] passes forward and up to those [*platysma*] moving the cheeks and inclining the head.[22] Between these there is another, third part [the medial branch of the dorsal rami?] which extends up to the summit of the scapula, and this is distributed to the muscles in that region and at the same time to the overlying skin, as each of the pairs mentioned before also sends a branch off to the skin. At the root of the nerves a part of it is mingled with each of the neighboring pairs, the fourth and sixth, and that which comes down to it from the fourth, being small, seems to be mingled particularly with that part of it where the phrenic nerves, collected from [the nerves coming from] the vertebrae in that region, have their greatest mass and pass down, one on each side, along the [mediastinal] membranes dividing the thorax.

When the next pair after this, the sixth, emerges behind the fifth vertebra, it combines to a great extent with those on either side of it,[23] but its largest part [*nn. subscapulares*] extends to the hollows of

[20] *Vide infra*, pp. 699–701.

[21] Splenius capitis, semispinalis capitis (complexus), and perhaps the longissimus group along with atlantoscapularis anterior. See chapters 8 and 12 and notes 31, 39, and 49 of Book XII.

[22] See chapter 8 and note 34 of Book XII.

[23] In the beginning of the brachial plexus.

the scapulae. By means of its anterior parts [filaments from the subclavian nerves to the phrenics] it also enlarges the phrenic nerves and, like the other pairs of cervical nerves, gives off to all the other vertebrae of this region certain small branches, the particular distribution of which I shall make clear more exactly in my special discussion of the nerves.

In this present book I have set out to explain only the gist of the [II, 255] matter for each of the pairs, to say, for example, that the seventh pair, emerging behind the sixth vertebra from the aperture common to the sixth and seventh, is very much commingled with both neighboring pairs, but that the greatest part of it extends to the upper arms, just as most of the eighth pair, emerging from the spinal medulla behind the seventh vertebra, reaches the forearms, though this pair too is mingled and interwoven with those on either side of it.

So too no little part of the pair [emerging] behind the eighth vertebra [T1], though this is also mingled with the one ahead of it, goes to the hands.[24] These [T1] are now[25] the nerves at the first intercostal space, and they have very little room, because the first ribs are also very small. This, in fact, is the reason why Nature began to form the thorax behind the seventh vertebra, even though the arms did not as yet have all [their nerves], because it was possible to use the pair behind the eighth vertebra for both regions, that is, for the first intercostal space and for the arms.

In a very wonderful way she has brought down to the diaphragm nerves from the spinal medulla in the neck and has conducted nerves to the intercostal muscles from each of the vertebrae touching them. Now the diaphragm differs from all other muscles not only in shape, but also in position and action; for its shape is circular and its position oblique, since its anterior and upper parts reach the sternum [II, 256]

[24] Daremberg (in Galen [1856, II, 66]) comments, "The anterior branch of the first dorsal [thoracic] nerve contributes through its upper branch to the formation of the brachial plexus, but one cannot say that this branch itself goes directly to the arm and still less to the hand; for the interlacement is such that after the anastomoses one can no longer distinguish the different elements of which each of the nerves is formed." Actually, the median nerve is made up of fibers derived from the last three cervical nerves as well as from the first thoracic.

[25] Kühn's text omits ἤδη, found in the manuscripts and included by Helmreich.

and it passes thence back and down farther and farther till it touches the spine, with which it unites at the loins. Its head, the point to which in all muscles the fibers are attached, is not, as one might suppose, in the region near the sternum, nor is it in the lumbar region, but in the sinewy center of the whole diaphragm. Accordingly, the nerves moving its fibers must come down from some source above and reach this point in order to extend the action equally to every part. For with the diaphragm as it actually is, it was necessary to have the head of the muscle either at its center or at the parts that are opposite the center[26] and describe a complete circle where they unite with the parts round about them. But if it was made for the sake of moving the thorax, it was necessary for its extremities to be where it unites with the thorax and for its head to be put opposite them all, finding no other place more suitable than the middle of the diaphragm where the pair of nerves obviously does reach it. If, on the other hand, nerves were inserted into the diaphragm at those parts where it joins the thorax, they would end in its most sinewy part at the middle of it, but certainly nerves that are to move muscles must be inserted not into the ends, but into the beginnings of them. This is the reason why the diaphragm alone of
[II, 257] the parts below the clavicles receives nerves from the cervical region of the spinal medulla, and not a one of the others does likewise. For when it was possible to send nerves in from parts near by, to bring them from a long distance would be the act of a Creator ignorant of what is better. Yet for this usefulness suspended nerves traversing the whole thorax reach the diaphragm. And of course, because they must come quite suspended and are to be inserted in the elevated part of the diaphragm, Nature has used the [mediastinal] membranes dividing the thorax to make their path secure; for stretched along these and adherent to them, the nerves are held fast and supported.

6. The construction of the thorax itself begins after the seventh vertebra, when it was no longer necessary to send nerves to any part lower down or to any part of the neck or arms.[27] For it was better

[26] That is, at the circumference; Daremberg (in Galen [1856, II, 67]) translates, "les points les plus distants du centre," a very free rendering.

[27] A strange remark, if one compares his statement in the preceding chapter: "This, in fact, is the reason why Nature began to form the thorax behind the seventh vertebra, even though the arms did not as yet have all [their nerves], because it was possible to use the pair behind the eighth vertebra for both regions, that is, for the first intercostal space and for the arms."

for the thoracic spinal medulla to furnish outgrowths from near at hand to all the parts in this region, and so at each intercostal space no small part of the nerves escapes outward through the muscles and is distributed first at the roots of the ribs to the instruments along the spine and then, particularly at the convexity of the ribs, to the bodies round about the thorax, just as near the sternum it is distributed to the parts in that region. Since all the parts above the thorax [II, 258] must have nerves from the cervical spinal medulla nearby, and all the parts around the thorax must also have them from the dorsal [thoracic] spinal medulla nearby, and since nerves must be sent from the cervical spinal medulla to only one of the lower parts, the diaphragm, and all these parts receive their outgrowths from the vertebrae I have mentioned, there was good reason for the neck to be terminated at this point [the seventh vertebra] and for Nature to begin creating the thorax below it.

Hence in man, the ape, and other animals whose nature is not very different from theirs, the neck was properly composed of seven vertebrae. Now I have shown that the neck is useful for two purposes (χρεῖαι), the first for the creation of the larynx in us, and the second in long-legged animals, for which it serves because of its length in the place of hands when they are getting nutriment from the ground. But it is not my intention to discuss these at this time. In man, then, and animals like him, the neck was properly constructed of seven vertebrae because such a size is suitable for the larynx and because all the parts which are better off if they receive their nerves from the cervical portion of the spinal medulla would then receive enough of them. For I have shown in my commentaries *On the Voice*[28] that the larynx, its principal instrument necessarily situated in the neck, is seen to become longer when [the neck] is [II, 259] extended and, when the neck is flexed to its greatest degree, is so exactly equal to it that no place is left vacant and yet the larynx does not strike against the bones on either side of it, against the jaw above or the clavicle below.

Since all parts of the body are in due proportion to one another as regards size, of course the thorax, too, necessarily has a size that is proper not only for itself but for the other parts as well. So if I was right when I showed that neither respiration nor [production of the] voice can take place without the aid of the thorax, and that first the heart and along with the heart the lung have need of its protec-

[28] See notes 3 and 4 of Book VI.

tion, Nature in creating the thorax had to keep in view these four ends: the voice, respiration, the size of the heart, and the size of the lung. You may look first at the size of the lung, which can be neither larger nor smaller than the division of the rough artery [the trachea]; for as long as this has not yet stopped dividing, the flesh of the lung must grow around it. Again, the rough artery has a breadth and length sufficient for respiration and the voice, as the action itself indicates. The generation of the lung depends on the rough artery, and the size of the thorax on the size of the lung, that is, if it was better for the whole broad space in it to be filled by the lung, as I have showed in my books on respiration.[29] Moreover, the heart has a suitable position in the thorax and a suitable size, if you recall what has been said about it in earlier discussions.

[II, 260] 7. Thus it is clear from what has been said that the thorax is of the proper size, and I have also shown earlier that the size of the vertebrae must gradually increase. In truth, Nature seems to have observed this rule admirably; for always the lower vertebrae are enough larger than those lying above them to carry them without pain and to be themselves borne with no difficulty by those placed below them. Now the whole thorax requires twelve such vertebrae; for it happens that the gradual increase in size of the vertebrae and the generation of the whole thorax make such a number suitable.

The five [lumbar] vertebrae of the spine that come next after these are made on the same plan as those in the neck. Since nerves from the spinal medulla are distributed to the spinal muscles, to those of the lower belly, and to whatever others are located in this region, outgrowths must first be made to go to these parts; afterward nerves must be sent to the legs; and then the sacrum must begin to be formed, which is to be like a foundation for the spine and serve to receive the bones of the ischium and ilium resting upon it. Without these, the pubic bones, which provide the animal with necessary advantages (χρεῖαι), could not be created, and the articulation of the legs with the hips would not be formed at all. It is first for the sake of these [bones] and then for the sake of the

[II, 261] bladder, uterus, and rectum that Nature has created the so-called broad bone, to which some have given the name "sacrum." Just as almost all of the nerve growing out from the first intercostal space arrives at the hand, so here in the same way the nerve issuing from the broad bone through its first aperture is mingled [in the lumbo-

[29] See notes 3 and 4 of Book VI.

sacral plexus] with those passing to the leg, so that below the diaphragm the pairs of nerves from the spinal medulla that pass to the muscles I have mentioned and to the legs need five vertebrae, and the sixth pair, that comes next after these, needs the first apertures of the sacrum. There are three other pairs of sacral nerves distributed to the adjacent parts;[80] for it was reasonable to grant nerves to these too from parts nearby. But I shall discuss the distribution of all the nerves in a separate section by itself; for my present purpose is not to treat of this but to explain the whole number of the vertebrae along with the size of the sacrum. In fact, it has already become clear that it was right for the neck to be formed of seven vertebrae, the thorax following it of twelve, and the lumbar region next of five, and for the sacrum[81] and all the other parts of the spine to be the size they actually are. Moreover, the sacrum itself has at its extremity an outgrowth [the coccyx] of cartilage for the same reason[82] that the sternum, the *acantha* of the whole spine, the head of the false ribs, and all parts of the body that are prominent and exposed have too; for I have already spoken of these many times. And it is articulated with the last lumbar vertebra in the same way that this is articulated with the others. [II, 262]

8. A strong ligament[83] binds together the anterior parts of all the vertebrae so accurately that many physicians think they are not so much bound together in this region as grown together. This ligament ends posteriorly in the tunic[84] that surrounds the meninges of the spinal medulla. In front, however, advancing a little, it is inserted on each side into the cartilage coating the vertebrae. As the vertebrae withdraw toward the rear from their junction in front, they gradually separate[85] and have all the space between them full of a white, viscous humor [the nucleus pulposus] very like that inter-

[80] This statement is perhaps based on observations made on the pig, sheep, or goat, in which there are four pairs of sacral nerves. It certainly does not refer to conditions in man or the ape. See Ellenberger and Baum (1926, *36*, *900*) and Howell and Straus (1933, *307*).

[81] See note 46 of Book XII.

[82] Literally, "for the sake of the same usefulness."

[83] The intervertebral fibrocartilages and perhaps also the anterior longitudinal ligament. See notes 58 and 64 of Book XII.

[84] This tunic seems to be the posterior longitudinal ligament and the ligamenta flava combined.

[85] In the ape the thoracic and lumbar regions of the spine are usually ventroflexed. See Sullivan (1933, *57*).

spersed in nearly all the joints. Indeed, the usefulness of such a juice is common to all parts which must move readily, as I have shown before.

All these marvelous things, then, are to be seen in the works of Nature; and there is also each of the meninges around the spinal medulla. In appearance they are exactly like those encircling and surrounding the whole encephalon, with the exception that there is no space between them as there is in the head. In this respect, certainly, they differ, for the thick membrane [the dura mater] is in contact with the thin [the pia mater] and clasps it all around, and outside the thick membrane there is added a third tunic that is
[II, 263] exceedingly strong and sinewy. Well, what is the reason for these things? For Nature does nothing in vain. The spinal medulla has some things in common with the encephalon and others peculiar to itself, and those they have in common have a common construction, whereas those peculiar to each have a construction peculiar to each and different. The common characteristics are that they have a similar bodily substance and that they are [both] sources of nerves. The peculiar characteristics are that the pulsating encephalon moves, though it is surrounded by a bone that does not move, whereas the spinal medulla does not move, though it is contained in the vertebrae that do. With good reason, then, the two meninges have been bestowed on both alike, the one membrane to unite the vessels in them and hold together their substance, which is exceedingly soft, and the other to cover and protect them from the surrounding bones; it is reasonable too that on the outside there should be these bones themselves, like a barrier and wall capable of receiving without pain the shock of whatever could cut or crush the meninges or injure them in any other way.

As regards the peculiar characteristics of each: because the encephalon pulsates, the thick membrane [the dura mater] stands away from it far enough to be able to receive it when it expands, but because the spinal medulla does not pulsate, the thick membrane comes into contact with the thin without leaving even a small space between them. And again, because there is no apparent movement in the bones of the head and vigorous movement in those of the spine,
[II, 264] no further covering is put around the encephalon on the outside of the thick membrane, whereas the spinal medulla has that third, sinewy, strong tunic [36] which I mentioned just now. For when the

[36] Helmreich brackets παχὺς καί, found in Kühn's text.

spine at times is flexed and becomes convex,[87] and at other times is extended, the spinal medulla, being flexed and extended along with it, would easily be crushed if such a covering had not been placed around it. Moreover, a viscous humor has been poured around this tunic, as it has been around the tunic binding the vertebrae together and around all the joints, the *glottis*,[88] larynx, urinary canal (it is soft fat around the eyes), and in short, around all parts which must move continually and which we should therefore fear would themselves suffer if they were dried out and would also have their actions destroyed. In the same way men smear the axles of wagons and chariots before [using them] with a moist, viscous juice to keep them from injury and make them move easily.

9. Has Nature, then, constructed so carefully all these things that have to do with the spinal medulla and the whole spine and yet failed to bring them veins and arteries? Or has she brought these from a place from which they ought not to come, or not in the quantity which was better, or has she brought larger or smaller ones than was suitable? Or is it just to admire her here too because she has provided each part of the spine with offshoots of the adjacent vessels, for each vertebra one pair exactly large enough to send branches into all the bodies around it? Now since one pair of nerves [II, 265] also grows out at each vertebra, it is clear that necessarily the number of the nerves must be equal to that of the arteries and of the veins. Hence you must consider that what I said about the nerves when I was explaining the place where they grow out has also been said about the arteries and veins, and you must admire Nature here too because she has chosen the place of exit that is safest both for the vessels themselves and for the vertebrae as well. For she has used one of the apertures I mentioned earlier when I was discussing the nerves for the passage of the three instruments, bringing the nerve out from within and the artery and vein inward from the outside.

Again, when you have recalled here also what has been demonstrated in other works [of mine] [89]—namely that each part of the animal attracts into itself nutriment from the vessels in its vicinity, that it cannot attract over too great a distance, and that for this reason vessels divide continuously—examine the fine apertures which are at the front of each large vertebra and through which

[87] Kühn's text omits *καὶ κυρτοῦσθαι*. [88] See note 41 of Book VII.

[89] *De nat. fac., passim.* See in particular III, 15 (Kühn, II, *209–214*; Galen [1928, *323–331*]).

nutrient vessels are inserted into it. For you will not find any of these apertures in the small vertebrae, because Nature understood that in the smaller vertebrae the force attracting from the vessels adjacent to the bones can remain intact, but that in the large verte-
[II, 266] brae it fails because of the long interval. The two apertures I have described earlier are sufficient, then, for the small vertebrae; through them the arteries and veins pass in and the nerves pass out. For the large vertebrae, however, Nature has had to contrive not only these but also the apertures that serve for the nutrient vessels. It is for the same reason, I suppose, that some slender vessels are inserted into all large bones, such as the humerus, femur, ulna, and tibia, and that none of the small bones needs them.[40] And so, just as Nature introduces into all the other members of the body, and into the parts of the spine as well, branches of slender vessels from arteries and veins that are adjacent, and not over a long distance from those that are far off, so in the same way she distributes nerves to the parts lying near each vertebra from the spinal medulla at that vertebra; for in all places where there is no other, greater necessity [to compel her], she avoids bringing slender vessels over a long distance.

I shall speak more in detail of these things in the book devoted to all the vessels together. I realize, of course, that I have referred to this book many times before this; in it I shall also speak of the cervical vertebrae, because they are the only ones having apertures in their transverse processes.[41] For even though most anatomists do not know this, it is not difficult for anyone who wants to, to discover that certain vessels pass through these apertures, especially
[II, 267] if he has read my *Manual of Dissection*.[42] What the usefulness of such a pathway is I shall tell in the sixteenth book, which is about the vessels, but now I shall add just one thing more and then pass on to a discussion of the scapulae. This one thing is to tell the reason

[40] Daremberg's comment here (in Galen [1856, II, 74]) is, "Ai-je besoin de relever ici cette erreur théorique de Galien?"

[41] Daremberg (in Galen [1856, II, 74]) apparently thinks that this is a projected, separate treatise. It seems, however, to be one more of the many references to Book XVI of *De usu partium*, where the distribution of nerves, arteries, and veins is "explained." The specific reference here to the cervical vertebrae and the vessels traversing the perforations of their transverse processes is found in chapters 11 and 12.

[42] *De anat. admin.*, XIII (Galen [1906, II, *146–147, 159–160;* 1962, *161, 175*]).

why Nature has produced the nerves of the diaphragm from the places I have described. I have shown earlier that it was better for them to be inserted into the middle of the diaphragm and that they must therefore be brought down from above. Why, then, did not Nature in the first place make them grow out high up, from the encephalon itself, and hence capable of being brought down in this way? And if it was better for them to grow out from the neck, why did she pass over the first three pairs and assign to them a part like a cobweb from the fourth pair, a considerable part from the fifth, and then from the sixth a part smaller than this but larger than the first part? For of course she could have produced them from the first three pairs or, again, from the last three in the neck, if she considered it very much better to collect them from many sources in order that, if one or two of these should be injured, the diaphragm would at least have the remaining one to serve it. Well, it is quite evident, I suppose, that because they grow out from the spinal medulla in the neck, they are stronger and hence better suited for energetic actions.[43] But Nature avoided putting the source of them near the thorax, so that they would not have to turn at a sharp angle when they passed to the mediastinal] membranes which divide the thorax [II, 268] and by which[44] they must be supported as they descend. Now we have learned that they grow out not from the anterior parts of the spine but from the sides, and since this happens at the part of the spinal medulla I have indicated, they have a gently sloping course as they pass to the middle region (for it is there that the dividing membranes are), but they would reach it only after a sharp bend if they arose from parts lower down. For this very reason in animals having longer necks than the ape no nerve at all from the fourth pair of spinal nerves goes to the diaphragm, and in those with very long necks none goes from the fifth pair either. For Nature always seems to guard against a long course not only for the nerves, but also for the arteries, veins, and ligaments. Thus the elevation of the fourth

[43] It will be remembered that in Books VIII and IX Galen says that (1) soft nerves are sensory and hard nerves motor; that (2) the encephalon, soft anteriorly where the sensory nerves arise, becomes progressively harder posteriorly; and that (3) the spinal medulla is harder still and hence still more capable of giving rise to nerves controlling vigorous motion.

[44] Reading ὧν with Helmreich for the ὃν of Kühn's text. Daremberg (in Galen [1956, II, 75]) has suggested οἷς.

pair of cervical nerves in the ape is the same as that of the sixth in animals with very long necks and of the fifth in those whose necks are moderately long.

10. It is time now to examine the parts of the scapulae and to set forth the skill of Nature displayed in them. If you should imagine them removed from the animal and no longer existent, you would have no way of conceiving how the joint at the shoulder could be made. Now in order to make it, the head of the humerus absolutely must enter a concavity, and it is for the sake of this concavity that
[II, 269] the neck of the scapula has been produced and that at the end of it a cavity [the glenoid cavity] has been carved out, of a size particularly suitable for articulation with the head of the humerus. This is the first and greatest usefulness for which Nature has made the scapulae, though for good measure there is another, additional usefulness, and this no trivial one, the protection of the parts of the thorax in this region. Seeing at a distance what will harm its anterior parts, we keep them safe by making haste either to jump aside and so avoid altogether what is coming against us, or to cast some protection before our breasts, or to snatch up some defensive weapon in our hands. Frequently we avert the danger just with our bare hands, deeming it better for some parts of them to be wounded, crushed, or shattered than for us to let the breast be injured. For the thorax itself, like the lung it contains, is an instrument of respiration and the heart is the source of all life so that injury to any such parts [45] would be dangerous.

The posterior parts are in equal danger, but we do not have an equal foreknowledge of what will cause injury, since we have no eyes [at the rear]. Here too, then, the just Nature had to find some clever device to avoid neglecting these places altogether. Hence first she affixed a sort of palisade, varying in shape, to the vertebrae of the spine, making those many outgrowths of which I have spoken, slanting them upward and down [the articular processes], producing them obliquely toward the sides [the transverse processes], and
[II, 270] extending straight ones along the whole length of it [the spinous processes]; and next she covered the parts of the spine on each side as far as the ribs first and most particularly with the scapulae themselves and then with plenty of flesh. For the same reason she

[45] Reading *τῶν τοιούτων* with Helmreich for the *τῶν ὁστῶν τοιούτων* of Kühn's text.

caused each of the scapulae to produce a spine of its own and so placed this second palisade before the parts of the thorax in this region.

Moreover, she properly uses this same spine over again for something else; gradually enlarging the upper end of it, raising it straight up, and joining it there with the clavicle, she formed the so-called acromium [46] to be a covering and protection for the enarthrosis at the shoulder and at the same time to prevent the head of the humerus from being dislocated upward and keep the scapula itself from separating forthwith from the thorax. For if she had placed nothing before the articulation at this point, it would be readily injured by everything striking against it from without, and the head of the humerus would easily slip up over the neck of the scapula, which has neither a deep cavity nor large rims. Or if the clavicle were not attached at this point, nothing would prevent the whole scapula, being unsupported, from falling upon the thorax, cramping the shoulder joint there, and impeding many of the movements of the humerus, whose whole ability to move in many ways depends particularly on its being well removed from the thorax. If the humerus [47] touched the ribs of the thorax or were placed very near them as it is in quadrupeds, we should not be able to turn the hand to touch the sternum, the opposite shoulder, the point of the shoulder, or the neck, as we cannot even now, whenever the humerus is dislocated and strikes against the ribs. For in such conditions we cannot raise our hands to any opposite part, because then the convexity of the ribs strikes against the humerus and pushes it back laterally and toward the outside. Now we should suffer this misfortune also in a normal state if [48] the acromium were not very far removed from the sternum and Nature had not put the clavicle between them as a support. [II, 271]

11. Here again you should observe with me that the Art fashioning animals is just in all of them, although certainly I have been striving to write my discourse on man alone. Sometimes, however,

[46] In *De usu partium* Galen uses the term acromium to mean the acromioclavicular articulation. For his treatment of it elsewhere, see note 51 of this Book.

[47] The subject is not expressed in the Greek, but "humerus" seems better than the other possibilities, "scapula," or "joint," though Daremberg (in Galen [1856, II, 77]) prefers the latter.

[48] Kühn omits εἰ μή, but translates it in his Latin version.

even if one guards against doing so with the greatest care, it is impossible to keep from [discussing] the structure of other[49] animals. Nature was not acting idly or at random when she withdrew the shoulder joint in man very far from the thorax, but placed them close together in quadrupeds; rather it was because an animal that was to make use of hands needed varied movement and hence needed this location [of the shoulder joint] in a free space, whereas
[II, 272] quadrupeds did not. For their fore limbs are not arms and hands, but, like their hind limbs, serve only for walking, and hence it was better for the legs to support the thorax. Moreover, it was for the same reasons that the breast was made broad in man and sharp and narrow in animals. Indeed, if its construction had been reversed, in man the hands' actions I have mentioned would be everywhere interfered with, just as if you had placed on the middle of the breast a long wooden plank extending from the neck to the hypochondrium; and in the other animals, if the breast were flat, the fore limbs would be prevented from supporting the thorax properly. Thus here too, as in everything else, Nature seems to have been perfectly just when she made the thorax broad and the shoulder joint well removed [from it] in an animal that is erect and biped, and when she made the thorax sharp in quadrupeds, attaching the scapulae to it and putting the legs underneath as a support.

The formation of the clavicle also shows the same foresight; for since the scapulae must be turned back toward the outside, Nature placed one of the clavicles in [each] interval between the sternum and the ends of the scapular spines. Now although the sternum is long, extending from the throat[50] to the hypochondrium, you would find no place for the articulation with the clavicles that would be more suitable than the one where it actually is; for there
[II, 273] the bone is very broad and strong and no rib as yet articulates with it. In the same way their junction with the scapulae was made in the place most advantageous for turning the latter outward properly, for protecting the shoulder joint, and for preventing its dislocation upward. Necessarily, then, man could not, even if he wished, walk on all fours, since in him the articulations of the scapulae are well removed from the thorax.

[49] Reading ἄλλων with Helmreich for the ἀλόγων of Kühn's text.
[50] The word for "throat" is σφαγή. See note 12 of Book VI.

Just as the ape has been shown earlier in my discourse to be in other respects a ridiculous imitation of man, so too with good reason this holds true of its limbs. For in the discussions devoted especially to the legs I have shown how very different its legs are from those of man, and I have shown this difference too in the construction of the hand. The ape resembles man particularly in the parts of its scapulae and clavicles, though it does not need to be like him in this respect for walking swiftly. For that very reason it is intermediate between the two kinds [of animals] and is neither perfectly biped nor perfectly quadruped but like a defective biped (for it cannot stand quite erect) and a quadruped that is crippled and slow because the shoulder joint is very far removed from the thorax, as if in some other animal it had been torn off and moved away toward the outside. Just as the ape, being an animal with a ridiculous soul, has its whole body for this reason ridiculously arranged, so too, because man has a reasoning soul and is the only godlike animal of [all] those on earth, his body is very well constructed for the faculty of his soul. I have shown earlier that he is the only animal to stand erect; I [II, 274] have shown too that he alone makes proper use of hands, and this will now seem no less true to you if you inspect the shoulder joint, the shape of the whole thorax, and the formation of the clavicle.

These things, then, are sufficient to demonstrate the skill of Nature, but what I am about to say will show it much more clearly still. Now why, instead of extending the clavicle straight from the sternum to the scapula, did she make the part of it near the throat itself convex on the outside and concave on the inside and farther on, contrarywise, make it slightly hollow on the outside and more convex on the inside? For none of these things is done idly or at random by Nature; rather, the clavicle, like the sternum, is made concave on the inside near the throat for the same reason (χρεία) that the sternum is, namely, to provide a suitable space for the instruments that pass down from above and up from below through the neck. But when it begins to get away from the throat and until it reaches the acromium, it turns gradually back toward the front as much as the end of the convex part turns toward the rear at the acromium, because if it merely made its way to the rear as it passed to the sides of the neck, it would not be far enough from the thorax. Here the clavicle is bound to the spine of the scapula by a small [II, 275]

cartilaginous bone,[81] which is not to be found in the ape; for in this as in other respects the ape falls short of the construction in man. Man has this extra bone for the sake of safety, inasmuch as the two ends of the bones are not just joined together with membranous ligaments, but for good measure another, cartilaginous, third bone

[81] This mention of a small cartilaginous bone concealed in the articular capsule of the acromioclavicular articulation is probably not, as one might think at first, an indication that Galen had inspected a human subject and found an abnormal sesamoid bone there. It is rather a reflection of an ancient idea that was entertained by pre-Galenic anatomists, that goes back as far as Hippocrates, and that arose from an ambiguous use of the term acromium. In *De articulis*, cap. 13 (Littré, IV, *116, 117*), Hippocrates says, "In those whose acromium has been torn away, the bone that has been torn away is seen to project. This is the bond of union [*σύνδεσμος*, ordinarily Galen's term for ligament] of the clavicle and scapula; for in this respect the nature of man differs from that of the other animals." This cryptic statement was apparently taken up and amplified by Eudemus, who is reported as follows by Rufus of Ephesus (*1879, 142*): "The acromium is the bond of union (*σύνδεσμος*) of the clavicle and the scapula; Eudemus says that the acromium is a little bonelet."

Galen's remarks on this subject in other works of his make it quite clear that here in *De usu partium* he is merely reporting a well-known tradition. Although, as we have seen, he has defined the acromium here as the acromioclavicular articulation, in his commentaries on Hippocrates' *De articulis* (Kühn, XVIII, pt. 1, *400*), when he is commenting on the passage of Hippocrates quoted above, he calls the acromium a cartilaginous bone lying upon the junction of the clavicle and scapula. In *De anat. admin.*, V, 3 (Kühn, II, *491;* Galen [1956, *127*]), he says, "In the ape do not look for another, third bone on the outer side of these two extremities [of the clavicle and scapula], for Hippocrates does not say that this is present in any animal other than man, and he goes on to say, 'For in this respect the nature of man differs from that of the other animals.'" And finally, in his *De ossibus ad tirones*, cap. 14 (Kühn, II, *766*), Galen says, "Some anatomists call the junction of the bones [the clavicle and scapula] the acromium. But there are some who say that besides the bones that are being joined there is another, third bone found only in man, and this they call the *catacleid* and acromium."

For further discussion of this question, see Littré, IV, *10–13*. Of course, this is just the sort of idea that Galen in his eagerness to demonstrate the superiority of human structure might be expected to welcome, but the whole passage offers a sorry contrast to his attitude on other occasions, in the matter of levator palpebrae superioris, for example. See chapter 10 and note 46 of Book X.

lies upon them and joins itself to the bones beneath it by certain other strong ligaments by which it is concealed. And the reason why it was made cartilaginous, when it must be exposed and be the first to receive the force of blows falling upon it from without, I have told earlier when I was speaking generally about all such bones.

12. It is now time for me to take up the discussion of the shoulder joint itself and to show first that Nature had good reason for making the head of the humerus perfectly round and the [glenoid] concavity surrounding it in the neck of the scapula small and inclined. Then I must show what muscles there are that move the joint, how many and how large they are, and what usefulness each of them provides, and I must show too that it was not better for them to be more or less numerous or larger or smaller, or to occupy any other position. Certainly the usefulness of making the head of the humerus round and the concavity of the scapula shallow and inclined is very clear, if anyone remembers what I said in the first books [of this work]. Since the whole arm was constructed for many, varied [II, 276] movements, it needed to have the head of the humerus rounded (for we should find no shape more suitable than this for making its motion easy) and to have a concavity associated with it that was not very deep and did not end in large rims. For if the joint of the humerus were enclosed in a shallow concavity but still restrained all around by large rims, it could not be rotated easily in every direction, though this rather than safety was its usefulness, since it was for the sake of this that the whole arm was created. Hence the head of the humerus is practically in danger of being continually dislocated, being held in such a small concavity that most of it projects and hangs unsupported. How is it, then, that it is not continually dislocated by vigorous movements? For so far as the structure I have already described is concerned, this would always be happening.

Here again you will admire the skill of Nature, if you observe what she has devised for safety's sake: three strong ligaments[52] binding the bone of the arm to the neck of the scapula in addition to the common one surrounding the whole joint, two curved outgrowths [the acromium and the coracoid process] of the scapula to protect the joint, and very large muscles on both sides of these to hold it fast. The broad, membranous ligament common to all joints [II, 277]

[52] *Vide infra.*

[the articular capsule] grows out from the lips of the [glenoid] concavity of the scapula and, accurately surrounding the whole articulation circularly, is inserted into the beginning of the head of the humerus. Two of the other three ligaments are exactly round like nerves, but the third is slightly flattened. The first [the short head of *biceps brachii*] grows out from the extremity of the anchor-shaped outgrowth [the coracoid process] and the second [the long head of *biceps brachii*], larger than the first, from the neck of the scapula, more precisely at that part [the supraglenoid tuberosity] of it where the rim of the concavity set upon it is highest. For this second tendon a safe support is provided by the head of the humerus, which has in its upper, anterior part a concavity [the intertubercular groove of the humerus] sloping downward very like a broad cut and as large as the ligament itself. The other ligament, the one I mentioned first [the short head], extends along the inner side of the head of the humerus. The remaining, third ligament [the superior glenohumeral ligament] arises from the same place as the second, but growing obliquely beneath it, is itself also inserted into the first beginning of the head of the humerus, like the broad ligament [the articular capsule] enveloping circularly the whole joint; for in a way it is a part of this.

The two first-mentioned ligaments extend into the muscle [*biceps brachii*] lying upon the humerus, the muscle which I said in the books on the arm is inserted into the head of the radius. Thus here too you may see that clever device of Nature's which I have already pointed out times without number, namely, her sometimes making one instrument because of its advantageous location suffice for many
[II, 278] uses. For since all muscles, as I have shown in books devoted especially to them,[53] need a certain amount of ligamentous substance, she has constructed these ligaments to be useful both to the muscle and to the shoulder joint. By binding the joint and holding it together, they keep it from being dislocated, and when they are dispersed in the muscle, from their own substance they provide it too with sufficient help. Thus the shoulder joint is protected on the one hand by the ligaments and on the other by the outgrowths [the processes] of the scapula, on the upper side by the one at the acromium, which some call coracoid, and on the inner[54] side by the one called an-

[53] See notes 6 of Book XII and 36 of Book I.

[54] Reading ἔσωθέν τε with Helmreich for the ἔξωθεν δὲ of Kühn's text.

chor-shaped and sigmoid.[55] Round about on all sides it is bound by very large muscles and tendons, which move the whole articulation and of which it is now time to speak.

13. The ends of these [muscles and tendons] are inserted on the bone of the arm. Certain of them raise the member and some draw it down; others bring it toward the sternum and certain ones move it away; and some of them rotate it in a circle. It is drawn toward the sternum by the medium-sized muscle [*pectoralis abdominalis*] [56] arising from the region of the nipple and immediately drawing the arm slightly downward so that it is the cause of adduction in a lower position. Another muscle [*pectoralis major, pars capsularis*] opposed to this grows out from the upper parts of the sternum and is the cause of adduction in a higher position. In addition to these there is a third muscle [*pectoralis major, pars sternalis*], that is double, or two muscles united; for you will speak truly whichever you say. They [II, 279] grow out from the whole breast bone, and when both are tensed, they bring the whole bone of the arm evenly toward the sternum. If one of them acts alone, however, the one growing out from the lower parts of the sternum causes adduction in a lower position and the other causes it in a higher position, but the adduction the latter produces is not in as high a position as that produced by the second muscle [*pectoralis major, pars capsularis*] I mentioned, nor is that produced by the former in as low a position as that produced by the first muscle [*pectoralis abdominalis*] I mentioned. The lowest [*pectoralis abdominalis*] of these four muscles is next to the small muscle [57] passing up from the region of the nipples, and the highest [*pectoralis major, pars capsularis*] is next to one part [*pars clavicularis*] of the muscle [*deltoideus*] which is at the top of the shoulder, the part, that is, that grows out from the clavicle.

[55] Note the difference in nomenclature from modern usage. The process now called coracoid (like a crow's beak) is described as anchor-shaped or sigmoid (that is, like C, the old form of the Greek Sigma), and what is the acromium in modern parlance becomes the coracoid. Note also that the "acromium" for Galen again means the acromio-clavicular articulartion.

[56] This description of the muscles moving the shoulder joint and the scapula is based on conditions in the ape. See Howell and Straus (1933). It will be helpful to consult the corresponding passages in *De anat. admin.* in Galen (1956, *120* ff.).

[57] Panniculus carnosus, pars thoracica. Cf. *De anat. admin.*, V, 1 (Kühn, II, *475–483;* Galen [1956, *120–123*]).

For this muscle has two heads, growing out both from the inner parts of the top of the shoulder, that is to say, from the clavicle, and from the outer parts beside the spine of the scapula, on its lower side. When this alone is tensed, the action raises the arm outward, inclining it a little laterally from a central, exactly straight elevation. The action of the other part, that which reaches the clavicle, similarly inclines it toward the inside. When both are tensed with equal strength, the arm receives an exactly straight, central elevation without being inclined to either side. Moreover, there are two other muscles [*supraspinatus* and *infraspinatus*], one on each side of the scapular spine, which have an action resembling that of the muscle
[II, 280] [*deltoideus*] I just mentioned; if they are tensed at the same time, they lift the arm straight up, but each acting alone will incline it slightly to one side.

In addition to those I have mentioned there is another, eighth muscle [*teres minor*], which grows out from most of the lower side [border] of the scapula and draws the member away toward an outer position, being placed in opposition to the pectoral muscles [*pectoralis major*, *pars capsularis* and upper part of *pars sternalis*], which are the agents of adduction in a higher position. Next after this one are the two muscular movements which turn the arm to an outer and lower position, but the muscle [*teres major*] growing out from the lower extremity of the lower side [border] of the scapula draws it farther outward, and the other [*subscapularis*], occupying the whole concavity of the scapula, turns the arm not so far outward, but farther downward. There remains one other muscle [*panniculus carnosus*] that draws the arm downward and carries it to the rear; this is continuous with the small muscle [*panniculus carnosus*, *pars thoracica*] which I mentioned earlier and which produces straight movements of the arm downward.

Now although this is the smallest of all the muscles, Nature was content with it alone because of the arm's natural tendency to move downward; for it requires a strong force to lift such a weight, but every body can move down even without a psychic action. And so it is just to admire Nature, who has constructed for raising the member a very strong, double muscle [*deltoideus*] at the top of the shoulder and two others [*supraspinatus* and *infraspinatus*] as well, one on either side of the spine of the scapula, but has assigned the
[II, 281] motion opposed to these to a single, small muscle [*panniculus carno-*

sus]. In general this is assisted to some extent by the lower pectoral muscles [*pectoralis abdominalis; pectoralis major*, lower part of *pars sternalis*], because their aponeurosis is united with it, and also at times by the muscle [*latissimus dorsi*] from the lower parts of the back. When the four are tensed at the same time for more vigorous actions, the arm is forcibly drawn down, but when there is no need of vigorous action, just the little muscle alone is sufficient by itself.

In all the others as well as in these, Nature has also gauged the size justly. Thus she has made the double muscle [*pectoralis major, pars sternalis*] arising from the sternum the largest, because it must be inserted into the bone of the arm along the length of it in order to bring the member toward the whole thorax. Moreover, if you should consider, as it is better to do, that this is not one double muscle but two that are united, you would certainly praise even more her justice in making the upper one much larger than the lower, since the more vigorous action has been entrusted to it. For I have already said only a little while ago that muscles lifting members need a stronger action because they have acting against them the tendency of bodies to move downward, whereas those muscles that draw members down are not only unimpeded by this but even greatly aided, since it acts together with them in the direction of their own effort and they are able with very little strength to perform their proper action. It is for this reason too that at all joints [II, 282] muscles rotating members are themselves strong and have very sinewy tendons, because such a movement is the most vigorous of all, being many times more powerful than a simple one. For if you think of many movements coming one after another, it is easy to see how much greater they are than a single one, and in the same way you should think of a member's movement of rotation as being like many movements juxtaposed. But perhaps you will think that Nature has forgotten her justice when you see the muscle [*latissimus dorsi*] passing up from the lower parts of the back; for it need not have been made large if it was meant to draw the arm downward, and you would be right to accuse her if it did only this. Actually, however, since it provides the animal with two other, additional movements, turning the arm to the rear and drawing down the whole scapula, you could no longer properly find any fault.

Turning now to a discussion of the scapula, since, because of the close connection of the subjects, I have mentioned one of the muscles

moving it, let us examine it, beginning with this very muscle we have been considering. To the many raising it, Nature has opposed this one alone, having made it grow out from the lower thoracic vertebrae [58] and then grow around the parts of the scapula in that region. With such an association it naturally draws down the scapula, just as the part continuous with this that passes up to the humerus was made for the sake of providing the humerus with that motion [of
[II, 283] rotation] which I have just finished discussing. But the part growing around below the scapula draws this downward; for it was better for us sometimes to move not only the articulation at the shoulder but also the whole scapula, and not merely by drawing it up and down, but by bringing it back toward the spine and forward toward the whole neck and breast. Now the scapula is drawn upward by the large, broad muscle [*trapezius*] that grows out from below the [scapular] spine and extends up to the occipital bone of the head [59] and also by the slender muscle [*rhomboideus, pars capitis*] that grows out from the same bones of the head and is inserted into the base of the [scapular] spine. Two other muscles pull it back toward the whole spine of the animal; the higher one [*rhomboideus, pars cervicis*] turns it up toward the cervical vertebrae, and the other [*rhomboideus, pars dorsi*] pulls it toward the dorsal [thoracic] vertebrae. When both muscles are tensed at the same time straight along the lines in which they extend, the movement of the scapula is toward the back. Moreover, the muscle [*atlantoscapularis anterior*] that arises from the lateral outgrowth [the transverse process] of the first vertebra and is inserted into the extremities of the scapula near the acromium [the acromioclavicular articulation] draws upon the acromium especially, but along with this it also draws the whole scapula toward the lateral parts of the neck, just as the slender muscle [*omohyoideus*] arising from the lambdoidal [hyoid] bone draws it forward; for this muscle too is inserted into the bone of the shoulder blade near the acromium. Furthermore, I think that the higher one [*pectoralis major, pars capsularis*] of the muscles passing
[II, 284] up to the scapula from the sternum draws upon not only the head of

[58] Kühn's text has the singular here.

[59] In chapter 6 of Book XVI the origin and insertion are reversed, and this is true also of the treatments in *De anat. admin.*, IV, 6 (Kühn, II, *445–449;* Galen [1956, *105–107*]), and *De musc. diss.* (Kühn, XVIII, pt. 2, *936–937;* Galen [1963, *480*]).

the humerus but also upon the scapula, since it is inserted into the ligament surrounding the whole articulation; for such tendons draw not only upon the bones into which they are inserted but also at times upon those associated in some way with these. This muscle is obviously inserted by a broad, tendinous sheet into the head of the humerus and into the anterior part of the ligament of the whole articulation. To all these muscles there is opposed only the one [*latissimus dorsi*] I mentioned first of all that comes from below; this, I suppose, should not be at all small for this very reason and also because of its other two uses. For it also draws down the arm and rotates it outward.

It is now time for me to bring this book too to a close.[60] In the following one I shall pass to an explanation of the parts concerned with generation and the skill Nature has likewise displayed in them.

[60] Note the omission of serratus anterior from this discussion. This is not because Galen did not know the muscle, which he describes unmistakably in *De musc. diss.* (Kühn, XVIII, pt. 2, *939–940, 990;* Galen [1963, *480–481, 492*]) and in *De anat. admin.*, V, 3 (Kühn, II, *493;* Galen [1956, *128*]). In the first of these occurrences he says its action is to "draw" the scapula, but in the others it is said to draw up or expand the whole thorax. If he was of the latter opinion when he wrote *De usu partium*, the omission here could be explained; for serratus anterior would be one of that group of muscles which he mentions in chapter 20 of Book VII, saying that he has discussed them in another treatise.

THE FOURTEENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Reproductive Tract]

1. Nature had three principal aims in constructing the parts of the animal; for she made them either for the sake of life (the encephalon, heart, and liver), or for a better life (the eyes, ears, and nostrils),[1] or for the continuance of the race (the pudenda, testes, and uteri).[2] I have given sufficient demonstrations in the preceding books [II, 285]

[1] Helmreich omits *καὶ χεῖρας* found in Kühn's text.

[2] Galen was following well-established custom when he usually (though not always) employed the plural in speaking of the uterus. He was thinking, of course, of the bicornuate uterus as two organs having a common outlet, and he explains his varying usage in *De anat. admin.*, XII (Galen [1906, II, *104*; 1962, *113–114*]), where he says, "You can separate the two uteri from one another and free the one from the other easily, up to the point where they come to a neck common to both, situated in their lower extremity. It is for this reason that the uterus is named in two ways. One of these follows the number which the grammarians call the 'singular,' and the organ is called 'the uterus.' The other follows the number which they call 'plural,' and it is then called 'the uteri.' Among the anatomists known to me, I know no one who preceded Hippocrates in designating the uterus in two ways, 'uteri' in the plural, and 'uterus' in the singular. And Plato follows Hippocrates in that, since in his work entitled Timaeus he says: 'And in women, from the same causes, whenever the so-called matrices or uteri, which is an internal organism with a desire to bear young, remains long without fruit beyond the proper time, that is difficult and hard for it to bear, so it becomes unruly and bad-tempered.' Thus you see, my friend, that this man also at one and the same time refers to the uterus in the plural and says 'uteri,' and then employs it in the singular and says 'organism.' And also he calls it at the end of his account once again 'uterus,' since he says with reference to it: 'When the harvest comes, culling as it were the fruit from the trees, they cast

that none of those formed for the sake of life itself or for a better life could possibly have been constructed more excellently if they were different from what they actually are, and so it still remains for me in this book to explain those that have to do with the continuance of the race.

2. Certainly Nature would have been eager to make the work of her hands immortal if she could have done so. But when her material did not admit of this—for anything composed of arteries, veins, nerves, bones, and fleshes could not be made incorruptible—she contrived what was possible to help it toward immortality, being like a good founder of a city, who not only takes thought for colonizing it in the first place but also plans how his city may be maintained always, or at least for a very long time. Now obviously no city has been so fortunate that its founder is no longer remembered because such a long time has passed [since its founding], but the works of Nature have already endured for many thousands of years and will endure hereafter; for she has discovered a wonderful art whereby, when an animal dies, she may always put a new one in its place. What this art is, then, that is displayed in man and all the other animals, to the end that every kind of living creature may avoid destruction and persist, safe and deathless forever, I intend to tell in this book, beginning with the following point: To all animals Nature has given instruments for conception, and to the instruments themselves she has joined a remarkable faculty to produce[8] pleasure [II, 286]

---

the seed in the uterus, as one casts it on the ploughed land.' Now since this is the position with regard to the uterus, you can give it a name which denotes one, in the singular, and say 'uterus,' on account of its neck, and of its external membranous covering—it is because of this membranous covering that many people do not know that it consists of two uteri—and, you may also give it a name referring to the plural and say 'the uteri,' because in fact there are two uteri, which a single mantle, a protective covering, envelops in common, and that is the membranous covering growing out from the peritonaeum. The two [*uteri*] have a neck common to both, that is, the part from out of which there emerges and comes to birth the foetus which will have been developed in one of the two" (translation by Duckworth). I have followed Galen's usage in every instance, translating as "uterus" or "uteri," as the case may be.

[8] Kühn's text omits the εἰς found before γένεσιν in Helmreich's text.

and to the soul that is to make use of them a marvelous, inexpressible longing to do so, which rouses and stings the animal so that even though it is foolish, young, and altogether without reason, it provides for the continuance of the race just as if it were perfectly wise. For knowing, as I suppose, that the substance from which she had created animals does not admit of perfect wisdom, Nature by adding a passionate pleasure to the use of the parts gave them in its stead the only thing which they could receive as an incitement to preserve and maintain the race.

3. So it is fitting to admire first this clever device of hers and then the construction of the instruments which she has given each animal in accordance with the form of its body. Some day you may hear from me about the other animals, when I add what Aristotle has omitted from his treatise; in man,[4] however—for it was to explain man's construction that this work was undertaken in the beginning—first, it is very clear and well known to everyone what degree of usefulness the nature of the pudenda has attained, since they have a suitable situation, size, shape, and general conformation. Then, when you learn the usefulness of each of the instruments that are concealed in the depths [of the body] and revealed by dissection, I am sure that you will admire the skill that has created them. In the
[II, 287] female [Nature] has located the uteri below the stomach, because she found that this place is best for sexual intercourse, for receiving the semen, and also for the growth of the fetus and its birth when it has been perfected. For you would not find any place in the whole body of the animal more suitable for any of the uses I have mentioned; it is best for coitus because it is far removed from the instruments of the face, most opportune for the growth of the fetus because it can be very greatly distended without pain, and most useful for birth because the fetus will emerge more easily if its exit is directed downward and is near the legs.

The neck [the cervix] of the uteri, which Nature has prepared as

[4] It seems to be reasonably certain that Galen had no first-hand knowledge of the anatomy of the internal reproductive organs in man. He had dissected them in various other animals but usually chose to describe them in the goat. See *De uteri dissectione* (Kühn, II, *887–908;* Galen [1962a]; *De anat. admin.*, XII (Galen [1906, II, *106, 110;* 1962, *116,* 120]); and Simon (in Galen [1906, II, *303*]). For an excellent summary of Galen's gynecology, see Lachs (1903), though, writing in 1903, he was naturally unable to include the material in the twelfth book of *De anatomicis administrationibus.*

the path by which the semen enters and the perfected fetus passes out, ends at the female pudendum [the vagina]. When the animal conceives, it closes so accurately that it allows not even the smallest quantity of anything to pass out from within or to be admitted inside from without, but during coitus it opens and is stretched so much that the semen traverses a broad path and easily reaches the hollow of the uteri, and at birth it expands to its greatest extent so that the whole fetus passes through it. With good reason, then, Nature made it sinewy and hard; sinewy so that it could alternately expand and contract to the greatest extent, and hard in order that it might not be damaged by such great changes and might be straightened out when the semen is received. For of course, if it should fall in upon itself and form coils and bends because it was so soft, these would prevent the semen from reaching the sinuses of the uteri quickly, and the fluid and pneuma in the semen would separate from one another, though they ought to unite, the one as the principle of motion, the other as the material suitable for the generation of vessels.[5] [II, 288]

Certainly, as I have shown in other works,[6] the menstrual blood is not the principal or suitable material for the generation of the animal. Whenever the fluid of the semen, borne by the innate pneuma, encounters the tunics of the uteri, it readily adheres like grease, because it is viscous and associates itself with rough bodies. Hence now, in one moment of time, many wonderful works of Nature are accomplished that have to do with the beginning of the animal's generation: the uteri themselves contract as quickly as possible around the semen; the whole neck [the cervix] closes, especially its inner orifice; the fluid spread on the roughnesses of the uteri, being stretched beneath their whole inner surface, becomes a thin membrane; and the pneuma, perfectly preserved in this on all sides and not dissipated, goes about beginning the movements natural to it. It attracts a thin moisture through the arteries and veins that reach the uteri, making it similar to the fluids that are fixed in itself, and then by means of these it prepares a certain thickness and mass. If, however, the pneuma, being airy and composed of small particles, [II, 289]

[5] Reading ἀγγείων with Helmreich for the ἐμβρύων ζώων of Kühn's text. For the appropriateness of "vessels" rather than "embryo," see *De foetuum formatione*, cap. 2 (Kühn, IV, *658–660*), where the formation of vessels at the beginning of generation is described.

[6] *De semine* and *De foetuum formatione*, *passim* (Kühn, IV, *512–702*).

did not fall quickly into the sinuses of the uteri but were delayed on its journey, it would quickly escape from the moisture and be destroyed as it evaporated.

To prevent anything of the sort from happening, Nature made the neck of the uteri moderately hard, so that while it is stretched and expanded during the entrance of the semen, it will be straightened and dilated sufficiently to be capable both of furnishing an unobstructed road for the semen and of closing the orifice afterwards. If it were immoderately hard, it would indeed be straightened easily but would not collapse readily and quickly, and similarly, if it were softer than it actually is, the whole neck could fall in upon itself more readily, but it would be difficult for it to straighten, tense, and dilate. Accordingly, to provide the two uses, which are contrary to one another, Nature has given it contrary qualities in just proportion, making it hard enough so that it can produce moderate breadth and straightness while it is receiving semen, and
[II, 290] blending in enough softness to make it capable of expanding and contracting readily to a great degree. So do not be surprised when you see in dissections of animals or find in the writings of Herophilus or some other anatomist that the neck of the uteri is crooked and winding at all other times, when the semen is not passing in or the fetus passing out; for this follows as a result of the structure I have just described, which is both moderately soft and moderately hard. In fact, if the neck of the uteri were immoderately hard, it would not be crooked when contracted, but as it is, since it was better for it to be sufficiently soft, it necessarily acquires certain wrinkles, bends, and twists when it loses its tension and falls in upon itself, and this contributes greatly to keeping the parts of the uteri from being chilled. For this reason, too, women feel especially cold during their monthly purges and during childbirth; for then the throat[7] of the uteri becomes straight and wide open, and hence, if it were always so, they would always be cold.

[7] Here ὁ στόμαχος; usually ὁ αὐχήν. That Galen really means the cervix when he speaks of the neck of the uterus is evident from what he says in *De anat. admin.*, XII (Galen [1906, II, *103*; 1962, *112*]): "You may name this organic part which lies between the vagina, the female pudenda, and the uterine cavity, the neck and cervix of the uterus" (translation by Duckworth). See also Simon (in Galen [1906, II, *300–301*]).

4. Now though the neck is single, Nature has not made just one hollow in the uteri. In the pig and certain other animals that must bear many fetuses [at one time], she has made very many sinuses, but in man and animals resembling man, just as the whole body is double with right and left sides, so too there is one sinus placed in the right part of the uterus and another in the left. For in all those [II, 291] animals which because of their bodily weakness must either be very short-lived or become food for stronger animals, Nature in her care lest any kind of animal perish has devised as a remedy for their continual destruction the bearing of many offspring.

Certainly this is a wonderful work of hers, but I am sure that you will think it beyond all marvels for the number of sinuses to be made the same as the number of teats. Indeed, it is no longer possible for the sophists to say here that it is an unreasoning cause or some unskillful chance that has made two sinuses in the human uteri and very many in the pig; for the fact that whatever the number of the sinuses is, the number of the teats is the same does away with the opinion that generation is accidental. But even if conditions in man and the pig were the result of chance, the fact that all other animals too always bear the same number of fetuses as they have teats could not seem even to the most shameless to have happened without forethought, unless these men should chance to be complete blockheads as well, or unless they should consider the coming of milk to the breasts just at the time when the fetus is perfected also to be the work of some unreasoning chance and not a proof of wonderful skill.

This surely, even if there were nothing else, is in itself enough to [II, 292] convince anyone that it is the result of skill; for of course no newborn animal could at that time digest solid food, and so for this reason Nature has prepared for it nutriment drawn from the mother, just as she did when it was still a fetus. For animals, such as all birds, which cannot on account of the dryness of their bodies provide a wet residue as nutriment, another clever device for nourishing their young has been contrived by Nature, who has endowed them with a surprising solicitude for their progeny, so that they do battle for them, daring to stand up to fierce animals before whom they would have quailed [8] before, and providing their young with suitable nutriment.

[8] Reading *ὑπέφριττε* with Helmreich for the *ὑπέφυγεν* of Kühn's text.

Well, some day I may explain separately in a special treatise the providence of Nature in dealing with all animals.[9] But as regards man—for my theme from the very beginning has been man—I have [already] shown that all the other parts of the body have been marvelously constructed, and indeed the generative parts are not inferior to the others. For just as two uteri ending in one neck have been made in woman, so there are also two breasts, each one like a faithful servant of its own uterus. Thus Hippocrates[10] has said, "If a pregnant woman is carrying twins and one breast withers, she loses
[II, 293] one child by miscarriage, a male if it is the right breast that withers, a female if it is the left." With this the following statement is in agreement: "Male embryos rather on the right side and females on the left."[11] Now I know that I am touching on a question of no little importance, and I realize too that one cannot explain satisfactorily the usefulness of the generative parts without speaking of their natural actions; for I have shown right at the beginning of this whole work that it is impossible to find the usefulness of all the parts of an instrument without knowing its action. Hence I shall do now just what I have done in all the preceding books, when I explained the usefulness of the parts by using as a basis for present discussions what has been demonstrated in other works [of mine].

I have told at some length in my book *On the Anatomy of Hippocrates*[12] that a female embryo is rarely found in the right uterus, and every day the close association of the breasts with the uteri is clearly evident, both when embryos die, as Hippocrates has taught us, and even before this, when the animal is in a normal condition. For the udders of growing animals are small, like their uteri, but in the adult that has reached the reproductive period they swell up together with the uteri to the proper size, and when this has been established for both instruments, the work of the uteri is to receive the semen and perfect the fetus, that of the udders to nourish
[II, 294] it when it has been brought forth. If you give your attention to the dissection of animals, you will see that in those that are still growing, the bladders are much larger than the uteri, but in those that have

[9] Reading ζῷα with Helmreich for the μόρια of Kühn's text.

[10] *Aphorismi*, sectio V, 38 (Littré, IV, *544, 545*).

[11] Hippocrates, *Aphorismi*, sectio V, 48 (Littré, IV, *550, 551*); cf. *De morbis vulgaribus*, VI, sectio II, 25 (Littré, V, *290, 291*).

[12] A lost work; see Kühn, I, *cxciii*.

reached maturity the uteri are larger than the bladders. For the bladder grows in proportion to all the other parts, because it offers the same service at all ages. The work of the uteri, however, cannot be rightly performed when animals are still growing or have already grown old, that is, if it is true that fetuses make use of superfluous, serviceable nutriment, of which there can be a superfluity only when animals are in their prime. Now in the elderly, nutriment is not well concocted on account of the weakness of the faculty, so that they must be content if enough is prepared for their own use, whereas in growing animals, though the faculty is strong and so concocts useful nutriment in great abundance, this must be consumed in two actions, nourishment and growth, and nothing is left over as a residue. Only in animals in their prime, whose growth has already ceased and whose faculty is still vigorous, is there a superabundance of useful nutriment, and hence Nature makes the uteri largest in these animals and small in the unperfected and the aged, because in the former a considerable size is necessary for pregnancy and in the latter, whose uteri are not to be active, a large size would be altogether superfluous.

5. Now have all these things taken place in the breasts and uteri because the instruments themselves knew by a certain power of [II, 295] reason what they had to do? But if so, would they not cease to be instruments at all and become reasoning animals instead, understanding the proper time and duration of motion? And if, on the other hand, you add to their structure a certain natural necessity that leads to these motions, will they not be kept instruments and parts of the animal, and will they not show forth the wonderful skill of the Creator? For just as there are those who imitate the revolutions of the wandering stars [the planets] with models which by means of certain instruments they endow with the principle of motion and who go away themselves while the instruments [continue to] act as if their creator were present and always controlling them, so in the same way, I suppose, each of the bodily parts by a certain consecution and succession of motion always from the very beginning acts without needing a supervisor. As for us, even if we cannot set forth clearly all the works of Nature (for they are exceedingly hard to explain), we must at least make an attempt to comprehend them all. We should try first to discover the reason for the close association of the breasts with the uteri, and then to explain why males are found

in the right hollow of the uteri and females in the other, how milk is generated, and why the uteri both increase and decrease in size together with the breasts. Before any of these things, however, we should seek to explain the nature of the male and of the female; for to me, at least, [the answer to] this problem seems to be like a source
[II, 296] and fount for the explanation of the others. Well, then, Aristotle[13] was right in thinking the female less perfect than the male; he certainly did not, however, follow out his argument to its conclusion, but, as it seems to me, left out the main head of it, so to speak,[14] which I shall now attempt to add, making the demonstrations correctly given by Aristotle and still earlier by Hippocrates the bases of my discussion and working out myself whatever is lacking to complete it.

6. The female is less perfect than the male for one, principal reason—because she is colder;[15] for if among animals the warm one is the more active, a colder animal would be less perfect than a warmer. A second reason is one that appears in dissecting. This is the particular matter which I just now hinted would be hard for me to explain, but since opportunity calls, I must essay it, and you who are reading these writings must not pass judgment on the whole truth of it unless you have first observed for yourself the things that I have described; for I well know that the sight of the parts will add what the argument lacks.

All the parts, then, that men have, women have too,[16] the difference between them lying in only one thing, which must be kept in mind throughout the discussion, namely, that in women the parts are within [the body], whereas in men they are outside, in the region
[II, 297] called the perineum. Consider first whichever ones you please, turn outward the woman's, turn inward, so to speak, and fold double the man's, and you will find them the same in both in every respect. Then think first, please, of the man's turned in and extending inward between the rectum and the bladder. If this should happen, the scrotum would necessarily take the place of the uteri, with the testes lying outside, next to it on either side; the penis of the male would become the neck of the cavity that had been formed; and the skin at the end of the penis, now called the prepuce, would become the

[13] *De gen. an.*, I, 20, 728a17–20, *et alibi.*
[14] Kühn omits the *οἷον* found in Helmreich's text.
[15] See note 78 of Book VII.
[16] Helmreich brackets *ἰδεῖν ἔστιν.*

female pudendum [the vagina] itself. Think too, please, of the converse, the uterus turned outward and projecting. Would not the testes [the ovaries] then necessarily be inside it? Would it not contain them like a scrotum? Would not the neck [the cervix], hitherto concealed inside the perineum but now pendent, be made into the male member? And would not the female pudendum, being a skinlike growth upon this neck, be changed into the part called the prepuce? It is also clear that in consequence the position of the arteries, veins, and spermatic vessels [the ductus deferentes and Fallopian tubes] would be changed too. In fact, you could not find a single male part left over that had not simply changed its position; for the parts that are inside in woman are outside in man. You can see something like this in the eyes of the mole, which have vitreous [II, 298] and crystalline humors and the tunics that surround these and grow out from the meninges, as I have said, and they have these just as much as animals do that make use of their eyes. The mole's eyes, however, do not open, nor do they project but are left there imperfect and remain like the eyes of other animals when these are still in the uterus.[17]

Now animals differ widely in their natures, as Aristotle[18] has shown at great length. First there are some that are [not far][19] removed from the plants, and these are the most imperfect, having

[17] The rudimentary character of the mole's eyes was well known to the Ancients before the time of Galen. For example, Aristotle says in *Hist. an.*, I, 9, 491b27–34: "All viviparous animals have eyes, with the exception of the mole. And yet one might assert that, though the mole has not eyes in the full sense, yet it has eyes in a kind of a way. For in point of absolute fact it cannot see, and has no eyes visible externally; but when the outer skin is removed, it is found to have the place where eyes are usually situated, and the black parts of the eyes rightly situated, and all the place that is usually devoted on the outside to eyes: showing that the parts are stunted in development, and the skin allowed to grow over" (translation by Thompson [1910], who says in his note on this passage, "True of *Talpa caeca* of S. Europe; the eyes of our common *T. europea* are rudimentary but distinctly visible"). Galen, however, as can be inferred from the definiteness of his comparison, has not merely copied Aristotle but has looked for himself. He uses the same comparison with the mole when he is treating the same subject in greater detail in *De semine*, II, 5 (Kühn, IV, *638–640*).

[18] *Hist. an.*, VIII, 1, 588b4–23.

[19] The text is corrupt here. Helmreich suggests the addition of *βραχύ τι*. Kühn includes "non longe" in his Latin version.

only the sense of touch; such are most of the testacea, which have not only no sensory instrument but also no well-formed member or viscus and lack little of being plants. Farther removed are those that are able to taste, farther still those that have an instrument for smell, and much farther even than these are the ones that have an instrument for hearing. Animals that have both these instruments and also one for sight are close to being perfect, and such are the fish, though they have neither hands nor feet. The lion and dog, however, have not only feet, but, in a manner of speaking, hands too, and this is true to an even greater degree of bears and apes. But
[II, 299] only mankind has a hand actually perfected and the reasoning power to use it as well, a power than which there is nothing more godlike in mortal animals.

Now just as mankind is the most perfect of all animals, so within mankind the man is more perfect than the woman, and the reason for his perfection is his excess of heat,[20] for heat is Nature's primary instrument. Hence in those animals that have less of it, her workmanship is necessarily more imperfect, and so it is no wonder that the female is less perfect than the male by as much as she is colder than he. In fact, just as the mole has imperfect eyes, though certainly not so imperfect as they are in those animals that do not have any trace of them at all,[21] so too the woman is less perfect than the man in respect to the generative parts. For the parts were formed within her when she was still a fetus, but could not because of the defect in the heat emerge and project on the outside, and this, though making the animal itself that was being formed less perfect than one that is complete in all respects, provided no small advantage (*χρεία*) for the race; for there needs must be a female. Indeed, you ought not to think that our Creator would purposely make half the whole race imperfect and, as it were, mutilated, unless there was to be some great advantage in such a mutilation.

Let me tell what this is. The fetus needs abundant material both
[II, 300] when it is first constituted and for the entire period of growth that follows. Hence it is obliged to do one of two things: it must either snatch nutriment away from the mother herself or take nutriment that is left over. Snatching it away would be to injure[22] the gen-

[20] See note 78 of Book VII. [21] A logical lapse.

[22] Reading *βλάπτειν* with Helmreich for the *οὐ βέλτιον* of Kühn's text.

erant, and taking left over nutriment would be impossible if the female were perfectly warm; for if she were, she would easily disperse and evaporate it. Accordingly, it was better for the female to be made enough colder so that she cannot disperse all the nutriment which she concocts and elaborates. Now an animal that is too cold cannot concoct, and on the other hand, one that is perfectly warm, though strong enough to concoct, is also strong enough to disperse. Hence one that falls not very far short of being perfectly warm is able both to concoct, being no longer cold, and to leave some [nutriment] over, since it is not [23] exceedingly warm. This is the reason (χρεία) why the female was made cold, and the immediate consequence of this is the imperfection of the parts, which cannot emerge on the outside on account of the defect in the heat, another very great advantage for the continuance of the race. For, remaining within, that which would have become the scrotum if it had emerged on the outside was made into the substance of the uteri, an instrument fitted to receive and retain the semen and to nourish and perfect the fetus. [II, 301]

Forthwith, of course, the female must have smaller, less perfect testes, and the semen generated in them must be scantier, colder, and wetter (for these things too follow of necessity from the deficient heat). Certainly such semen would be incapable of generating an animal, and, since it too has not been made in vain, I shall explain in the course of my discussion what its use is.[24] The testes of the male

[23] Reading *οὕτω* with Helmreich for the *οὐκ οὕτω* of Kühn's text.

[24] The question of the production of female semen is one on which Aristotle and Galen differed. Aristotle seems not to have known the ovaries in vivipara and denies that the female contributes semen at all. According to him, her contribution is the material cause, the catamenia or menstrual blood, that furnishes the material which contains the parts *in potentia* and from which the fetus is formed by the male semen acting as the efficient cause and contributing the principle of motion. At times, however, he wavers from this position by suggesting that the menstrual blood itself may be semen in an impure state. See *De gen. an.*, I, 18–20, 725a11–728b22; II, 3, 737a27–29. Galen, on the other hand, knowing the ovaries, the "female testes," which he says (*De semine*, II, 1 [Kühn, IV, *596–597*]) had been described by Herophilus, insists that the female does indeed produce semen. In fact, he had seen, so he thought, the oviducts full of thick, seminal humor. See *De semine*, II, 1 (Kühn, IV, *593–594*). Lesky (1950, *1404*) thinks that this humor was in all probability tubal mucus. The roles played, according to

are as much larger as he is the warmer animal. The semen generated in them, having received the peak of concoction, becomes the efficient principle of the animal. Thus, from one principle devised by the Creator in his wisdom, that principle in accordance with which the female has been made less perfect than the male, have stemmed all these things useful for the generation of the animal: that the parts of the female cannot escape to the outside; that she accumulates an excess of useful nutriment and has imperfect semen and a hollow instrument to receive the perfect semen; that since everything in the male is the opposite [of what it is in the female], the male member has been elongated to be most suitable for coitus and the excretion of semen; and that his semen itself has been made thick, abundant, and warm.

[II, 302] 7. Now do not think that the semen moves according to one set of rules for the generation of male animals and according to another for the generation of females; for if it did, there would not result the principle of an animal of the same kind, the laws of motion having been wholly changed.[25] But, as I said just now, the animal with less perfect motion becomes a female and the one with more perfect motion becomes a male. The cause of this more or less perfect motion you would probably attribute to the inequality in heat and cold, and if you were a good natural philosopher, you would refer every particular to this one principle. How, then, can this principle be applied to fetuses? To those[26] who think that the female too emits a fertile semen, it does not seem surprising that whenever the motions generated in it are stronger than those in the male, the fetus that is engendered is female. But these people in the first place do not understand that they are positing two principles of motion in conflict with one another. For if the female semen has as much as

---

Galen, by the semen of both male and female in the development of a new individual will become clear as one reads further in *De usu partium*, and the subject is treated in great detail in his *De semine* and *De foetuum formatione*, both in Kühn's fourth volume. Suffice it to say here that both semens have in his opinion both the material and efficient causes and that the menstrual blood is merely nutritive. For an excellent summary of the positions of both Aristotle and Galen, see Adelmann (1966, II, 734–747).

[25] Reading *τῶν λόγων ὅλως . . . ὑπαλλαττομένων* with Helmreich for the *τοῖς λόγοις ὅλοις . . . ὑπαλλαττόμενον* of Kühn's text.

[26] Democritus, for example; see Aristotle, *De gen. an.*, IV, 1, 764a6–11.

possible of the principle of motion, it has absolutely, of course, the same as the male and must be mixed with the male and thenceforth act as one with it. Or if it does not need to be mixed, what prevents the female alone from emitting semen into herself and thus bringing the fetus to perfection? And yet, this does not appear to happen. The [female semen], then, clearly stands absolutely in need of the male and if so, is necessarily mixed with it, and one motion results [II, 303] from the two combined; for it is impossible for one semen to move in one way and the other in another, and still contribute to the generation of a single animal. In short, to think that there is one path and order of motion for the female semen and another for the male is the mark of men untrained in logical reasoning about natural things. For whether it is the female semen or the blood descending into the uterus that brings with it a principle of motion, this will doubtless govern exactly the same motion as that in which the male semen shares.

This is very clearly seen in hens; for these conceive the so-called wind eggs [27] without intercourse with the male, and that these eggs lack something of being perfect is manifest because an animal cannot be generated from them. Now it is clearly evident that they have entirely the [same] form as other eggs; for the warmth of the male is all they lack to make them perfect. This, however, cannot be true of animals that walk; for since these are far more moist than birds, the female semen [28] is exceedingly weak and unable to advance to that state of motion in which it could impress an artistic form upon the fetus. Only if a certain kind of animal has a temperament dry enough to be able to use up to some extent the superabundant cold moisture in the female semen can it make without the aid of the male a fetus like the egg of birds. But, [they say], in walking animals do [II, 304] we not find in the conception called by physicians a mola, which is an inactive, unformed flesh, something that is analogous to the [wind] egg? Well, if they mean that the female semen progresses so

[27] Wind eggs (that is, infertile eggs) are so called because at one time it was believed that in the spring the breezes have a certain fecundating power. Aristotle has a great deal to say about wind eggs; see, for example, *Hist. an.*, VI, 2, 559b20–560a17, and *De gen. an.*, III, 1, 749a34–749b7. For the source of the tales told of pregnancies induced by the winds, see Thompson's (1910) note to the first of these passages, and see also Zirkle (1936).

[28] Reading *σπέρμα* with Helmreich for the *σῶμα* of Kühn's text.

far, it will be clear to everyone first that they grant little artistic action to it, and perhaps this little would appertain to the menstrual blood alone; and it is clear secondly that they are not speaking the truth in their account of what goes on. For no woman has ever been observed to conceive either a mola or anything else of the sort without the aid of a man, in the way that birds produce eggs without the male. Hence it is better to suppose that the male semen represents the principle of motion and that the female contributes something to it toward the generation of the animal. How great this something is which she contributes I shall tell a little later on, as soon as I have finished all the present discussion.

Now you would learn from the anatomists themselves that when the semen is first cast [into the uterus] and for a long time thereafter, neither pudendum is formed by this one principle, and it is not apparent whether the fetus is male or female. Later, however, [the sex of the fetus] is distinguished and becomes clearly evident, having the semen itself as one cause of its being what it is, and deriving
[II, 305] another cause from the uterus.[20] How each fetus has one of these causes straight from the beginning but receives the other later on, I think I shall show not by plausible reasons, but by clear demonstrations which are based on dissections and in which I am sure that Nature's skill will appear marvelous to you, if you give your attention to what I say.

Well, then, where the vena cava first arises from the liver and, still suspended, bends down along the spine, it has the right kidney lying to the right of it and next, a little lower down, the left kidney lies on its left.[20] There is an outgrowth of a very large venous vessel [*v. renalis*] from it into each kidney, and there is also to be seen below[21] these another couple of vessels [*aa. renales*] just as large, issuing from the largest artery [the aorta], that lies along the spine, and, like the veins, these are inserted into the kidneys. But inasmuch as the right kidney lies near the liver and the left lower down, the vessels inserted into them are the only ones to be allotted one special characteristic not to be found in any other vessels arising either from the vena cava or from the great artery. For all the others grow out as

[20] Reading *μήτρας* with Helmreich for the *μητρὸς* of Kühn's text.

[20] See note 20 of Book V.

[21] That is, dorsal to; Galen is looking down at his subject as it lies on its back on the dissecting table.

pairs from the same sites[83] in each of the vessels [the vena cava and aorta], but the veins and arteries to the kidneys do not make their exits from the great vessels at the same sites; the exit of the vessels [II, 306] for the right kidney is as much higher than that of the vessels for the other one as the right kidney is higher than the other. Next after these vessels a pair of arteries and a pair of veins pass to the generative parts, and these ought to start from the same sites; for no longer does one pair reach an elevated instrument and the other a low one, the left uterus having the same position as the right, and both testes being similarly placed. Of the vessels that pass to the generative parts, however, the ones [*a.* and *v. ovarica*, *a.* and *v. spermatica interna*] going to the right uterus and right[85] testis start from the great vessels themselves that are along the spine, the vein from the vena cava and the artery from the great artery, but those that reach the left testis in the male or the uterus on that side in the female (and there are two of these vessels, one artery and one vein) do not start from the great vessels themselves, but from the vessels passing to the kidneys.[84]

Hence it is clear that the left testis in the male and the left uterus in the female receive blood still uncleansed, full of residues, watery and serous, and so it happens that the temperaments of the instruments themselves that receive [the blood] become different. For just

[83] That is, from the same level.

[85] Literally, "to the testis there," that is, to the testis on the right side; reading ταύτῃ with Kühn for the ταύτης of Helmreich's text. In spite of the weight of the manuscript evidence for ταύτης, the emendation, which appears in only one manuscript, seems justified in order to make the two halves of the sentence balance.

[84] But of course the left internal spermatic artery arises from the aorta, just as the right spermatic does. Cf. the somewhat different but still erroneous account of the origin of the spermatic arteries given in chapter 10 of Book XVI. Galen does nothing to correct the error in *De anatomicis administrationibus*, and in *De venarum arteriarumque dissectione*, cap. 9 (Kühn, II, *822;* Galen [1961, *365*]), he says simply that the arteries accompany the veins. Perhaps he really did not see the true origin of the left spermatic and was honestly reporting what he thought he saw, but the fact remains that his mistake was very convenient for his theory of sex determination, as will become apparent. For excellent, detailed reviews of what she calls the "left-right theory," and of Galen's embryological ideas as a whole, see Lesky (1950, *1263–1293, 1401–1417*), and see also Nardi (1938a).

as pure blood is warmer than blood full of residues, so too the instruments on the right side, nourished with pure blood, become warmer than those on the left. And further, these parts had the
[II, 307] advantage in position [85] from the very beginning; for I have demonstrated many times [86] the correctness of Hippocrates' statement that parts lying in a straight line necessarily get greater benefit from one another. So do not be surprised any more if the right uterus and the testis lying on that side are very much warmer than those on the left, because they not only are nourished differently, but have also been placed in a straight line with the liver. Moreover, if this has been demonstrated and it has been granted that the male is warmer than the female, it is no longer at all unreasonable to say that the parts on the right produce males and those on the left, females. In fact, that is what Hippocrates meant when he said, "At puberty, whichever testis appears on the outside, the right, a male, the left, a female." [87] That is to say, when the generative parts first swell out and the voice becomes rougher and deeper—for this is what puberty is—Hippocrates bids us observe which of the parts is the stronger; for of course, those that swell out first and have a greater growth are the stronger.

Here, to keep you from misunderstanding something in my discussion, a distinction must be made: a part is said to be stronger or weaker than another in two senses, either in general and naturally in respect to the whole race, or in respect to the structure of this one,
[II, 308] individual animal. For in every sort of animal the heart is stronger than the liver, the arteries stronger than the veins, the nerves [sinews] than the fleshes, and all the parts on the right side than the [corresponding] ones on the left. But by some chance some Dion or Theon could have the right half of his head or the eye on that side weaker than the other half or the other eye. In the same way the stronger testis could in general be the right, whereas in some particular individual it might be the left. Now in most cases the left testis

[85] Reading τῇ θέσει with Helmreich for the τῆς φύσεως of Kühn's text.

[86] For example, in chapter 6 of Book V. I have been unable to find precisely this statement in the Hippocratic writings, but it is approximated in *De victus ratione*, I, 6–7 (Littré, VI, *478–481*).

[87] That is to say, if the right testis appears first, the individual will father males, if the left, females. See *De morbis vulgaribus*, VI, sectio IV, 21 (Littré, V, *312–313*).

is more varicose than the right and for this reason the scrotum surrounding it is looser, but in not a few persons you would find that the opposite was true, the right testis having been attacked by some disease when it was first being formed, and in these cases the left one would be the stronger. Furthermore, whenever the right kidney had a position close to the other—for this does happen sometimes, though rarely—outgrowths from the vessels implanted in it are found passing to the right testis in the male and to the right uterus in the female.

To speak generally, then, whenever some little thing goes wrong with any part of an animal while it is first being formed, that part is weaker and more sickly throughout life. For such a fault, first untimely intercourse of the male with the female and later the regimen of the pregnant woman are to blame. But there is another [II, 309] place where these things are spoken of.[88] Whenever the right testis has been made weaker than the other, the left is the first to show itself at the time called puberty, and in this there is an indication that such an animal is a producer of females, just as, in case the right testis remains normal and swells out first at puberty, the animal, so far as it depends on him, becomes a producer of males. For since a principle [also] springs from the female, it sometimes happens that the female-producing semen, warmed by the right uterus, is made into a male fetus, or that the male-producing semen, chilled by the left uterus, changes into the opposite [sex]. In fact, it is not at all surprising that when the semen is [only] a little colder and the uterus is much warmer, it adds to the semen what is lacking [to make the fetus male]; but if the semen should be very much chilled and then fall into the right uterus of an aging animal, it would get no help at all from the uterus. Hence, since there are two principles for the generation of males, the right uterus in the female and the right testis in the male, and since generally the uterus is the better able of the two to make the fetus like unto itself because it is associated with it for a longer time, there is good reason for the fact that for the most part male embryos are found there and females in the left uterus; for in most cases this [left uterus] makes the semen resemble [II, 310] itself. But sometimes, if it is overcome by the power of the heat in the semen, it could allow the fetus to become male rather than

[88] See chapter 10 of Book XI, *ad fin.*

female. These cases are rare, however; for they require a great excess [of heat]. Most frequently the male fetus is found in the right uterus and the female in the left, the cause of this being the origin of the veins that nourish the uteri.

8. Now I am going to explain why the breasts have so much in common with the uteri; for this too indicates an amazing skill on the part of Nature. Since she prepared both these parts to be of service in a single work, she has joined them by means of the vessels [*aa.* and *vv. thoracicae internae*] which I have said in my discussion of the thorax go to the breasts, by bringing down veins [*vv. epigastricae superiores*] and arteries [*aa. epigastricae superiores*] to the hypochondrium and the whole hypogastrium, and then by attaching these to the vessels [*aa.* and *vv. epigastricae inferiores*] which come up from the parts below and from which veins extend to the uterus and scrotum.[89] In fact, these are the only vessels in the animal which, arising from regions above the diaphragm, descend to the lower parts of the body, and the only ones which begin below and pass upward. For the parts [the uteri and breasts] that I mentioned earlier are the only ones needing to be connected by vessels, in order that whenever an embryo is being formed and is growing in the uteri, it alone may be flooded with nutriment from both parts by the common veins, and in order that when the child has been born, all the nutriment may in turn flow to the breasts. This is the reason
[II, 311] why the female cannot menstruate properly and give suck at the same time; for one part is always dried up when the blood turns toward the other. Now when a woman is at the prime of life, in the time before conception Nature each month evacuates through the vessels extending to the uteri whatever surplus accumulates, but when she is pregnant, it is through these vessels that the embryo attracts nutriment. Hence the veins in this region are long and broad enough both to nourish the embryo abundantly and to accumulate always a surplus. Since this surplus accumulates in these common vessels during the whole of pregnancy as if in reservoirs of nutri-

[89] "Scrotum" (*δσχεον*) seems out of place in a discussion of the connection of uterus and breasts, though of course the scrotum according to Galen is the male counterpart of the uterus. There is no variation noted in the manuscripts, but I venture to suggest that a suitable emendation here would be *δρχιν*, testis, that is, the female testis or ovary.

ment, enlarging and distending them to the limit and, as it were, flooding them, it seeks some place to go. But there is no place other than the breasts, into which the distended, burdened veins conduct it, and at the same time the mass of the whole abdomen, bearing against them because of the pregnancy and compressing them, thrusts it toward the place that yields to it. Thus it is that Hippocrates [40] says, "Milk is akin to the menses when the eighth month is gone and the nutriment passes over [to the breasts]." [41] Thus it comes about too that when there is something the matter with the fetus so that it no longer attracts sufficient nutriment, or when something happens to be wrong with the woman's body so that it no longer prepares sufficient blood for the fetus, in these cases the order [II, 312] of the works of Nature is confused and upset, and necessarily the breasts are affected in the opposite way, filling with milk prematurely when fetuses are weak and afterwards becoming dry when the uteri are in need. "If milk flows freely from the breasts of a pregnant woman," so Hippocrates has also said, "it is an indication [42] that the fetus will be weak," [43] because of course all the surplus left in the veins by a weak fetus unable to attract enough to nourish itself suitably rises to the breasts. Again, when he says, "If a pregnant woman's breasts suddenly become withered, she miscarries," [44] one must think that in this case the fetus is strong but does not have plentiful nutriment, so that first it attracts blood to the uteri from the common veins and in so doing makes the breasts wither, and a little later is aborted, when its nutriment gives out altogether. All such questions as these, however, are physical [physiological] problems, mentioned now because of their consecution with what I have proposed to explain.

It was the special aim of my present discussion to tell the usefulness of the close relation between the breasts and uteri and the [II, 313] usefulness of [deriving] the vessels that lead to the left testis and left uterus from those implanted into the kidney on that side. For Nature

[40] *De morbis vulgaribus*, II, sectio III, 17 (Littré, V, *118*, *119* and note 12).

[41] Kühn's text omits the temporal clauses.

[42] Kühn's text omits σημαίνει, supplied by Helmreich.

[43] *Aphorismi*, sectio V, 52 (Littré, IV, *550*, *551*).

[44] *Aphorismi*, sectio V, 37 (Littré, IV, *544–545*).

has contrived all these things, preparing a twofold principle of generation for embryos in order that one may become male and another female. And this is how matters stand in these respects.

9. I must tell next why a very great pleasure is coupled with the exercise of the generative parts and a raging desire precedes their use in all animals at their prime. However, I shall now penetrate not to the first and most important cause (since I have said in previous discussions that Nature has contrived all such things so that the race may continue incorruptible forever) but to the cause derived from the material and the instruments.[45] For animals acquired this desire and pleasure not simply because the gods that formed us wished a vehement desire for love to be born in us or a vehement pleasure to be coupled with it, but because a suitable material and instruments had been prepared for this purpose.

The arteries and veins coming to the generative parts from the vicinity of the kidneys pass by the fundus of the uteri and, mounting upon the sides of them, divide into two parts; one of these parts then leaves the sides [and goes] to the female testes [the ovaries] lying
[II, 314] adjacent to the uteri, and all the other, passing to the fundus, gives off various branches that enter it.[46] There the ends of the vessels distributed to the left sinus of the uterus are joined to the ends of those branching into its right sinus, so that there is a slight but nevertheless appreciable transfer of serous moisture to the right uterus; indeed, this moisture must now have still another, very great usefulness in addition to the one mentioned above; for it has an acrid, biting quality, and there is particular need of this kind of juice, which naturally stimulates the parts to act and makes their action pleasurable. Now if I may in order to make my narrative clear give little, insignificant examples of the wonderful works of Nature, reflect with me on the sort of thing that happens when these serous humors are heated, as they frequently are, especially when acrid humors collect under the skin of the animal and then itch and make it scratch and enjoy the scratching. Whenever, therefore, there is not only a moisture of this sort needing to be evacuated and hence stimulating and provoking its own evacuation, but also a great deal

[45] See chapter 12 and note 57 of Book VI.

[46] In the ruminant the uterine branches of the internal ovarian veins and arteries are large and distinct. See Ellenberger and Baum (1926, *671–672, 699*).

of warm pneuma requiring to be exhaled, we must consider that there is an extraordinary, excessive pleasure. And since Nature has made these parts much more sensitive than the skin for the sake of [II, 315] the same usefulness, it is no longer to be wondered at that the pleasure inherent in the parts there and the desire that precedes it are more vehement.

This is also the reason why offshoots from the vessels inserted into the right kidney often pass directly to the uterus that is in a straight line with it; for since these serous residues must have two uses, the first to make the parts on the left colder, the second to make possible a strong desire [to use the instruments] and a vehement pleasure in their use, the first is always present in the left-hand parts and the second sometimes in those on the right because of the long vessels. There is in addition something else that is of no little help in this, namely, [in the male] the glandular bodies [the seminal vesicles] lying on both sides of the neck of the bladder, bodies which are seen to contain a fluid like semen, but very much thinner. I shall speak of this, however, a little farther on. The semen itself is a pneuma and like foam, so that if ever it is emitted into the outer air, there soon appears to be much less of it than when it was first emitted; it dries up quickly, because it is viscous, and, unlike mucus and phlegm, it does not persist for a long time or preserve its original volume [II, 316] without evaporating. The moisture in these glandular bodies is thin, watery, and unconcocted, whereas that of the semen is thick, viscous, and full of vital pneuma.

10. When the semen falls into a suitable place, it becomes the principle of generation of an animal, but when it falls into an unfavorable one, the pneuma quickly escapes from it and there is left the viscous humor which subsides into itself. Here is the cause of the generation of this humor [the semen]: The descending part of the vessels [*aa.* and *vv. ovaricae*] which go to the uteri and which I have said branch at their sides is coiled very much as the vessels [*aa.* and *vv. spermaticae internae*] going to the male testes are. The vein lies on the top and the artery underneath, and both make the same large number of coils like the tendrils of vines variously interwoven. In this interweaving the blood and pneuma passing to the testes are very greatly concocted, and it is possible to see clearly that the humor contained in the first coils is still like blood and that in the succeeding coils it keeps getting whiter and whiter until in

the very last ones, that end in the testes, it has been made absolutely white. The testes in turn, being porous and spongy, receive the
[II, 317] humor given a preliminary concoction in the vessels and concoct it thoroughly, the male testes making it perfect for the generation of the animal; for these are larger and warmer, and the humor brought to them is already more elaborated because of the long distance [it has traveled] and the power of the concocting vessels. The female testes, on the other hand, make a humor less perfect, both because they are smaller and colder and because it is less elaborated when they receive it.

I think that anyone who remembers the demonstrations in my book *On the Natural Faculties* will easily discover why blood long delayed in the vessels becomes white. For I showed there that every part makes its nutriment resemble itself;[47] so why should it still be surprising that the tunics of the vessels, being white, change the blood into a semblance of themselves? But perhaps someone will ask why this is not seen to happen in a single one of the other vessels, a question to which it is easy to reply that the blood does not spend such a long time in any other vessel; for there is no other vessel in which there is a single such coil, not to mention so many of them, lying one upon another.[48] And if elsewhere in the animal the blood did delay and did not flow rapidly through and were not evacuated, it would of course be possible to find such a juice there. Furthermore, the moisture natural to the vessels, that in the tunics themselves from which they are nourished, is of this character. Thus it is not at all surprising if a spermatic juice accumulates when the blood
[II, 318] stagnates, so to speak, in these coils.

Well, when the testes have received this and elaborated it, the male testes perfectly and the female less adequately, clearly there will be need of another vessel to take it over and lead it off to be expelled, and here, if one is well versed in the dissection of the parts, he cannot but marvel at the skill of Nature. Since it was necessary for the male to send the semen outside his body and for the female to send it into herself, the vessels receiving it from the testes in the male

[47] *Passim;* see in particular I, 10 (Kühn, II, *20–22;* Galen [1928, *32–35*]), III, 1 (Kühn, II, *143–144;* Galen [1928, *222, 223*]).

[48] But see chapter 4 of Book IX, where the retiform plexus (the *rete mirabile*) is explained. The two passages are hardly consistent.

[the ductus deferentes] were extended to the pudendum and there opened into the channel [the urethra] through which the urine passes out; in the female they [the Fallopian tubes] were inserted into the uteri themselves, where they cause the semen to be expelled into the free space within. Now these things are certainly marvelous, but what I am about to tell is much greater still. Since the two semens do not have similar uses, because they are dissimilar in quantity and faculty, the spermatic vessels are also not similar in either shape, breadth, or length. In the male they are broad and long and have certain sinuses [the ampullae] when they get near the pudendum, whereas in the female they are narrow and short; for such a vessel is large enough to receive and transport the scanty, thin [female] semen. If the male vessel, on the other hand, were not made long, broad, and convoluted, how would it receive a large quantity [II, 319] of thick semen? How would it transport it readily? And how would it implant a mass of semen all at once in the uteri?

Yes, these works of Nature are marvelous, and there is in addition the general tensing of the generative parts in coitus, in order that, as I have said earlier, the neck of the uterus may be straightened and opened and at the same time the semen may be evacuated. Indeed, from severe attacks of epilepsy [49] and from the disease called gonorrhea you may learn how great a power the spasm, so to speak, of the parts that accompanies the sexual act has to expel what they contain. For in violent attacks of epilepsy semen is expelled because the whole body and with it the generative parts are strongly convulsed, whereas in gonorrhea only the spermatic vessels themselves are affected. Now in coitus they have the same sort of tension with which they are affected in these diseases, and so they expel the semen; and I have told earlier how the nature of the semen necessarily produces desire for the sexual act and the pleasure experienced when the parts are used.

11. Besides contributing to the generation of the animal, the female semen is also useful in the following ways: It provides no small usefulness in inciting the female to the sexual act and in opening wide the neck of the uteri during coitus. It would be next in [II, 320]

[49] Cf. *Hippocratis epidemiorum III. et Galeni in illum commentarius*, cap. 4 (Kühn, XVII, pt. 1, *521*), where Galen writes, "Democritus has written that coitus is a little epilepsy."

order, after I have reminded you of what I have said in my book *On the Semen*[50] to tell how great a thing it is that the female contributes to the generation of the animal. For I have shown there that when the female is to conceive, the male semen remains within the uteri, as Hippocrates[51] has said, and that the generation of the membranes, as also of all the vessels has as its source the male semen. This is then further concocted and nourished right at the start by the female semen, because this is closer to it in character than blood is, and everything that is nourished can take its increase more easily from what is similar to it. I have shown too in my commentaries *On the Semen* that the allantoic tunic is also formed from the female semen. The humor produced in those glandular bodies [the seminal vesicles] is poured out into the urinary passage in the male along with the semen,[52] and its uses are to excite to the sexual act, to make coitus pleasurable, and to moisten the urinary passageway. [In the male it has a peculiar, special use, like the one the female semen has;
[II, 321] for the nature of the semen in the female testes is very like that of the humor contained in the glandular bodies of the male, because the force and the heat of the male concocts the juice in these parts too so thoroughly that it does not in any way fall short of being female semen.][53] This is the reason, I suppose, why they do not hesitate to call the passageways arising from these bodies spermatic vessels, and indeed, Herophilus was the first to call them *parastatai*[54] *adenoeideis* (glandular assistants), since he had previously called those that grow out from the testes *parastatai cirsoeideis* (varicose assistants).[55] [But because the female is colder than the male, the

[50] *De semine, passim;* see in particular I, 7, and II, 4 (Kühn, IV, *535–539, 622–624*).

[51] *De genitura*, cap. 5 (Littré, VII, *476, 477*).

[52] Helmreich omits *φερόμενον . . . ἐκχεόμενον*, found at this point in Kühn's text.

[53] This passage is bracketed by Helmreich because of its absence from the best manuscripts and the Latin version of Niccolò da Reggio.

[54] Reading *παραστάτας* with Helmreich for the *προστάτας* of Kühn's text.

[55] The ductus deferentes and particularly their ampullae. In *De semine*, I, 15 (Kühn, IV, *565, 567*), Galen says, "The spermatic canal, which some call the varicose assistant (*παραστάτης κιρσοειδής*) and which draws off the geniture, passes up thence [from the epididymis] to the outgrowth of the pudendum. . . . Nature also makes the spermatic canal more varicose near the neck of the bladder, and it is from this

liquid in her *parastatai adenoeideis* is unconcocted and thin, so that it is of no assistance in the generation of the animal. Properly, then, it is poured outside when it has done its service (χρεία), whereas the other liquor, that of the male, is of course attracted into the uteri. That this liquid not only stimulates to the sexual act but also is able to give pleasure and moisten the passageway as it escapes, you may best learn from what follows: It manifestly flows from women as they experience the greatest pleasure in coitus, when it is perceptibly shed upon the male pudendum; indeed, such an outflow seems to give a certain pleasure even to eunuchs. Thus you could not want a clearer proof than this.] [56] [II, 322]

It is clear too from the very nature of this liquid, I suppose, that it moistens and softens the passageway; for since it is sticky, so to speak, and thick like olive oil, it smears the passageway to prevent its being dried out, collapsing, and keeping both urine and semen from passing through easily. Moreover, I have shown that there are certain other glands formed for the sake of the same usefulness, such as those at the pharynx, the *glottis*,[57] the rough artery [the trachea], and the intestines. Now recently there was a certain man all of whose parts in that [urinogenital] region were thin, unnourished, dry, and shriveled, and he seemed to me on that account to be incapable of urinating unless there was first a very great quantity of liquid accumulated in his bladder, because the channel was dry and fallen in upon itself. He needed, therefore, a great deal of urine sent vigorously down from above all at once to open the channel by the strength of its rush; otherwise the man was quite unable to urinate. And the cure proved that I was right about the cause; for when I moistened the whole region with oily ointments and built up with extra nourishment his entire body, which was extremely thin, espe-

---

that the name 'varicose assistant' has been given it." Cf. *De anat. admin.*, XII (Galen [1906, II, *120* and note 403; 1962, *131*]), where Simon also points out that the *parastatai adenoeideis* (the seminal vesicles) may very well included the prostate.

[56] This passage is bracketed by Helmreich, again because of its absence from the best manuscripts and the Latin version of Niccolò da Reggio. Its contents also make it highly suspect; for elsewhere Galen twice states plainly that *paratatai adenoeideis* are not present in the female. See *De semine*, II, 1 (Kühn, IV, *598*), and *De anat. admin.*, XII (Galen [1906, II, *113*; 1962, *123*]), and cf. Hyrtl (1880, *425–428*).

[57] See note 41 of Book VII.

cially the parts in this region, I restored him to health with these remedies. Now in coitus this humor [from the seminal vesicles] escapes all at once along with the semen, but at other times very
[II, 323] gradually and therefore imperceptibly. Hence I was not [58] wrong in thinking that a man in whom this humor had been thoroughly dried up by frequent coitus and who then, like the man I just mentioned, had difficulty in urinating would be cured if I ordered him to live temperately.

All these things have obviously been prepared by Nature with foresight, and in addition to these there is also the generation of the so-called horns [of the uterus]. If I was right when I demonstrated in my book *On the Natural Faculties* [59] that both the other parts of the body and the uteri above all have a faculty by which they attract a quality appropriate to themselves, then the uteri absolutely must have a canal prepared for the attraction of such a juice. But the juice most appropriate to the uteri, the juice which they have been formed to receive, is the semen, and since there are two semens, two kinds of canals have been formed for the uteri. One of these is called the neck [the cervix] by anatomists, which is for the attraction of the male semen and which I have said extends to the female pudendum, and the other is the horns, which are for the semen from the female's own testes. The horns accordingly tend upward toward the flanks, become gradually narrower and have extremely narrow ends where they are attached each to the *didymus* of its side (for *didymus* is the name which Herophilus gives the testis). The attaching vessel [the Fallopian tube] is analogous to those called *parastatai*
[II, 324] *cirsoeideis* [the ductus deferentes] in the male and is the one that I called spermatic just now. It too has the muscular bodies that in the male pass down to the testes from the hypogastric muscles,[60] and so in this respect also the female animal has all the parts which the male has. If some of them are smaller and some larger [than the corresponding parts in the male], here too we must admire the skill of Nature, who did not make any part in the female smaller when it needed to be larger, or conversely, larger when it needed to be smaller.

[58] Kühn's text omits the negative with disastrous results.

[59] I, 12–13 (Kühn, II, *29–30;* Galen [1928, *48, 49*]).

[60] Here Galen equates the round ligament of the uterus with the cremaster muscle in the male, as he also does in *De anat. admin.*, XII (Galen [1906, II, *103;* 1962, *113*]).

12. I have said earlier that it was better for the male to have larger testes and spermatic channels. Hence, since this was better, Nature had good reason to extend the horns of the uteri upward and bring them up near the testes in order to make the connecting spermatic vessel [the Fallopian tube] short, whereas in the male she has done the opposite, as I have told in this book. For if no clever device had been invented for the formation of the spermatic vessels and the testes lay one on each side of the root of the *kaulos* [the penis] (for that is what the male pudendum is called), not only would she have failed to make the vessels longer than they are in the female; she would even have made them much shorter. Accordingly, she contrived for them a long, circuitous route, conducting them first up toward the flanks and then down again through the inner parts as far as the place where the pudendum grows out and where the semen must be discharged. Here she then made them varicose [at [II, 325] the ampullae], very greatly broadening and dilating them in every way as much as possible and preparing ample receptacles for a large quantity of semen. Now if you are willing to listen carefully to what I say and become eyewitnesses of Nature's works by addressing yourself to the dissection of animals, you will see that the male spermatic vessels are greatly superior and that they are many times as long, broad, and deep as those of the female.

These, then, are the reasons why the testes of women have been made very small and produced one on each side of the uteri in the epigastric region, but those of men are many times as large and have been brought down to the region below the abdomen so that they do not touch it at all. For if Nature had placed them in the abdomen too, not only would they be cramped for room and themselves cramp the parts in this region, but in addition she would necessarily have curtailed the length of the spermatic vessels. As it is, however, since these are brought up from below and then down again, they gain considerable length, whereas if they merely passed down from above, they would then lose as much as half of the length they now have. The testes of women, on the other hand, are very small indeed and need send out only small vessels, so that the position they now have, one on each side of the uterus and a little above, and with- [II, 326] drawn from, the horns, is a most suitable one. One may learn most particularly from fishes and from birds too that Nature has given no little thought to the size of the spermatic vessels in the male. For since these animals for the sake of producing many offspring at once

must collect a very large quantity of semen and since it was therefore better for the testes to be located in a warm place in order that they might thoroughly concoct the affluent humor more quickly and elaborate it for the generation of useful semen, she did not simply bring them near the openings emitting the semen and establish them there—for if she had, they would be short—but moved them far forward and attached them to the diaphragm. Certainly this place is warmest of all, being covered by four viscera, the heart and lung above, and the liver and spleen below. Moreover, the interval in the middle,[61] all of which the spermatic vessels had to occupy, was very great. Everything seems to have been admirably contrived by Nature in every kind of animal, and perhaps some day it may be possible to speak of the others. In man, however—for it is with him that I am concerned in this treatise—in man, whose spine is very much shorter in proportion to the other parts than the spines of fishes, birds, or all other animals, and whose testes themselves are
[II, 327] large, such a location was unsuitable for them. For in addition to other considerations, he does not need such an abundance of seminal fluid as those animals, and because the human testes are so large and warm, they are capable of producing a moderate amount of semen even without being placed near warm instruments. And this is enough to say about their position.

13. As regards the length of the spermatic vessels—for that is the subject from which my discourse has been digressing—one must admire Nature for the way in which she brings them first up from the testes toward the flanks and then down again to the male pudendum, where she presently opens them into the channel which leads from the bladder and through which the urine also escapes. Now it is proper to admire her not only because she found such a circuitous route in order to make them long, but because of the way too in which she has provided for their safety. For she has used the flute-like channel [the inguinal canal] from the peritoneum by which she conducted downward the vessels nourishing the testes for the upward course of the spermatic vessel too, contriving this one channel as a common means of safety for the three kinds of vessels [vein, artery, ductus deferens]. As she leads them down again from this point, she protects them laterally by the ischium, in front by the

[61] That is, the distance from the testes to the pudendum. Daremberg's rendering (in Galen [1856, II, *122*]) is incorrect.

bone at the pubis, and at the back by the broad bone [*os sacrum*].

Indeed, the fitting together of these bones is so marvelous that it is not easy to explain. The so-called broad or sacred bone has been laid under the end of the spine as a foundation. At its sides two bones [*os coxae*] are united with it, which are many times its size, extremely [II, 328] irregular in shape, extending (the greater part of them [*os ilii*]) up toward the flanks, but projecting a little laterally and downward [*os ischii*], and going to meet one another with rounded outgrowths [*os pubis*] of considerable size in front where they are united by means of cartilage. All these bones which I have been describing have their inner surfaces concave, hollow, and smooth, some more and some less but all to some extent, so that they produce a single, large, bony vault, covering and protecting all the parts of the animal occupying the cavity within it, both the spermatic vessels and other parts as well. First, the bladder lies beneath the pubic bones; for that is what anatomists usually call the rounded, bony outgrowths which I mentioned just now and which I said unite with one another. Next after these [the bones and the bladder] in the female are the uteri, and after the uterus comes the rectum. In the male, on the other hand, it is chiefly the spermatic vessels that descend through this region. Nature has made the tunic of these exceedingly stout, because they are long and must be violently stretched and contracted in coitus, and since this is more marked in the male than in the female, the tunic of the *parastatai cirsoeideis* [the Fallopian tubes and ductus [II, 329] deferentes] has been made stronger in the male. For the same reason the *parastatai adenoeideis* [the seminal vesicles] [82] have been made much weaker than these, since they are very small and contain a humor of a thin consistency.

Thus in all things Nature has been most just, distributing strength and weakness, thickness and thinness, and all the other qualities according to merit. Indeed, if in dissections you should examine the size of each of the veins, arteries, and nerves arriving at the genital parts, you would admire, I am sure, the justice of the Creator. For nerves of moderate size arrive there, but the veins and arteries are not only as large as possible but also double. One pair [*a.* and *v. spermatica* (*ovarica*) *interna*] arises from the region of the kidneys,

[82] It seems likely that Galen meant to say that the *tunics* are much weaker.

and, as I have said, divides into branches to the testes and the funduses of the uteri. The other [*a.* and *v. uterina* and *vaginalis; a.* and *v. pudenda interna*] is derived from the vessels [*a.* and *v. iliaca interna*] at the sacrum and is inserted into the lower parts, where in the female the neck of the uterus and in the male the part called the penis first grow out. In fact, all the lower parts of the uteri, their neck [the cervix], and the parts at the female pudendum are nourished from these vessels, as the parts at the male pudendum are too. These vessels are useful in one way because they are large, and in another because there are two pairs of them; for since the uteri procure nutriment not only for themselves but also for the fetuses, they need large vessels, and the testes need large ones too, because
[II, 330] they must not only be nourished but also generate the semen. Moreover, it is very clear to everyone that the pair of arteries and veins [*a.* and *v. uterina* and *vaginalis; a.* and *v. pudenda interna*] arriving at the genital parts only to nourish them ought not to contain blood still uncleansed and excrementitious, whereas the pair [*a.* and *v. spermatica* (*ovarica*) *interna*] providing in addition to nutriment those certain other benefits (χρεῖαι) which I showed a little while ago to be inherent in the vessels from the kidneys must have serous, acrid blood that is not all useful.

For these reasons, then, the vessels [*a.* and *v. uterina* and *vaginalis; a.* and *v. pudenda interna*] coming from [the vicinity of] the broad bone [os sacrum] start from large vessels [*a.* and *v. iliaca interna*] lying nearby, and you would not find any region closer from which to bring veins, nerves, and arteries over a shorter distance to the genital parts. For here Nature observes the rule which I have already mentioned many times before, that she should bring nutriment to the parts to be nourished over the very shortest distance, but in the case of the other source from the kidneys she would seem to have forgotten herself, if one did not know the reasons (χρεῖαι) which I have told earlier for bringing the vessels down from above. In the female, of course, the length of the interval is less conspicuous, since the uteri lie within[68] the abdomen, but in the male, since the testes are suspended, the veins and arteries coming to them from the kidneys are obviously longer. Thus all the things which I have
[II, 331]

[68] Reading ἐντὸς κατὰ τὴν γαστέρα κειμένων τῶν ὑστερῶν for the ἐν τοῖς κατὰ τὴν γαστέρα τόποις προκειμένων τῶν ὑστερῶν of Kühn's text.

said correctly confirm one another and in addition show Nature to be just in everything.

A pair of nerves [*n. pudendus*] extends along beside the vessels arising from the sacrum and divides with them, just as nerves accompany, and divide with, arteries and veins arriving at other parts. For if vessels that nourish must be conducted either over the shortest interval or through regions that are safe, it is clear that nerves rightly should have both these advantages too, with the result that they arise from the same places and travel the same paths as the vessels. However, although the genital instruments receive extra arteries and veins coming down from above, these with good reason are not accompanied by any nerve from the lumbar region of the spinal medulla; for it was not better for a nerve to be conducted over a long distance. Moreover, the thickness of the nerves is nicely adjusted to their usefulness. Since, as I have shown before, there are three ends to be gained in the distribution of nerves to all the parts—sensation in the sensory instruments, motion in the instruments of motion, and in all the others perception of what will cause pain—very few nerves are needed by the uteri as a whole or (in the male) by all the parts at the testes and scrotum,[64] because they do not serve for accurate sensation or any voluntary motion and are not channels for the residues, as the intestines are. The male penis, on the [II, 332] other hand, as well as the neck [the cervix] of the uteri and the other parts at the pudendum, needing as they do extra sensation for sexual intercourse, with good reason receive a larger share. And so, if you bear in mind that the liver, spleen, and kidneys have been shown to need [only] very small nerves and that this is also true of the genital parts with the exception of those at the pudendum, and if you then see in dissecting animals that the genital parts receive for their share just as small nerves as these viscera do, and that only the parts at the pudendum have more considerable ones, I am certain that in this too you will admire the justice of Nature. Hence this pair of nerves [*n. pudendus*] is neither as exceedingly small as those of the liver, spleen, and kidneys, nor as considerable as those for the stomach, but so far as possible is midway between them in thickness, because it must provide the instruments with a compound usefulness, in some parts with a usefulness like that of the nerves of the liver and

[64] Helmreich omits *εἰς ἅπαντα τὰ μόρια νομῆς* found in Kühn's text.

kidneys and in the parts at the pudendum with one like that of the nerves of the stomach.

14. In earlier books, when I was explaining the instruments of the nutriment, I have already told the main reason why all the intestines and the stomach were formed with two tunics, when one was sufficient for the uteri as well as for the two bladders [gall and
[II, 333] urinary], but now I must also tell as much as is important for the elucidation of the uteri. Nature has made the substance of the bladders hard and resistant to injury because their sole work is to receive residues. For the intestines and stomach, however, which are instruments of concoction rather than receptacles for residues, a fleshlike substance was more suitable. For Nature did not cause them to be created in order to receive bile, phlegm, or other, serous residues frequently flowing down from the whole body, but though they were formed for other tasks, she did use them at the same time as channels for the residues. Hence with good reason the form of their bodily substance has been suited to their actions, and the number of their tunics has been increased for this additional usefulness.[65] For there was danger, as I showed in the books devoted to these instruments, that the inner one of the tunics would at times be eroded and get into a bad condition, and so Nature added a second tunic outside the first in order to confine the trouble to this one alone.

For the uteri, however, which are nourished with pure, useful blood, one tunic was enough, and since they must not only attract the semen in coitus, but also retain the fetus during the time of pregnancy and expel it when perfected, Nature has skillfully constructed them of every kind of fiber.[66] Now in this connection I have shown many times that each of the instruments attracts by the
[II, 334] action of straight fibers, expels by means of transverse fibers, and retains by the action of all of them together. The [peritoneal] membrane surrounding both uteri on the outside holds them together in one place, protects them, and attaches them to the neigh-

[65] See note 23 of Book IV.

[66] It is, of course, the muscular coat which is described here, and from which the mucous membrane is not distinguished. See the similar treatment in *De anat. admin.*, XII (Galen [1906, II, *104–105;* 1962, *114*]), and the much inferior description in *De uteri dissectione*, cap. 6 (Kühn, II, *896–897;* Galen [1962a, *80*]).

boring parts. Moreover, they have certain other bonds with the bodies at the spine and other surrounding parts, and these bonds are all so exceedingly lax that you can see nothing like them in any other part; for there is no other that can be very greatly expanded and can then contract again into a very small compass. The ligaments must of course accompany the whole viscus and expand together with it without being broken off themselves or permitting it to stray off or trespass too much on the places occupied by other parts.

As for the situation of the uterus, I have said earlier that its neck ends at the female pudendum, which is properly located where it is, and if the neck must be turned downward, it is clear that all the rest of the cavity must be placed in the region of the abdomen. Why, then, was the bladder placed in front, the rectum at the back, and the uteri in the middle between them? Was it not that it was better for the uteri when expanded to their greatest extend in pregnancy to have something like padding behind them at the spine and something in front of them as a defense? For they become exceedingly thin at the time of pregnancy, because their depth [thickness] is used up in increasing their size, and so they are weakened. Moreover, because of their mass they spread into all the adjacent spaces. Thus they [II, 335] could not be so close to the bones lying round about them without pain and injury, unless some part had been interposed.

Now why did Nature not insert the spermatic vessel [the ductus deferens] into the testes themselves instead of putting the part called the epididymis between them? The answer is that the exceedingly soft, porous, spongy testes could not safely be united with the dense, strong, hard spermatic vessels. Hence here too Nature appears to have done the thing which I have many times already shown [her doing], that is, she does not conduct into the same place parts with substances that are opposites, but always strives to place between them some bond bringing them into accord. For the epididymis is as much stronger, denser, and harder than the testes as it falls short of the spermatic vessels in these qualities. Furthermore, the parts of it inserted into the spermatic vessels are very hard, those inserted into the testes are very soft, and the intermediate ones are all in proportion; those nearer the spermatic vessels are the hardest, and again, those nearer the testes are the softest for the same reason.

But why are not the epididymides at the female testes [the ovaries] perceptible and clear, and why do they seem to be either lack-

ing altogether or very small indeed? Is it not primarily because the female testis itself is small and the spermatic vessel [the Fallopian
[II, 336] tube] is small too, so that it is not at all surprising that the part joining them should also be small? Then, too, the difference between their substances is a slight one, and not very great as it is in the male. Moreover, the male testes are softer and more moist than those of the female and the male spermatic vessels are harder. In the female the opposite is true, the spermatic vessels being less hard for the reasons I have given and the testes less loose-textured, porous, and moist, because their substance is colder; for they have not been inflated and leavened, so to speak, by the innate heat. With good reason, then, the substances [of the two parts] are nearly alike [in the female], since the testes have been made harder and the spermatic vessels inserted into them are softer, and hence there was no necessity for the parts to be joined together by a large body which would gradually recede from the hardness of one of them and approach the softness of the other.

Since the male testes are suspended, a muscle [*cremaster*] comes down to each of them from the region of the flanks, in order that these too may have their share of voluntary motion. I have demonstrated in my commentaries *On the Semen* what the semen from the female contributes to that of the male, what the nature of each is, and all such subjects, and I should now bring this book to a close at this point; in the next I shall point out all the skill of Nature as displayed in her treatment of the fetus.

THE FIFTEENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS [II, 337]

[The Reproductive Tract, the Fetus, and the Hip Joint]

1. Although to preserve the race Nature has devised the many wonderful instruments which have been described in the preceding book, I feel sure that when you see in dissections the construction of the pudendum, the wisdom displayed in its creation will seem no less wonderful to you than that displayed in creating the others. Now in the first place (and this is a common fact and well known to all), since it was better, as I have shown earlier, to make two animals to generate, Nature constructed for one of them parts suited to receive the semen and for the other, parts suited to emit it; secondly, she endowed them with faculties that would make good use of the instruments; and thirdly, there is the fact that all parts of the instruments, even the smallest, have the best position, size, contexture, and form, in short, all the qualities which I have said times without number are proper to bodies. In fact, you cannot find a single part in them that is superfluous or deficient, that ought to be transposed or differently formed, or that lacks density if density is suitable for it, or looseness of texture when this is what it needs, or a channel if its task is to expel, or a cavity if it must receive. No, you will find them all arranged to the height of perfection, each with reference to its own usefulness.

For example, you could not conceive of any better place to locate the two pudenda, either in the whole body or within the region they [II, 338] now occupy, even if you moved them only a little in any direction, forward, back, up, or down. In the preceding book I have explained sufficiently why they needed to be placed in the particular region

where they actually are, but now give me your attention while I explain that within this region itself they could not be rearranged even very slightly and be the better for it. Where else, indeed, would you be willing to place the pudendum of the male (for I shall begin with this)? Would you put it nearer the anus than it is now? But [then] it would overhang the anus itself and make it difficult to expel excrement, unless perhaps you think it better to have the penis always tense and protruding. If so, however, you would merely be postponing the difficulty; for although it would cause no trouble when excrement was expelled, the penis would become a source of annoyance in every other aspect of life and would be easily injured, just as the hand would if a man should carry it around stretched out in front of him. Perhaps, then, it was better to place the penis further up on the pubes or hypogastrium? But here again you must add whether it should be always tensed or always lax, or should be be capable of tensing and relaxing by turns.

Now if it were always tense, it would be easily injured and in
[II, 339] addition would be a lifelong nuisance, being useful only at the time of coitus; if it were always relaxed, it would then be completely useless and never capable of doing what it was made to do; but if it is relaxed and tensed by turns, it is proper first to marvel because it has obviously now been made such as reason has found that it ought to be, and then to consider what construction would best enable it quickly to change into such antithetical conditions. If it were made like a vein, would it be filled and emptied easily, and would it besides be strongly tensed while it was filling? Well, the substance of blood does not take so kindly to such speedy filling and emptying as that of air, pneuma, or some such quick-moving material does, and, moreover, the tunic of a vein would not endure strong tension while being filled; for it is strong, sinewy substances that are useful for such actions. Perhaps, then, it would be better if the penis were made like an artery. But in addition to the drawbacks I have already mentioned in speaking of the veins, the arteries also pulsate at their own rate, and when they have been filled you could not bid them remain so, nor, when they were contracted, could you forbid them to expand again.

So was it better to make the penis like a nerve? Here, however, the difficulty is to tell from what sort of a nerve to make it. For the nerves properly so-called, those that grow out from the encephalon

and spinal medulla, not only have no perceptible cavities and do not naturally expand and contract but also in acting with tension have the disadvantage of being soft. What Hippocrates [1] calls ligaments and more modern physicians call connective nerves are not unsuited to acting with tension, since they are hard, but they too have no cavities. The nervous bodies that grow out from the muscles and are called tendons by Hippocrates [2] are altogether useless for constructing the penis, not only because like those already mentioned they have no cavities, but also because they are not so hard as the ligaments. Now if there are three kinds of nervous bodies in all, if those having the encephalon and spinal medulla as their source are found to resemble those [the tendons] growing out from the muscles in being unsuitable in two respects (for they are softer than the penis ought to be, and they have no cavities), and if those [the ligaments] produced from the bones are useful insofar as they are hard but useless because they are not hollow, there is no kind of nerve remaining that is fit to use in constructing the penis. I have shown that neither arteries nor veins are suitable, and it is clearly evident that neither flesh, glands, bone, cartilage, nor anything else of the sort is in any way suitable either. [II, 340]

Ought we not, then, first to admire the wisdom and providence of the Creator? Indeed, though it is far easier to recount in words the generation of everything that has been made than actually to construct the works themselves, my discourse falls so far short of the wisdom of the One who has created us that I cannot even explain the things he has so easily made. Secondly, along with our admiration and lack of words to tell of the clever device used in constructing the pudenda, we must try dissection of the part and see if our Creator has not discovered some kind of substance that is suitable for the penis. Then, if we should find nothing that cannot also be observed in some other part, we must admire the way in which he has created from the same instruments actions that are not the same. If, on the other hand, we should find some bodily substance not to be observed in a single other part, we ought here again to praise the Creator for his foresight and ought never to leave alone what we [II, 341]

[1] *σύνδεσμοι*; see, for example, *De arte*, cap. 10 (Littré, VI, *18*, *19*).

[2] For example, in *De fracturis*, cap. 11 (Littré, III, *452*, *453*). For the many other occurrences of both *τένοντες* and *σύνδεσμοι* in the Hippocratic corpus, consult Littré's index.

have sought out before testing it thoroughly in dissection. Well, at some time or other you have already seen it[3] when some physician was demonstrating to those who care about the works of Nature. But if you have not, you should at least examine now the sinewy (nervous), hollow body [the corpus cavernosum of the penis] growing out devoid of moisture from the bones called pubic. For this is what we have just been seeking by means of reason without finding it, and what we should never have found if we had not been taught by dissection. In fact, we did not presume to imagine a thing which we had not seen in any other part of the entire body. If we were really natural philosophers, we would certainly understand that since the substance proper for pudenda must be both hard and
[II, 342] hollow, it grows out from bone as all the other ligaments do, and that it is the only one of them all to be hollow, because its usefulness requires it to be so.

These are the things, then, that our Creator wished to be made, and since they have been made, do not attempt or venture to find out how it was done. For how could you reasonably bring yourself to inquire how things were made, the existence of which you would not have discovered if you had not been taught by dissection? It is enough for you to have made as great a discovery as this, that every part has been constructed to be what its usefulness requires, and if you undertake to investigate how a part has been made such as it is, you will stand convicted of not realizing either your own weakness or the power of the Creator. But now that you have found out that the parts of the pudendum (whatever they should be called—nerves, or anything else you please) absolutely must grow out from bones, because the substance proper to them is such as I have told earlier and because it was better so in view of their actions, so that the whole pudendum by growing out from a firm substance may be kept straight and unbending, let us return to the subject from which my discourse has thus far been digressing.

2. At the beginning of my discussion of the position of the pudenda, I have showed that the part called the penis must be engendered from bones. If so, it might indeed be nearer the anus than it actually is, but this was not better, as I have shown earlier,
[II, 343]

[3] Reading *εἶδες οὖν ἤδη ποτὲ* with Helmreich for the *εἰ δ' οὖν εἶδές ποτε* of Kühn's text.

and it could not possibly be placed [higher up than] [4] the pubes; for there is no bone there. Hence it grows out from the pubic bones, from their upper parts especially, since it will thus be farthest from the anus and will be better situated for coitus. Why it does not grow out from their left or right sides [5] you will learn from what follows: I have said many times already even in this work that when a certain part is unpaired, it must have a central location; that on the other hand, if there is a pair of parts, [Nature] wishes them to be equidistant from the center, that if in rare instances they do not maintain this distance, one must seek the reason for the variation, as I have shown in speaking of the liver, and that if the same distance is maintained, it is superfluous to mention it.

Now since I have said enough about the position of the penis and the nature and origin of the hollow, spongy nerves [the corpus cavernosum] in it, let us explain [6] the rest of its construction, though I shall omit here what seems obvious to all. For example, some one might demonstrate that the penis must be single or that it must have arteries, veins, and a skin, discussions that no longer have anything to do with examining the usefulness of the parts but are derived from the problems of natural philosophy. Another such question is how it happens that the penis is tensed voluntarily and sometimes without the exercise of the will. For that it does happen when the hollow [II, 344] nerve is filled with pneuma is appropriate to the business now in hand; how it happens belongs to a work on natural philosophy. Keeping in mind this restriction, I must now add to my discourse what is lacking.

3. It remains in the first place to discuss what I mentioned briefly [7] just now, the necessity for the penis to be perfectly tensed in coitus. It is useful for the penis to be perfectly tensed not solely for the sake of coitus, as one might perhaps think, but also for dilating and straightening the channel [of the penis] in order that the semen may

[4] Supplying *ἀνωτέρω ἢ*, obviously needed if this statement is to bear out that in the last chapter at the point where the digression on the substance of the penis began. Daremberg (in Galen [1856, II, *135*]) without comment renders the phrase "au-dessus de pubis."

[5] Helmreich brackets *ἢ νῦν ἐστιν* found in Kühn's text.

[6] Reading *ἐξηγησώμεθα* with Helmreich for the *ἐξηγησόμεθα* of Kühn's text.

[7] Kühn omits *βραχέως*.

be ejected as far as possible. For if the channel does not lie in a straight line because it is bent or collapsed at some point, the semen is checked there. Thus, since in so-called hypospadiacs the channel is twisted by the ligament at the end of the penis, these are unable to beget, not, of course, because they do not have fertile semen, but because it is checked in the bends of the penis and cannot go on its way. The cure is consistent with this explanation; for when the ligament is cut, they do beget. Now this defect would always afflict everyone, if Nature had not provided a way for the channel to become broad and perfectly straight in coitus. There is another, second device employed by Nature to make this same change, namely, the position of this sinewy (nervous) substance itself and the juxtaposition of the muscles on each side. For the channel for the
[II, 345] semen extends longitudinally in the lower parts of the penis and is centrally located. Upon it lies the hollow nerve [the corpus cavernosum], and at each side of it are two muscles [*bulbocavernosus* and *ischiocavernosus*], which are to broaden the channel by pulling upon it in both directions as if they were hands, while the whole penis remains without bending. And of course such a construction would also tend to keep this channel straight. It is useful, then, for the channel to be kept very broad and perfectly straight during the evacuation of the semen in order that the whole mass of it may reach the sinuses of the uteri all at once and as quickly as possible.

Moreover, since the bladder had been placed near by, it was not better to make a second channel for the excretion of urine but rather to use again the one for the semen. Properly, too, the neck of the bladder has occupied the whole region of the perineum, passing up from the anus, upon which it rests at first, as far as the place where the pudendum grows out. In women the neck of the bladder does not extend so far because the pudendum does not project; rather, it is the female pudendum itself that rests upon the anus, and the neck of the bladder comes to an end at the upper [anterior] side of the pudendum and pours out the urine there, having no need to be either very much bent or as long as it is in man.

[II, 346] As for the outgrowths of skin at the ends of the two pudenda, in woman they [the labia majora and minora] were formed for the sake of ornament and are set in front as a covering to keep the uteri from being chilled; in man it was impossible not to have them at all, if we remember any of my previous discussions in which I

showed how male and female animals are formed,[8] and besides, they [the prepuce] serve as an ornament. The part called *nympha* [the clitoris] [9] gives the same sort of protection to the uteri that the uvula gives to the pharynx; for it covers the orifice of their neck by coming down into the female pudendum and keeps it from being chilled. These, then, are the parts of the instruments of generation, and anyone even without my help can discern how marvelously they have been constructed in respect to their size, form, combination, and all other attributes.

4. It is hard to explain clearly the things that Nature has artistically devised for the animal while it is still in the uterus, as she forms it, brings it nutriment and pneuma from the mother, and makes ready good places for the residues, but certainly if these things are accurately observed in dissection, they at once force the beholder to admire them. There is a thin membrane called the amnion, which is placed all around the fetus and receives from it something like sweat.[10] Outside this lies another, thinner one which they call the allantois, and this is connected by a passage with the bladder of the fetus and collects within itself something like urine from the fetus up [II, 347] until birth. Round about these [11] is placed the chorion, lining the whole inside of the uterus, which consequently nowhere comes in contact with what lies beneath, and it is by means of this chorion that the fetus is attached to the mother. At the mouth of each of the vessels which extend to the inner side of the uterus and through

[8] That is to say, the female has the same parts as the male, differing only in arrangement because the male is hotter than the female. See chapter 6 of Book XIV.

[9] Lachs (1903, *16*) says that Galen makes no mention of the clitoris, but the word used here, *νύμφη*, is defined by Rufus of Ephesus (1879, *147*) as "the muscular bit of flesh in the midst, which some call the *hypodermis* and others the clitoris (*ἡ κλειτορίς*)." *νύμφη* is used again in the same sense by Galen in *Introductio seu medicus*, cap. 10 (Kühn, XIV, *706*), a work attributed to him, but of suspected origin.

[10] The following description of the fetal membranes and umbilical cord certainly does not fit conditions in man, where the allantois never escapes from the body stalk, the placenta is discoidal, and the umbilical cord contains two arteries but only one vein. Galen is obviously describing conditions in some ruminant, the goat, perhaps, since in *De anat. admin.*, XII (Galen [1906, II, *106* ff.; 1962, *116* ff.]), where a similar description is found, he says that he is describing the goat.

[11] Reading *τούτοις* with Helmreich for the *τούτῳ* of Kühn's text.

which the menstrual blood passes into it, another vessel is generated in pregnancy, an artery at the mouth of an artery and a vein at the mouth of a vein, so that the number of vessels generated is the same as the number of mouths that penetrate to the inner side of the uterus. Binding these vessels together there is a membrane, thin but strong, that grows around all the vessels on the outside and is inserted into the inner parts of the uteri. In all the parts between the mouths this membrane is stretched double beneath the uterus, and it branches off with all the vessels I have mentioned and accompanies them, each side of it clothing half of each vessel in such a way that this double membrane is a covering and protection for them and binds them to one another and to the uteri.

Where it first grows out from the uterus, each vessel is small, like the extremities of the roots of a tree where they taper off into the
[II, 348] earth. After the vessels have advanced a little, they come together in pairs, and when the two have become one, each of these [new] vessels in turn comes together with another of the same kind,[12] a process which does not cease until all the small vessels have been united into two large ones like trunks, that grow down into the fetus through the region of the umbilicus. There are in all four vessels there, two arteries and two veins, for no vessel combines with another of the other kind, veins always coming together with veins, and arteries with arteries. Hence this must now seem to you a primary work of Nature's, even if I do not say so; for it is proof of marvelous skill, not of unreasoning chance, that in the course of such a long journey, when so many vessels are mixed up together, no vein has ever yet been found implanted in an artery, nor any artery in a vein, but [each] always recognizes the vessel that is suitable and unites with this alone.

Is it not also an indication of marvelous foresight that in animals which naturally leap a great deal, like deer and goats,[13] the out-

[12] *ὁμογενῶν*, having the same origin, that is to say, a vein formed by the union of two smaller veins unites with another vein similarly formed, and the arteries behave in the same way.

[13] I can account for this singling out of the deer and goat only by the fact that whereas the cotyledons of other ruminants, the cow for example, are convex and even stalked, those of the deer are much flatter; the goat's are actually concave, and the fetal half of the cotyledons covering the dichotomous arrangement of the chorionic villi seems thicker. See Bolk, Göppert, Kallius, and Lubosch (1933, VI, *192–195*).

growth of the vessels is joined to the uteri not just with thin membranes, but also with viscous fleshes like grease? Indeed, the fact that no vein or artery is inserted into the fetus at any place other than the umbilicus, which occupies the middle of the entire animal, [II, 349] is in itself a mark of no common skill. Is it not marvelous too that the veins do not pass by the liver to be inserted into some other viscus and that the arteries do not go to some other place instead of being carried to the great artery,[14] which grows out from the heart itself? And it is a token of no mean skill that the interval between [15] is not determined by chance and that the vessels are not inserted into these instruments at any random places, but that the veins are inserted into the concavity of the liver and the arteries into the part of the great artery at the loins. Now one can see that as soon as the veins have passed the umbilicus, they come together and become one vein, which is then invested with strong membranes and bound up with the adjacent bodies until it reaches the viscus. For it must arrive first at the source of the veins in the fetus and then be distributed from that point in every direction.

The arteries, of course, must be inserted into the source of the [fetal] arteries, that is, into the left ventricle of the heart, but since this has been moved very far up from the region of the umbilicus, it was dangerous to bring the arteries up, suspended as it were, over such a long road. What, then, was left to be done that would be any better than to bring them over the shortest distance to one of the vessels growing out from the heart? Well, there is the largest artery [II, 350] [the aorta] which grows out of the heart and lies along the middle of the spine, occupying the whole length of it, and so it was necessary to make the arteries coming from the uterus to the fetus open into this and be attached to it. In fact, this is where they do arrive and are attached, and here too Nature has obviously done nothing in vain.

Why, then, did she not bring them along by the shortest path to the great artery? For the shorter path is the safer and the one Nature herself more often employs, as I have shown in preceding books. Or must we in this instance too admire her foresight? For when paths have no other advantage over one another, she chooses the shortest, but when greater safety is gained from using a longer route than is to

[14] That is, into its branches, the common iliac arteries.

[15] This rather clumsy expression apparently means the distance between the umbilicus and the insertions of the vessels.

be had from a shorter, she does not hesitate to go around by the longer way. Certainly in this case it is obvious that she has chosen instead of the short, dangerous path one that is longer but perfectly safe. Indeed, with good reason she avoided leading the arteries straight from the umbilicus to the spine, whether they persisted as two or even if they became one, since they could not rest upon any instrument for any part of the journey, and since too this region was already occupied by the intestines and kidneys. However, because the bladder was near at hand, as it is particularly in the fetus, where its fundus is adherent to the region of the umbilicus, the arteries
[II, 351] could easily mount upon it and, descending along the whole bladder as if it were a sort of ladder, make their way to the great artery. They did not, however, simply mount upon it; for, carried on a convex surface, they would not hold steady unless they were bound to it in some way. Hence Nature attached them to the bladder, each on its own side, with strong membranes and so, being now, as it were, a part of the bladder itself, they are conducted safely as far as the great artery. Such is the foresight with which matters have been arranged for the arteries.

Why is the vein inserted not into the convex part of the liver, but into its concavity? The reason is that the vessel of the bile had been placed there, and it was better for the blood to be purified before being distributed to the whole animal. And why were the veins themselves united immediately after passing the umbilicus, whereas the arteries remain paired for a long distance? Is it not because it was safer for the veins to come together and make one larger vessel? For a larger thing is always less liable to injury, and the vein had to be inserted into a single part of the liver. The arteries, on the other hand, which were to be carried safely upon the bladder and which do not arrive, immediately at least, at the left ventricle of the heart, were under no necessity to be made one. Doubtless, if Nature had conducted these up without support to the heart, as the veins are conducted to the liver, she would straightway have united them too.

5. There are four of these vessels, then, at the umbilicus, two
[II, 352] arteries and two veins, with the urachus in their midst. For the urachus is what anatomists are wont to call the canal from the fundus of the bladder which draws the urine off into the allantoic membrane that I mentioned a little while ago, so called because it is shaped like a sausage (ἀλλᾶς). Of the four vessels surrounding

the urachus, the veins are on the upper side, since it was better for them to go straight up to the liver, and the arteries are on the lower side, because it was better for them to pass downward, supported on the sides of the bladder. Thus Nature has at once established each pair of vessels in a suitable place, and through them, as if through trunks, the embryo attracts blood and pneuma from the uterus. Between all these trunks and the little vessels inserted into the uterus itself there is a sort of rooting of the trunks, and it is this rooting that is called the chorion, being a multitude of vessels which cannot easily be counted and which are joined together with a thin membrane. I have said before that this membrane is double and told why; for all the vessels of the chorion pass through the midst of it [between the layers] and are held together and covered by it.

Of the other two membranes, the one called allantoic, which I have said opens into the bladder by way of the urachus, was prepared as a receptacle for the urine, because it was far better that the fetus should void its urine not at the pudendum but at the umbilicus, [II, 353] as it actually does. In fact, since the membrane called the amnion surrounds the entire fetus and receives the other kind of liquid, it was not reasonable to mingle the urine with such a one as this.[16] It clearly appears that the liquid in the allantois is not only thinner and yellower than that in the amnion, but also more acrid, so that it grievously offends with its odor those dissecting the membrane. The fluid on the order of sweat that accumulates in the amnion is poured all around the fetus, since it cannot harm the skin. The urine, however, is led off and kept separate, coming in contact neither with the skin nor with the veins of the chorion, so that none of the neighboring parts may be injured by its acridness.

The fluid in the amnion, on the other hand, is of considerable use; for the fetus, as if swimming in it, is lifted and held up so as to be less heavy for the cords that attach it to the uterus. And this was the thought in Hippocrates'[17] mind when he said, "When pregnant women miscarry at two or three months for no apparent reason, their cotyledons are full of mucus and cannot support the weight of [II, 354] the fetus but break off." What he calls cotyledons are the mouths of the vessels arriving at the uterus (for I have shown this in other

[16] "Such a one as this," is the amniotic fluid, called by Galen at the beginning of chapter 4, "something like sweat."

[17] *Aphorismi*, sectio V, 45 (Littré, IV, *548*, *549*).

works of mine) [18] and he says that when they have become somewhat charged with mucus, they are not able to hold and support the embryo, but give way and are broken off by the weight. In fact, this would happen to all pregnant women if the fetus were not made lighter by swimming in the fluid of the amnion and if the downward pull exerted on the union of the vessels with the uterus were not lessened. But those who say that by swimming in the fluid of the amnion the fetus becomes lighter for the mother [to carry] are utterly ridiculous, because they do not understand that she also supports the fluid itself.

These fluids have in addition another, common usefulness, which is manifest at the birth of the animal, namely, that the fetus when moistened by abundant fluid issues more easily from the neck of the uterus; for at that time the membranes necessarily rupture. And not only is the moisture useful for making the fetus slippery, it also prepares the neck of the uteri to dilate easily and to its greatest extent; for, bathed in these fluids, it becomes softer and is more easily dilated. The best proof of what I have said is that when the fluid flows out ahead of time all at once, the midwives themselves
[II, 355] have to imitate Nature by introducing some liquid to soak the neck of the uteri. Surely the works of Nature are altogether ingenious, and, as I have shown many times, she makes additional use for the better of all the things that will otherwise exist of necessity. Thus, although these fluids surrounding the embryo were engendered necessarily, she also used them in order that the fetus might be carried painlessly and might be readily expelled at birth.

If the membranes are so thin and so like cobwebs that they are easily torn in dissection unless you handle them gently,[19] how is it, then, that they are not torn at times when the mother runs and jumps? Here too is one very clever device of Nature's, who knows that it helps most in making all thin bodies resistant to injury if they are applied one to another. Materials woven of interlaced woolen threads or some other fibers or hairs gain the greatest strength from this composition, though each of the components by itself is naturally very weak. If, then, the components are not only associated

[18] In *Hippocratis Aphorismi et Galeni in eos commentarii* (Kühn, XVII, pt. 2, *838*), *De semine*, I, 7 (Kühn, IV, *537–538*), and *De uteri dissectione* (Kühn, II, *902–906;* Galen [1962a, *81–82*]).

[19] *μετρίως*, moderately.

with one another (as in these materials that we weave and interlace) but also perfectly united as well, their strength is multiplied many times by this union. Hence it is nothing wonderful if four [20] membranes lying one upon another gain strength from this composition, but it is most wonderful that they not only rest upon one another but have also grown together in many places and in many others are [II, 356] knit together by slender, fibrous processes; for Nature wished to unite them as much as she could in order that they might all get from one another the strength that was wanting in each one by itself. But (perhaps someone will reply) why, then, did Nature not make each of them strong right from the beginning, seeing that she provides for the resistance to injury of all the parts? The reason is that if she had made them thick and hard—for she could not bestow strength upon them in any other way—she would have hung upon the mother a weight of very great mass, which not only would be distressing to her, but would also unnecessarily narrow the space for the fetus. Moreover, each membrane would become hard to break through at birth. So in order that all the space in the uterus may be left free for the fetus, that the mother may not be wearied by so much weight, and that the membranes may rupture easily at birth, Nature has properly made them all thin, but has devised safety for them by joining them to one another.

What is the device that she employs (for this remains to be told) to ensure that, although the neck of the bladder already has the channel which the animal uses to urinate after birth, none of the urine will pass into this [during embryonic life] and all of it will ascend to the umbilicus and urachus? For when the bladder has an outlet on each side, the urine does not have to be evacuated at the urachus rather than at its neck. What physicians have said on this [II, 357] subject is extremely absurd, though plausible enough when one first hears it. For, accepting these two things as agreed upon by common consent, namely, that our excretion of urine is under the control of our will, and that the fetus does not yet make use of such actions, they conclude from these that there is good reason for the urine to be excreted at the umbilicus, since of course no muscle like the one at the neck of the bladder has been established at the umbilicus to serve the animal's voluntary action. Most important considerations

[20] The supposed two layers of the chorion together with the amnion and allantois.

have escaped these men, however, and they are entirely mistaken, because they do not know either that this muscle does not have the office of constricting the neck of the bladder,[21] or that the fetus does not yet make use of voluntary actions, or that when the perfected animal chooses to urinate, it does not relax this muscle established at the urinary channel and release its tension in the same way that it relaxes those at the anus when it wishes to empty the bowels. For excretion takes place when the bladder naturally contracts upon the fluids within it, and when we choose to void a larger quantity of urine quickly, the epigastric muscles too assist. But I have said enough about these matters in my commentaries *On the Natural Faculties*[22] and *On the Movement of the Muscles*,[23] and in my *Manual of Dissection*.[24] And in my commentaires *On Demonstration*[25] and *On the Teachings of Hippocrates and Plato*, I have said that what is contained in the uterus is already an animal, at least when
[II, 358] all its parts have been formed.[26] Even if it were not an animal that is contained in the uterus, the matter would be just as difficult; for the muscle closing the mouth of the bladder will be idle. Moreover, when the bladder contracts around the fluid in it, it is reasonable that excretion should take place to some extent through both channels, not just through the one at the umbilicus.

Such, then, is the difficulty in the argument; Nature's work itself, however, shows in every respect her inventiveness, and as soon as you see this in the dissection of embryos, you can discover the cause[27] by reasoning. Now when you have divided the peritoneum

[21] See chapter 16 and note 55 of Book V.

[22] *De nat. fac.*, I, 13 (Kühn, II, *30–38;* Galen [1928, *48–61*]).

[23] *De motu musculorum*, II, 8 (Kühn, IV, *454–458*).

[24] *De anat. admin.*, VI, 14 (Kühn, II, *584–588;* Galen [1956, *169–171*]), XII (Galen [1906, II, *120;* 1962, *130*]).

[25] A lost work and one of Galen's earliest; see Kühn, I, *cxcvi*, and Walsh (1935, *579–589;* 1936, *65–71*).

[26] I have not found this idea stated explicitly in *De placitis Hippocratis et Platonis*. Perhaps it was included in the first four chapters and part of the fifth of Book I, which have not come down to us. In several places, however, such a belief is implied. See Books II, 8, V, 6, and VI, 6 (Kühn, V, *277, 465–466, 555–560*). There is also the spurious work, *An animal sit id, quod in utero est* (Kühn, XIX, *158–181*), which may yet to some extent reflect his point of view.

[27] That is, the reason why the urine is excreted through the urachus rather than the urethra.

lying in front of the bladder, do these two things at the same time: raise the umbilicus, and compress the contents of the bladder by grasping it with the hand. You will then see the urine run out into the allantois through the channel at the umbilicus. Furthermore, if in turn you compress the allantois itself, you will fill the bladder, and then by compressing the bladder again you will fill the membrane, and what has happened will itself teach you that it is because of the straightness and size of the channel at the umbilicus that the urine flows out first through it. For the urachus is many times as wide as the neck of the bladder, and so far as straightness is concerned, they cannot justly be compared; the neck of the bladder is very much bent and the urachus is perfectly straight, because of course the whole umbilicus is raised and suspended, as it were, from the uterus by the vessels of the chorion. Moreover, no muscle has been placed around the outside of the urachus to guard against an untimely escape of the residues, as the muscle at the neck of the bladder does after birth. In fact, there is no unsuitable time for the fetus to excrete such a residue, as there is for [animals] already perfected. For the latter a muscle has with good reason been established to allow nothing to pass except at the bidding of reason, but in embryos this would be superfluous and in vain—and Nature does nothing in vain. [II, 359]

6. Now that I have said enough about these matters, let us turn to the other features of the embryo's construction in which it differs from animals already born and explain Nature's skill as displayed in these. Among them, not the least worthy of admiration will be the large size of the liver right from the beginning, as soon as it is possible to distinguish clearly that each of the fetal parts has been formed, and this also holds true up to the time of birth. Indeed, in the first periods the liver predominates to a greater degree in comparison with the other parts, and much of this predominance lasts till birth. Next in order, the encephalon and heart are proportionally larger than the other parts, and this happens because the liver is the source of the veins, the heart of the arteries, and the encephalon of the nerves. It was reasonable, then, that just as craftsmen first make firm the foundations of a house, the groundwork of a temple, and the keel [28] of a ship and afterwards rear their structures safely on these foundations, so in animals Nature should in the same way

[28] See note 10 of Book III.

[II, 360] cause the different kinds of vessels to grow out, each from its own proper source already safely established, and extend them into the whole body. Since the fetus, being governed for a very long time like a plant, gains a greater advantage (χρεία) from the veins, she made the source of these very strong right from the beginning of its generation; for the encephalon, the heart, and the instruments that have grown out from them must have the advantage provided by the veins, because without blood they cannot either be generated or grow, whereas before the liver and veins are perfected, they have little need (χρεία) for arteries and none at all for nerves. This, then, is the reason why Nature made the veinlike kind [of instruments] strong and large right from the beginning and then began to enlarge each of the others in turn.

Why is the lung red in animals while they are still fetuses, and not whitish as it is in perfect animals? The reason is that it is nourished at that time like the other viscera, by vessels [*vv. pulmonales*] having a single, thin tunic; for during gestation blood reaches these vessels from the vena cava. In animals after birth, however, the passageway [the foramen ovale] connecting the vessels [with the vena cava] is stopped up, and a great deal of pneuma falls into them, but very little blood, and that extremely thin. Moreover, the lung is then kept in continuous motion as the animal breathes, and thus the blood, dashed about by the pneuma in the double motion which it has from the arteries and acquires from the lung, becomes thinner and softer
[II, 361] than it was, and like foam. For this reason the nature of the lung's flesh changes from being red, heavy, and dense to become white, light, and loose-textured, and this, as I think I have said, is a most useful thing for the lung as it follows the thorax in the movements of respiration; for its weight would make it hard to move if it had received a flesh like that of the other viscera. And so it is right to admire Nature here too, because when the viscus needed only to grow, she supplied it with pure blood, and when it was changed so that it moved, she made its flesh light as a feather in order that it might be easily dilated and compressed by the thorax. This is the very reason, then, why a passageway [the foramen ovale] was made connecting the vena cava and the venous artery [*v. pulmonalis*] in the fetus. Inasmuch as this vessel, however, serves as a vein for the viscus, it was necessary, I suppose, for the other one [*a. pulmonalis*] to change into the usefulness of an artery, and therefore Nature also

connected this one to the great artery [the aorta], but in this case, because there was a space between the vessels, she created another, small, third vessel [the ductus arteriosus] to join the two. Since the other two vessels [the vena cava and *v. pulmonalis*], however, were in contact with one another, she cut a sort of hole [the foramen ovale] that was common to both and devised a membrane there, like a lid readily pushed back toward the vessel [*v. pulmonalis*] of the lung, so that it might yield to the rush of the blood flowing to it from the vena cava but prevent the blood from coming back into the vena cava again. [II, 362]

Well, all these works of Nature are admirable, but beyond all admiration is the later closing of this aperture I have mentioned. For in animals either just born or a day or two old, and in some that are four or five days old and on occasion even older, it is possible to find the membrane at the aperture uniting with it, but not yet [fully] united. When in an animal that has been perfected and has reached its prime of life you see the whole place accurately sealed, you will not believe that there was ever a time when it was pierced through. On the other hand, if in fetuses and newborn animals you see the membrane supported only at its root and the whole body of it swinging free in the cavity of the vessels, you will [be] much more [inclined to] think it impossible that it will ever admit of an exact union. Even if one attempts to unite sinewy, thin bodies immediately after they have been divided, he will not succeed, and still less, of course, if they have hardened[29] after a lapse of time. Yet that membrane attains an exact union as time goes on, and is not prevented from doing so by being sinewy and thin or by being continually moved and shaken. So too, although all the other parts are growing, the vessel [the ductus arteriosus] connecting the great artery to the vein of the lung [*a. pulmonalis*] not only does not grow, but also obviously becomes more and more slender, so that in the course of time it wastes entirely away and dries up. That Nature [II, 363] has accomplished all such things with skill is indicated by the usefulness found in each of them, and the power by which she does this is beyond our finding out; for we do not even have any faith at all that a thing is possible, unless we have seen it plainly and often. But I shall now stop writing about these matters, since I have told about

[29] Reading τυλωθέντα with Helmreich for the τελεωθέντα of Kühn's text.

them on a few occasions earlier in my discourse, when I was discussing the instruments of the pneuma.

7. I shall recall to you a certain other work of Nature's, equally wonderful, but known to everyone even before dissection. For there is no one who does not know about the orifice of the uteri, how it is accurately constricted and closed during the period of pregnancy, and how it opens to its greatest extent at the time of birth. This birth takes place when the fetus has already been perfected so that it can be nourished by mouth. During all the remaining time it is impossible to introduce even the head of a probe into the neck of the uteri, but at birth the whole animal comes out through it. Hence, just as we see clearly that the membrane [of the foramen ovale] mentioned just now unites with the vessels though it passes human comprehension how this happens, so too in regard to the uteri everybody
[II, 364] knows that their orifice opens widely enough to provide easy egress for the embryos, but we can do no more than wonder how it happens. Nature, however, has contrived remarkable devices for this and everything else that has to do with birth. For by putting the head of the fetus first, next to the neck of the uterus, and by making with it a way for the other parts, she took great care to see that the fetus should approach the neck of the uterus in the right way and should come out through it without hurting any limb or dislocating any member. Indeed, if the embryo should approach the exit obliquely or crosswise, or if it should come longitudinally, but not as it actually does,[80] either it would not fit into the [canal] at all,[81] as happens sometimes, though rarely, or a leg or arm, fitting into it[82] before the head, would make the exit difficult for the other members. Now if the emergence were to take place[83] properly three or four times [in comparison to] once when birth was impeded, it would then follow that out of four hundred embryos, for example, one hundred would have difficulty. But since this is seen to happen only once in many thousands of births, it should serve to remind us of the good things that we enjoy from the Craftsman who formed

[80] That is, if it should emerge feet first.

[81] Reading ἤτοι τὴν ἀρχήν with Helmreich for the ἢ κατὰ τὴν κεφαλήν of Kühn's text.

[82] Reading ἐναρμοσθέντα with Helmreich for the ἐκπίπτοι of Kühn's text.

[83] Kühn adds a negative here.

us, and should make us realize clearly not only his wisdom, but also his power. For what Phidias or Polyclitus [84] is so good a creative artist as to make but one mistake in many thousands of works difficult of execution? [II, 365]

Then is it right to praise Nature only for these things, or has the greatest wonder of them all—the instruction of the animal being born in the actions of all the parts—not yet been told? [85] For not only did she prepare a mouth, esophagus, and stomach as instruments of nutrition; she also produced an animal that understands right from the beginning how these are to be used, and she instilled into it a certain instinctive faculty of wisdom by which each animal arrives at the nutriment suitable for it. I shall explain all the other animals at another time. For man she prepared milk as nutriment, producing two things at one appointed time, nutriment in the breasts of the mother, and in the infants to be nourished an eager desire for such a juice. Now if the nipple of a breast is put into the mouth of a newborn child, he immediately compresses it with his lips, immediately draws in the juice by opening his jaws, and then by curving his tongue pushes it down into his throat, as if he had practised this for a long time. Thereupon, the esophagus transfers it into the stomach and does so as if it had been taught; next the stomach, after having the benefit of the juice, passes on what is left to the intestines, and these then transmit it from one to another till it reaches the last. Next in store for the infant is the production of teeth, so that he may not be a perpetual burden to his mother, and with them comes the action of chewing, self-taught, like the others. Everything else follows in its turn, but the explanation of it all is another story. And now, since I have finished what I proposed with the exception of a few things, it is time to pass on to these. [II, 366]

8. What remains of the entire treatment of the subject is to tell about the muscles which move the diarthrosis at the hip and about which I have said nothing at all, and to devote one book to the instruments common to the [whole] body, that is, to the arteries,

[84] Architect and sculptor of Sicyon, who flourished in the fifth century B.C. and is known for the beauty of proportion achieved in his work. He is famous for his statue of an athlete so perfectly proportioned that it is called the Canon. See chapter 1 of Book XVII, and cf. *De temperamentis*, I, 9 (Kühn, I, *566*).

[85] But see chapter 3 of Book I, where this point has already been made.

nerves, and veins. The next book after this, being the sixteenth [counting] from the beginning, will take up the argument concerning these, but let us speak now of the muscles moving the joint at the hip. I have told in the thirteenth book why this must be useful for less varied but safer movements than the shoulder joint. Moreover, as regards the bones themselves, I have told in the third book what their nature is and how they are very well constructed in view of the action for the sake of which they were made; for the similarity of the subjects led me to a common discussion of them, but I shall speak in this book of what is peculiar to the joint at the hip alone and cannot be explained in conjunction with any other.

Nature has created the legs as instruments for walking, four of them for the horse, dog, beef, and all such animals, but man alone among animals that go afoot has two. The ape has legs like those of the human infant just trying to use them for the first time, and in
[II, 367] fact, the ape both goes on all fours like a quadruped and uses its anterior limbs as hands. When a man is grown, he no longer uses his anterior limbs as feet, but the ape forever plays a double game, being constructed for two things, both to clamber up swiftly, like creeping animals, and to run unsteadily, like a little child; for it could not be well constructed for both things. Hence the digits of its feet were very deeply divided from one another and some of the muscles moving the knee joint were brought low down on the tibia.[36] So too in this animal the character of the hip joint approaches that of the joint in man, but they are not exactly alike, just as the hand and arm [also fail to resemble their human counterparts]. Furthermore, the fleshy muscles [*glutei*] forming the buttocks are, like all its other parts, ridiculous; for I have shown that the animal is a ludicrous imitation of man. In man they are beautifully arranged both for the decency of the necessary parts and for keeping the anus compressed and painless in the act of sitting. Since these muscles alone are undersized in the ape and all the rest are arranged very much as they are in man, test in the ape the account I shall give of the muscles moving the joint at the hip; for anatomists before my time have used this animal to teach the subject of these muscles. But just as they
[II, 368] have overlooked many, many other things, throughout the body, so

[36] Particularly biceps femoris; see chapter 16 of Book III and also *De anat. admin.*, I, 2 (Kühn, II, *222–223;* Galen [1956, *3–4* and Singer's note 24]).

here too there are whole muscles which they failed to see. I myself have written a special, separate treatise *On the Dissection of the Muscles*[37] and have also explained in my *Manual of Dissection* how many muscles there are in this region and what their forms are, while at the same time I indicated the reasons why my predecessors have gone wrong in regard to them.[38]

Since, then, this joint had to be flexed when the leg was raised and extended when it was set down, and since these movements constitute its most important action—for it is less useful to bring the leg inward toward the other leg and move it outward and away again, and still less so to rotate it in either direction—anyone might immediately demonstrate the skill of Nature from the differences in the size and number of the muscles. For she has made the ones that extend and flex the limb largest and most numerous, those that move it laterally next after these in size and number, and then the ones that rotate it even smaller and fewer. Thus the first classification of the muscles is properly held to be threefold and is determined by the usefulness of the movements. When I have divided each of these three classes again into two parts, I shall explain the superiority of the muscles in the more useful division. Now the flexor muscles have [II, 369] been made smaller and less numerous than the extensors; the adductors are smaller and less numerous than the abductors; and those that rotate the femur are of about equal value.[39] These are the main points of my discourse; let me now give the demonstrations of them.

The actions of the legs, those for which they were made, are walking, running, and standing. Walking and running are accomplished with the legs in opposition to one another, whereas in standing they are placed alike. In standing each leg is supported by the ground and they are equally tensed, but in walking and running one is supported while the other is carried past it, and the one that remains firm exerts the greater effort.[40] In fact, the leg that is carried past moves only itself, but the one that is supported not only tenses

[37] *De musc. diss.* (Kühn, XVIII, pt. 2, *1000–1007;* Galen [1963, *494–496*]).

[38] See note 29 of Book II.

[39] That is to say, the muscles rotating the femur in one direction are about as large and numerous as those rotating it in the other.

[40] Cf. chapter 5 and note 16 of Book III.

itself directly but also carries the whole body, bearing a weight double the one it bore earlier, when the legs were standing. Now in carrying the leg past [the other] the muscles flexing it are the more active, but in standing the muscles that cause extension remain strongly tensed, because, if they relaxed even a little, the animal's whole body would be in danger of collapsing. The leg is bent at the groin when we lift it, and if you wish to keep the limb in this position, the flexor muscles must be tensed. It is extended when we put it down on the ground and has its greatest extension and most
[II, 370] extreme tension when we are standing.

Hence Nature with good reason entrusted this work to many large, strong muscles; first, to the one [*gluteus maximus* and *tensor fasciae latae*] [41] which covers the whole joint at the rear and corresponds to the one [*deltoideus*] at the shoulder; second, to the one [*gluteus medius*] following this, which arises from all the outer sides of the bone of the flank [*os ilii*] and is inserted into the highest part of the great trochanter, occupying also a little of the anterior part; third, to the one [*gluteus minimus*] next after this, which grows out from the outer and lower portions of the bone of the flank, is implanted into the first, inner parts of the great trochanter, and then also grows around the anterior parts of it; and fourth, besides these, to the one [*piriformis*] growing out from the broad bone [*os sacrum*] and inserted into the great trochanter from its entire posterior part as far as the summit. The first one mentioned of all these exerts a strong, straight extension when it draws up the femur by its two extremities [that is, by the extremity of *gluteus maximus* and that of *tensor fasciae latae*], but if you tense only one of these, it causes no longer a straight upward pull but one inclined to the side. The second muscle raises the head of the femur and at the same time draws it toward the inside [medially]. Each of the other two raises it slightly; one of them [*piriformis?*] rotates it outward, the other [*gluteus minimus?*] rotates it inward, [and they do so] a little more
[II, 371] than they raise it, but much less than the other muscles [*obturatores externus* and *internus*] which have the same work and which I shall explain last.

For now I shall go on as I have begun and speak first of the

[41] Gluteus maximus and tensor fasciae are fused anteriorly in the ape. See Howell and Straus (1933, *149–150*).

extensors, next of the flexors, and then of those producing lateral motion. But since the motions of most muscles are composite because Nature, as I have already said many times, is careful always to produce for animals many actions with few instruments, I shall therefore necessarily mention among the muscles extending the leg those that produce some other, additional motion. The first [*gluteus maximus* and *tensor fasciae latae*] of all the four muscles I have mentioned, the one which I have said is analogous to the one at the shoulder and which extends the leg by means of two insertions, produces a perfectly straight motion when it acts with both these, but a motion very slightly inclined to the side when it acts with only one of them. So too the muscle [*gluteus medius*], mentioned as the second, extends and at the same time draws slightly inward [medially] the head of the femur. Similarly, the third [*gluteus minimus*] and fourth [*piriformis*] extend it very slightly, as I have said, and rotate it a little more. Besides these muscles, there is another, fifth one [*adductor magnus*],[42] which is the largest of all the muscles in the body and which clings to the whole bone of the thigh on its inner and posterior parts as far as the knee. The posterior fibers of this muscle, which arise from the ischium, hold the leg firm as they extend the diarthrosis. The fibers that grow out along the lower parts [of the muscle] from the pubic bone also do this [II, 372] just as much, along with a very slight movement inward [adduction]. The fibers that are higher than these adduct the femur, and in the same way the highest of all adduct it and at the same time draw it up.

The flexors of the diarthrosis are opposed to these five muscles and are fewer and smaller then they. There is the muscle [*psoas major* and *iliacus*] [43] that comes straight down from above from a double origin and is inserted by a single tendon into the summit of the small trochanter. Accompanying this is the muscle [*pectineus*] that is inserted into the same trochanter lower down but has its origin from the anterior parts of the pubic bone, and beside it is placed another, oblique one [*adductor brevis*], which is like a part of the largest

[42] Apparently, adductor longus is also included and perhaps quadratus femoris as well. *Vide infra* and see note 49.

[43] In the ape these two muscles meet and fuse before they pass over the brim of the pelvis. See Howell and Straus (1933, *149*).

muscle [*adductor magnus*] and has a similar action. The fourth muscle [44] [*rectus femoris*] extends the diarthrosis at the knee by the aponeurosis passing over the kneecap. This muscle incidentally [45] flexes the femur, but the other three do so as their principal action; the one [*psoas* and *iliacus*] coming down from above [also] inclines it inward [rotates it medially] a very little; those [arising] from the anterior parts of the pubic bone [*pectineus* and *adductor brevis*] incline it inward a great deal and draw it up slightly; but the fourth [*rectus femoris*], which I have said flexes the femur incidentally and was not made primarily for the sake of the joint at the hip, causes great upward tension and flexion, yet far less than the first named. For that one, taking origin from the loins [*psoas*] and from the
[II, 373] inside of the bone of the flank [*iliacus*], extends to the small trochanter, whereas the one [*rectus femoris*] extending the diarthrosis at the knee, the action for the sake of which it was made, takes origin from the straight spine [46] of the bone of the flank [*os ilii*], and therefore, when it is tensed, it naturally not only draws up the tibia toward itself, but also flexes the femur; for of course, if it grew out from the lower side of the diarthrosis at the groin, it would move only the tibia. In fact, Nature acted providently in making this muscle grow out from above the diarthrosis at the groin in order to provide another, extra movement necessary to the animal.

The muscles adducting the femur are these: Two of those mentioned previously [*pectineus* and *adductor brevis*], that have their origin from the anterior parts of the pubic bone, are capable not only of adducting the member, but also of flexing it moderately. Another, third one [*gracilis*] is not to be compared with these [47] in length, for it is very long; it grows out from the anterior parts of the

[44] Kühn's Greek text omits τέταρτος, but the translation of it appears in his Latin text.

[45] κατὰ συμβεβηκός, accidentally.

[46] Probably not the anterior inferior spine of modern terminology, but the whole surface of the ilium above the acetabulum. From the way in which Galen goes on to speak of the origin of rectus femoris, it is evident that he was thinking of the one immediately above the acetabulum and overlooked the part arising from the anterior inferior spine. In the ape, as Keith (1894, 271) says, "The duplicity of the rectal origin may be easily overlooked, and was probably overlooked by those observers that record the absence of one head."

[47] Reading τούτους with Helmreich for the τοῦτο of Kühn's text.

pubic bone and lies alone the whole member as far as the knee, on the inner side of the head of which it comes to an end.[48] Moreover, the inner part of the largest muscle [*adductor magnus*] has the same action. The muscles moving the femur toward the outside [that is, abducting it] are one part [*tensor fasciae latae*] of the muscle [*gluteus maximus*] mentioned first of all and the muscle [*piriformis*] which arises from the broad bone [*os sacrum*] and which I have said rotates the femur slightly.

There remain two other muscles [*obturatores, externus* and *internus*] [49] that move it, and these have their origins one from the inner, and the other from the outer, parts of the pubic bone. Both wind around the part called the ischium and arrive at the same place, being inserted by strong tendons into a single concavity situated in the posterior parts of the femur, just where the great trochanter begins to grow out. Of all the muscles I have mentioned, these are the only ones which turn and rotate the femur by drawing it each one toward itself; for, as I said in my first enumeration of the muscles that extend the member, when these rotate it a little, they do so only secondarily and slightly, being formed by Nature primarily to extend the joint at the hip. All the muscles moving the femur have been said to have a number and size corresponding to the usefulness of the movements which they control, but along with number and size the usefulness of the origin and insertion of each muscle, and of its position between these points likewise at once becomes evident. For when they are drawn up toward their first origin, the extremity that is being pulled must draw the member along with it. Hence the muscle drawing the member up necessarily comes down from parts that are higher up, and muscles moving it laterally must originate [II, 374]

[48] It was surely a slip on Daremberg's part (1856, II, *156*) when he identified this muscle as rectus femoris. Cf. chapter 16 of Book III.

[49] Note the absence of any mention of the gemelli and quadratus femoris, which are also unmentioned in *De anatomicis administrationibus*. In the rhesus monkey the gemelli are combined in a single muscle sheet (see Howell and Straus [1933, *152*]) and may possibly be referred to by Galen in *De musc. diss.* (Kühn, XVIII, pt. 2, *1006;* Galen [1963, *496*]), where he remarks that the obturators are attached to the ischium by fleshy slips. This seems especially likely in view of the fact mentioned by Keith (1894, *253*) that "the fibres of the inferior gemellus may be continuous with the ischial fibres of origin of the obturator externus." Quadratus femoris, I suspect, Galen took to be part of adductor magnus.

from inner parts if their task is to move it inward, and from outer parts if they are to move it outward. Since the femur must be turned and rotated in some of its movements, Nature curves in a circle
[II, 375] either the whole body of the muscles charged with this action or only their tendons. For straight muscles move members with simple motion, drawing them in a straight line toward those parts to which the heads of the muscles extend, but muscles whose whole bodies or even whose tendons are curved produce a motion that is circular rather than straight. Thus the two muscles [*obturatores*] named last, which are inserted on the great trochanter and which have a course that is oblique, not straight, toward the member to be moved, must control a motion that corresponds to their situation.

THE SIXTEENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

[The Nerves, Arteries, and Veins]

1. In the preceding explanations of the parts I have already spoken not infrequently of the instruments common to the whole body, that is, of artery, vein, and nerve, but I have thought it better not just to speak of them in scattered places but to bring together all that needs to be added into a single survey. It is clear that here too the discussion will have as hypotheses things previously demonstrated: that the encephalon is the source of the nerves, the heart of the arteries, and the liver of the veins. Since these instruments must be [II, 376] distributed to the whole body, give me your careful attention while I explain how justly this has been done. Now if it appears that larger ones have been given to some parts and smaller ones to others in accordance with the value of each part, and if this is found to hold true throughout the body, we shall commend Hippocrates for calling Nature just; and if they are seen to pass to each part in entire safety, we shall declare her to be not only just, but also skillful and wise. It makes no difference, of course, whether the explanation begins with the encephalon, heart, or liver; for the common statements concerning the three sources are necessarily made at the same time, the nature of the subject not permitting us to do otherwise even if we wished, and those [1] pertaining to each one separately can be finished in addition to the common ones previously discussed whenever one desires.

What, then, are the common statements concerning the three

[1] Accepting Helmreich's emendation, *οἵ τε*, for the *ὅτι θ'* of Kühn's text. Helmreich omits the *οἱ λογισμοὶ* which follows immediately in Kühn's text. Hippocrates calls Nature just in his *De fracturis*, cap. 1 (Littré, III, *412–415*).

sources? Since the object is to bring an artery, vein, and nerve to each part, and some of the parts are far removed from the sources, it was surely much better not to make as many instruments grow out as there are parts, or in fact very many of them at all, but to make one very large instrument grow out from each source like a trunk, and as this proceeds, to distribute branches of it, so to speak, to the parts near by. Just so in bringing fresh water to a city and distributing it, the experts have made one very large aqueduct connected to the source and have sometimes portioned out some of the water to certain other places even before it reaches the city; or if they have not done this, at least they have distributed it within the city to all parts of it in such a way that no part is without water. And precisely as we approve particularly of those who not only distribute the water to all parts but likewise do so most justly, so we shall praise Nature too if we find her wholly just. If there are two kinds of justice, one intelligible to the common man, the other befitting the craftsman, and if Nature is seen to have chosen rather the one befitting the craftsman, we shall praise her much more. You may, if you wish, learn what this sort of justice is like by listening to the most divine Plato,[2] who says that the ruler or craftsman truly just must observe an equality based on merit. For in the cities equal volumes and weights of water are not distributed to every place; a greater share is given to the public baths or to some grove sacred to the gods, and a lesser to the fountains in the streets and to private baths.

[II, 377]

2. Well then, it is time for you to examine this same skill in distribution as it was first practised by Nature in animals. One very large artery [the aorta] has been produced from the heart like a trunk divided into many branches and twigs. Another vessel, a vein, which is called hollow because of its size [the vena cava], passes from the convexity of the liver upward and downward and resembles a sort of double trunk; for some parts of our body are higher than the liver and some are lower. In the same way you will also see the artery that grows out from the heart branch immediately into two unequal divisions, the larger one passing downward because the greater part of the body is below, and the smaller being distributed to the parts above the heart.[3] The spinal medulla grows out from the

[II, 378]

[2] *Laws*, VI, 757 (Plato [1920, II, *519–520*]).

[3] See chapter 5 and note 22 of Book VI.

encephalon as a trunk similar to those just mentioned and supplies nerves to all the parts below the head. It would indeed be surprising if no vein, artery, or nerve appeared to run back toward its own source, but it is still more surprising that whereas a very large number of each kind [of instrument] branches, as I have said, each from its own source into the parts farther off, a very few vessels and a very few nerves are allowed to make a bend and run a double course,[4] so to speak, and this is done not idly or by chance but for the sake of a marvelous usefulness. For whenever one part among very many has been provided with a construction different from that of the others because of its changed usefulness, wise Nature, mindful of each particular part, is clearly discovered to have exercised in respect to it the height of justice and forethought. I consider [II, 379] it a very great proof of her skill that lateral offshoots have been made from only one of the trunks leading from the sources, that of the nerves, and this because usefulness made it necessary.

It is no small proof too that although nerves go everywhere in the body, they are not inserted into bones, cartilages, or ligaments, or into all the glands either; for there are two kinds of glands.[5] Now the substance of bones has been placed beneath the other parts in many places as a support and base, and in many others as a rampart and wall; for these are the two uses of bones. Cartilages are spread on some parts of them, such as the joints, to make them smooth, and Nature also uses cartilages occasionally as moderately yielding bodies. Hence it was superfluous for bones and cartilages to be given a share in sensation or voluntary motion. Ligaments too have no need of either of these, since like cords they attach certain other parts to the bones or the bones to the other parts. And certainly fat, being placed like thick grease upon the membranous and sinewy parts of the animal, does not need nerves at all. This is both its origin and usefulness: it is generated from the fat in the blood, poured out by

[4] See chapter 14 and note 57 of Book VII.

[5] The two kinds of glands, according to Galen, are first those such as the pancreas and thymus, which merely support vessels where they branch (see, for example, chapter 2 of Book V and chapter 4 of Book VI), and second those such as the salivary and intestinal glands and the seminal vesicles, which produce a humor to moisten parts in the vicinity (see, for example, chapter 11 of Book XIV). He states this clearly again in *De semine*, II, 6 (Kühn, IV, *646*), where he credits the anatomist Marinus with having made the distinction.

[II, 380] slender veins, and deposited upon thin, dry bodies in order that it may constantly moisten with natural fat those which have been dried out and rapidly hardened by long fasts, violent labors, or severe heat. Glands that serve as a foundation, so to speak, for the division of vessels certainly need no nerves to do this work, because they need neither sensation nor voluntary motion, but as for the glands prepared in order to generate fluids useful to the animal, just as they sometimes receive veins and arteries that are perceptible and large, so too they receive nerves in accordance with the common law governing all the parts of this sort which I shall now explain to you.

For voluntary motion Nature has constructed in animals one kind of instrument, called muscle. Hence, although all nerves have both faculties (I mean both sensation and motion), the other parts receiving them are not moved at the bidding of the will, but only feel, such parts, that is, as the skin, membranes, tunics, arteries and veins, intestines, the uterus, bladder, stomach, all the viscera, and the second kind of glands. And why need I say that the sense instruments must have nerves for sensation, when I have already spoken of them all in earlier books devoted especially to them?

It is necessary even now, however, to recall that Nature has not inserted a nerve into any part without a purpose, and that when parts needed only sensation or only voluntary motion she did not
[II, 381] insert nerves into them at random, but gave all soft ones to those requiring them for accurate sensation, all hard ones to those requiring them for voluntary motion, and both kinds to those needing both; for I suppose that here too Nature has been provident and has prepared for sensation a nerve more easily affected and for motion one more capable of acting. Accordingly, parts such as the eyes, ears,[6] and tongue, that are not only moved simply in obedience to the will but also have sensation over and above that sense of touch common to all the parts, have both the hard and soft kinds of nerves. In these parts the soft nerve is inserted into the special sense instrument and the hard one into the muscles. The stomach, on the other

[6] The ears moved in obedience to the will! Galen's attention here has once more slipped away from man to the animals with whose anatomy he was more familiar. But he deals with this matter from the point of view of comparative anatomy a little farther on, in chapter 6 of this Book.

hand, the liver, all the intestines, and the viscera have one kind of nerves, namely, the soft kind, just as the teeth do too. These are the only bones to have nerves, both because they are bare and exposed to whatever they encounter and because they must perceive and determine flavors along with the tongue and all the other parts of the mouth as well. I have also shown in preceding books that to parts under the constant necessity of encountering objects that cut, crush, erode, heat or chill them excessively, or alter them in any other way whatever, Nature has given an extra share of sensation, in order that the animal, reminded by the pain to come to its own aid, may get rid of the cause of the distress before the part is injured. It is for this reason, then, that soft nerves have been inserted into the teeth too [II, 382] and certain fibers growing off from the nerves belonging to each part are implanted everywhere in the skin. For the skin does not have a separate nerve of its own in the same sense that a certain nerve reaches each of the muscles; rather, fibers from the underlying parts extend to it, being formed both as a bond of attachment for these parts and as instruments of sensation. This is what I have to say about the distribution [7] of the nerves in general.

3. It is time now to take up their distribution in particular. To begin with, since there is a great difference in the nature, position, and actions of the parts, it was better to send from the encephalon nerves that were larger and at the same time softer to the parts that must be made more sensitive than others, and to give nerves that were also larger but harder to parts that were prepared to make many strong movements. And obviously Nature has kept to this rule so strictly in all the parts that neither does a small nerve or a hard one ever go to a part needing extra sensation, nor a large one to a part not needing to feel any more than it needs to be vigorously moved, nor a soft one to a part whose usefulness lies in the strength of its motion.

Into each eye a nerve [*n. opticus*] is inserted of such a size as is not to be found in any other of the largest parts; in fact, you cannot find a softer nerve anywhere, and even though the eyes are very [II, 383] small parts, they alone, because their usefulness is so exceedingly valuable, have received nerves that are both very large and at the same time very soft. For this sense is the most precise of them all,

[7] Kühn omits *νομῆς οἵδε* found in Helmreich's text.

recognizing from a distance the greatest number of qualities appertaining to bodies and the most important ones, that is, their color, size, shape, motion, position, and distance from the observer. Imagine, please, many grains of millet or something smaller scattered on the ground; if you recognize precisely first the position of each and then the other attributes I have just mentioned, I think you will admire the accuracy of this sense and the multitude of services it renders to animals; for without it you could not even count the grains of millet, much less recognize their color or substance. And it gives notice[8] of things at a distance too, perceiving that some are moving and others are at rest, and how some are connected with one another and others are set apart. Since, then, sensation consists in receiving impressions and since the motion which the the nerves produce in the muscles consists in acting, the soft nerve [*n. opticus*] has properly been inserted into the principal instrument of sight itself in the eye, and the hard nerve [*nn. oculomotorius* and *abducens*[9]] into the muscles moving it. In the same way, to the tongue, which is a small part too, Nature has also given the two kinds of
[II, 384] nerves, a soft one [*n. lingualis*] so that it may perceive flavors, and a hard one [*n. hypoglossus*] because it must be moved in many various ways. To each sense instrument for hearing she has conducted one soft nerve [*n. vestibulocochlearis*], and to those ears which must move she has also sent other, hard nerves [*n. auricularis posterior, rami temporales* of *n. facialis*]. And the nose, the teeth, and the whole palate have their share of soft nerves [the olfactory lobes,[10] *rami alveolares* of *nn. maxillaris* and *mandibularis, nn. palatini*]; for these parts also need extra sensation.

If you compare these nerves with the optic nerves, however, you will think them very hard and small; for again, in addition to the other qualities I have already mentioned, the optic nerves have perceptible channels,[11] and it is on account of these channels that they have been made thick. You cannot admire Nature as she deserves for her construction of these nerves if you do not know how we see. Accordingly, if you are willing to use a good deal of your leisure time in testing the demonstrations I have given in the thir-

[8] Reading διαγγέλλει with Helmreich for the διαστέλλει of Kühn's text.
[9] See note 31 of Book IX.
[10] The lobes rather than the nerves themselves; see note 20 of Book VIII.
[11] See note 42 of Book VIII.

teenth book of my treatise *On Demonstration* and in certain other places[12] to show that the instrument of vision has a luminous pneuma always flowing to it from the encephalon, you will admire the structure of the optic nerves, which have been made hollow within in order to receive the pneuma and which extend up as far as the ventricle itself of the encephalon for the same reason. For they grow out from the place where the two anterior [lateral] ventricles come to an end toward the side, and this *thalamus*[13] itself, so to speak, of the ventricles was made for the sake of these nerves. Anatomists have not recognized this marvelous work of Nature's because they have not followed the ventricles to their ends, or considered for what purpose these have been so formed, or seen that [II, 385] the upper origins of the optic nerves are attached to the ends of the ventricles. For these reasons, then, the nerves for the eyes have been made hollow, very large, and very soft, though the other sense instruments also have large, soft nerves.

The hands and feet, however, are diametrically opposed to these parts in action, substance, and position.[14] Their actions are performed vigorously and with tension, their substance is hard, and they are located very far from the head. Hence no nerve from the encephalon extends to them, nor to the whole members either; for both the arms and legs receive hard nerves from the spinal medulla alone. All the other parts below the face are also supplied with nerves from the spinal medulla, though the intestines, viscera, and in addition the instruments of the voice are exceptions, because some of these parts need especially to be connected with the encephalon, and certain others, which require only sensation, share the same nerves since they are close by. For nerves [from the encephalon] had to go to the heart and liver because it was absolutely necessary for the sources of the faculties governing the animal to be connected, as I

[12] See note 19 of Book X; for the treatise *On Demonstration*, see note 25 of Book XV.

[13] Not the thalamus of modern terminology, but the slit in the lateral ventricle where Galen thought the optic nerve begins. See note 42 of Book VIII and cf. Hyrtl (1880, *539–541*) and Simon (in Galen [1906, II, *338*]).

[14] Reading *θέσιν* with Helmreich for the *διάθεσιν* of Kühn's text. Note once more how the improved reading of the manuscripts to which Helmreich had access has restored the balance and logical sequence of the text.

have demonstrated in my work *On the Teachings of Hippocrates and Plato*,[15] and nerves must likewise go to the stomach and particularly to its [cardiac] orifice, which, as I have shown, also stands in need of extra sensation. Because the voice, which reports the
[II, 386] thoughts of the mind, is the most important of all the works of the soul, it must of course be produced by instruments receiving nerves from the encephalon, and so primarily for the sake of these instruments nerves [*n. vagus*] from the encephalon are extended far from their source. Along with them, as I have said, certain small outgrowths are distributed to the intestines, kidneys, spleen, lung, and esophagus, and I shall speak of these a little later.

4. Let us now speak of those parts for the sake of which primarily nerves come down from the encephalon, and let us begin with those that have to do with the voice. Here again my discussion will be based on what has been demonstrated about the voice; for in the beginning I have shown that the usefulness of a part cannot be determined before the action is known. Since, then, the larynx is the principal and most important instrument of the voice, and since it is composed of three cartilages and has the epiglottis[16] within it and

[15] *De plac. Hipp. et Plat., passim;* see, for example, VII, 3 (Kühn, V, 600 ff.).

[16] Galen obviously means here the same structure described as the *glottis* in chapter 13 of Book VII, and not the epiglottis, of which he gives a good description in chapter 16 of the same Book. In *De locis affectis*, I, 6 (Kühn, VIII, 50), he commits the same error, saying again that the epiglottis is *within* the larynx, and this time he actually calls it the principal instrument of the voice. Even though Vesalius (1555, *188*) claims that the confusion of glottis with epiglottis was a common error of scribes copying Greek manuscripts, it seems hardly fair to blame these lapses on the manuscript tradition; for there are no similar ones either in *De usu partium* or in Galen's other anatomical works, and Helmreich reports no variant readings. It is interesting to speculate that these two passages may be responsible for the monumental confusion to be found in the Arab sources and in the works of the pre-Vesalian anatomists, where epiglottis is used freely for *glottis*, and, what is worse, for the whole larynx. Certainly, the error is not traceable to Aristotle, Hippocrates, or Rufus of Ephesus, all of whom define the epiglottis as the lid of the larynx. Berengario da Carpi (1521, *cccxcii* verso) did his best to overcome the difficulty, but it was Vesalius (*loc. cit.*) who with his usual lucidity finally brought order out of the chaos. Kassel's (1912) failure to realize the error in the passage cited from *De locis affectis* is the only defect in an otherwise fine summary of Galen's conception of the production of the voice.

nearly twenty muscles to serve it, it is your task to consider how Nature has distributed nerves from the encephalon to all these muscles. Some of them are placed somewhat transversely, others obliquely, and others straight, but the position of the latter is not altogether the same for all. For certain ones of them begin above and with their lower ends move some parts of the larynx, whereas conversely the others begin below and act with their upper extremities.[17] It was right, I think, that a nerve should be sent from above into muscles passing down from above, that the source of the nerves for muscles passing up from parts below should be below too, and that transverse and oblique muscles should also be provided with sources for their nerves that accord with the way in which they are placed. In my book *On the Voice*[18] I have shown that both the muscles [*thyrohyoideus*] reaching from the hyoid bone to the thyroid cartilage and those [*sternothyroideus*] reaching from these two [muscles][19] to the sternum are muscles which pass down from above, and that those [*thyroarytenoideus* and *cricoarytenoideus, posterior* and *lateralis*] moving the arytenoid cartilage are muscles which pass up from below. [I have shown too] that four of these [*thyroarytenoideus* and *cricoarytenoideus posterior*] are perfectly straight and two [*cricoarytenoideus lateralis*] are inclined toward the oblique, that those [*cricothyroideus*] attaching the lower extremities of the thyroid cartilage to the innominate [cricoid] cartilage are slightly oblique, and that, moreover, the muscles [*constrictor pharyngis inferior*] attaching the largest of the three cartilages to the esophagus have transverse fibers inclined toward the oblique, some more and some less. [II, 387]

To these muscles (for we may as well begin with these) Nature has sent two outgrowths of nerves from the sixth pair,[20] one of which [*n. laryngeus superior, ramus interior*] at the summit of the thyroid cartilage enters the interior of the larynx, and the other of which [*ramus externus*] goes to the transverse muscles [*constrictor*

[17] For a detailed discussion of these muscles, see chapter 11 of Book VII.

[18] A lost work; see notes 3 and 4 of Book VI.

[19] Daremberg (in Galen [1856, II, *166*]) supplies "cartilages (the cricoid and thyroid)" instead of "muscles," but it seems more sensible in view of the context for "these two" to be the two thyrohyoidei.

[20] Galen's sixth pair comprises the vagus, glossopharyngeal, and accessory nerves. The outgrowths described here are of course from the vagus. See note 41 of Book IX.

pharyngis inferior], whence it gives terminal branches to the muscles [*sternohyoideus? sternothyroideus?*] extending to the sternum.[21] These two pairs of nerves are inclined to an oblique position, but there is another, third pair descending to the muscles [*thyrohyoideus*] that raise the thyroid cartilage, and since this needs
[II, 388] a more elevated source, it could not be made to come down from the sixth pair to muscles leading toward the stomach. Nature, however, contrived to insert into these a straight nerve [*n. hypoglossus*] coming down from the encephalon above. There are two of these nerves [*ramus descendens* and *ramus thyrohyoideus*] extending down over the whole larynx on each side, one [pair] on the right and one on the left, and indeed their ends are inserted into the muscles [*sternohyoideus*] leading down to the sternum from the hyoid bone. In fact, at times they are extended to the lower muscles [*sternothyroideus*], which I have said begin at the thyroid cartilage, just as nerves from the sixth pair are sometimes inserted into the upper ones [*sternohyoideus*]. It is commonly characteristic of all animals, however, that these muscles receive nerves only from these pairs, because, having a downward-sloping position and serving the voice, they needed to have nerves that descend from the encephalon. Nature, then, has been both just and skillful in establishing these nerves.

In the larynx there are three other pairs of muscles [*thyroarytenoideus* and *cricoarytenoideus*, *posterior* and *lateralis*] most necessary for the production of the voice, as I have shown, and since these have a straight position such that their heads are below and their ends above, it was of course necessary to send nerves into them from below. Now the encephalon is not situated below, and so nerves would have to be brought from the spinal medulla, indeed from the lower parts of it, and a most just Nature in doing so would
[II, 389] have to be unfair if the most important instruments of the voice

[21] This error is corrected in *De anat. admin.*, XI (Galen [1906, II, *69*; 1962, *76*]), where Galen says: "But the other of the two branches of the nerve . . . you will see coming to the side of the larynx, where the thyroid cartilage connects with the oesophagus, and the transverse muscle binds the two with one another. . . . And this branch splits and breaks itself up in the muscle here indicated, of which I said that it is disposed transversely, as well as in that muscle [*M. cricothyroideus*] which binds the first cartilage [*thyroid*], at its end, with the second cartilage [*cricoid*]" (translation by Duckworth).

were the only ones for which she provided nerves coming neither from the encephalon nor from the first parts of the spinal medulla. Let us see, then, how perfectly she has provided for these two things, namely, supplying what was necessary for the action and avoiding the injustice of giving the muscles nerves unworthy of them. Well, she decided to bring nerves [*nn. recurrentes*] down from the encephalon, like the others I have spoken of earlier, by way of the sixth pair, from which nerves must also be given to the heart, stomach, and liver, but to make them run a sort of double course, carrying them first to parts below the larynx and then bringing them back up again to its most important muscles.

They could not run back without making a turn, so that Nature was forced to seek a turning-post, so to speak, for the nerves, around which she might bend them, checking their downward progress and beginning there to bring them toward the larynx. This turning-post, of course, had to be a solid body having a transverse, or at least very oblique, position; for the nerves could not possibly turn back from their downward course without bending around some such body. But there was no such body anywhere in the neck, and it became necessary for Nature to bring the pair of nerves down into the thorax and look for the turning-post there. As soon as she found one, she bent them around it and brought them back up through the neck again to the larynx. She did not, to be sure, make flexions of equal value for them, and here she would seem to have been unmindful of [II, 390] justice, since she assigned unequals to nerves of equal value. For she led one of them very far down through the thorax, whereas she brought the other back toward the neck after not much [of a downward journey].

What, then, is the reason for these things? It is not a difference in the nerves (for they are of quite the same value) but in the construction of the regions through which they pass. That is to say, in the free space in the left side of the thorax the largest of the arteries [the aorta], which I have said grows out from the heart like a trunk, first emerges obliquely but then immediately divides, the larger part being supported down along the spine and the smaller passing up to the clavicle. Here [22] Nature distributes one part of it [*a. subclavia*

[22] That is, where the aorta first "divides"; the following account of the vessels arising from the arch of the aorta shows clearly that Galen was describing conditions in some kind of ape. See Lineback (1933, *249–250*

sinistra] to the scapula, the arm, the left side of the neck, and whatever other parts are situated in this region; the other part [*truncus communis*] she extends up along the sternum and divides again into two unequal parts, making the one on the left, which is smaller, a carotid artery [*a. carotis communis sinistra*] and extending obliquely the larger one on the right [*aa. anonyma* and *subclavia dextra*], from which, as it advances a little way, many outgrowths are given off. For a certain artery [*a. thoracalis suprema*] goes to the upper parts of the thorax; another [*a. thoracica interna*] descends along the sternum to the right breast; and before these, to be sure, the right carotid [*a. carotis communis dextra*] grows off, rising steeply. Then the oblique remainder of the artery [*a. subclavia dextra*], after reaching the place where the first rib grows out, is
[II, 391] distributed to the scapula, the arm, and the parts on the right side of the neck. Such being the difference between the right and left sides of the thorax, let us recall that the two nerves [*nn. vagi*] from the sixth pair descend along with the carotid arteries, supported and protected by their proximity and by common coverings. Accordingly, it was necessary to conduct each nerve to this place where the arteries are first produced, as I have just indicated, and then to extend from that point some part of it which would be brought back to the larynx. Since there the nerves must exchange their downward course for an upward one, they must necessarily have a turning-post.

What, then, will be the best turning-post for each of them? The one on the left could not possibly be bent at the place where the [left common] carotid first grows out; for the part [*truncus communis, a. anonyma*] of the great artery which ascends along the sternum and from which the carotid is split off is almost straight, being [only] slightly inclined toward the right side of the whole thorax. The other offshoot [*a. subclavia sinistra*] of the ascending artery, the offshoot that goes to the left scapula and arm, has nearly the same position; for this too as a whole is almost straight, being [only] slightly inclined toward the auspicious (left) [23] arm. There

---

and figure 79) and note the perfect agreement with Galen's description. See also chapter 10 of this Book and note 22 of Book VI.

[23] The left side was called auspicious euphemistically and with propitiatory intent, because bad omens were supposed to come from the left. In the same way, the Black Sea was called the Euxine (kind to strangers) precisely because it was so unkind.

remains for the nerve, then, one available turning-post, the stem itself of the largest artery, wonderfully constructed for the nerve to [II, 392] use, not only because of its size but also because of its strength and position. Nature accordingly chose this very artery and wound around the base of it an offshoot [*n. recurrens*] from the sixth pair, which, as it ran back up, she applied to the rough artery [the trachea] in such a way that it was carried upon this and ascended safely to the larynx.

On the right side of the thorax, however, there was no such turning-post. Then do not seek for one that is not there and do not accuse Nature for finding different turning-posts for the two nerves, but consider what better one could be found in the left thorax than the one I have mentioned. For you will not find any that would be preferable, just as on the right there is also none better than the one that Nature found. Then what is this turning-post? It is difficult to explain such skill in words; for Nature's inventiveness in finding the turning-post is so incredible that if you did not see it, you would think that the man explaining it was romancing rather than telling the truth. Nevertheless, since I have found words to describe other things, I must not hang back from telling this tale either. I shall ask you to recall the artery [*aa. anonyma, subclavia dextra*] which I mentioned a little while ago as being placed obliquely in the right thorax, as first giving off the steeply ascending [right] carotid artery, and as then in its remaining part extending obliquely to the first rib. Since the right nerve descends through the whole neck close to the carotid as far as the place where the latter first arises, see whether you can suggest a better place for a turning-post for the nerve than that which Nature found. In fact, the point where [II, 393] the oblique artery [*a. subclavia dextra*] branches off next after the carotid was necessarily the only place (even though it was perilous) for the nerve to make its turn; for if there were some other preferable to this, Nature would have done better to abandon this and go to the other. Actually, however, precisely because there is no other and this turning-post just mentioned is the only one in the right thorax, Nature, though recognizing that it was perilous, was reduced by necessity to using it but did everything possible to provide safety.

First she split off the recurrent nerve from the large nerve where the latter first reaches the oblique artery [*a. subclavia dextra*] and then, placing the recurrent nerve on the back of this artery, she wound it around in the angle formed by the outgrowth of the

carotid artery. For she brought the nerve down on the outer [lateral] side of the carotid artery, but when she had wound it around the larger artery [*a. subclavia dextra*] in the angle formed by the two vessels, she began gradually to lead it back from that point along the inner [medial] side of the carotid artery, placing it on the right side of the rough artery [the trachea]. And when it is extending upward after the turn, Nature stretches out to it from the sixth pair the handlike outgrowth [24] which binds it to the large nerve and makes both its turn and its ascent safe. The portions of the nerve on the two sides of the turn are supported on both the right and left by
[II, 394] the outgrowths [*rami cardiaci inferiores?*] of the sixth pair which it makes to the parts in this region. Moreover, at the larynx itself these recurrent nerves with which this whole discussion of mine has been concerned are mingled to some extent with the nerves [*n. laryngeus superior*] which I mentioned in the preceding discussion and which I said grow off from the sixth pair and go to the depths of the larynx. Parts of the recurrent nerves reach the same place as those nerves in all the animals I know (though you may see this most clearly in the bear, dog, beef, and other such animals), Nature contriving strength and force for both nerves from their association with one another. For I have already said before this that interlacing weak bodies conduces to making them both strong.

5. Somewhere in what precedes [25] I have said something about the nerves that extend to the viscera and intestines, but I must add what is lacking. A certain portion of the nerves [*nn. vagi*] from the encephalon also reaches this region; the share of all the other parts is small, but that of the orifice of the stomach is of considerable size, because Nature has made this part an instrument of the desire for food, lying as it does at the gateway, so to speak, to all the instruments which she has prepared for the governance of the nutriment. And so she has brought this nerve down from above, pure and
[II, 395] unmixed with any other, hard nerve; on the way she gave off a small part of it to the esophagus, lung, and rough artery [the trachea], and

[24] See chapter 15 and note 61 of Book VII.

[25] See chapters 7 and 13 of Book IV, chapters 8 and 9 of Book V, chapter 6 of Book VI, chapter 11 of Book IX, and chapter 2 of this Book. The following description of the vagus and the sympathetic trunk should be compared with that in *De anat. admin.*, XIV (Galen [1906, II, *198–202*; 1962, *217–222*]).

from the same pair she gave the liver and heart each a pure nerve for the reason I have told earlier.

To all the other parts below the diaphragm and within the peritoneum, however, a part of these nerves extends that is no longer pure, but mingled with nerves from the spinal medulla; for some nerves from the thoracic spinal medulla itself and from two or three vertebrae below the thorax are added to the nerves passing to the roots of the ribs [*truncus sympatheticus*]. As these nerves proceed, they are mingled with the remnant of those [*nn. vagi*] which descend to the stomach and which are also independently mingled with nerves from the spinal medulla. From the mixture [*plexus coeliacus*] of all these nerves, nearly all the parts within the peritoneum receive their nerves, gaining strength and force from the mingling of nerves from the spinal medulla, and sensation more precise than that of the other parts from nerves from the encephalon.

There is also, of course, another marvelous work of Nature's, which has been unknown to anatomists; for in a small nerve which she must conduct over a long path or in one which is to serve for the vigorous movement of a muscle, she interrupts its substance with a body [a ganglion] that is thicker than the nerve but similar to it in other respects. In fact, its appearance at first sight will make you think it [another] nerve that has been rounded up and has grown upon and around the first, but when you dissect it, you will see [II, 396] distinctly that it is not an excrescence or overgrowth, but a certain substance resembling the nerve and quite united with it, being exactly like the part that enters it and the part that extends away from it again. Accordingly, just from its substance, which is similar to that of a so-called *ganglion*,[26] a thickening of the nerve results so that the part coming after it is clearly seen to have a larger diameter than the part before it. You will see this substance in some other parts too, and indeed, in these nerves[27] descending from the encephalon it is found not once or twice, but six times. The first one is in the neck a little above the larynx; the second is where they enter the thorax and

[26] *τὸ γαγγλίον*, primary meaning, an encysted tumor on a tendon or aponeurosis. See Hyrtl (1880, *230–231*) and cf. *De anat. admin.*, XIV (Galen [1906, II, *198*; 1962, *217–218*]).

[27] From what follows, surely these nerves are the sympathetic trunks, not the vagi.

pass toward the roots of the ribs; and the third is where they first leave the thorax.[28] Thus, since such a substance is found three times on each side of the animal, right and left, I was right when I said that it occurs six times in these nerves. This is enough to have said about them.

6. It would be next in order to explain the distribution of the other nerves that grow out from the encephalon and descend to the neck and the scapulae. Now in these cases, although it was possible for Nature to use the spinal medulla in the neck as the origin of all the nerves in this region, she was not acting idly or in forgetfulness of this when she brought them from a distance; rather she inserted them into those muscles that have an elevated position and
[II, 397] also draw the scapula toward the head. Thus, into the broad muscles [*trapezius*] of the scapula, which were mentioned first and which begin at the occipital bone of the head and end at the spine of the scapula[29] she inserted a nerve [*n. accessorius*] of considerable size produced along with the others which I have said grow off in the sixth pair.[30] But these [two spinal accessory] nerves come steeply down to this same place for the reasons (χρεῖαι) I mentioned just now, and they are inclined toward the sides of the neck, passing suspended in this region as far as the muscles to which they have been hastening from the beginning. In fact, these muscles receive very large nerves[31] not only because they are themselves large but also because they have a vigorous action; for they draw the whole scapula upward. Next after these, nerves [*nn. accessorius* and *cervicales III* and *IV*] of considerable size have been given by Nature to the muscles [*atlantoscapularis anterior*][32] that arise from the first vertebra and are inserted into the top of the scapula; for the motion of these muscles too is strong. But the muscles [*sternocleidomastoideus*][33] which rotate the head and whose extremities reach the sternum and clavicle have nerves [*nn. accessorius* and *cervicales II*

[28] The first two of these ganglia are evidently the superior cervical and stellate; the third may well be the celiac, as Daremberg (in Galen [1856, II, *172*]) thinks.

[29] The origin and insertion of this muscle are reversed in the account given in chapter 13 of Book XIII, *ad fin.*

[30] See note 41 of Book IX.

[31] Reading *μεγίστων . . . μετειλήφασι νεύρων* with Helmreich for the *μέγιστον . . . κατειλήφασι νεῦρον* of Kühn's text.

[32] See note 39 of Book XII. [33] See note 35 of Book XII.

and *III*][34] from many sources because their motion is composite, being produced by straight fibers lying next to one another. For this reason, where [the muscles] first grow out,[35] offshoots from the nerves [*n. accessorius*] going to the large muscles [*trapezius*] of the two scapulae are inserted into them, and then [they receive nerves] from the cervical vertebrae [*nn. cervicales II* and *III*] in order that the separate sources, by drawing the muscles toward themselves, may in turn give them varied motions. Thus, muscles having an oblique position must be provided with sources of motion established in different places, and accordingly, the first parts of these muscles are given a portion of nerves [*nn. accessorius*] coming from above. [II, 398]

Moreover, nerves [*nn. accessorius* and *hypoglossus*] from the encephalon are given to the muscles [*palatoglossus* and *palatopharyngeus*] that are near the tonsils and to those [*thyrohyoideus*] which in animals with loud voices are among the muscles [inserted] on the lower rib [the greater cornu] of the hyoid bone and which in some animals are attached to the upper part of the sides of the first [thyroid] cartilage, because these parts have to do with the voice. There is another pair of slender nerves [*n. glossopharyngeus*] that reaches the root of the tongue, and these nerves are particularly clear in those animals in which the aforesaid muscles are very small indeed. This pair of nerves grows out in the pair called the sixth by Marinus[36] and is present in all animals with some resemblance to man, though it differs [in different animals], as I have said. For in those that have loud voices or are equipped for biting, these nerves are used more for the muscles attached to the hyoid bone, because these are large, but in others they extend more to the pharynx and the root of the tongue. None of the other nerves

[34] In the ape, according to Howell and Straus (1933, 97), only the ventral ramus of the second cervical nerve anastomoses with a branch of accessorius.

[35] κατὰ μὲν τὴν πρώτην ἔκφυσιν. Daremberg (in Galen [1856, II, 173–174]) takes this to mean where the *nerve* first issues from the cranium. But in view of the facts that branches of accessorius are distributed to the upper parts of sternocleidomastoideus and then (ἐφεξῆς) spinal nerves reach it lower down, and that Galen was aware of this (see the following sentence), it seems probable that he was thinking of the "outgrowth" of the muscle, not of the nerve.

[36] Cf. chapter 14 and note 58 of Book VII, and notes 20 and 41 of Book IX.

growing out from the encephalon descends below the face; they are all distributed rather to the muscles of the face and to the sense instruments. I have spoken earlier about the distribution of these and
[II, 399] it would be superfluous now to mention it again. It is better to pass on to the cervical spinal medulla and show how Nature has also distributed the nerves from this source most justly.

To begin with, then, just as she has given some portion of a nerve from the encephalon to parts below the face and has done this not idly or at random but for the sake of the uses I have mentioned, so too she does not hesitate to bring from the neck a portion of nerves from the spinal medulla up to the head. In those animals in which the temporal muscles are very large and the ears are large and easily and freely moved, these nerves are large, but in other animals which have none of these characteristics, like man and the ape, they are extremely small. For in these animals the temporal muscle is small and the ears practically motionless and also as small as they very well can be[87] in some. Hence in them the nerves too that pass up to the head are small; two of these [*n. occipitalis major*][88] pass up from the posterior parts and two [*n. auricularis magnus*] from the sides, and they are distributed to the skin and to each ear. And just as these animals have [only] traces of muscles in the vicinity of the ear, so too the nerves that reach this region are very small. On the other hand, just as in animals that have large ears easily moved the ear is wreathed about by a circle of many muscles, so too it is wreathed by large nerves distributed to them. These nerves branch off from the second pair in the neck; for since all nerves must go to the heads of
[II, 400] the muscles, they had to come up from below. Since, moreover, in animals in which the temporal muscle is very large, Nature has placed the head of it also near the occipital region, a portion of a nerve[89] from the neck is with good reason inserted into it, passing up through the parts at the occiput. Its head is so situated, especially

[87] Accepting Helmreich's emendation, ὅτι καί, for the ὅτι μή of the manuscripts and Kühn's text.

[88] See chapter 5 of Book XIII.

[89] Probably auricularis magnus, which may arise from C_2 or C_3 or both; see Howell and Straus (1933, *309*). For in *De anat. admin.*, XV (Galen [1906, II, *212, 213;* 1962, *233, 234*]), Galen mentions such a branch when he is describing the distribution of both the second and third cervical nerves. See also Galen's *De nervorum dissectione*, cap. 13 (Kühn, II, *847;* Galen [1966, *332*]).

in the animals called saw-toothed and then also in those having a large [lower] jaw; for Nature constructed a large temporal muscle in these animals because they needed a strong muscle, the first kind to enable them to bite vigorously and the second to support the jaw.

Now the broad, thin muscle [*platysma*] [40] moving the cheek and lateral parts of the mouth (the muscle which [anatomists] before my time used to destroy, tearing it off along with the skin), makes manifest Nature's wonderful skill. For since this muscle has many sources [41] and terminates at the cheek and lips, opening the mouth [by drawing it] toward the sides, it has all its fibers passing to these parts, and along with these the nerves pass too. Thus the fibers arising from the *acantha* [42] of the cervical vertebrae are accompanied through the neck to the anterior [ventral] parts of it by a great many very large, transverse nerves,[43] because the membranous ligament [the fasciae] that holds the fibers grows out from the *acantha*, and the most important source of the muscle is in this region. But the nerves accompanying the fibers that pass up from the scapula and clavicle are smaller and these too follow the course of the fibers. [II, 401] Since there is a single outgrowth on each side from each of the cervical vertebrae and each outgrowth has the root of the nerve directed transversely, it is wonderful how the nerves are inserted into those fibers which are in the anterior parts of the muscular outgrowth; for the nerves are bent to an upward course around certain turning-posts cleverly found by Nature, turning in some cases around muscles or arteries or veins and in others by means of membranes which she has pierced with small foramina of the same size as the nerves. Again, an oblique nerve is more easily inserted into fibers that are oblique. But the fibers passing from the *acantha* at the back excite greater admiration of the works of Nature; for these too,

[40] Daremberg (in Galen [1856, II, *175*]) here corrects his former errors and identifies this muscle as platysma. See chapters 13 and 15 and notes 47 and 50 of Book IX.

[41] Including the nuchal portion of the muscle absent in man.

[42] See chapter 15 and note 56 of Book XII.

[43] These may be both posterior and anterior rami of all but the first and second cervical spinal nerves. *Vide infra* and cf. *De anat. admin.*, XV (Galen [1906, II, *212–213, 216, 352;* 1962, *234–237*). In *De nervorum dissectione*, cap. 12 (Kühn, II, *846;* Galen [1966, *332*]), a branch from the second cervical nerve also is said to proceed to platysma.

as they advance, must be accompanied by nerves, as indeed they are seen to be. Now anyone seeing these nerves will think that they grow out from the very bones of the *acantha*, but this is not the case; for their source is the cervical spinal medulla, and they first grow out through the common apertures at the sides of the vertebrae. Indeed, the nerves issuing from the spinal medulla have only this one source, at each side of each vertebra, but how wonderfully Nature distributes them as soon as they pass beyond the place where they grow out [44] from the vertebrae! Some she conducts transversely to
[II, 402] the posterior and anterior parts of the neck, and certain others she bends around turning-posts [so that they become] straight, steeply descending, or oblique. Since this variation appears in the outgrowths of the nerves, anyone (that is, if he dissects accurately) will find the matter of the nerves coming away from the *acantha* still more wonderful and difficult.

So this very great work of Nature's has also been unknown to those who seem most skilled in anatomy; for when they did not know this muscle [*platysma*] at all, how could they know any of the nerves in it? Nature conducts an offshoot from each transverse outgrowth of all the nerves in the neck after the second through the depths to the posterior region until it reaches the root of the *acantha;* thence with the aid of the *acantha* she leads it up as far as the aforementioned ligament [the fasciae], which is thin and broad like a membrane; and then, piercing this with very small foramina of the same size as the nerves, she brings the nerves forward again through the neck. Indeed, if you remove the intervening muscles, you will see that as soon as each of the nerves has grown out from the spinal medulla, it first passes back transversely upon the muscles in the depths of the neck, then comes up superficially under the skin, also transversely, and, resting upon the broad ligament (for [Nature] uses this for everything), begins to run back again; for it turns in the
[II, 403] foramina of the ligament. Thereafter, the nerves cling closely to it and are carried and conducted by it. Now all the other parts of that broad, thin muscle [*platysma*] (there is one of them on each side) are interwoven with nerves in this way, but the parts of it that are carried along the masseter muscle from the root of the ear through the cheeks make use of the nerve [*n. facialis*] that issues from the

[44] Reading ἐκφύσεις with Helmreich for the ἀποφύσεις of Kühn's text.

blind perforation [45] and has an arrangement similar to that of the fibers in this region and a source nearer at hand.

A work and a marvel of Nature's such as this has been unknown to the anatomists, just as many other extraordinary devices in the construction of the animal have been too. In fact, physicians have not known that there are three pairs of muscles [46] which draw back both the neck and head, four other pairs [*recti capitis posteriores, majores* and *minores; obliqui capitis, superiores* and *inferiores*] which surround the joint of the head at the first and second vertebrae and move back the head alone without the neck, and certain others [47] which move it laterally in both directions. But, as I have shown earlier, Nature has not done any of these things idly. She has created the spinal medulla as the source of the nerves moving all these muscles and has made the course of each nerve to accord with the movements of the muscles, doing this also no less throughout the animal. Now just as in the muscles of the neck [48] the course of the nerves runs from the lower parts upward because the muscles move [II, 404] the head forward, so the source of the nerves [*n. dorsalis scapulae*] for the two muscles [*rhomboideus, pars cervicis* and *pars dorsi*] moving the scapula back toward the dorsum is in the neighborhood of the *acantha* and the nerves accompany the muscles and divide along with their fibers as far as the scapula.[49] For Nature conducts nerves to these muscles too through a very deep region and inserts them into the heads of the muscles, bringing them back over the same road but higher up and placed transversely.

So likewise in the large muscle [*latissimus dorsi*] next to these, which, adhering to the lower borders of the scapula, draws it downward by means of the insertions there and, passing up through the

[45] The facial canal; see chapter 10 of Book IX.

[46] Splenius capitis and semispinalis capitis (complexus), etc.; see chapters 8 and 12 and note 31 of Book XII.

[47] Sternocleidomastoideus; see chapter 8 and note 35 of Book XII.

[48] That is, the anterior vertebral muscles, longus capitis, etc.; see chapter 8 and note 34 of Book XII.

[49] To make of this sentence understandable English which would convey Galen's intended meaning required the taking of certain liberties. Literally translated, it would read, "so the source of the nerves, . . . being placed at the region of the *acantha*, goes forth along with and is divided together with as far as the scapula."

axilla, draws down the arm along with the scapula, you would find all the nerves [*n. thoracodorsalis*] arranged and placed in the same way in respect to the fibers, especially where it extends up along the ribs to the axilla. If you are willing to strip all the skin from the thorax and observe the course of the nerves, you will see that it is not simple or single, but very diverse. That is to say, nerves passing downward from above are distributed to the skin and membranes; but as for the muscles lying beneath them (both this muscle [*latissimus dorsi*] under discussion, which is one of the largest, and the thin muscle [*panniculus carnosus*] which comes after [lies below] the skin and membranes and of which anatomists have been entirely ignorant), none of these nerves [50] has been led astray and implanted in them. Rather, you can see the nerves passing by one another and being distributed each to its proper part.

[II, 405] 7. You will see in the thorax too, as in the neck, many other muscles, some of which receive nerves descending from above, whereas others, contrariwise, receive them ascending from below; and the nerves are distributed as they pass to the ends of the muscles where they move the parts. For you can see the muscle [*panniculus carnosus*] [51] that comes up from the false ribs and the breast to the shoulder joint lying very close to the one that comes down from the neck [52] and expands the anterior parts of the thorax. You can see too the one [*subscapularis*] at the concave parts of the scapula, and this is also very close to the same muscle [*scalenus brevis anterior* and

[50] That is, none of the nerves which, "passing downward from above, are distributed to the skin and membranes."

[51] Daremberg (in Galen [1856, II, *178*]) identifies this muscle as pectoralis major, but for Galen the muscle "that comes up from the false ribs and the nipple" is always panniculus carnosus. See chapter 13 and note 57 of Book XIII.

[52] Daremberg (in Galen [1856, II, *178–179*]) identifies this muscle as sternocleidomastoideus, but it is rather scalenus brevis anterior and perhaps scalenus longus. See Howell and Straus (1933, *97–98*) for a description of the scalene muscles in the rhesus monkey, where they differ from their counterparts in man. Scalenus brevis anterior and scalenus longus do "expand the anterior parts of the thorax," as Galen says this muscle does, whereas he has given to sternocleidomastoideus only the task of moving the head. Moreover, sternocleidomastoideus can hardly be said to be very close to subscapularis. Part of Daremberg's trouble lay in the faulty text, restored by Helmreich. See note 53, *infra*, and see also *De anat. admin.*, V, 3 (Kühn, II, *495;* Galen [1956, *129*]).

perhaps *scalenus longus*].[53] Similarly, the muscles [*pectorales*] passing from the sternum to the arm are close to the one mentioned first [*panniculus carnosus*]. On the one hand, to these muscles passing upward nerves[54] are distributed that issue from the intercostal parts of the thorax, and certain other nerves[55] come bending obliquely from the farthest tendinous parts [of the muscles] near the neck. On the other, to the muscles [*scaleni*] coming down to the thorax from the neck nerves are sent from the cervical part of the spinal medulla [twigs from the cervical plexus]. Having spoken in some detail in my books *On the Causes of Respiration* and *Manual of Dissection*[56] about the course of the nerves in the intercostal muscles, I do not need at this point to explain further the skill of Nature [in distributing them]. Similarly, I need say nothing more about the course of the nerves for the diaphragm; for these were described in the thirteenth book [of the present work].

With equal reason, however, I should not omit what has not been described anywhere previously and what does not have a construction like that of the parts I have just explained. The muscles [*deltoideus*] at the point of the shoulder extend the whole arm and need a strong nerve, since they lift a very large part up and sometimes lift it very high.[57] Of course, too, this nerve must be inserted into the upper part of the muscle. From what source, then, are we to bring one so elevated up to it? Now a nerve cannot be brought up to an elevated muscle lying [immediately] under the skin from the circumambient air, or from the head by way of the superficial muscles of the neck (for it would have a very dangerous journey), or from the neck obliquely and superficially. We, indeed, are accordingly unable, so it seems, to discover even in our talk a nerve suitable for the muscle at the point of the shoulder, but this too has been actually accomplished with the greatest of ease by Nature, who [II, 406]

[53] Reading τούτῳ γ' αὐτῳ with Helmreich for the τοῦτον αὐτὸν of Kühn's text.

[54] *N. thoracodorsalis?* See Howell and Straus (1933a, *312*).

[55] *Nn. pectorales anteriores* coming to the pectoral muscles and panniculus carnosus; see Howell and Straus (1933a, *314–315*).

[56] *De causis respirationis* (Kühn, IV, *469*) and *De anat. admin.*, VIII, 4 (Kühn, II, *667–675*; Galen [1956, *208–211*]), and XIV (Galen [1906, II, *199–200*; 1962, *218–220*]).

[57] Kühn's text omits ἔστιν ὅτε πάμπολυ, the translation of which, however, is included in the Latin version.

has produced it [*n. axillaris*] from the spinal medulla at the fourth and fifth vertebrae of the neck and brought each part of it [the anterior and posterior branches] to the outer and upper part of the shoulder so concealed in the depths that it does not come to view at all. In fact, near the neck of the scapula and the diarthrosis at the shoulder she has prepared for these [two divisions of the nerve] a course in the deepest part of this region, bringing one of them to the upper part of the neck of the scapula, threading the other through below this part, and then bending both of them around to be distributed to the muscles raising the arm. And with the same forethought and skill Nature has distributed nerves to all the other muscles of the scapula as well.

[II, 407] 8. I have told previously about the nerves going to the arms, how they arise and are interwoven.[58] I have also said that Nature creates such minglings of nerves for the sake of safety, and hence she takes care to do so particularly among those nerves that are unsupported or that must follow a long path. I have said too that it was safer for the nerves, arteries, and veins branching into the limbs to go through the inner parts. I shall therefore explain briefly the course of the nerves in the whole arm and then pass on to what comes next in my narrative. Now all the nerves going to the hand have been so cleverly concealed that even most physicians are unfamiliar with them. Sunk deep within, they travel through the inner parts of the upper arm to the forearm, but when they approach the diarthrosis at the elbow, which is all fleshless and bony, they are carried superficially on the bones under a skin that is devoid of flesh, and so they would be in great danger, following a most perilous route, if Nature to provide for their safety had not found just such a clever device as is actually there. For, increasing the size of the inner head [the medial epicondyle] of the humerus, she concealed the nerve [*n. ulnaris*] that arrives at the little fingers in the space between this head and the elbow [the olecranon], and the nerve [*n. medianus*] that arrives at the large fingers she carefully threaded through the middle of the diarthrosis in the deepest part of this region between
[II, 408] the ulna and radius. Next, covering both nerves with the inner [volar] muscles of the forearm, which are very large, she carried them to the wrist, where she then began to divide them, using the prominences of the bones for protection, concealing them, and

[58] See chapter 5 and notes 23 and 24 of Book XIII.

winding them around the bases of the prominences. She brought another, third nerve [*n. radialis*] to the outer [dorsal] side of the forearm and used the fleshiest muscle [*brachioradialis*] in that region to protect it. And she properly distributed the larger nerves to the parts on the inner [volar] side of the arm, because it is also through these that the hand performs all its actions.

In the legs too she has displayed the same skill, concealing the nerves in some places under prominences of the bones and in others under the large muscles, and distributing more of them to the large muscles or to those provided for powerful actions, and fewer to the smaller ones or to those performing no vigorous action. These are common goals, kept in view by Nature in her construction of the parts not only in the arms and legs but also throughout the body of the animal. The nerves of the legs, however, differ from those of the arm in respect to the course they follow, which I shall now explain in the following way: All the nerves leading to the hands travel through the inner side of the upper part of the limb, but this is not true of all those going to the leg. For with the exception of a very few, of which I shall speak a little later, they all pass down through the posterior parts of the thigh, and this has followed of necessity from the difference between the joints at the shoulder and hip. The one at the shoulder has been placed at some distance from the [II, 409] cervical vertebrae from which the nerves arise, but the one at the hip has been closely joined to the lumbar vertebrae and also to the so-called sacred bone, whence the nerves, crowded together,[59] descend to the legs in the fashion I have described in my *Manual of Dissection*.[60] Since, then, there was [at the hip joint] no such intervening space as is found at the axillae in the case of the arms, it became necessary for Nature to lead the nerves growing out from the lateral parts of each of the vertebrae down through the posterior regions of the thigh, having there a very large muscle [*biceps femoris?*] beneath which to hide them. How marvelously, before conducting them to the thigh,[61] she also conveyed the nerves in the space between the head of the femur and the broad bone [*os sacrum*], concealing them both under the bones and under the

[59] In the greater sciatic foramen.

[60] *De anat. admin.*, III, 10–11 (Kühn, II, *397–406;* Galen [1956, *83–87*]), and XV (Galen [1906, II, *239–241;* 1962, *262–264*]).

[61] Reading ἐκεῖνον *with Helmreich for the* τὸ σκέλος *of Kühn's text.*

muscle [*gluteus maximus*] covering the diarthrosis behind and corresponding in position and usefulness to the one [*deltoideus*] at the shoulder!

Thence she conducted them, now in safety, through the depths of the thigh as far as the popliteal region, distributing a nerve to each of the muscles of the thigh according to its worth. From the popliteal region she conducted the nerves through the calf of the leg, which is entirely fleshy, bringing some [*n. peronaeus superficialis*] into the outer [lateral] region of the leg and some [*n. tibialis*] to its inner [medial] parts, whereas some [*n. peronaeus profundus*] she also brought down through the middle of it, distributing them to the muscles there. Those which she led through the inner parts of the
[II, 410] calf she conducted to the under parts of the foot [*nn. plantaris medialis* and *lateralis*], concealing them along the talus and tibia. Those that pass through the outer parts of the calf she also concealed along the talus and fibula and conducted to the anterior and upper parts of the foot [*nn. cutaneus dorsalis, medius* and *intermedius*].

If you are willing to examine in an actual dissection all that I have told you, what you see with your own eyes will convince you further and force you to admire the works of Nature. For [you will see] why, even if a nerve does go astray at some one point, it nowhere ascends upon the rims of either the tibia or fibula and is never conducted along the convexity of the talus and fibula, and why Nature always conceals it under the edges of the bones, winds it around the bases of their necks, and so makes its course safe. Thus you cannot see any nerve exposed either at the elbow, where it is bare of flesh, or at the knee or the anterior parts of the leg, but you can see them everywhere located in the depths between the barriers of the bones, cartilages, ligaments, or fleshes. If I were to explain these things for each nerve, drawing out my narrative with particulars, the book would be in danger of being prolonged indefinitely. So let it be sufficient to have told the main points, especially since I explain the construction of each of these nerves in my *Manual of Dissection*, and if the lover of truth goes to this in order to examine the account of each muscle and nerve, I shall not object; indeed, I urge him to do so. For thus he will be better persuaded by what I have said.

[II, 411] 9. Now, however, it is time to turn to what still remains of this

subject. Since the muscles [62] growing out from the pubic bones had to have nerves, it was necessary to bring them some by way of the inner parts too. For, as I said a little while ago, not all could be brought [through the posterior parts], both because the region where the nerves grow out faces outward and still more because the space is narrow. In fact, the nerves passing down from above had to make their way between the head of the femur and the pubic bones. This space, moreover, was occupied by other parts that could not be transferred elsewhere. Indeed, the artery and vein [*a.* and *v. iliaca communis* and *externa*] branching from the great vessels at the loins could not betake themselves to the legs by any other route, and besides, the muscle [*psoas major* and *iliacus*] that is inserted into the small trochanter and flexes the diarthrosis, and in addition to these the [spermatic] cord that in the male extends from the peritoneum, together with the vessels contained in it, most necessarily make their way through this region. Since, then, all the nerves could not descend to the legs through it and the muscles I have mentioned had to have some, a nerve [*n. obturatorius*] sufficient for them alone arrives at their heads, passing through the large aperture [*foramen obturatum*] in the pubic bone. There is also a nerve [*n. femoralis*] of considerable size which grows along and together with the vessels both for their sake and for the sake of the regions traversed by them [II, 412] as far as the knee, and which is far removed from the course of the posterior nerves. Offshoots of this nerve likewise supply the whole skin of this region, just as the small muscles in the neighborhood of the anus, bladder, and pudendum, the membranes here, the bladder, uterus, and perineum are supplied [by nerves issuing] from the apertures of the so-called broad bone [to form the sacral plexus]. For when no other usefulness forbids, Nature loves to send nerves, veins, and arteries into the parts from sources near at hand, and for this too she should be greatly admired. Of course, when it is useful, she does not hesitate, as a lazy [63] workman would, to bring them from a distance, but when nothing else forbids, she distributes them to all parts from the nearest sources. For she is equally careful to do nothing that is insufficient and nothing that is superfluous. Indeed, there are only four arteries and four veins which she has brought on

[62] See chapter 8 of Book XV, *ad fin.*

[63] Reading ἀργοῦ with Helmreich for the ἀγαθοῦ of Kühn's text.

long journeys from other regions for the sake of most necessary uses,[64] which I have already explained in my preceding commentaries and which I shall now recall to your mind, leading my argument back to its source.

10. Now that I have given an adequate explanation of the nerves, it is time to turn to the distribution of the vessels, and I must speak first about the arteries. There is a certain very large vessel [the aorta], which, as I have said before, grows out from the left ventri-
[II, 413] cle of the heart like a trunk and is distributed into the whole body.[65] Immediately after it grows out from the heart, this very large vessel divides into two parts, one of which bends down along the spine in order to send arteries to all the parts below, whereas the other passes up to the head to furnish branches of vessels to all the parts above the heart. As I have said before,[66] the division is an unequal one, because there are more of the animal's parts below the heart than above, and the descending portion of the artery is as much larger than the portion ascending to the throat as the number of the lower parts exceeds that of the parts above. Here at once are works showing no small degree of justice and skill, and even greater than these is Nature's provision for the safety of the artery, which grows out suspended and hence must pass unsupported both upward and downward through the whole thorax; for she placed the lung under it as a support, surrounded it with membranes like ligaments, and conducted it by the shortest path to parts that are very secure and firmly seated.

The descending portion of it is fixed at a point just opposite the place where it grows out; inclining to neither one side nor the other, but going by the straightest, most direct route, it mounts
[II, 414] upon the fifth thoracic vertebra. The other, [ascending] portion, as soon as it has grown out, immediately gives off a certain part of itself [*a. subclavia sinistra*] which extends to the left scapula and axilla and which, carried upon the lung and supported by [mediastinal] membranes, passes up as far as the first rib without dividing; for it was not safe to divide it while it was suspended. In that re-

[64] The spermatic veins and arteries and the internal thoracics; see chapter 10, *infra*, and chapter 7 of Book XIV.

[65] Kühn omits *εἰς ἅπαν τὸ σῶμα*, but translates it in his Latin version.

[66] In chapter 5 of Book VI and chapter 4 of this present Book; see also note 22 of Book VI.

gion, accordingly, it then sends one part [*truncus costocervicalis*] of itself to the first intercostal spaces; another [*a. thoracica interna*] extends beneath the whole sternum to the hypochondrium and breast; and a third [*a. vertebralis*] goes to the cervical part of the spinal medulla, passing through the apertures of six vertebrae after sending out offshoots along the way to the muscles in the vicinity. The remainder of this artery is distributed to the entire left arm and to the scapula. The other, larger part [*truncus communis*] of the whole ascending artery, attaching itself as soon as possible to the bone [the sternum] at the middle of the chest, passes straight up to the throat (*σφαγή*) from the place where it is given off.

Now do not look merely at this feature of the arteries, but examine closely the region also where the different parts of the artery first mount upon the bones; for you will see not only that a bone has been prepared as a bulwark and foundation for each part, but also that in addition to these a membrane has been placed under one of these vessels [the descending aorta], that the cartilage which lines the inner [ventral] parts of the vertebrae has been prepared like soft bedding for it, and that the other vessel [*truncus communis*], which ascends to the throat, has a very large, soft gland [the thymus] placed beneath it like a couch. Certainly, if there were in [II, 415] the thorax no other vessel or part passing down from above or up from below and needing this same assistance, the spine at the back and the sternum in front would provide just the [two] parts of the great artery with the service and usefulness of which I have been speaking. As it is, however, with the vena cava passing up from below and with the esophagus and vein [*v. azygos*] that nourishes the thorax passing down from above, it was fitting not to overlook the safety of those parts either but to cover and unite them, support them with padding,[67] and give them bones as protective barriers. Indeed, these things have obviously been done, and nothing, not even the least detail, has been neglected by the Creator of animals.

First, though he could have attached the esophagus to the sternum and the vena cava to the spine, he did the opposite. For the spine is closer to the esophagus than the sternum is, and the sternum is nearer the vena cava than the spine is, since the esophagus from its beginning is carried through the whole neck by being mounted on the

[67] Reading *ὑποστορέσαι* with Helmreich for the *ὑποστηρίξαι* of Kühn's text.

vertebrae, and the vessel which passes up from the right auricle of the heart and is continuous with the [inferior] vena cava (and hence is called the vena cava by many physicians) is near the sternum. And it was better to make the bone closer to each part its bulwark, rather
[II, 416] than [to choose] the one farther away and bring a suspended vessel back through the whole breadth of the thorax to the opposite side. Then, too, another advantage has resulted for each of the parts from this position of theirs. That is to say, the esophagus goes in a straight line with the stomach lying upon the spine and receiving it and thus is not compelled to leave [the thorax] through the middle of the diaphragm, where there is already a necessary aperture giving passage to the vena cava, and when the vein reaches the throat and is associated with the artery from the heart, it readily obtains a suitable situation. The artery also is at once kept in such a position that as [the vessels] pass through the neck and divide, the arteries are in the depths and the veins lie upon them.

Furthermore, it was not only by locating the esophagus, the artery [the aorta], and the vein [*v. azygos*] nourishing the lower parts of the thorax upon the spine and by extending the vena cava beneath the sternum that Nature arrived at the best results; for she also avoided placing the esophagus, artery, and vein one upon another or putting the esophagus, artery, and vein one upon another or putting the esophagus in the middle and the artery at the side. Rather, she extended the artery along the middle of the vertebrae and the esophagus alongside it.[68] For the artery obtained a position as much safer than that of the esophagus as its importance for life is the
[II, 417] greater. And that the esophagus traverses the middle of all the cervical vertebrae and the first four of the thoracic too is no inconsiderable proof of what I have said; for when it was the only part passing along them, it was not better for it to abandon the safer path and go by one not so safe, nor was it better, when it encountered a more important instrument, for it not to yield precedence. Moreover, the vein [*v. azygos*] that nourishes the lower eight ribs of the thorax on each side, being smaller than the artery, is extended alongside of it; but I shall speak of this vein a little later on, when I am discussing the veins, and return [now] to the artery.

Passing through the lower parts of the thorax, the largest artery,

[68] Compare this account of the course of the esophagus and aorta through the thorax with that in chapters 5 and 6 of Book VI.

which has been the subject of my discourse, sends off outgrowths [*aa. intercostales*] on each side to the regions of the intercostal muscles; in fact, the greatest portion [*rami anteriores*] of the outgrowths branches into these muscles, but a part by no means small [*rami posteriores*] also escapes into the outer muscles of the thorax. For it was neither safer nor shorter to bring arteries to these or to the diaphragm from any other source, neither from any other artery nor from any other part [of this artery]; rather they must be brought from this very artery and from that part of it where it goes through the diaphragm.[69] Certainly it was better for the stomach, spleen, and liver not to receive arteries from any other source, but to get them only from this largest artery[70] as soon as it arrives in the parts below the diaphragm. From this same region the artery [*a. mesenterica superior*] distributed to all the intestines arises, because [II, 418] the summit of the mesentery is close by and not only the artery but also the vein [*v. mesenterica superior*] and nerve [*plexus coeliacus*] had to begin at this point to branch into all the coils of the intestines. Again, since the kidneys come next, a pair of very large arteries [*aa. renales*] is implanted in them. Now I have spoken about the size of these arteries when I was discussing the kidneys, but I shall tell here why they do not grow out from some other part of the [great] artery. Nature seems to use the largest of the vessels like aqueducts, sending out to all the parts nearby in every region through which they go side-channels or conduits, as it were, which differ in size according to the worth and usefulness of the parts receiving them, but which are all dispatched over the shortest interval. In accordance with this principle the branch of the [great] artery distributed to the right kidney has its point of origin higher than that of the branch going to the left kidney, because the position of the kidneys themselves is not the same, as I have shown before. Thus it is not surprising that although the arteries passing to the thorax on the left originate at the same level[71] as those on the right, the outgrowth

[69] Note that here, as in Galen's *De venarum arteriarumque dissectione*, cap. 9 (Kühn, II, *820;* Galen [1961, *364*]), the superior and inferior phrenic arteries are not distinguished, perhaps because the superior phrenic is lacking in the pig, carnivora, and ruminants; see Ellenberger and Baum (1926, *667*). In fact, nothing is said by Lineback (1933, *255*) of a superior phrenic artery in the rhesus monkey either.

[70] By way of the celiac artery.

[71] Literally, "from the same place."

into the right kidney was made at a higher point than that into the left, so that each might correspond to the position of the instrument receiving it.

[II, 419] It is more worthy of remark that outgrowths [*aa. spermaticae (ovaricae) internae*] leading to the testes [both male and female] come next after those to the kidneys, that the one arising from the left side always certainly receives something from the one leading to the kidney and sometimes even avails itself of this source exclusively, and that the one on the right always arises directly from the great artery, sometimes, however, receiving in addition a contribution from the outgrowth going to the kidney.[72] That they must indeed somehow receive some unpurified, serous material has been demonstrated in the fourteenth book. Although it has also been already mentioned in that book that they coil variously as they approach close to the testes, it will do no harm to recall this here too; for unless it is provided with a suitable explanation, something of which I have just spoken and which is generally and naturally the rule in all parts of the animal seems to be vitiated. Now Nature conducted arteries and veins to all the [other] parts over the shortest interval, as I have said, and only to the testes and breasts did she bring them not from vessels near by but from those at a distance, not being forgetful of her first aim, by Zeus,[73] but choosing a better one; for both milk and semen are generated from perfectly concocted blood. It is the length of time which the blood spends in the vessel conducting it that permits the perfect concoction of these, and of necessity blood spends more time in longer vessels and the longer vessels are always
[II, 420] those that come from a distance. Properly, then, Nature brings blood and pneuma to the testes and breasts not from vessels nearby, but from those that have traversed a very long interval.

Yet, since the semen needs a more perfect elaboration, the length of the interval alone was not enough for it, as it was for the milk. For in that case[74] Nature would be unjust, bestowing equal parts, similar in every respect, on things that are unequal and dissimilar. Hence she not only brought arteries and veins down to the testes

[72] I do not know what these contributing vessels from the renal arteries might be. See chapter 7 and note 34 of Book XIV.

[73] Kühn's text omits μὰ Δία.

[74] That is, if no device other than the length of the conducting vessels had been used in the production of the semen.

from a distance, as she did to the breasts, but also coiled them variously before inserting them, thus securing for the materials, I think, a protracted association with the vessels that carry them. Now the veins are coiled only in this region, but the arteries are coiled here like the veins, and also very much so in the so-called retiform plexus [*rete mirabile*] for the very same reason (χρεία). For in the encephalon these arteries nourish the psychic pneuma, the nature of which differs greatly from all the other pneumas [75] so that it is no wonder that it needs nutriment very much concocted and elaborated beforehand and altered in every way. You would find no other arteries or veins coming from a distance into any other part, but all of them coming over a very short interval after branching from the great vessels. But I shall speak of the veins a little later on.

The next outgrowths from the great artery after the ones I have [II, 421] mentioned are those to the epigastric muscles [*aa. lumbales*]; for vessels could not be brought to these muscles over a very short interval from any other source. Moreover, along the entire course of the great artery, beginning at the fifth thoracic vertebra and extending over the whole spine, there are certain [posterior] branches of small vessels [*aa. intercostales, lumbales*] inserted into the spinal medulla; these are generally divided into two parts and send one not inconsiderable portion back to the spinal muscles. They penetrate within the bones [the vertebrae] where these come together and where the nerves issue from within, and there are two outgrowths at each junction because there are two apertures, one on the right side of the spine, the other on the left. All these very numerous pairs of small arteries are found along the whole length of the spine; there is the same number of them as of the nerves issuing from the spinal medulla, and along with the veins they penetrate the thin membrane [the pia mater] surrounding the spinal medulla. Moreover, at each offshoot of an artery, the one that is their stem, so to speak, and descends along the middle of the spine decreases in size, like the trunks of trees after branches have grown out and like the flow of rivers after conduits have been led off from them. Consequently, if you compare the size of it at the fifth thoracic vertebra with its size at the last vertebra, you will think that it has grown much smaller. Futhermore, in this entire region the [II, 422]

[75] The other pneumas were the natural, produced in the liver, and the vital, produced in the heart. But see my Introduction, pp. 47–49.

vena cava, extending along the spine in a more elevated position [76] than the artery, passes down from above along with it; for it was fitting that each should keep the position which it had in the beginning, since there was nothing new to make necessary a change, and fitting too that the thinner [walled] vessel should be carried upon the thicker. But when, having passed the region of the spinal medulla,[77] they were about to branch into the legs, since it was better here, as in the whole body, for the veins to lie upon [superficial to] the arteries, Nature in preparing for their course through the legs changed their position for the sake of safety.

Certainly she did not neglect the structures in the neighborhood of the broad bone [*os sacrum*], but distributed to them arteries and veins corresponding to their size and usefulness. For she inserted small vessels [*aa.* and *vv. vesicales, superiores, mediales,* and *inferiores,* and *plexus vesicalis*] into the bladder and two large ones into the uteri, since these are intended to nourish not only the uteri themselves but also the fetus that will be contained therein. Accordingly, she scattered the vessels [*aa.* and *vv. ovaricae*] coming from the region of the kidneys and arriving at the testes [the ovaries] as far as the fundus of the uteri, and from the vessels passing into the legs, at the same place from which in the male vessels go to the penis, that is to say, from the loins, she made vessels [*aa.* and *vv. uterinae* from *aa.* and *vv. iliacae internae*] grow off both into the parts at the neck [of the uteri] and into the parts below the testes. From these
[II, 423] regions too for the sake of a close association [78] venous vessels [*vv. epigastricae inferiores*] [79] return upward and are attached to those [*vv. epigastricae superiores*] which come down from the breasts and of which I have spoken before, in the fourteenth book. These veins go through the depths to meet one another, but there are other, superficial ones [*vv. circumflexae ilii superficiales*] at the outer ends of the hypogastric muscles near the groin. From the same regions a single pair of small vessels [*aa.* and *vv. pudendae internae* (or

[76] From the point of view of the dissector, as the subject lies on its back.

[77] Reading τὸ περὶ τὸν νωτιαῖον with Helmreich for the τὸν νῶτον of Kühn's text.

[78] Of the breasts with the uterus; see chapter 8 of Book XIV.

[79] In chapter 8 of Book XIV arterial vessels are also said to behave in the same way.

externae?)] goes to the parts at the pudendum, and the remaining pair of veins [*vv. epigastricae superficiales*] leading to the genital parts and associated with the breasts and thorax go to meet the ones descending superficially from the breasts [superficial branches of *vv. epigastricae superiores*].

In what precedes I have already said in speaking of the course followed by the vessels into the legs that they go by the safest path, extended upon the inner parts. For as they traverse this path, the whole member must become their bulwark on the anterior and outer sides, and on the inner side itself, where their route lies, they must be protected by the very large muscles lying upon them; in fact, it is under and through these that they pass. At the groin Nature has put large glands [*nodi lymphatici inguinales*] at the divisions of the vessels as a support and has even laid some on their outer sides [80] to cover them. Thus, nowhere in the limbs, and in neither the hands nor the feet, are the great vessels superficial; they rather pass through the depths well covered, as I have said. This holds true more [II, 424] for the arteries than for the veins, inasmuch as the arteries are the more important and are in greater danger of causing hemorrhage if they are cut. Some of the small vessels, however, necessarily proceed toward the skin to provide nutriment for the parts there. I should like now to tell something about the distribution of the vessels to each muscle, but I see that the account would be exceedingly long. Hence I think it better, now that I have told the aims [of Nature] in constructing them, to refer for the detailed scrutiny of them to my *Manual of Dissection*, in which many other things omitted here will also be fully worked out. Some time ago I wrote out these exercises in two commentaries, but at present it seems desirable to write another, longer account to include a treatment of all particulars.[81]

11. I therefore return now to the other artery, which you can see distributed from the heart to the neck, scapulae, arms, and face, and to the whole head. For, like the descending artery, as it passes through the thorax it sends outgrowths to the intercostal muscles, the spinal medulla, and the parts outside the thorax, and in addition to these there are outgrowths which go to the breasts and the usefulness of

[80] Reading κατ' αὐτῶν with Helmreich for the πρὸς τὰ of Kühn's text.

[81] See note 12 of Book II. In *De anatomicis administrationibus* the distribution of the vessels in the lower extremities is treated in chapters 12 and 13 of Book III (Kühn, II, *406–414;* Galen [1956, *87–90*]).

which I have told earlier, and others going to the scapulae and arms. On each side one artery [*a. carotis communis*], the part remaining
[II, 425] after these outgrowths, passes up to the head, and all parts of the face and neck are interwoven with branches of these vessels. The spinal muscles receive outgrowths from the vessels branching to the scapulae, and from these same vessels, as soon as they emerge from the thorax into the neck, offshoots [*aa. vertebrales*] pass through the lateral apertures of each of the first six vertebrae as far as the head. In fact, the artery is no longer extended along the vertebrae themselves, as it is along all [the rest of] the spine; for it is most necessary that the muscles [82] drawing the head forward should be placed there, since they cannot be transferred elsewhere. Moreover, the esophagus and also the rough artery [the trachea] in front of it must be placed upon the vertebrae, as I have shown in the books where these parts are particularly discussed, and hence in this case a similar insertion could not be made into the spinal medulla.[83]

Indeed, I consider that here too Nature has executed an admirable work, such as is often produced by artists who carve in relief, when they perforate what they are making and polish it to make it beautiful or extraordinarily accurate. For though in this case also she could have used the lateral outgrowths [the transverse processes] of the vertebrae as a protection in conducting the arteries destined for
[II, 426] the spinal medulla up along them as far as the head, she did not do so, not being content with only this protection. Instead, she pierced each outgrowth with a regular, round hole and made paths for the vessels out of the rows of apertures. And since the outgrowths have been placed in succession, the intervals between the apertures where the nerves emerge from the spinal medulla are not large. It is at these intervals that small offshoots [*rami spinales*] from the artery penetrate into the spinal medulla; for here too Nature uses the apertures for the nerves also for the entrance of the vessels and conducts through them not only the arteries but the accompanying veins as well. When the vessel [*a. vertebralis*] ascending to the head has passed the first vertebra, it divides into two terminal branches, one of which goes inward to the hinder part of the encephalon; the other is distributed to the muscles surrounding the joint of the head and is

[82] Longus capitis, longus colli, rectus capitis anterior, and rectus capitis lateralis. See chapter 8 and note 34 of Book XII.

[83] Similar, that is, to the arrangement whereby branches from the aorta reach the spinal medulla.

attached to the ends of the vessels located in the thin meninx.[84] Outgrowths from the vessels [*a. suprascapularis?*] of the scapulae are interwoven through the superficial muscles and the skin. For nowhere in the body can any muscle be found that lacks a vein or artery; rather, these come over the safest and shortest routes from regions nearby to be inserted into all muscles.

Now Nature did not conduct the pair of arteries [*aa. axillares, brachiales*] leading to the arms over an exposed, superficial course but, insofar as she was able, hid them in depths. In the axilla, where [II, 427] they first branch into the muscles around them, she placed stout glands [*nodi lymphatici axillares*] at the points of division both above and below as a support, putting them on the outer sides of the vessels themselves like protective shields, just as she did for those at the groin. Thus she conducted the vessels through the inner parts of the upper arm, distributing them to all the muscles, and then she brought them, again safely, through the inner and medial parts of the diarthrosis at the elbow to the forearm, scattering them everywhere and not overlooking any muscle, but giving vessels of suitable size to them all according to their worth. Like the vessels in the legs, I shall tell about these too in my *Manual of Dissection*.[85]

12. In this section I shall mention briefly the remaining pair of

[84] The difficulties here seem insurmountable. It has become evident that in his account of the arteries arising from the arch of the aorta Galen was describing conditions in the ape, but if he had continued to do so in the region now under discussion, some mention of the union of the vertebral arteries to form the basilar would naturally be expected. If he was describing some ruminant, he probably would not have missed the contributions of the vertebral to the *rete mirabile*. If, however, the animal was a pig, in which there is no such contribution, he should have seen the vertebral end in its anastomosis with the descending branch of the occipital. Yet, as he will soon say, he thought that one branch of the cerebral carotid wandered back to anastomose with the terminal branches of the vertebral, and this perhaps explains his reference here to "vessels located in the thin meninx." Could this mean that he thought of the cerebrospinal, an offshoot of the cranial branch of the occipital in the pig, as a continuation of the vertebral? And if so, could the second of his two terminal branches of the vertebral be the descending branch of the occipital itself? Certainly, the picture he paints is far from clear, and he was probably not clear in his own mind; for nowhere in any of his other works does he say anything to clarify the situation. For the vascular relations in various animals in this region, see Ellenberger and Baum (1926, *621, 622, 624, 640–641, 657–660, 663*).

[85] *De anat. admin.*, III, 8 (Kühn, II, *391–393;* Galen [1956, *79–80*]).

arteries, which since ancient times have been called the carotids and which, buried deep in the neck, go straight up to the head. As they go, certain of their slender branches are inserted into the muscles in this region and into the glands and veins, as well as into the spinal medulla itself;[86] for not only arteries divide, but also the veins that lie near them in the depths where the sixth and seventh vertebrae are
[II, 428] joined. One part of these [veins (*v. vertebralis*)] goes straight through the apertures in the lateral outgrowths [the transverse processes] of the first six vertebrae, as I have told in my *Manual of Dissection*,[87] and the other [*v. cervicalis profunda*] is carried obliquely on the sixth vertebra alone, which has therefore been made larger than the others. Each of the [common] carotid arteries divides into two parts, one [*a. carotis interna*] going more toward the back, the other [*a. carotis externa*] more toward the front, and each of these parts divides again in two. Then one branch [*a. facialis*][88] from the anterior part arrives at the tongue [*a. lingualis*] and the inner muscles of the lower jaw [*a. submentalis*], and the other [the main stem of the external carotid], though placed nearer the surface than this [first branch], nevertheless is also covered by large glands [*gl. parotis*] and passes up [as *a. temporalis superficialis*] in front of the ears as far as the temporal muscle. Here it branches and its posterior part [the parietal branch] goes up to the crown of the head, the ends of the vessels on the left side of the head anastomosing freely with those of the other side, and the ends of the inner [deep] vessels anastomosing with the outer [superficial] ones.

The other part [*a. carotis interna*] of the carotid artery, which I have said passes more posteriorly, also first divides into two branches, very large but of unequal size; the smaller one [*a. condyloidea*][89] goes up more to the rear into the base of the *paren-*

[86] The text of this sentence is obviously corrupt. As it stands, it fails to make sense; for what arteries are inserted into veins? It contains a violent *non sequitur* such as Galen would hardly have tolerated; and the next sentence has apparently been accidentally transferred from some point near the end of chapter 14.

[87] *De anat. admin.*, XIII (Galen [1906, II, *146–147, 159*; 1962, *161, 175*]).

[88] This description of the distribution of the external carotid fits conditions in the ape. See Lineback (1933, *253–254*).

[89] This description fits conditions in the pig, where the condyloid artery does indeed arise, not from the occipital artery as in other animals,

cephalis, being received by a large, long aperture [the hypoglossal canal] situated at the lower end of the lambdoidal suture. The other [the main stem of the internal carotid] passes up anterior to this [first branch] through the aperture [the carotid canal] in the petrous bone and goes to the retiform plexus [*rete mirabile*]. This, I have said earlier, underlies nearly the entire base of the encephalon, being formed from these arteries and providing a not inconsiderable usefulness, indeed, one more important than that of any other part. Accordingly, Nature has established it in the place that is safest of all. I need not explain anything further about it now; for I have told about it before, when I was explaining the parts of the encephalon. If I add only this one thing, I shall be content to bring to a close my present discussion of the retiform plexus: A pair of arteries [*aa. carotides cerebrales*] of considerable size passes up into the encephalon itself, and these, mingled with the veins of that region, form the choroid plexus in the ventricles of the encephalon and are interwoven with the thin meninx [the pia mater]. There are also certain other, small arteries passing posteriorly and anteriorly, the former to the *parencephalis* and the outgrowth of the spinal medulla, the latter [*a. ophthalmica interna*] to the orbits of the eyes together with the nerves leading to the eyes. The ends of the posterior vessels are joined to the vessels [*aa. vertebrales*] that pass up in the apertures of the cervical vertebrae, as I said a little while ago, and the ends of the anterior ones going to the eyes are joined to the vessels of the face and nose. [II, 429]

To speak briefly, in the face and in the whole head Nature has joined very many arteries to arteries and veins to veins, bringing those from the right side to the left, and those from the left side to the right; those from the anterior regions to the rear, and again those from the posterior regions to the front; those from the outer parts inward, and those from the inner parts outward. Moreover, one can see a great many small arteries like fibers passing from the vessels of the thick meninx [the dura mater] outward through the bones of the head and others from the outer vessels penetrating inward, and both kinds are joined together in the diploë of the bones. Indeed, throughout the body of the animal arteries are mingled with veins [II, 430]

---

but from the internal carotid, after which it follows the course Galen indicates here. See Ellenberger and Baum (1926, *66*, *108*, *623*, *624*, *663*).

and veins with arteries,[90] and both veins and arteries are mingled with nerves and the nerves with these, a condition clearly to be distinguished in many places by careful dissectors; for the small size of the vessels makes them hard to detect unless you pay very careful attention and are a practiced anatomist. And of course the usefulness of such a complete interweaving is very evident, if, that is to say, it is a useful thing for all parts of the animal to be nourished, have sensation, and preserve a due proportion in their innate heat. Thus, if you intercept the nerves of any part with cords, the arteries and veins in it become altogether devoid of sensation, whether you burn or cut them, or even if you wish to crush them.

Here is something else you should also know about, something which is common to nearly all arteries and veins, namely, that when they are inserted into a muscle, a viscus, or some other part, they
[II, 431] always send some additional slender offshoots to bodies in the vicinity. The veins sometimes send out great numbers of them that are of considerable size, and the arteries too send out some, though these are generally fewer in number and of smaller size. The reason is that all parts, whether hot, cold, hard, or soft, need to be nourished, but they do not have an equal need of preserving an exact degree of the innate heat. For if parts that have a naturally cold temperament are ever very severely chilled, they endure it, live, and are warmed up again without harm. But I have pointed out all these things elsewhere and [particularly] in my books *On the Usefulness of Respiration*[91] and *On the Usefulness of the Pulses*,[92] and as I said right at the beginning, I need not seek to demonstrate in this treatise any natural action; for a knowledge of actions comes before the discovery of uses, and so it is after acquiring that knowledge that I am writing this present work, which employs those actions as hypotheses and bears witness in its turn to the correctness of my demonstrations.

13. Now you will find certain veins without arteries, but no artery without a vein paired with it. Here you must understand that a paired artery is not one that touches a vein or is joined to it by membranes—though this is true of most of them—but one that has been produced for the sake of the same usefulness. You will under-
[II, 432] stand more clearly what I mean as the discussion itself proceeds. Just

[90] See chapter 10 and note 43 of Book VI.

[91] *De usu respirationis* (Kühn, IV, *470–511*).

[92] *De usu pulsuum* (Kühn, V, *149–180*).

as the artery growing out from the left ventricle of the heart is like a trunk for the arteries throughout the body of the animal (for I have just shown that they all arise from it), so in the same way the veins throughout the body of the animal grow off from the vena cava like branches from a main stem. Again, the veins of the stomach, spleen, and mesentery are analogous to the arterial roots [*vv. pulmonales*], so to speak, that come from the heart and divide in the lung, and the veins of the liver are analogous to the real arteries [*aa. coronariae cordis*] of the heart. Moreover, you should consider that the part of the vena cava that descends resting upon the spine is analogous to the larger, descending portion of the great artery, and that the part ascending to the throat is analogous to the smaller portion. As for all the rest of the veins distributed from these, you should consider that the ones accompanying the arteries display the same skill which I have explained when speaking of the arteries, and that those that proceed alone are encompassed by the same kind of skill as the arteries and have the same purpose, but are altered a little because of certain special uses of their own which I shall now explain.

14. Nature has distributed the veins to each part with consummate justice, to the homogeneous parts only according to the different kinds of them,[98] but to the heterogeneous according to the quantity of material flowing away from them and thus making it necessary for the bodies of animals to be nourished. For if nothing [II, 433] flowed away or were evacuated from the parts and their condition remained always the same, what need (χρεία) would there be of nutriment and what fear of old age or death? But since we do need to be nourished because we are depleted, the quantity of nutriment must be equal to the quantity of material flowing away. The greatest quantity of material flows away from warm, soft bodies and those that move continuously or vigorously, and the least from cold, hard bodies and those that subserve moderate actions; for cold condenses, contracts, and presses bodies together, preventing effluxes, whereas heat, contrariwise, rarefies, relaxes, thins, and dissipates them. Moreover, if the actual substance is too hard and stony, it is stable and difficult to evacuate, but if moist and soft it is quickly resolved into vapor by heat and quickly destroyed and exhaled. The lung, for example, has all the properties which make for easy evacuation; for

[98] That is, according to whether a given part is cartilage, bone, fat, or parenchyma, etc.

it is very soft and warm and is kept in constant motion. The properties of the bones, on the other hand, are diametrically, so to speak, opposed to these; for bones are hard, cold, and for the greater part of our life without motion, and hence their substance is stable and difficult to dissolve. So do not be surprised that Nature has distributed to them veins so small as not to be clearly visible even if the
[II, 434] animal is big, whereas a very large vein [*a. pulmonalis*] from the heart has been inserted into the lung. For here, in sending to both parts as much nutriment as they happened to need, she has acted justly, as she has in other cases too. Now then, I have been comparing two parts, one of which needs a very great deal of nutriment, and the other very little. Between these [two extremes] lie all the other parts, some of them losing more by evacuation and needing more nutriment, and others losing less and needing less. For some, like the heart, although their substance is harder, consume more nutriment because of their large quantity of heat, and others, like the encephalon, even though softer, dissipate less because of their lack of heat.

The largest of all the veins in the animal grows out from the liver into both the upper and lower parts of our bodies. Near the liver short, broad veins [*vv. renales*] branch off to the kidneys, not, by Zeus, because the kidneys need a great deal of nutriment, but because, as I have shown, these veins serve the kidneys like attracting gullets to draw in the serous residues. Thereafter, all the remaining distribution along the whole spine and in the legs is very similar to that of the arteries; for nowhere is there an artery without a vein, but wherever you see an arterial vessel, there is necessarily a vein too. However, a few veins unaccompanied by arteries do branch off into the bodies near the skin, and this happens to a greater extent in
[II, 435] the outer [lateral] and anterior sides of the legs and arms, because these have a less important location than the inner [medial] sides, and the same is true in all the other parts. Futhermore, the whole distribution of the veins from the porta of the liver to the intestines is made along with arteries. That to the omentum, spleen, and stomach takes place where a single vein emerging from the liver branches into them all and, as it begins to divide, finds plenty of arteries[94] [*a. coeliaca* and its branches] to divide along with it,

[94] Reading εὐπορεῖ τῆς μεγάλης ἀποπεφυκυιῶν with Helmreich for the ἀπὸ τῆς μεγάλης ἀποπεφυκυίας of Kühn's text.

arteries which grow off from the great artery when this first gets outside [below] the diaphragm. All these things Nature has obviously done with forethought, and her distribution of veins from the vena cava in the thorax has also been most excellent. When the vena cava first passes up from the convex parts of the liver, it sends large outgrowths [*vv. phrenicae inferiores*] into the diaphragm. Then, when it has already touched the heart, it sends off the one [*v. azygos*] that nourishes eight ribs on each side, and if you see how Nature suspends, as it were, this outgrowth from the parts above and transports it safely supported on bodies in the vicinity as far as the spine, I know that her skill and forethought will seem to you not inconsiderable in this instance too.

In what precedes I have told about the veins of the heart, lung, and other such parts. I have also told in a common discussion about the vessels, both arteries and veins, that lead to the breasts and testes, because these vessels have a common usefulness, and in the same way there is a single discussion for the veins and arteries arriving at the [II, 436] arms. Just as in the legs, so here too Nature sends to the outer and anterior sides of the upper arms special, superficial veins unaccompanied by arteries. I have promised to tell in the *Manual of Dissection* about the further distribution of these vessels to each part and their course through the whole member. And just as here [in the arms and legs] there is one vein in excess, so too in the neck there is a second, superficial jugular vein [*v. jugularis externa*] that is unaccompanied [by an artery], but there is only one artery on the right side and one on the left. [Passing] through the depths along with the arteries called carotid, the jugular veins in that region are divided as the arteries are, except that a large artery [*a. carotis interna*] goes up through the aperture [the carotid canal] in the petrous bone to the retiform plexus [*rete mirabile*], as I said when I was discussing the arteries, and that what is left of the deep jugular veins [*v. jugularis interna*] goes up to the encephalon, making use of all [86] [the rest of] the aperture [the jugular foramen] that is used by the sixth pair of nerves. I told about the vessels of the encephalon itself when I was explaining the usefulness of its parts, and so it is now time to bring this book to a close.

[86] Kühn omits ὅλῳ.

[II, 437]

THE SEVENTEENTH BOOK OF GALEN ON THE USEFULNESS OF THE PARTS

"Epode"

1. There yet remains this last book for me to write about the usefulness of the parts of the human body. In fact, no part is left of which I have not spoken in particular, but since they do not all have the same or an equivalent usefulness, it would be better to draw distinctions among them and to tell what is peculiar to each of them. Now the action of a part differs from its usefulness, as I have said before, because action is active motion and usefulness is the same as what is commonly called utility. I have said[1] that action is *active* motion because many motions occur passively and those which happen to bodies when other bodies move them are even called passive. Thus the bones in the limbs have a motion produced by the muscles that are in the limbs and move the bones now outward, now inward at their articulations. With respect to the first principle of motion, which is the authoritative part of the soul, the muscles play the role of instrument, but with respect to the bone moved by them they play both this role and that of the efficient also.[2] Hence the
[II, 438] usefulness of first importance to animals is that which is derived from actions and the second is that from the parts; for there is no part which we desire for its own sake, and a part deprived of its action would be so superfluous that we should cut it off rather than wish to keep it. Indeed, if there were any such part in the body of an animal, we would not say that the whole had any certain usefulness.

[1] Galen makes the same statement in *Methodus medendi*, I, 6, II, 3 (Kühn, X, *45–46, 87*). In *De plac. Hipp. et Plat.*, VI, 1 (Kühn, V, *506*), action is called *efficient* motion, and in the first and third of these three passages it is said to arise from itself.

[2] For Galen on the causes, see chapter 12 and note 57 of Book VI.

But since neither man nor any other animal has such a part, we say that Nature is skillful.

At any rate, let me tell what I felt the first time I saw an elephant; those who have seen the animal will readily comprehend, and those who have not will not have much difficulty if they attend carefully to what I am about to say. In the place where other animals have a nose, the elephant has a narrow, free-swinging part, so long that it reaches the ground.[8] When I first saw this, I thought it superfluous and useless, but when I saw the animal using it like a hand, it no longer seemed so, the usefulness of the part being bound up with that of the action; for the usefulness of a part is made manifest through its useful action. The elephant handles everything with the end of this part, folding it around what it receives, even the smallest coins, which it gives to its riders by stretching up to them its [II, 439] proboscis—for that is what they call this part of which we are speaking. Hence just as this part, if the animal did not need it at all, would be superfluous and Nature, who formed it, would not be perfectly skillful, so now, since the animal performs most useful actions with it, the part itself is shown to be useful and Nature to be skillful. Later on, when I also saw that the part is pierced at the end and learned in addition that the animal breathes through these apertures as if through nostrils, I realized that clearly the part is useful for this purpose too. And when the elephant died and I dissected the channels leading from the apertures up to the root of the part and found that just as in us, these have two ends, one reaching the encephalon itself and the other cut through into the mouth, I admired the skill of Nature more than ever. When I also learned that in crossing a river or lake so deep that its entire body is submerged, the animal raises its proboscis high and breathes through it, I perceived that Nature is provident not only because she constructed excellently all parts of its body but also because she taught the animal to [II, 440] use them, as I pointed out at the very beginning of this whole work.

Certainly, for recognizing the skill of Nature it is sufficient to look

[8] In spite of his obvious first-hand experience, also spoken of in *De anat. admin.*, VII, 10 (Kühn, II, *619–620;* Galen [1956, *187*]), Galen has chosen to base this account of the elephant's trunk on Aristotle. See *Hist. an.*, I, 11, 492b17–21, II, 1, 497b22–31, and *De part. an.*, II, 16, 658b33–659a36. Notice Galen's careful distinction between what he *saw* and what he *learned*.

at the outside of the body of the animal and watch the actions of the several parts; it is sufficient, that is to say, for those who propose to consider and judge them correctly and not, like enemies of Nature,[4] to insult them. Some folk, however, by first assuming such substances for the elements of bodies that they cannot be joined together by Nature's skill have been forced to war against her. And that the elements cannot be so joined you may learn from what follows: That which is to form anything whatever with skill must either at least touch the outside of it or pervade the whole thing that is being formed. Since, however, the indivisible, jointless[5] bodies which some posit as elements are not, according to these very men, naturally formed [into a body] by anything either touching[6] the outside of them or permeating throughout their substance, it remains for them to build the structure of perceptible bodies by a chance interweaving with one another. But a chance interweaving of elements seldom produces a useful work of art and frequently produces something useless and good for nothing. This is the very reason, then, why men who claim that primary bodies are such as those
[II, 441] introducing the atoms hold them to be are unwilling to think that Nature is skillful; for though they see clearly as soon as they look at every animal's outer aspect that it has no part without a use, they try to find just some one thing, apparent either at first glance or from dissection, that will serve for contradiction. Consequently, they have imposed on me the necessity of explaining all the parts and of extending the discussion even to things that are not useful for the treatment, prognosis, or diagnosis of disease, as I did when I took under consideration what muscles move the tongue and how many of them there are.

Here is something to wonder at in these men who say that Nature has no skill, namely, that they praise sculptors for making the parts on the right side precisely like those on the left but fail to praise Nature, who in addition to making the parts equal also supplies them with actions and more than this with usefulness that is taught to the animal right at the beginning, as soon as it is born. Or is it right to admire Polyclitus for the symmetry of the parts in his statue called

[4] The atomists; this is the final attack on their detested theories.
[5] Reading *ἀνάρμων* with Helmreich for the *ἀμερίστων* of Kühn's text.
[6] Reading *ψαῦον τῶν* with Helmreich for the *ψαυόντων* of Kühn's text.

the Canon [7] and yet necessary to deprive Nature not only of praise but of all skill—Nature, who exhibits the symmetry of the parts both on the outside, as sculptors do, and also deep below the surface? Or was it not Polyclitus himself who was her imitator, at least in what he was able to imitate? But he could imitate her only in the external features, where he had seen the skill involved, and he began [II, 442] with those that are most obvious, such as the hand, an instrument most characteristic of man; for it has five fingers with flat nails at their ends, three joints in each finger, and movements the number and kinds of which I explained in the first book, everything displaying the utmost skill. And yet even aside from all this, the symmetry itself is indicative of marvelous skill; for sculptors, using many tools in the making of their statues, achieve it only with difficulty.

I am not speaking as yet about the correspondence in the size of each part, such as those seen in the arm itself, which, as I showed in the first book, Nature made as a prehensile instrument, just as she made the leg as an instrument of locomotion. It is possible, however, to see how she has used the very best proportion in establishing the size of the arm. Since she hung this member from the scapula, it would be slow in its movements and unsuited to its actions if she had extended it down to the feet and much more so if it were allowed to trail on the ground, although the longer it was, the better suited it would be for getting hold of something at a distance. Since, however, a short arm would be very good at handling things but at the same time not so good at seizing things at a distance, and since an arm good at the latter action would be slow in its movements, she increased its size up to a point where it was not yet slow in its movements. Hence for a man who is truly examining the works of Nature just the mere sight of the arm before dissection is sufficient, [II, 443] but, as I have said, if some enemy of Nature's sees the skill exhibited in its inward parts too, as I explained it in the first two books, he will lie awake nights trying to find any one of the things he has seen which he can disparage. In the same way, anybody truly examining both the due proportion in the size of the legs and the usefulness of each of their motions will not only praise the skill of Nature but also marvel at it. For if you imagine a man whose legs are only half the proper size, you will understand, I think, first how hard to move and

[7] See note 34 of Book XV.

how heavy he will find the body above them, second, how unsteady he will be if he tries to walk, and third, how impossible it will be for him to run.[8]

So too if you consider the size of the thigh in relation to the leg and of the leg in relation to the foot, you will find Nature utterly skillful, just as you also will when you consider the relative size of the parts of the foot itself and of the hand. The parts of the arm likewise correspond marvelously to one another; for there is a marvelous proportion between the upper arm and forearm, between this and the hand, and between the different parts of the hand. And surely all these parts display the skill of the Creator. Nay, the proper proportions of the fingers alone are enough to demonstrate the same skill, at least to anyone not an enemy of Nature's. Why, indeed, is there never anybody who has fingers three times the normal size?
[II, 444] Or why, again, does no one ever have them as small as the first phalanx in each of them?

Now I say that it is because such sizes would destroy their usefulness, but you, O most noble accuser of the works of Nature, have no regard for any of these things and see only that out of ten thousand times ten thousand men she has made a single one with six fingers. If Polyclitus made one such small error in a thousand statues, you yourself would not blame him and you would say that his accusers had no judgment. Well, then, look at this from another angle and see what you would say if Nature went wrong in a thousand cases and succeeded in only one. Would you not say that the one successful case was the result of chance, not of skill? And if she went wrong in ten thousand cases, would you not be still more justified? But as it is, when you see that Nature has failed with one single man not out of just a thousand or ten thousand, but out of ten thousand times ten thousand, you dare refer to chance what she has done correctly, thus treating her with a most remarkable sort of justice! Come now, if you were present at a contest of tragic and comic actors, would you condemn as unskillful the one who made but one mistake out of a possible ten thousand, and praise as skillful the one who got only one thing right? This is great nonsense and is clearly the work of men who are shamefully trying to save the elements which they were wrong in positing in the first place. For

[8] For some modern meditations on proper size, see Haldane (1928, *20–28*).

when they see that these are destroyed if it is conceded that Nature is skillful, they are compelled to be shameless. And yet, as I have said, it was not at all necessary to examine all the parts of the body in dissection; for the external aspect of any one of them would be [II, 445] enough to demonstrate the skill of the One who created it.

No more is it necessary to mention the equality and usefulness of the eyebrows, the ears, the eyelids or eyelashes, or of one pupil in relation to the other, or of anything else of the sort that demonstrates the marvelous wisdom and power of Nature, when this common thing, the part called the skin, is enough to demonstrate her skill. If anyone regards it as a separate structure and sees that for the most part it is continuous but that in a few places it has perforations, he will certainly look to see whether these have been made at random and nothing enters or leaves the body by way of them to any good purpose, or whether they all have a remarkable usefulness. Now one of the perforations was made to permit the entrance of food and drink and also of the air around us, and another to give egress to the liquid and solid residues. The passage through the nostrils for the pneuma is bored through into the first of these and into the second comes the passage for the excretion of the semen. There are other channels too that lead up through the nostrils to the encephalon itself and serve as an outlet for residues; the body is also pierced with perforations in other places so that the animal may be able to hear through these; elsewhere it has been cleft so that the animal may see; and nowhere is there a perforation without a use. Just so there is neither a production of hair nor a complete absence of it except where each is especially necessary, as I have shown—production of it on the head, brows, and eyelids, and absence of it on the palms of the hands and soles of the feet. [II, 446] Certainly, no muscle anywhere is united with the skin without a reason, but this union is found only in those places where it serves a necessary purpose (*χρεία*), as I have shown. Who could be so stupid, then, or could there be anyone so hostile and antagonistic to the works of Nature as not to recognize immediately, from the skin first of all,[a] the skill of the Creator?

Who would not straightway conclude that some intelligence possessed of marvelous power was walking the earth and penetrating its

[a] Reading *πρώτου* with Helmreich for the *καὶ πρώτων* of Kühn's text.

every part? [10] For you see everywhere that the animals produced all have a marvelous structure. And yet, what part of the universe is more ignoble than the earth? Nevertheless, even here there appears to be some intelligence reaching us from the bodies above, and anyone seeing these is at once forced to admire the beauty of their substance, first and foremost that of the sun, after the sun that of the moon, and then of the stars.

It is reasonable to suppose that the intelligence dwelling in them is as much better and more perfect than that in earthly bodies as their bodily substance is the purer. For when in mud and slime, in marshes, and in rotting plants and fruits animals are engendered [11] which yet bear a marvelous indication of the intelligence constructing them, what must we think of the bodies above? But you can see
[II, 447] the nature [12] of the intelligence in man himself when you consider Plato, Aristotle, Hipparchus, Archimedes,[13] and many others like them. When a surpassing intelligence comes into being in such slime—for what else would one call a thing composed of fleshes, blood, phlegm, and yellow and black bile?—how great must we consider the pre-eminence of the intelligence in the sun, moon, and stars? As I meditate on these matters, it seems to me that a certain not inconsiderable intelligence pervades even the very air surrounding us; certainly the air could not partake of the sun's light without receiving its power too. I am sure that you will also regard all these things in the same way when you examine carefully and justly the skill displayed in animals, unless, as I have said, you are prevented by some doctrine which you [14] have rashly posited about the elements

[10] The following passage reflects strongly the Stoic doctrine of the world soul. Cf. also Aristotle, *De part. an.*, I, 5, 644b22–645a26, and *De gen. an.*, II, 3, 736b3–737a1.

[11] The doctrine of spontaneous generation was taken for granted in antiquity and persisted unquestioned till the seventeenth century, when Francesco Redi led the attack on it. In the eighteenth century it was the subject of a prolonged controversy between Lazzaro Spallanzani and John T. Needham, the latter defending and the former seeking new grounds for discrediting it. It was Louis Pasteur who dealt the final blows that destroyed it.

[12] Helmreich omits the λογικὴν found after φύσιν in Kühn's text.

[13] For Hipparchus, astronomer, mathematician, and geographer, who flourished in the second century B.C., see Sarton (1927, I, *193–195*), and for Archimedes, "the greatest mathematician, physicist, and engineer of antiquity," who flourished in the third century B.C., see *ibid.*, *169–172*.

[14] Reading ἔθου with Helmreich for the ἔθεντο of Kühn's text.

of the universe. Thus, when anyone looking at the facts with an open mind sees that in such a slime of fleshes and juices there is yet an indwelling intelligence and sees too the structure of any animal whatsoever—for they all give evidence of a wise Creator—he will understand the excellence of the intelligence in the heavens.

Then a work on the usefulness of the parts, which at first seemed to him a thing of scant importance, will be reckoned truly to be the source of a perfect theology, which is a thing far greater and far nobler than all of medicine. Hence such a work is serviceable not only [II, 448] for the physician, but much more so for the philosopher who is eager to gain an understanding of the whole of Nature. And I think that all men of whatever nation or degree who honor the gods should be initiated into this work, which is by no means like the mysteries of Eleusis and Samothrace.[15] For feeble are the proofs that these give of what they strive to teach, but the proofs of Nature are plain to be seen in all animals.

In fact, you must not suppose that such skill as I have been explaining in this book is displayed in man alone; on the contrary, any other animal you may care to dissect will show you as well both the wisdom and skill of the Creator, and the smaller the animal the greater the wonder it will excite, just as when craftsmen carve something on small objects. There are such craftsmen even now, one of whom recently carved on a signet ring Phaëthon drawn by four horses, each with its bit, mouth, and front teeth so small that I did not see them at all except by turning the marvel around under a bright light, and even then, like many others, I did not see all the parts. But when anyone was able to see any of them clearly, he agreed that they were in perfect proportion. For instance, we had difficulty in even counting the sixteen limbs of the four horses, but [II, 449] to those who could see them the parts of each one appeared marvelously articulated. Yet not one of these displays more perfect workmanship than the leg of a flea, and besides, the whole leg of the living, nourished, growing flea is pervaded by skill.[16] It is reasonable,

[15] Reading ἅπαντας . . . ἀνθρώπους . . . ἔχουσαν with Helmreich for the ἅπαντες γὰρ . . . ἄνθρωποι . . . ἔχουσιν of Kühn's text. Galen has used the comparison with the mysteries once before, in chapter 14 of Book VII. For a discussion of the textual difficulties presented by this sentence and an ingenious and logical solution, see Renehan (1965, *64–66*).

[16] For Pliny's wonder at the perfection of the flea in spite of its small size, see his *Nat. hist.*, XI, 1 (1940, *432–435*).

however, that the wisdom and power of the skillful Creator of the flea should be sufficiently great to preserve it, increase its size, and nourish it without difficulty. At all events, if the Creator's skill is such when displayed incidentally, as one might say, in insignificant animals, how great must we consider his wisdom and power when displayed in animals of some importance!

2. This is one very great advantage which we gain from this work [on the usefulness of the parts], not as physicians, but, what is better, as men needing to understand something of the power responsible for usefulness, a power which some philosophers say does not exist at all, let alone its providing for animals. Another, secondary advantage is that it is helpful in determining the affections of parts deep within the body, and for this a knowledge of action is likewise of use. For just as anyone who has learned that walking is the work of the legs and concoction of food the work of the stomach knows at once that in the case of a person unable to walk it
[II, 450] is some part of the legs that is affected and in the case of a person failing to concoct or concocting badly it is the stomach, so anyone who has learned that the work of reasoning is carried out in the encephalon will know that delirium, phrenitis, lethargy, madness, and melancholia occur when the encephalon is affected either primarily or through sympathy. It is therefore the same with usefulness as with action. Walking is destroyed when the nerves and muscles of the legs are affected, and in the same way it is also destroyed when one of the bones is broken or becomes separated from its proper articulation. If, however, we did not know that it is because they have bones that the legs support us, we should also be entirely unaware that the animal suffers when the bones are affected. For determining the part affected, then, a knowledge of usefulness is no less advantageous than a knowledge of action. The situation is again the same when it comes to prognosis. For just as the substance of the bones in the legs is useful in walking, so the incurable affections occurring in them, such as dislocation with ulcer, will indicate a future incurable impairment of walking. And if a dislocation remains incurable even though not ulcerated, as in dislocations of the hip, not only will this show plainly that the leg will necessarily be lamed, but it will also indicate the type of lameness, as Hippocrates[17] has written in his book *On Joints*.

[17] *De articulis*, cap. 60 (Littré, IV, *256–261*).

A third advantage offered by this work [on the usefulness of the parts] in addition to those I have mentioned is its testimony against the sophists, who do not concede to us that crises in diseases are the work of Nature and who deny her any forethought where animals are concerned. For when they frequently suggest that the usefulness of the parts (of which they know nothing) does not exist, they suppose that they are thus doing away with the skill of Nature. And then they make a mock of Hippocrates, who thinks it right to imitate what Nature is accustomed to do in crises.[18] We ourselves are then forced to survey the usefulness of all the parts, even of those that are of no assistance in diagnosis or prognosis of affections. But the physician in his practice will in fact derive the greatest benefit from this work, just as he does from a work on action. Indeed, when he is cutting into parts that for some reason are in bad condition, when he is cutting around them or excising them, or when he is removing arrows or darts, if he understands the usefulness of the parts, he will know which ones he should cut into freely and which he should avoid. [II, 451]

3. This book like a good epode sets forth these many and great advantages of the work I have now completed. By "epode" I do not mean the magician[19] who uses enchantments; for we know[20] that the melic poets, called lyric by some, have not only a strophe and an antistrophe but a third song as well, an epode which they used to chant standing before the altars and, as they say, singing hymns of praise to the gods. And so, likening this book to such an epode, I have given it that name.

[18] I cannot find this advice in the Hippocratic corpus. The references (*Aphorismi*, I, 22, and IV, 2) given by Daremberg (in Galen [1856, II, 210]) seem not to apply.

[19] Ἐπῳδός has this meaning also.

[20] Reading ἴσμεν with Helmreich for the μὲν of Kühn's text.