

THE ORIGINS OF THE SYMPATHETIC NERVOUS SYSTEM FROM VESALIUS TO RIOLAN

by

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VESALIUS' ILLUSTRATION of the 'sixth pair' of cranial nerves in the *De Humani Corporis Fabrica* shows the sympathetic trunk arising as a branch of the vagus in a position corresponding to the top of the thorax (see fig. 1). The text is the verbal equivalent of the illustration. Although of all Vesalius' work, the cranial nerves are perhaps the most open to criticism,¹ this error remained uncorrected for half a century. Some reasons are suggested in this paper for Vesalius' mistake, and an attempt is made to follow its subsequent history.

VESALIUS' SOURCES

What Galen had to say, or appeared to say, on the anatomy of the nervous system was naturally of prime interest for Vesalius. We know that Vesalius was well acquainted with three at least of Galen's anatomical works, *De Usu Partium*, *De Dissectione Nervorum*, and *De Anatomicis Administrationibus*. The most obviously useful of these was *De Dissectione Nervorum*, of which Vesalius was asked to contribute a revised text for the Giunta edition of the complete works of Galen, 1541–1542.² His knowledge of it did not improve his opinion of it, and in the *Fabrica* he warns his readers that he can 'barely recommend a fragment' of it.³

The translation he was called upon to revise was that by Antonio Fortolo⁴ of an incomplete version of the work. Vesalius' emendations are mostly superficial: occasional rephrasing to the advantage of meaning, and the use of more modern terminology.⁵ Twice he modifies the content of the work, adding *statim post exortum* to the description of the connection of the fourth to the third cranial nerve, and observing that the sixth pair never (rather than 'not always') sends branches to muscles reaching from the throat to other parts.⁶

Apart from this, Vesalius' revised text is the same as Fortolo's:

The sixth conjugation of nerves arising from the brain employs the foramen which penetrates [the skull] at the inferior extremity of the suture that has the appearance of the Greek letter λ , [the lambdoid suture] but its origin consists of three nerves arising directly from the brain, which, having emerged from the skull, are in many places mingled with each other and with others lying near, which will be soon described
. . . as has been remarked, these nerves descending to the lower parts of the head are mixed with each other; firstly that which arises from the third conjugation and then that from the two most recently mentioned [the sixth and seventh pairs]. Moreover, the first and second conjugation of nerves from the spinal medulla enter into association with these nerves. It will very often seem to you that the spinal nerve goes from one to the other, like a link, common to both; for while it increases the bulk of one of the nerves as if being added bodily to it, it decreases

the bulk of the nerve it leaves. These things throw a great deal of obscurity over the discovery of these nerves by anatomists, who exchange contradictions with each other in ignorance. For they have written that certain things never appear in any animals, not even in the single class of apes, as if this was a permanent state of affairs. In fact, several of these things appear not only in apes, but in the same manner in all animals, six kinds of which I have referred to in the books on anatomical procedures . . .

. . . These things are dealt with exactly and at length in the books on anatomical procedures, where also is treated the arrangement of those three nerves which issue through the foramen at the termination of the lambdoid suture. Nevertheless, almost everyone thinks there is but a single nerve on either side, which adheres to the carotid artery . . . [Galen goes on to describe the recurrent laryngeal nerve] . . . These nerves [of the sixth pair] have a complex distribution beyond the *septum transversum*, for they accept several nerves from the nearby spinal medulla, distribute them to the viscera, and finally mix with those nerves we have described as coming from the third conjugation through the neck and thorax. And again, everyone thinks that those nerves, which are stretched down against the roots of the ribs, are branches of the sixth conjugation.⁷

It is to be noted here that Galen appears, in the last sentence, to be setting up an opinion of other anatomists in order to knock it down again, as he has done in previous paragraphs. However, he does not knock it down and the reader is left in some doubt as to whether this is Galen's own point of view of the sympathetic trunk (identifiable by its association with the 'roots of the ribs'). Indeed, between attacking other anatomists and referring the reader to his own larger work, Galen gives an ambiguous and unsatisfactory account of the sympathetic trunk; unless the fault lies in the 'corrupt and mutilated' available Greek text, of which Gadaldinus complained.⁸

Whether or not this was why Vesalius did not think much of *De Dissectione Nervorum*, there is no doubt that he followed Galen's advice to consult the larger *De Anatomicis Administrationibus*. (Apart from the references in the text, Galen observes elsewhere that the former of these two works had been intended as an introductory textbook summarizing the relevant parts of the latter).⁹ In any case, *De Anatomicis Administrationibus* was the second of the three texts that Vesalius was preparing for the Giunta edition. In book fourteen¹⁰ of this work Galen describes with great precision the separate origin and cervical course of the sympathetic trunk. Unfortunately, all that was available of this work to the West, until the nineteenth century, were the first eight books and a fragment of the ninth, and so Vesalius' search for enlightenment would have been in vain.

It is certain that *De Usu Partium* was of much greater use to Vesalius. Singer¹¹ observes that Vesalius' cerebral anatomy is based on it, and in book four, chapter nine of the *Fabrica*, which deals with the sixth nerve, Vesalius refers to the seventh book of *De Usu Partium*, where Galen deals with the recurrent laryngeal as a branch of the sixth pair. Vesalius rather grudgingly recommends his readers to Galen's work.

It is probable that the edition of *De Usu Partium* that Vesalius used was that published in 1528 in Paris by Simon Colinaeum—Simon de Colines—of Nicholas of Reggio's translation from the Greek. The rather late arrival of Galenism in Paris increased its impact which coincided with Vesalius' studies there, from 1533 to 1536.¹²

In book seven, to which Vesalius refers us, of this edition, Galen describes the innervation of the muscles of the throat from the sixth pair of nerves and observes that as this conjugation is so large, although it loses many branches to these muscles in its descent through the neck, nevertheless much of it remains to reach the thorax

'whereupon it produces the first division into two of the nerves, stretching to the thorax itself and the root of the ribs'.¹³ This is more or less the equivalent of Vesalius' illustration on p. 319 of the *Fabrica*.

Later¹⁴ in *De Usu Partium* Galen describes the sixth pair at greater length. The stomach and viscera need sensory nerves, which have to come from the soft matter of the brain, the spinal cord, hard, giving rise only to motor nerves. The sixth pair is therefore unusually long and soft, and needs the strengthening thickness of ganglia and the support of other nerves in plexuses. It is to be regarded as a collection of very many nerves, with origins in the brain as diverse as the viscera they serve, and bound in a common membrane only for mutual protection and support. He seems reluctant to discuss where the nerve to the roots of the ribs leaves the main trunk, perhaps because the dissection is in fact a difficult one in man, but more likely because the animals he dissected had common vago-sympathetic trunks of different lengths. Perhaps the description of the sympathetic trunk in *De Anatomicis Administrationibus* is much better because it was written so late¹⁵ in Galen's life, presumably when his anatomical experience was greater.

In his early teaching dissections, Vesalius sometimes saved himself the trouble of describing the third pair of cranial nerves by referring his students to the *Institutiones Anatomicae* of his old teacher Guintier. This is a compression of Galenic anatomy, and dismisses the sixth pair very briefly.¹⁶ There is nothing that could be of use to Vesalius.

These seem to be the only sources for Vesalius' nervous anatomy. His own paraphrase of the ninth book of Rhazes' *Almansor* is concerned with medication, and we may assume that he was unwilling to borrow from the rather medieval anatomists who preceded him.

THE ILLUSTRATION OF THE NERVES

So Vesalius' illustration of the sixth pair seems to be either a pictorial reconstruction of Galen's words, or a simplified representation of animal anatomy. This illustration in the *Fabrica* is derived from a drawing Vesalius had made as a teaching aid at his early dissections. There were six or seven of these early illustrations, each the result of sketches over a period of time, and showing 'considerable representation of simian anatomy'.¹⁷ The liver is that of an ape, and the *venae cavae* are ungulate, or drawn from Galen. Vesalius published the illustrations in 1538 to forestall plagiarism. These *Tabulae Anatomicae*, or *Tabulae Sex* as they are sometimes known, contain no illustration of the nerves, yet there was such a drawing among the original teaching illustrations, as Vesalius remarks in the introduction. Moreover, a copy of this drawing was stolen and published in 1539.¹⁸ This plagiarism resembles the nerve-plate of the *Fabrica* in that the sympathetic trunk arises as a branch of the vagus some way below its origin, but there is no suggestion of connections between the sympathetic trunk and the spinal nerves.

A surviving sketch of the third pair of nerves from the teaching diagram of 1537 by one of his students shows similarities with the published plagiarism and with the final illustration in the *Fabrica*, so it is not unreasonable to assume that Vesalius' ideas on the origin of the sympathetic trunk were established by 1537. In any case

the woodcut of the nerves for the *Fabrica* were completed in the next year, to judge by Vesalius' remarks in his *Venesection letter*.¹⁹ This argues that the illustration of the nerves was prepared before Vesalius had much anatomical experience of them in man. The recurrent laryngeal nerve from the sixth pair is not human,²⁰ any more than the sympathetic trunk; presumably the most readily available animal, with the exception of the dog (from which Vesalius drew the hyoid²¹) was the cat, which has a joint vago-sympathetic trunk down to the level of the first rib.²²

Vesalius' text reveals little more than the diagram it accompanies. He does however observe that the sixth pair emerges through the foramen 'which admits the smaller branch of the *soporalis* artery [internal carotid] and the larger branch of the internal jugular vein at the same time'.²³ That is, he made no distinction between the jugular foramen, from which the vagus emerges, and the carotid canal, into which disappears the upper extremity of the sympathetic trunk.

VESALIUS' DISSECTION MATERIAL

1537 was Vesalius' first year at Padua as a professor, and it is unlikely that he had so soon developed the independence from Galenism which marked his later work. Having accepted a Galenic account of the sixth pair of nerves, he did not revise his opinion for either edition of the *Fabrica*, 1543 or 1555—that is, for eighteen years.

The reason for this was almost certainly lack of suitable material. Vesalius seems to have learned only Galen and practical animal anatomy from Sylvius²⁴ and little more from Guinter in Paris. It is not known how many dissections Vesalius attended or performed, but material was certainly scarce. Normally the cadavers were those of executed criminals: this had been so since 1478 at least, and in the last decade of the fifteenth century dissections were becoming increasingly expensive because of payments made to those who brought the body of the executed criminal to the place of dissection, and to those who removed the head to be buried at night to 'avoid the outcry of the people'.²⁵ Vesalius himself dissected a hanged prostitute.

Whether or not availability of material was a limiting factor, certainly the condition of the corpse of a criminal executed by hanging or decapitation, or by one followed by the other, as above, would have prevented Vesalius from obtaining an accurate picture of the fine anatomy of the neck, however much he was inspired to prove Galen wrong. Dismissing Vesalius' early autopsies as unlikely to progress further than the major internal organs, we know that his first dissection as professor at Padua should have been, according to statute,²⁶ performed upon an executed criminal. This was probably the case, as the body was of an eighteen-year-old youth, otherwise of 'excellent constitution without any abnormalities'.²⁷ By this time Vesalius had made his drawing of the cranial nerves.

The same situation existed while Vesalius was preparing the *Fabrica*. From 1539 he was supplied with the bodies of executed criminals—mostly male, to the detriment of his female anatomy—principally by a sympathetic judge of the criminal court, who even held up executions until a convenient time for Vesalius.²⁸ In the *Fabrica* Vesalius mentions his dissections of at least three hanged criminals, and two decapitated.²⁹ His last dissection at Padua was another prostitute who had died of 'pleurisy', and there must, of course, have been many opportunities to examine

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unmutilated bodies. Nevertheless, unutilated male bodies were probably as difficult to obtain as those of pregnant females, and his errors in the anatomy of the latter³⁰ are the equivalent of those in the former.

ETIENNE

A notable exception to the flood of plagiarisms which followed the publication of the *Fabrica* was Charles Etienne's *De Dissectione Partium Corporis Humani*. This was published in 1545 but had been nearly completed by 1539 and then delayed by a dispute. Some of the plates are as early as 1530. Most of the anatomy contained in it is 'pre-Vesalian'³¹ in quality, but Etienne had done a considerable amount of dissection, and while the viscera, for example, are falsely represented, the illustration of the nerves seems to show personal experience, and unlike Vesalius, Etienne shows the vagus and sympathetic trunk arising separately from the skull.

Etienne seems to have had little difficulty in obtaining material for dissection, and discusses whether to use man or apes.³² He took his doctor's degree in 1542 in Paris, and being a member of the well-known publishing family that had put many of Galen's writings before the world (he was for a time foreman in his brother's printing house) no doubt he was well versed in Galenic anatomy. Like Vesalius, he refers his readers to the seventh book of *De Usu Partium* for the anatomy of the recurrent laryngeal as a branch of the sixth nerve. Also like Vesalius, Etienne uses *De Dissectione Nervorum*, but thinks enough of it to quote at length from the passage given above. The text he uses is Fortolo's, and while he alters the sequence of several sentences, and inserts a parenthetical addition, he retains intact—as did Vesalius—the sentence in which Galen remarks on the common idea of the origin of the sympathetic trunk, the last in the above quotation.

However, Etienne's originality appears in his 'explanation' of Galen's statement: 'The [sixth] nerve arises from that part where the head is connected to the neck, near the tortuous and rocky pathway which the cartilages of the ear make by mutually running together, and immediately from its origin it emerges as two branches'.³³ (See fig. 2.) The larger of the two is the sympathetic trunk, descending along the length of the vertebrae with branches to the viscera, while the smaller is the vagus, adhering to the carotid artery, and giving rise to the recurrent nerves. The illustration shows no regular connection between the sympathetic trunk and the spinal nerves. Later in the text,³⁴ Etienne does describe such a series of connections, but unfortunately he has taken most of this part of his description unaltered and unacknowledged from the same part of Fortolo's translation of *De Dissectione Nervorum* that has been given above, and part of which Etienne had already quoted. This, of course, contradicts his own 'explanation' of Galen, as it relates the relevant foramen to the lambdoid suture, gives the triple origin of the sixth nerve and retails the ambiguity over the 'origin' of the sympathetic trunk in the thorax.

It seems probable that Etienne was looking at the carotid canal and sympathetic trunk. No doubt the 'part where the head is connected to the neck' is the occipital condyle, while the tympanic part of the temporal bone seems to correspond to Etienne's 'tortuous pathway'. His description would apply either to the carotid canal or jugular foramen, but it is notable that Etienne does not identify the foramen by

the usual phrase 'at the termination of the lambdoid suture'. The lambdoid suture is that bordering the occipital bone, which at the base of the skull forms a boundary of the jugular fossa and foramen, while the carotid canal pierces the petrous portion of the temporal bone. So with some confidence we can identify the foramen that Galen describes in *De Dissectione Nervorum* as the jugular foramen, as he uses the descriptive phrase above. Vesalius included the carotid canal with the jugular foramen, and Etienne seems to have made the only other possible mistake, and includes the jugular foramen with the carotid canal. However, unlike Vesalius, he does not confuse the nerves associated with the respective foramina. It is tempting to think that Etienne's 'tortuous rocky pathway'—*plexuosam illam viam petrosis impressam* is partly the modern 'petrosal' portion of the temporal bone, with its carotid canal. Not being aware that there were two foramina, Etienne assumed that he was discussing the same foramen as Galen, and seems unsure whether to oblige his readers with a preference for his own or Galen's views.

EUSTACHIO

That Etienne's book appeared after rather than before Vesalius' *Fabrica* no doubt lessened its impact and any interest in his novel 'explanation' of Galen. Another historical accident also withheld the work of another opponent of Vesalius' views on the nervous system: Eustachio. Eustachio's engravings on copper (Vesalius' and Etienne's illustrations were woodcuts) which show a 'truly magnificent sympathetic system'³⁵ had been completed by 1552, but following Eustachio's death, were not rediscovered and published until 1714. The sympathetic trunk is clearly shown as separate from the vagus (see fig. 3), but there is no representation of the skull or its foramina. Nor is there any verbal description of the plates.

Eustachio was greatly attached to Galen's anatomy, and he defended it against Vesalius by painstaking investigations. Working in Rome, he was unconnected with the North Italian universities, and with a greater interest in comparative anatomy, he was less likely than Vesalius to fall into the error of representing animal anatomy as human.

FALLOPIO

Another original investigator was Vesalius' successor in the chair at Padua, Fallopio. He is well known for his description of the ganglion on the sixth pair of nerves, and he followed the lower course of the nerve with as great an interest. 'I have two bodies before me now; I cut them, and I see it in both'.³⁶ The 'olivary body' is formed on the sixth nerve 'when it is outside the skull'³⁷ and below it, by accepting cervical nerves, the sixth pair forms a plexus, which descends through the whole neck on both sides. It is from this plexus that arises the nerve which descends to the roots of the ribs, 'however much Vesalius may say that it arises from a branch sent from the great sixth pair descending through the neck, to the first thoracic vertebra'.³⁸ So Fallopio traced the 'origin' of the sympathetic trunk to a higher point than Vesalius had, but (more realistically) had got lost in its complex of communications with the vagus and cervical nerves.

Vesalius accepted the amendment, adding³⁹ that the plexus resembled the arrange-

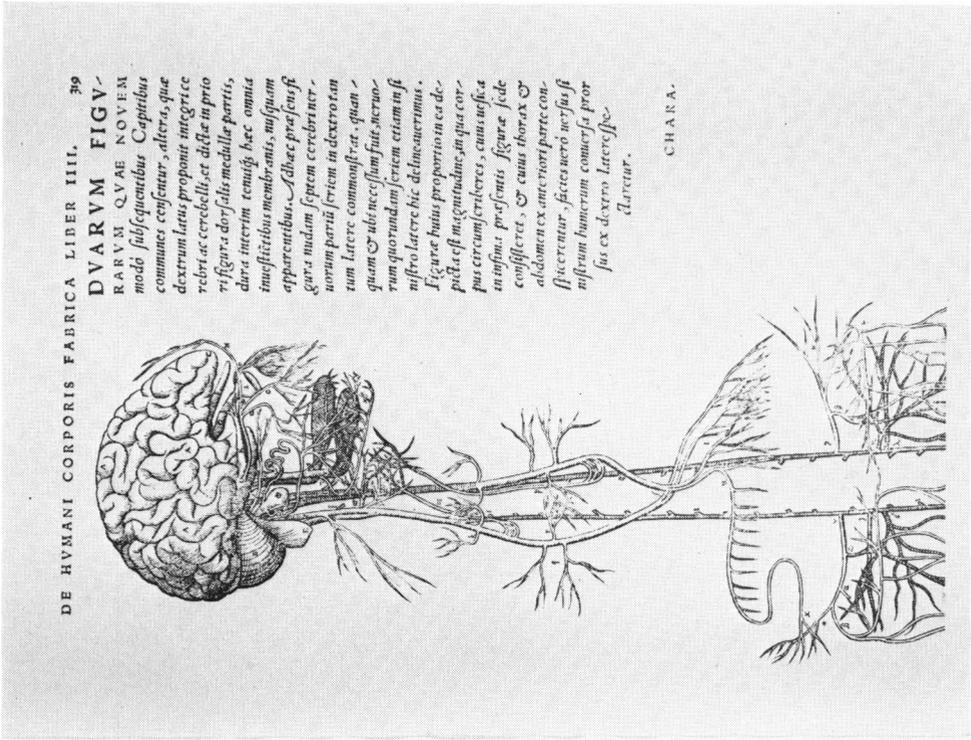


Figure 1
Vesalius, *Fabrica*, 1543, plate of the nerves, showing division of the 'sixth pair.'

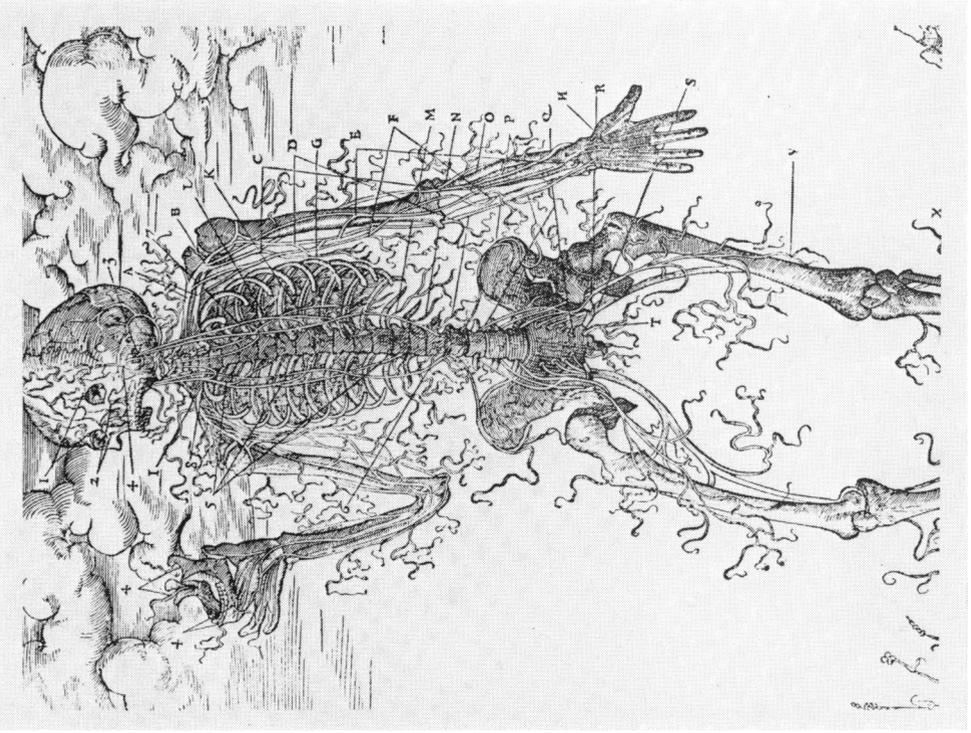


Figure 2
Carolus Stephanus, *De dissectione partium corporis humani libri tres*, Paris, 1545, showing the separate origins of the vagus and the sympathetic trunk.

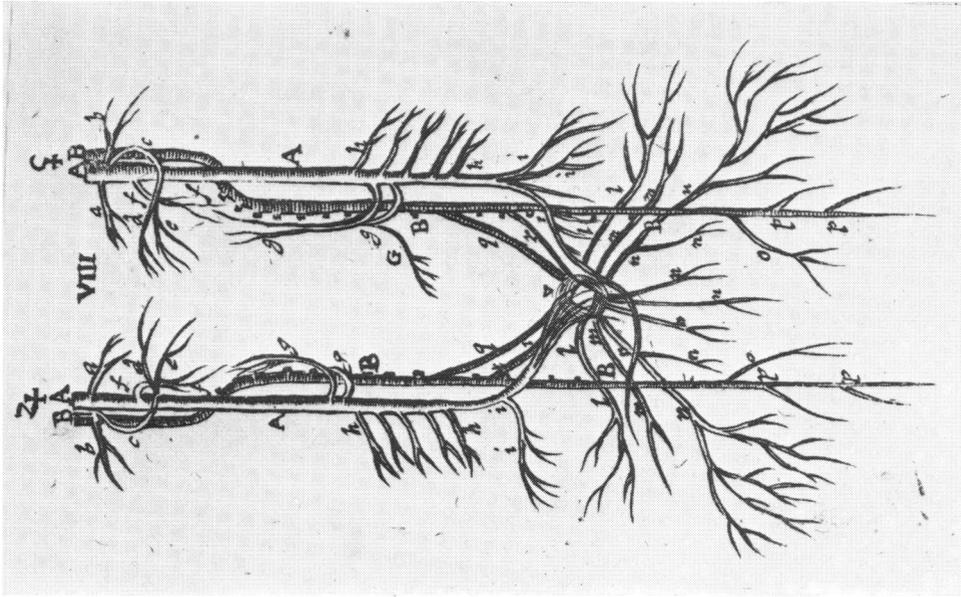


Figure 4
J. Riolan, *A Sure Guide or the Best and Nearest Way to Physick and Chyrurgery*, trans Nicholas Culpeper, London, 1657, showing the separate course of the two sets of nerves.

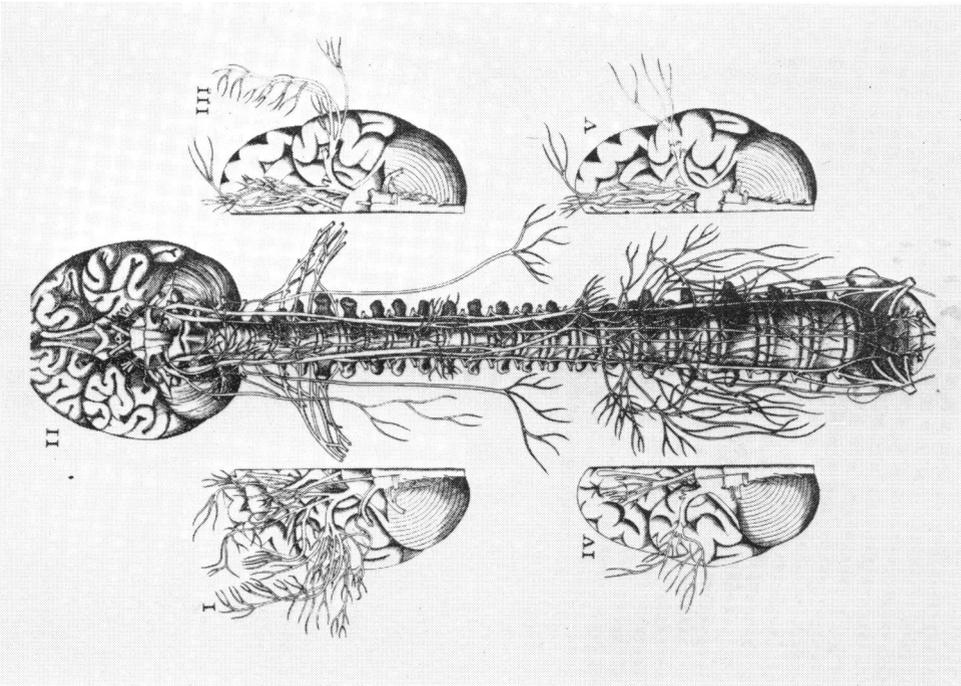


Figure 3
Bartholomaeus Eustachius, *Tabulae Anatomicae*, Rome, 1714, showing the separate origins of the sympathetic trunk and the vagus.

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ment of cords on a cardinal's hat, and that the ganglia could be seen better in the neck of a pig than in man. Besides which, he concluded, had not Fallopio read *De Usu Partium*, where in the sixteenth book Galen describes such bodies at length?

GUIDO GUIDI

Fallopio's views were accepted by Guido Guidi (Vidus Vadius) in an anatomical work finished some time before 1569, when he died. As with Eustachio, the work was published posthumously (in 1611) and another voice opposing Vesalius was temporarily silenced. Guidi's nervous anatomy is Galenic—the usual *De Dissectione Nervorum* and *De Usu Partium*—and the sixth pair divides at the top of the thorax 'as if it were double'⁴⁰ to give rise to the sympathetic trunk. Like Etienne, he gives his own views—or rather Fallopio's—in an explanation of Galen.

BAUHIN

Sixteenth-century anatomy is rounded off by Caspar Bauhin, whose scholarly works, discussing those of previous anatomists, were of great influence. The sympathetic trunk by now had acquired a name, having previously been described merely as a branch of the sixth pair. It was the costal nerve, one of the three branches of the sixth, the other two being the stomachic (lower vagus) and recurrent. (In the second half of the seventeenth century the costal became the 'intercostal', which name had earlier been reserved for the spinal nerves which communicated with the costal in the thorax.)

This terminology appears in Bauhin's *De Corporis Humani Fabrica* of 1590,⁴¹ and the anatomy is more fully stated in his *Anatomia . . . Historia* (1597) and the *Institutiones* of 1604. Here the sixth nerve descends from the foramen between the occiput and temporal bone, between the carotid artery and jugular vein, and divides at the clavicle into a large exterior and small interior branch. The latter is the costal, and the former gives rise to the stomachic and recurrent.⁴² The same account is given in the more important *Theatrum Anatomicum*, 1605, but Fallopio is mentioned in relation to the origin of the costal; like Vesalius, Bauhin compares the plexus to the cords of a cardinal's hat.⁴³ Vesalius' nerve-figure is given.

A further account of the sixth nerve appears in the *Vivae Imagines Partium Corporis Humani*, 1620, which is largely taken from the *Theatrum*. Bauhin records many different opinions of the origin of the costal nerve, from the usual two works of Galen to Vesalius, Colombo, Piccolomini and Fallopio. No Galenic justification is found for the thoracic origin of the costal nerve in any of Bauhin's works, and the copious references to Galen in the *Institutiones* cease when the description reaches this point and begin again with the anatomy of the nerve in the thorax. The same is true of the *Vivae Imagines*, but here the thoracic origin of the costal in Vesalian orthodoxy is omitted (despite the persistence of Vesalian illustrations), Fallopio's opinion alone being quoted. Mention is made of the opinions of Riolan.⁴⁴

RIOLAN

Riolan had invigorated the study of anatomy at Paris, which had languished since Sylvius' time, becoming a very popular teacher—Harvey, for example, lectured from

both Riolan and Bauhin—but was well known for his steadfast adherence to certain ideas. He disagreed with Harvey over the circulation of the blood, perhaps because of his admiration for classical anatomy and physiology, and he detested anatomical illustrations, perhaps for the same reason or perhaps as Haller suggests, simply because of Vesalius' success.⁴⁵ At all events, as neither Sylvius or Riolan thought much of Vesalius, no doubt the latter's influence counted for less in Paris, 'isolated and independent'⁴⁶ than elsewhere.

There was moreover, a long-standing tradition of dissection; when Riolan published his first anatomical work, he was twenty-seven, but had been dissecting for eight years. This work was the *Schola Anatomica* of 1608, which was included in his father's *Opera Omnia* in 1610 as *Anatome*. After giving the orthodox division of the sixth pair of nerves at the clavicle into costal, stomachic and recurrent, as the opinion 'of all anatomists', he goes on to say 'I have always observed that the costal is produced not from the sixth conjugation, but from the spinal medulla, through the foramen which is formed between the last vertebra of the neck, and the first of the back'.⁴⁷ He does not give the usual works of Galen as authority for either opinion, employing only the *De Anatomicis Administrationibus* for the function of the costal at the ribs.

Perhaps Riolan was looking at the lower cervical ganglion of the sympathetic trunk, which sends grey *rami communicantes* to the seventh and eighth cervical nerves.⁴⁸ This is also suggested by his slightly different description in his *Anthropographia* of 1618: the costal 'arises from the last three vertebrae of the neck, and is augmented in its descent by the addition of two or three small fibres at the highest parts of the thorax'.⁴⁹ Another account of the origin of the costal nerve appears in the 1626 edition of the *Anthropographia*, and this we may take as Riolan's final opinion: 'The costal nerve, which all anatomists derive from the sixth pair, arises from the same point of the brain as the sixth pair, is strengthened by a ganglion as it emerges from the skull, and descends undivided through the neck. When it reaches the last three vertebrae of the neck, it is surrounded by another ganglion, is increased by the addition of three small nerves, and descends into the thorax'.⁵⁰ This seems to be a clear recognition of the upper and lower cervical sympathetic ganglia.

The same account is given in later publications. The *Anthropographia* that appeared in 1649 and the *Encheiridium* of the same year employ the same words⁵¹ and the *Opuscula Anatomica Nova* contains 'Remarks on Bauhin's *Theatrum*' in which Riolan criticizes Bauhin's account of the nerves of the liver. Bauhin had said these were derived from the costal which in turn was derived from the sixth pair. Riolan observes that the costal is in fact drawn from the brain *vertebras inferioris cervicis perreptando*, by which phrase we must, in view of the clear statement in the *Anthropographia*, take to mean 'creeping closely over the vertebrae of the lower neck', presumably, that is, in close association with the spinal nerves that he mentions elsewhere. The phrase could also mean that the costal descends from the brain inside the vertebral canal and emerges through the lower cervical vertebrae, which recalls his earlier opinion.⁵²

That indefatigable popularizer of medical science, Nicholas Culpeper, 'astrologer and gentleman', translated a selection from Riolan's works into English: *A Sure*

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Guide, or the Best and Nearest Way to Physick and Chyrurgery. This contains the observation that the costal nerve arises from the same point of the brain as the sixth pair, a statement not supported by the figure showing the base of the brain, but with some confirmation in the rather crude illustration of the nerves⁵⁸ (see fig. 4). So with Riolan, after several earlier accidental delays, Vesalius' error was finally rectified.

ACKNOWLEDGEMENT

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