The thorax in history 4 Human dissection and anatomical progress

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We saw in the last article that no contribution was made in the early Western middle ages to the medical sciences of anatomy and physiology. The “knowledge” of the learned consisted of strangely metamorphosed relics of ancient learning in literary and pictorial forms. The bulk of Hellenistic science was preserved by the Arabs.

The period covered by this article—the later middle ages and the earlier renaissance—can be divided approximately into three: from ignorance to confusion, from scholasticism to scholarship, and from authority to progress. Each of these refers to a new assimilation of old knowledge, and only at the end of our period do we find the production of new knowledge from observation taking a considered place in anatomical studies.

From ignorance to confusion

When interest in the West began to turn again to medicine, it was from the Arabs that medical knowledge came, through contacts established by trade and wars. Arabic medicine dominated the later medieval period, up to the fifteenth and sixteenth centuries, when a wave of medical humanism turned scholars against the “barbaric” Latinised Arabic texts and encouraged them to seek out the original Greek texts. The study of old authors was associated at the beginning of our period with the rise of the universities, of faculties of medicine, and of professional associations of physicians. It was the translators of the *schools* in this institutional sense who were important in the acquisition of Arabic science. In Montpellier, for example, the number of lay practising physicians led to the formation of professional schools, but their elevation to *university* status meant assumption of control by the Church. The resumption of anatomy in a literary guise in the West depended on a Church that had retained the language of Rome, and also on geographical and historical points at which a cultural interchange could be effected with the Arabic civilisation.

The most famous of the medieval medical schools, Salerno, was so situated.¹ Some of the myths surrounding the school at Salerno have only just been critically examined.² There is no firm evidence that the school existed before the tenth century, despite its own claim to be a classical foundation. The first traces of medical literature associated with Salerno date from the eleventh century, and it is practical in nature, without theoretical interest.

The first of the translators from Arabic was Constantine the African (ie, from Islamic North Africa), who went to Salerno in about 1077 (but it is not clear whether he taught at the school). He later moved to the monastery of Monte Cassino, where most of his translations seem to have been made. One of his pupils, Johannes Afflacijs, also of Arab descent,³ took the Constantinian tradition back to Salerno, and thereafter the name of the school was associated with the Constantinian translations.

The school reached its peak in the twelfth century, when there was a change from the purely practical in medicine to an interest in its theoretical content—magical, astrological, or philosophical. In other words the introduction of scholasticism was associated with the reception and assimilation of Arabic medicine in the Constantinian translations. This theoretical interest also expressed itself by the late twelfth century in the habit of commenting on texts used in teaching. This scholastic treatment was the beginning of the attempt to unravel the confusion that arose in the West during the reception of Arabic and Greek medicine. The early empirical period of medicine at Salerno was a professional, practical affair carried on in ignorance of the complexities of Hellenistic medicine. The second-hand and altered medicine that began to arrive from the Arabs was different from what was already known. Its Hellenistic origin was not recognised, it was replete with strange technical terms, and Constantine often omitted the author's or compiler's

name from his translations, further obscuring the attribution of works.

By about 1270 a standardised collection of simple medical texts had become established at Paris, Naples, and Salerno as the basis of medical education. This collection, known as the *Articella*, was drawn partly from Arabic sources and partly from Byzantine Greek. For example, the work at the head of the list, the first to be studied by the medieval student, was the *Isogoge* of Joannitius, who is widely held by historians to have been the Arab Hunain. This is a persistent piece of medieval confusion, for Joannitius was probably Byzantine.⁴

The *Articella* contains very little anatomy, and the major source for ideas on the structure and function of the thorax remained a translation by Constantine of Haly Abbas's *Liber Regius*, itself derived from Galen. Constantine called his version the *Pantegni*, and it was an important source for a remarkable series of anatomical texts that originated in Salerno in the first half of the twelfth century. They are remarkable not because of their anatomical content but because they were designed to accompany the dissection of a pig. The first "Salernitan demonstration" is the so-called *Anatomia Cophonis*, more correctly known as the *Anatomia Porci*.⁵

The reasons for producing a short dissection guide to the pig are given in the opening words of the work: "Because the structure of the internal parts of the human body was almost wholly unknown, the ancient physicians, and especially Galen, undertook to display the positions of the internal organs by the dissection of brutes. Although some animals, such as monkeys, are found to resemble ourselves in external form, there are none so like us internally as the pig, and it is for this reason that we are about to conduct an anatomy upon this animal."

The mention of the recurrent laryngeal nerves in the paragraph that follows makes us certain that this is Galenic anatomy at root, but, it has to be admitted, very corrupt. Nothing illustrates this better than the description of the organs of the thorax. The vena cava, from the liver, is said to enter the "lower auricle" of the heart, whereupon it becomes the principal artery of the body, giving rise to all others, including that which draws air from the lung. A little later, in contrast, when dealing with the artery and vein of the abdominal cavity, both are said to come from the head: "The artery is formed from all the arteries of the head, which unite to make up one great artery . . . the great vein is made up of all the veins of the head . . ." The great vein and great artery are clearly, from their relative positions, the

aorta and vena cava in the abdominal cavity, but the heart is not mentioned at all. The entire description is foreign to Galenism, but very close to that of the two fundamental vessels arising from the head described by several writers centuries before Galen, who have been discussed in earlier articles. Is this some survival of the ideas of the Greek "cerebral pneumatist" school, to use the terminology employed in an earlier article? Another clue to the sources of the work is provided by the terminology, which although partly Arabic seems also to depend on Greek terms. The work is therefore pre-Constantinian, and an attempt to bring it up to date was made when Arabic anatomy became better known.

Further light is thrown on the *Anatomia Porci* by a related treatise, the so-called second Salernitan demonstration. This work also shows quite clearly that the dissection of animals (again a pig) was being practised in twelfth-century Salerno. Instructions for dissecting the animal are once more given, together with similar descriptions of what will be found and of the diseases that are likely to be located at the parts described. The topics are treated in the same order, and both treatises are imprecise on the same subjects, notably the blood vessels. Neither work discusses the skeleton. Clearly the two works are near contemporaries, and in fact several aspects of the *Anatomia Porci* are criticised in the other treatise, which refers to it as a "recent booklet." This suggests an active programme of assimilating the new Arabic anatomy and reconciling it with the old. Could it be that the strange, early Greek flavour of the description of the heart and vessels given in the *Anatomia Porci* derives from some monastic survival of a Hippocratic work? It is known that *On the Nature of Man*, which has a suggestively similar account of the blood vessels, survived in the West.

Instructions for killing the pig by cutting its throat are given, and also advice on how to retain as much blood in the body as possible for the better inspection of the vessels. The odd account given in *Anatomia Porci* of the vena cava entering what is presumably the right auricle "from below" is repeated, including the statement that it becomes the aorta. Perhaps this is derived from a misunderstanding of the Arabic, for the author again attempts to clarify an earlier text, and uses the Arabic *adorthi* for aorta. A similar problem is seen in the discussion of the Latin term *os ventris*, its Greek equivalent *stomachos*, and its Arabic counterpart *meri*, "although according to Constantine *meri* includes under the one term both *os ventris* and oesophagus."⁶

A third text completes this family of anatomical demonstrations. This is the *Anatomia Mauri*. Maurus was a teacher at Salerno in the second half of the twelfth century, and the manuscript discovered by Sudhoff containing Maurus's anatomy must have been written while Maurus was still alive. This anatomy resembles the *Anatomia Porci* more than the second demonstration, both in size and content, but like both is clearly designed to accompany the dissection of a pig.

The feeling given by this group of three anatomical texts is of keen interest in the newly discovered fragments of anatomy and a flurry of activity to fit the new Arabic knowledge in with the Greek and to demonstrate it with the dissection of a pig. Later anatomical works, from the end of the twelfth century, lose this practical flavour and are much more concerned with philosophy and physiology, and they are more systematic, claiming also to deal with *human* anatomy. The difference is one of approach, for the same Constantinian sources are used, and we may call the new attitude scholastic. The first such work is a text that appears in various manuscripts and has been attributed to different authors. It is commonly known as the *Anatomia Ricardi*, but in a variant form in another manuscript it is attributed to a "Magister Nicolaus," so we cannot be certain of its authorship. Nevertheless, it is still known as the *Anatomia Ricardi (Salernitani)* and generally accepted as the fourth Salernitan anatomy,⁷ of the early twelfth century.

The partial dependence of the *Anatomia Ricardi (Salernitani)* on the earlier Salernitan anatomies is clear, but there are some odd features. Like the *Anatomia Porci* it begins with a discussion of the reasons why anatomy was studied among the ancients, and Galen's name is again mentioned. The author proceeds to describe two methods of "dissection" among the ancients, however, of which the first, he says, was vivisection, practised upon condemned criminals delivered by request to the anatomists from the authorities. Such vivisections proceeded from the nervous system to the organs of respiration and the heart, thence to the nutritive system, and finally to the organs of generation. This account probably derives from the Western Christian tradition after the accusations made by Tertullian and St Augustine against Herophilus and Erasistratus, but it is not easy to find the source of the sequence of operations in the vivisection. The nervous system and the organs of respiration are precisely those that could be profitably investigated by vivisection, particularly with regard to function, as Galen showed so

dramatically on animals. Investigation of the heart would follow naturally from that of the organs of respiration, because of the belief of the heart's role in respiration. Any attempt to see the heart in action would naturally precede the vivisection of the nutritive viscera.

For humanitarian and religious reasons, continues the author of the *Anatomia Ricardi (Salernitani)*, such practices are no longer possible, and recourse must be had to the female pig, the animal most similar to man internally. Despite this practical note, the text of the work is marked by an extreme scholasticism of approach. As anatomy is an account of the parts of the body, what is a "part"? Is a part that which is devoted to a certain function, as opposed to a fractional part, such as a quarter?

Again, there is an attempt, in the medium of Latin, to explain terms derived from foreign sources: "note that *diastole*, *elevatio*, and *thesis* all have the same meaning, while *systole* is identical to *depressio* or *arsis*."⁸ Such glosses were evidently necessary, for the readers or auditors of this author were not expected to know Greek. There were, however, Greek-speaking areas still existing in Italy, although there seems to have been a virtually complete separation of the Greek and Latin monastic communities in the region of Salerno.⁹ There were certainly a few Greeks at Salerno, according to Stephen of Antioch, and men familiar with Arabic.¹⁰ Stephen himself added an Arabic-Latin-Greek glossary to his translation of Dioscorides.

After explaining the meaning of systole and diastole, the Salernitan author remarks on the relationship between the heart and the brain. The heart is said to derive its nourishment from the brain, which is regarded as the root of all the organs, so that man is like a tree upside down. The tree analogy is to be found in Galen, but it is not an inverted tree; rather, the idea recalls the ancient Greek angiological scheme in which the brain is said to be the origin of the blood vessels, a scheme that is also recalled by the *Anatomia Porci*. Again this suggests that there was some as yet unknown Greek source, probably in Latin translation, for this family of anatomical treatises. Apart from one of the Hippocratic treatises suggested above, there may be some influence here from Plato, who uses the inverted tree analogy¹¹ to explain how the divine soul in the head is positioned closer to, or rooted in, the heavens. It is also possible to interpret Plato's ideas on the marrow (the brain and spinal cord) understood as the seed of the body and his cryptic remarks on the vascular system in a way that agrees with the

Salernitan notion of the brain as the source of the organs.

The heart and vessels

The Anatomia Ricardi (Salernitani) has a curious account of the heart and major vessels that resembles that of the earlier Salernitan demonstrations. The greater detail of the new account, however, allows us to make an attempt at discovering the common origin of all the Salernitan descriptions. It is again a question of the degeneration of anatomical knowledge as it passed through different ages and different cultures. Let us start with Galen, whose descriptions lay at the source of all these medieval accounts and with whose ideas we are familiar. If we look again at the diagram of Galenic cardiac physiology (fig 1) we see the vena cava, A, from the liver approaching the right auricle. The auricle was not a structure distinct from the vein, in Galen's view, but simply a sinewy expansion of it. At this point, then, the vena cava appears to divide into three: the largest branch entering the right ventricle, C to D; another branch departs to supply blood to the rest of the body (the superior portion of the vena cava, B), and a small branch nourishes the heart itself (the coronary vein, not shown in the diagram for the sake of clarity). We may also recall that the pulmonary artery, E, was a vein for Galen and the pulmonary vein an artery. Venous blood from the liver crossed the ventricular septum to become

Fig 1 Galenic cardiac physiology. For explanation see text April issue, page 158.

arterial, whence it departed by way of the aorta.

Now, we know that Galen's account reached the medieval West by way of Haly Abbas's *Liber Regius*. Here the Galenic account of the venous side of the heart emphasises the venous route from the liver to the lungs through the right auricle and ventricle. This is achieved at the cost of identifying the largest of the "three branches" of the vena cava with the arterial vein (the pulmonary artery).¹²

The brevity of Haly's statement does not do justice to Galen's description and gave little scope for later translators. Constantine's account, taken from Haly, is shorter still. The route from liver to lung is sketched out again, but in introducing the term "vein that is called an artery" Constantine does not make it clear that this is not a separate structure.¹³ The three brief sentences of Constantine's description seem to be the basis of the account found in the Salernitan anatomies, in which the "vein that is called an artery" becomes "the artery derived from the vein" that is, the aorta with the venous artery as a branch. Later on in the same work, however, Constantine is somewhat clearer on the Galenic anatomy and terminology of the vessels. Constantine also describes how arteries arise from the left side of the heart and have two coats, points that have become incorporated in the Salernitan anatomies. His account here (later in the same book) of the pulmonary vein, "venous artery," from the left ventricle to the lung seems to have been corrupted in the *Anatomia Ricardi (Salernitani)*, so that it is thought to be a branch of the aorta that reaches the lung. Constantine follows Haly closely here also, even quoting Haly Aristotle's name in connection with the term for the main artery, which in Constantine's Latin emerges as *orithi*, from the Arabic version of *aorta*. Constantine contrasts the Aristotelians in this respect with the "physicians" who call the vessel *audax*.

From scholasticism to scholarship

The Salernitan anatomies were very influential. In particular the *Anatomia Ricardi (Salernitani)* formed an important source for the great encyclopedias of Vincent of Beauvais and Bartholomew the Englishman, for both of whom the Salernitan work was anonymously "The Anatomy" as if it were simply the standard work on the subject. The encyclopedists therefore repeat the account of the heart and vessels that we have just met,¹⁴ but by now new sources were becoming available. Vincent quotes from Avicenna, who retails Aristotle's description of the three-chambered heart. Vincent

also knew of Galen's cardiac physiology from a source that was more modern, but still corrupt, the *De Juvamentis Membrorum*. Broadly, there were three groups of authorities that were much more detailed than Constantine's translations: the Arabs, the biological works of Aristotle, and the corrupt version of Galen's *De Usu Partium* just mentioned.

This short and corrupt *De Juvamentis Membrorum* provides us with a good example of the difficulties of early scholarship. It is an incomplete and unsatisfactory Arabic (or Syriac) compression of *De Usu Partium*, and because of its earlier arrival in the West and particularly because of its convenient length and secondary simplicity (*De Usu Partium* is a complex work) it remained very popular, misleading such authors as Peter of Abano and Mondino. Comparison of the short version with the full translation from the Greek completed in 1322 illustrates many of the features of the transmission of anatomical knowledge: problems of technical terminology, the use of analogy, and the "principle of reduplication." The latter explains how an anatomical description in passing through several different languages tends to collect synonyms from the different languages for the same structure: in each case the recipient translator or encyclopedist multiplied *structures* to fit the new *names*, so that, for example, the body-wall membranes of the thorax multiplied in number as Arabic, Greek, and Latin anatomical traditions were assimilated in our period.

The problem of the use of analogy is illustrated by the case in which Galen, in the Greek of *De Usu Partium*, had used the term *thorax* for a chest.¹⁵ Here the meaning of this technical term was made clear by the descriptive context, but no corresponding term of sufficient accuracy existed in the language receiving the work (either Arabic or Latin) and the translator borrowed the word for "oven" to denote the rigidity of the thorax as a heat-containing structure holding the heat-producing heart. This word is *clibanus* in the Latin of *De Juvamentis Membrorum*, the remainder of the sentence remaining intact from the original.¹⁶ Naturally *clibanus* does not carry the same force or precision as a technical term as Galen's *thorax*.

Two examples of confusion from lack of technical vocabulary in the recipient language will suffice. In the first three chapters of the seventh book of *De Juvamentis Membrorum* there is a summary of Galen's views on the flow of blood through the heart and vessels. Arterial blood is not clearly distinguished from venous (chapter two) and the term "artery" is not used by the

translator (it appears only in the later, interpolated chapter headings). Without the term "artery" (for which the Arabs had no word) the translator is thrown back on the term "pulsatile vein" to describe the same structure. Now, one of the critical areas in the history of anatomy has been Galen's specious justification of the term "arterial vein" and "venous artery" for the pulmonary artery and vein, respectively. Such terminology was necessarily not available to our translator, who was obliged to use the clumsy "the pulsatile vein that looks like a non-pulsatile vein" and its opposite. Moreover, for Galen, the pulmonary vein pulsed, but with a unique motion, following that of the chest, not the heart. Correspondingly, the pulmonary artery did *not* pulse, according to Galen, as it was a vein. Any question raised as to the true function of this vessel, as in the early work on the pulmonary circulation, would have involved the attentive but unfortunate reader of *De Juvamentis Membrorum* with the unmanageable concept of a pulsating non-pulsatile vein that resembled a pulsating vein and which Galen said did not pulse.

We may take another example of the restricted terminology available to the translator, the word *coopertorium*. This term in medieval usage means generally a cover, and can apply to structures as different as a lid for a pot and a suit of armour. It is used in *De Juvamentis Membrorum* to designate the valves of the heart, no word in Latin existing which suggested the essential characteristic of a valve, that it allows only a unidirectional flow through it. We may take it that neither the word for, nor the idea of, a valve existed in the mind of the twelfth-century translator, because such objects were not widely known. It was natural enough for Harvey to draw an analogy from his environment of renaissance machinery and describe the valves as "the clacks" of a water pump, but the twelfth-century reader would be further confused in attempting to understand how "covers" were bound up in the pulsation and non-pulsation of vessels, and in the direction of flow of blood. The mechanical absurdity of the mitral valve in Galen's description, whereby it differentiated between air and blood in its incomplete closure, which caused Harvey to cry in exasperation "Good God! How do the mitral valves hinder the return of air and not blood?"¹⁷ although fully apparent in Reggio's translation (which Harvey used) of *De Usu Partium*, is not clear in *De Juvamentis Membrorum*. In chapter seven of book seven, the action of the valve is omitted entirely, and in chapter four the vagueness of the text does not throw the anomaly into relief.

But to return to the new sources mentioned above—Aristotle, Galen, and the Arabs—it was soon found that they did not agree with each other. Bartholomew, for example, presents these differing opinions but does not choose between them or attempt a reconciliation. While the new translations eliminated much of the confusion referred to in an earlier section, the very fullness and complexity of the new texts provided a vast intellectual problem for the West. In medicine it was necessary for the educated physician to be master of at least part of the ancient ideas. More generally the purpose of education was to supply scholars who were able to comprehend and pursue the ancient culture. The system evolved to bring students up through the complexities of the new inheritance was scholasticism, a device of the schools in which alone could the co-operative venture be established. Scholasticism in the medicine of the Western middle ages was from the first a teaching device that related medicine to the other parts of knowledge and necessarily dealt extensively with classification and analysis. The word “scholasticism” still labours under the pejorative meaning applied to it by the renaissance humanists who found it over-logical, dry, and insufficiently Hellenistic. We should regard scholasticism not as a frame of mind but as a technique for dealing with new information. In the period we are now dealing with it gave coherence to the whole ancient world-picture, and it gave way to scholarship as the texts themselves were purified and correctly attributed. Such scholarship finally showed the disagreements among the ancient authors, *auctors*, whose authority, *auctoritas*, had been unquestioned. By then another authority could be called on to settle such disputes—the authority of the dissected body.

The beginnings of human dissection

The new translations, like that of the *Canon* of Avicenna by Gerard of Cremona and that of Aristotle's biological works by William of Moerbeke, who worked from Greek manuscripts, ushered in a new era for anatomy. The period of the early Salernitan anatomies was at an end, hastened by the sacking of Salerno in 1193 by the emperor Henry VI. Bologna and Padua became the new home of anatomy and both made significant contributions. Bologna was also the home of the law school, and the scholastic techniques that were practised on the texts of Justinian came also to be used on those of Hippocrates and Galen. Moreover, there were often legal reasons for conducting post-mortem examinations, and it may be

that the sister professional faculties of law and medicine exercised a mutual benefit. Padua was the university of Aristotle, where his biological and methodological works received more attention than at, for example, the more northern universities, which concentrated their attention on his logical works. Aristotle's scientific method gives due place to the use of the senses, and his own use of the method in his biological works remained a topic of study in Padua up until the time it had such a salutary effect on William Harvey.

For our purposes these developments had two effects. Firstly, the difference between Aristotle and Galen in terms of procedure and achievement was greatly sharpened; it became a general issue of the rival claims of the “philosophers” who followed Aristotle and of the “physicians” or Galenists. Secondly, from the end of the thirteenth century dissecting the human body became standard university practice, ultimately becoming a statutory requirement for the medical degree.

It is not surprising that there was interaction between these two facets of university life. It still took some two centuries for university men to realise that the second of these two, human dissection, could be the final arbiter in the first, the dispute between the philosophers and physicians.

Peter of Abano was one of the first to attempt to resolve the conflicts of the Galenists and the Aristotelians in his *Conciliator of the Controversies which are waged between the Philosophers and the Physicians*.¹⁸ The greater weight of evidence brought forward by Galen for much of his anatomy obliged Peter to retreat somewhat from an absolutely Aristotelian position. To make such a strategic withdrawal easier, he prepared a general statement that covered much of the ground in dispute and in particular the question of whether the nerves arise in the heart or brain and whether the veins originate in the liver or heart. One part of the body, he says, may be the *principium* of another in two ways: in the primary sense, *radicaliter*, the second part having its roots and essence in the first, or the second part may arise from the first in a mere physical or phenomenal way, without having its essence in the first. So the heart is the centre of the body, the seat of the soul. In several senses it is the source of the other parts and their functions. “For the heart is like the sea, agitated by winds, and from it flow three great rivers, one of which flows through the whole body carrying spirit and blood through the artery called aorta. . . . Another river flowing thence rises to the brain so that the nerves may be generated from the brain, from a matter related to a matter of the heart and that of the brain. . .

This river, held back in its progress by an upper obstacle, produces a lake, that is, the brain, from which, laterally, originate smaller rivers, of which the largest is the spinal medulla, and the seven smaller rivulets are the seven pairs of nerves. . . . Also from this sea arises, at the right auricle of the heart, another river . . . by which the matter of the heart is connected to the matter of the liver."¹⁹

In this way Peter is able to accept a Galenic morphological anatomy and deal with such Galenic problems as the terminology of the arterial vein and venous artery, without yet departing from Aristotle. We have met the beginnings of the technique in Avicenna, who had the same problems with the same two authorities. The conflict between these two is most acute where Galen is on his strongest ground, that the nerves arise from the brain, and Aristotle on his weakest, that they arise from the heart. So strong is his desire to have his authorities agreeing, that Peter spends much time on this particular argument. So ingenious are the arguments, and such is the vigour with which they are expressed, that it is difficult not to see the matter as a very live issue at the time, and it is difficult for the same reasons to summarise. Can we not say that the nerves arise *virtualiter* from the heart, the source of all "virtues," powers, and structures, and merely *materialiter* from the brain, as appears from the similarity of the material of the brain and of the nerves? Is not the heart, the first-formed, the *embryological* origin of the brain and nerves? Is not Avicenna right in saying that the brain and nerves, as Instruments, should be distant from the heart, the Principal they serve? Although Galen appears to be on strong ground in showing the loss of function of a nerve when severed between its termination in a muscle and its "origin" in the brain, must we not agree with our predecessors that our true origin is in the heart, which is the sun of the microcosm, just as the sun itself is the "first" of the macrocosm? Harvey was to use the same analogy in the opening words of his dedication of *De Motu Cordis* to the king. Unlike Harvey, of course, the pre-Copernican Peter did not mean the sun was the centre of the macrocosm, but that it influenced the motions of the other planets; it was perhaps "a common mirror in which all [the planets] look and from which all borrow some patterns for their own motion," in the words of Campanus of Novara, writing half a century before Peter.²⁰

Peter of Abano even appears to draw evidence from Galen that the nerves originate in the heart, but here we must take him to task. He refers to a passage in the seventh book of *De Juvamentis*

Membrorum in which Galen appears to say that a strong nerve arises from the right auricle of the heart and joins the vena cava in the middle of the chest. In fact, Galen held that the heart was two-chambered, and what we call auricles were for him merely "sinewy" outgrowths of the vessels entering the heart. The abbreviation and corruption of the original passage in *De Usu Partium* in its passage from the Greek to Syriac or Arabic (or from either into Latin) reintroduced the traditional confusion between "sinew" and "nerve," and at the same time changed "ventricle" into "auricle." The result was that Galen appeared to be saying that the *nervus* was a structure additional to the auricle, and not, as he had said in the Greek, that the auricle was sinewy. We cannot blame Peter for the corrupt state of his sources, but he knew of, at least, the original work from which the medieval treatise was abbreviated, and while we may possibly excuse him for using the *nervus* of the latter treatise in the sense of "nerve," he was not justified in claiming that this represented the origin of the nerves, for book nine of *De Juvamentis Membrorum* retains much of the force with which Galen argued, in *De Usu Partium*, that the brain was the source of the powers and the substance of the nerves. Peter, moreover, was well aware of the distinction between nerves, ligaments, and tendons, for he quotes Haly Abbas on the subject.

Similar arguments are rehearsed in relation to the origin of the veins and do not need to be repeated, except for Peter's observation that some authors say that veins originate in the brain, because the membranous coats of veins are composed of nerves, or because Plato had said that the head is the root of the human tree. We have already seen that this may also be the source of the same idea in the Salernitan anatomies. It is in relation to the question of the origin of the veins that Peter claims to have performed vivisections (presumably of animals) and to have observed in the dying animal that it is the point of attachment of the vena cava to the heart that is the last to stop beating, and is therefore the most noble, the source of the veins.²¹ He later repeats that he has seen this "many times through dissection,"²² and he makes the same assertion about the parts of the eye. There seems no reason to doubt that Peter made, or observed, a dissection in a Salernitan manner, and it is interesting that he can draw upon practical experience in attempting to consolidate the Aristotelian doctrines that flourished at Padua and among its later pupils.

Most of the early practitioners of human dissection seem to have been pupils of one man,

Taddeo Alderotti, and possibly the practice can be traced back to him. Several historians have tried to pin down the period in which dissection started to the space of a few years. We know Taddeo as a perceptive commentator in the medieval fashion on the texts of antiquity, two of which are of particular interest to us here. The first is Galen's *Ars Parva*, in which Galen sets out in the opening words three "methods," the interpretation of which greatly troubled many commentators. They were discussing whether Galen's methods were methods of teaching medicine or of making discoveries within it. Galen was, in fact, an ardent supporter of the observational method, heavily supported by deductive reasoning, and the medieval search for the sources of his and other methods could only have served to highlight the relation between teaching and discovery, and the observational method, which could, after all, be used in both. Almost certainly Galen's remarks in the *Ars Parva* were in fact concerned with teaching, and as certainly the first use of the observational "method" in the West that catches our interest was the use of human dissection to supplement the verbal anatomy of the texts with visual images. This was a natural development from the Salernitan demonstrations of the pig.

The second commentary we are interested in was Taddeo's examination of the *Isagoge*²³ of Johannitius, whom we have met before. Here Taddeo shows the very heart of the scholastic technique by asking of the text before him a certain number of formal questions in fixed order. These were repeated for every new text that came in the student's ken and, designed after all, by intelligent and learned men, they gave the student the feeling that he understood the text to the extent to which he obtained answers. This technique was known as the *accessus ad auctores*,²⁴ and a very significant form of it was used by a late Alexandrian commentator on another text of Galen, the *De Sectis*.²⁵ This was the first work to be studied in the Alexandrian medical curriculum, and in it Galen discusses the medical schools of his day and their attitude to human dissection. We have seen in an earlier article how the Empirics avoided dissection as disgusting and unnecessary, while the Rationalists considered anatomy to be the fundamental medical science. The Alexandrian commentator elaborates on the Rationalists' case by setting out in a formal manner a list of six points to be noted in the examination of every organ in every dissection: its shape, size, position, connections, number, and temperament. This commentary was almost certainly known to Taddeo and was certainly known to the most important

of his pupils, the practical anatomist Mondino.

In these ways we may perhaps trace the importance of discussions of theory, "method," and so on in the origins of human dissection. A practical component of this new departure was surgery. To the end of the twelfth century there was no distinction between physicians and surgeons in terms of medical education. It was only after a decree of the Lateran Council of 1215 that clerics in the major orders were forbidden to practise surgery or cauterisation, with the result that surgeons could not be housed in universities dominated by the Church. While in Paris the distinction between physicians and surgeons was rigidly observed,²⁶ in the more secular universities of northern Italy surgical teaching was part of the medical curriculum. As a result, the literate and practical surgeons produced a number of treatises, including sometimes sections on anatomy in which practical observation was mixed with traditional learning. An early example of such a surgeon was William of Saliceto, who was clearly familiar with human dissection and with the works of the ancients. With surgical empiricism he avoids the theoretical foundations of literary anatomy and gives most of his attention to superficial features that the surgeon needed to know. He carefully tells his readers how to make incisions in the thoracic wall, avoiding the nerves and blood vessels by following the line of the ribs; moreover, such incisions "leave beautiful scars."²⁷

Mondino and the "middle venter"

The Bolognese anatomist Mondino drew together most of the sources we have discussed above, the Salernitan demonstrations, the biological works of Aristotle, the Arabic compilations, and *De Juvamentis Membrorum*. He missed the publication of Nicholas of Reggio's translation of *De Usu Partium* from the Greek by half a dozen years or so. The purpose of Mondino's *Anatomia* was to supply a dissection guide for surgical education. In terms of size alone the book is bigger than any of the preceding Latin anatomies, and it remained popular in Italy for some two centuries.

It was, in other words, fundamental for the development of anatomy in the West, and it is of great interest to see what he had to say on the thorax and its contents. Despite its practical purposes Mondino's text gives some attention to the philosophical relations of anatomy, and we find that the examination of thoracic structures was determined by both practical and theoretical considerations. The first stage in a medieval dissection was the opening of the abdomen. This was re-

garded as the first of the three body cavities, the bellies or "venters," the other two being the thorax and the head. The head was the most noble of the three, but was opened last. Almost certainly what determined the actual sequence of operations was the fact that putrefaction of the dead body affected the intestines first, and they had to be removed hastily before proceeding to the other cavities. The theoretical justification for this sequence was that the abdomen housed the most basic faculty of the body, the vegetative or nutritive, on which the higher faculties depended. The thorax was the middle venter, containing the "spiritual organs," that is, those concerned with respiration—the lungs, heart, and arteries. The heart housed the vital faculty by means of which the venous blood from the liver was transformed into arterial and the body warmed and vivified. This faculty was second in nobility, depending on the activity of the vegetative faculty of the abdomen and supplying arterial blood to support the nobler Animal or Rational Faculty of the upper venter. Within each venter Mondino examined each organ according to the rote of observables laid down by the Alexandrian commentator, and notwithstanding the surgical need for knowledge of gross morphology, Mondino rationally pursues his analytic mode of presentation down to the "similar" parts or tissues, the ultimate components of the body.

No medieval dissection, in the absence of preservatives, could be extended beyond four days, and so there were natural limits to the detail of a dissection guide that was intended to be followed closely by the dissecting teacher. The scarcity of bodies meant that a single cadaver had to display all organs. Only later could a body be used for dissecting a single organ or system, and a far more detailed account of anatomy built up from successive note-taking. Therefore Mondino's descriptions are not very detailed, and they depend almost entirely on the old authors. It must be repeated that the purpose of a medieval dissection was to reinforce the words of the texts with the visual images of dissection: Mondino was not a *research* anatomist. Thus Mondino's account of the heart shows the conflicting influences of Aristotle and Galen, but probably at second-hand, through Avicenna. The importance given to the heart by Mondino is the first aspect of Aristotelian influence. Its central position is said to be suitable for any organ that is the "source and ultimate root of all the organs." Aristotle had said that the heart was the first organ to be seen in the developing embryo and that it determined the disposition of the subsequent organs. The Galenists on the con-

trary held that the three fundamental vesicles in the spermatic foam, representing the future liver, heart, and brain, were formed in that order (another theoretical justification for the sequence of dissection). Mondino also has passages that recall the connection suggested by Aristotle between the brain (Mondino says the central ventricle) and the heart (in a central position) in terms of psychic activity and nervous connection. The idea is Aristotelian, but the route by which it reached Mondino was not necessarily direct. There is, for example, a very similar idea in the *Anatomia Ricardi (Salernitani)*.

The most obvious influence from Aristotle on Mondino is the latter's description of the heart as three chambered. There are several curious features about this statement. Firstly, it is accompanied by instructions explaining how to dissect the heart to make the three cavities appear; secondly, he does not, as we might expect, take the idea of the third ventricle from Avicenna, for the details of its function are quite different; and thirdly, the details of its structure, when finally given, are very little different from details that would also apply to the Galenic septal pores. Mondino, in fact, appears over-anxious to reconcile his authorities, but does not appear to have fully understood them. It has been suggested above that the medieval reader of *De Juvamentis Membrorum*, which Mondino quotes more than any other anatomical text, could hardly have had a clear idea of what Galen had originally written, particularly about the heart and lungs. Such oddities as appear in Mondino's account of the heart probably derive from such a misunderstanding.

One of the oddities of Mondino's account of the heart is his description of the auricles. As we have seen, Galen regarded these structures as merely sinewy extensions of the veins, but after him they were increasingly regarded as separate structures. Mondino misinterprets their function as one of reserve capacity in the event of excessive production of blood or spirit in the ventricles. This implies a lack of clear awareness of the functional direction of the valves, one of those results of translation where no adequate terminology existed to express the idea of the original. It is precisely this case that was mentioned above in relation to the translation of *De Juvamentis Membrorum* where the rather weak term *coopertorium* was employed. That Mondino did not understand the structure and function of the right auricle and its relations to the vena cava is clear from his description of the valves. Blood, he says, enters the heart from the liver through the *vena chilis*

and past an inwardly looking valve. After some concoction, most of the blood is then expelled "through the same orifice,"²⁸ while the remainder is sent to the lungs and across the septum. For this reason, observes Mondino, the inwardly pointing valve of the right ventricle *does not completely close*. Mondino may have mistakenly transferred this detail from Galen's account of the valve of the *left* ventricle, which is clear enough in *De Juvamentis Membrorum*,²⁹ and it is interesting to recall that the Hippocratic *De Corde*, like Mondino, attributes to the *right* ventricle an incompletely closing valve.

It appears to have been observation rather than the influence of Aristotle that made Mondino put the origin of the *vena chilis*, the lower vena cava, in the heart and not in the liver, "since she is united to the substance of the heart and doth not go through it, but is greatest next her base and root, like the stock of a tree."³⁰ For the anatomy of the vessels of the lung, however, Mondino necessarily returns to Galen, for he has no other authority. He uses Galen's terminology, the *vena arterialis* and the *arteria venalis*, and Galenic reasons for their anomalous structure. This comes directly from *De Juvamentis Membrorum*, and Mondino uses a phrase very similar to one found in the latter work when discussing the reciprocal service paid by the heart to the lung in transmitting blood to it, in exchange for the lung's service in sending air to the heart.³¹ Had Mondino had the full text of *De Usu Partium* he would have seen that the passage he used was immediately preceded by another in which Galen discusses the number of ventricles in the hearts of different animals and refutes Aristotle's opinion. This passage³² was omitted by the medieval translator of the abbreviated work, and so a false idea persisted through Mondino in Western anatomy for many years.

Tradition and innovation

Erroneous ideas about the structure and function of the thoracic organs, derived from misunderstanding Galen or indeed from understanding Aristotle, had a curiously long life in the West and were not finally displaced until the sixteenth century. Traditional ideas were "authority" in the sense used to describe the third of the periods described at the beginning of this article.

One set of traditional anatomical ideas was expressed pictorially. These pictures are the "situs" figures, so called because their purpose was to display site or position of the organs (figs 2 and 3). Unlike the earlier manuscript tradition of the "five

figure series" the situs figures were often printed, but like their earlier counterparts they were in no sense derived from anatomical observation but were the result of repeated copying from earlier examples. The anatomical details consequently became very corrupt, but then, they were not intended as serious anatomical studies. Rather they belong to the "fugitive sheet" tradition of illustration³³—diagrammatic pictures of the human insides published on single sheets and sold to the public at large with brief descriptions of the organs in the vernacular rather than in the scholar's Latin.

Most of the examples we know seem to be German in origin. It seems to have been a medieval manuscript tradition that was perpetuated by the early appearance of the printing press in Germany. Whereas the cultural developments of Italy had produced the italic hand and had banished the grosser aspects of medievalism in anatomy, the printing press in Germany secured a long future for the still Gothic handwriting and for the common situs figures.

Meanwhile, developments in Italy had produced a state of affairs that was to be of immense importance in the history of anatomy. The ability to draw a three-dimensional object satisfactorily on paper had been developing over the second half of the fifteenth century. By the end of the century two other crafts had also reached maturity. These were the engraving of wood, which made it possible to match the sophistication of a line drawing but in a permanent and reproducible form, and the printing press, which made possible the production of hundreds of invariant copies of both text and illustration. This virtually ended the unequal rate at which these two elements of an illustrated book had degenerated in the manuscript tradition (the scribe's business being to copy words without necessarily being a skilled artist). Naturalistic art is a craft that had to be taught as much as reading and writing and as a body of knowledge and technique accumulated, it came to be applied to anatomy in the renaissance as an eminently successful way of identifying and memorising the parts of the body—the aim of anatomical education.

We can only afford to glance at the artists' own investigations into anatomy, which, however much they improved art, had little effect on anatomical history. Leonardo da Vinci must fall into the same category, for his magnificent anatomical work remained unpublished and virtually unknown.³⁴ This was a great loss, for he was particularly interested in the heart, to judge from the number of drawings he made. Some of

Fig 2 *Situs figure from Hundt's Antropologium. Viscera are extremely schematised, and have many features in common with Peyligk's situs figure, although they preserve the traditional orientation. The urogenital organs are included. Entirely traditional heart and lungs are characteristically shown without connections to other organs. Indeed situs figures may all be illustrations composed from individual "single organ sketches" of great antiquity.*

these early drawings are traditional—for example he represented the non-existent pores in the ventricular septum—but Leonardo developed novel techniques of injection and moulding to study the valves of the heart. He also experimented on the heart of a living animal by thrusting a sharpened rod through the chest wall into the substance of the heart and noting how the external end of the rod traced out the motions of the heart, the chest wall acting as a pivot. His anatomical drawings of the heart and vessels improved greatly

after he had the opportunity of human dissection. He recognised the heart as four-chambered, muscular, and the source of all vessels, all of which was contrary to Galenism. He even thought quantitatively about the function of the heart, concluding that some seven ounces of blood passed through it in an hour.

The artists of Leonardo's time pursued anatomy much more vigorously than the medical anatomists. Not all of them were led into investigating the deeper structures, but their common interest

Fig 3 Situs figure from 1513 edition of Peyligk's *Compendiosa capitis phisici Declaratio*, published in Leipzig. Note extreme conventionalism of brain ventricles and viscera. Five-lobed liver clutches at the stomach as if with fingers, and is counterbalanced by spleen. Intestines are intertwined in an elegant knot, and diaphragm is reduced to a line. Traditional heart-lung representation is so corrupt as to be virtually unidentifiable. The heart, cor, is shown on left of figure, the lung, pulmo, on right. Both are presented on a background of the stomach. The trachea, usually known as "harsh artery" because of its coarse cartilaginous structure and air-carrying (ie, arterial) function, is here called "vocal artery," vocalis arteria (sic).

in the superficial muscles (for the purposes of representing the body in action) stimulated great activity on the part of the anatomists in an area that had been traditionally ignored in the medieval dissections, which had concentrated exclusively on the three venters. Many of the early printed anatomical figures of the *medical* anatomists are directed to the artists, not to the school-anatomists.

The thorax in the pre-Vesalian period

We have now reached a period when, shortly after Mondino, the major sources for anatomical and physiological knowledge of the human body were known. It was also a period when human dissection became widespread in the universities, yet no progress was made in establishing the structure

and function of the thoracic organs. There was a strange delay in understanding the works of Aristotle and Galen on this subject, in attempting any reconciliation between the two authors, and most of all in using dissection to favour one author against another or as a research tool. The period until the sixteenth century was occupied by textual scholarship, but whether this was a necessary prerequisite for progress or was simply a filler of a gap caused by other historical causes is not clear. The Italians depended on the work of Mondino, who was largely unknown in France, where the medieval Guy de Chauliac was preferred. The Germans had no scholarship in the field to speak of, but produced plagiarising anatomical publishers of the early sixteenth century.

Guy de Chauliac, following Galen, describes the heart as consisting only of two ventricles, yet Galen's intercommunicating septal pores have become a single passage. This might be an attempt on Guy's part to accommodate within his scheme Aristotle's third ventricle, but the single passage acts in a Galenic, not Aristotelian manner, and Guy's description of it does not agree with that given by Aristotle, Avicenna, Mondino, or the Salernitan anatomies.

In describing the vessels of the lung Guy does not show the influence of Mondino and the Salernitan anatomies, who in turn were not able to understand the classical sources. Guy says the arterial vein (the pulmonary artery) arises at the right auricle as a branch of the vena cava. This belief seems to have originated in a slight misunderstanding of Mondino's statement that the vena cava brings blood to the right ventricle, where the blood is concocted and expelled through the *same* orifice to the whole body, "yet not the whole is expelled, for a certain portion of it is expelled to the lung and another part is sent over to the spirit."³⁵ In other words, Mondino does not in this passage make it clear by what route the blood leaves the heart and enters the lungs, and Guy's interpretation seems to be that this route, the arterial vein, is simply a branch of the vena cava leaving the heart. A little later, however, Mondino does describe the separate orifice of the arterial vein, but Guy, claiming that there is but a single orifice in each ventricle, cannot agree. Thus on the *left* side of the heart he has the venous artery (pulmonary vein) and aorta arising as two branches of a vessel from the single orifice. This inaccuracy extends to his description of the valves of this orifice, which are said to close "at convenient times," without reference to diastole or systole. Anatomical and physiological progress needed a firmer footing than this (fig 4).

Progress came only when the texts of the Greeks and the Arabs had been assimilated and compared. The industrious scholar found that at certain points his authorities were irreconcilable, and that certain passages in his authorities were irremediably corrupt. The sound Galenist knew that Galen had said that others would come in time to discover things unknown to Galen himself; and the follower of Aristotle's observational method found himself with opportunities in the practice of human dissection. All of these things were the elements of the revival of anatomy, yet they fell into place only gradually. The late medieval anatomist felt inferior to the ancients in his abilities and preferred to take their account of the human body as true. Yet he had several difficulties, the first of which was how to deal with the corrupt passages. Another was the possibility that the body itself had changed since the classical period—not only was modern man inferior in intellect, but also physically, for which evidence may be found in the new diseases like the *morbus gallicus*.

The first sign that medieval man entertained the modest hopes of extending the medical work of the ancients was the use of the analogy of modern man as a child standing on the shoulders of a giant, able to see further not by reason of his own abilities but as a result of the work of the ancients: science is cumulative. It was then possible to use the ancients' methods of procedure and discovery to treat diseases unknown to them. The fifteenth century growth of post-mortem examinations must have spurred the idea of progress. In the anatomical literature we find that the first use of dissection apart from its teaching role was as an independent authority in the restoration of corrupt passages.

From authority to progress

We can illustrate the general remarks just made by reference to three authors in the immediately pre-Vesalian period, Gabriele de Zerbis, Berengario da Carpi, and Niccolo Massa.³⁶

De Zerbis's anatomical textbook of the early sixteenth century combined a practical dissection guide in the manner of Mondino, which de Zerbis introduces with the heading *Textus*, with a commentary designed to include philosophical discussion, which he calls *Additio*. The *Textus*, like the text of Mondino, follows the rote of observables set down by Johannes Alexandrinus so rigorously that de Zerbis is often in the absurd position of having a scholastic heading of "number," for example, when dealing with organs like the heart or head, the number of which in any body is so

Fig 4 Seventh figure from illustrated anatomical manuscript of Guido da Vigevano (about 1345). Dissector is preparing to remove front of rib cage by a procedure described by Guy de Chauliac: "If you want to make a good anatomy of the contained parts, you must make an incision in the chest along the sides and remove the anterior part, proceeding cautiously on account of the mediastinum. The interior parts will then appear to you."

obvious that de Zerbis has no text to follow his heading. The book is halfway between a medieval commentary and a renaissance text book, and we find from its content that de Zerbis, master of the anatomical commentaries that had preceded him and the most bookish of the authors considered in this section, is not far from launching out on a new technique of anatomical discovery based on sense observation. Twice he insists that describing the structure of the heart and valves is difficult

enough even with the employment of the sense of touch, but without them it is impossible. We should certainly be inclined to believe that this was the remark of a practical anatomist, particularly when he appears to be able to resolve uncertainties among the ancients by means of dissection: "Because the internal parts of the body are unknown or incompletely known, according to Aristotle, so the anatomy of these ventricles [of the heart] should be capable of being shown more

clearly by anatomy: the heart of the human body should be cut firstly at the right side and at the cusp; this should be done with caution lest another wall be cut. There will appear to the anatomist the right ventricle, having two orifices. . . ."³⁷ After this the ventricular wall is to be cut to show the left ventricle. Despite all this, de Zerbis has no refutation of the existence of the septal pores, nor of the common idea that these pores somehow correspond to the third ventricle of Aristotle. What does cause us to think twice about these apparently first-hand observations of de Zerbis is that the instructions for incising the heart are precisely the same as those given by Mondino. De Zerbis gives us in an *additio* the views of Aristotle and Avicenna, and the very different opinion *secundum medicorum traditionem*, which he follows in the *textus*. In this "opinion according to the tradition of the physicians" he even quotes, in the *textus*, from *De Juvamentis Membrorum*, in which, as noted above, an error in translation brought into existence a "ghost" anatomical structure, a "sinew" that connected the vena cava to the right side of the heart, derived from and preserved alongside Galen's "sinewy" auricle.

At about the time when human dissection was introduced in the medieval West, the scholastic commentators added new categories to the list of observables during such a dissection as set down by Joannes Alexandrinus. The most important additions were the kind of disease that every organ, considered in turn, was apt to suffer. Thus Mondino and many anatomists after him ended their brief descriptions of the organs with a mention of a pathological condition that would be of use to the surgeon. This *practical* medical interest provided another route towards anatomical progress when the idea of the decline of modern man was accepted, for it emphasised the use of the senses in precisely the area—new diseases—where there was no ancient authority to rely on. Benivieni published a list of post-mortem examinations in 1506, and expressed surprise when he was refused permission to make one such examination.³⁸ Thorndike³⁹ gives interesting details of a fifteenth-century necropsy performed on the body of a son of the householder *in order* to gain knowledge of the cause of the disease so that the other children could be protected from it.

The mixture of observation and authority that we found in de Zerbis is also found in Berengario da Carpi, but here the balance is very much more in favour of observation. He had the practical interest of a Benivieni, derived from his surgical background. Da Carpi in fact made a virtue of his skill in dissection, his scholarly comparison of

texts, his cautious disagreements with Galen, and above all, his observational method. All this he compounded into a system of research and *discovery* that he called *anatomia sensibilis*, that is, anatomy based on what was perceptible, not on "reasons" used by other anatomists to infer the existence of structures, as Galen had argued for the existence of the pores of the cardiac septum on the grounds that nature does nothing in vain.

Such a technique could hardly fail to bring da Carpi into conflict with Galen, notably in connection with the organs of the thorax. Da Carpi tells us that it was not uncommon at the time for voices to be raised against Galen's account of the anomalous structure of the arterial vein and venous artery, and he himself had the "greatest difficulty" in seeing the pores in the cardiac septum in the human subject. He reported that the pores were seen more easily in the hearts of oxen. The technique was probably then as later to boil the hearts until they almost fell apart, but still we are bound to find in da Carpi's method a "reason" for the existence of the pores derived from the existence of Galenic physiology. Indeed, although da Carpi relishes his disagreements with Galen, and although *anatomia sensibilis* is explicitly opposed to anatomy received through the *auctoritas* of the *auctores*—the authors' "authority" as used in the title of this section—yet we find there is a real struggle going on in da Carpi's anatomical exposition between the implementation of his own research techniques and the momentum of old ideas. He falls into Mondino's error in describing an imperfectly closing valve at the entry of the vena cava into the heart and a two-way motion of blood across it. He is still concerned to reconcile his authorities, and he adopts the philosophers' interpretation of Aristotle's troublesome description of the three-chambered heart in assuming that Aristotle's middle ventricle corresponds to the left ventricle of the modern (sixteenth century) description of the heart. The physicians' interpretation was that Aristotle's third ventricle was to be identified with the septal pores of Galen. This discussion leads naturally to the debate between two schools of thought over the origin of the veins. Da Carpi sensibly says it is impossible to speak of the "origin" of the veins unless we are speaking loosely or metaphorically. In the latter case there is a sense in which the veins, as the physicians say, arise from the liver, a conclusion adopted by da Carpi as "nearer to truth, reason, and observation (*sensus*)."⁴⁰ Of the opinions of the philosophers he prefers those of the peripatetics, he says, who believed that the veins originate in the head. Here

he quotes Syennesis, whose account he had doubtless read in Aristotle. Further traditional elements in his writing are the discussions of function, of humours and complexions, and of causality. Thus a common problem for the medieval anatomist was the existence of a fat at the base of the heart. Had not the ancients declared that the efficient cause of fat was cold? Yet is not the heart the very source and fount of heat? Da Carpi poses the question again, but one feels that the taste for such scholastic questions is being lost, when their resolution is unobtainable by observation. Be cautious when writing books on anatomy, warns da Carpi, and trust in sense as he does, not authority.⁴¹

The last of the Italian pre-Vesalian anatomists we have to consider in this article is Niccolo Massa. His short anatomical work is completely renaissance in style in avoiding the commentary-style that even da Carpi had used. Like da Carpi Massa extolled the observational method, and made da Carpi's point more forcibly by arguing for an *anatomia sensata*, the anatomy of perceived, not perceptible, structures.

By Massa's time the Italian school of anatomists had produced a growing body of anatomical doctrine that did not depend entirely on the ancients, and a scholarly appraisal of Galen's works. With or without Vesalius it possessed truly scientific methods of procedure and was well on its way to producing an objective account of the body. Yet such accounts are essentially static, and the new departure of the sixteenth century was anatomy conceived in morphological terms. Not until the next century were similar observational techniques turned to physiological problems, and most of the sixteenth-century anatomists remained entirely Galenic in their physiology. We have seen above that it was not always clearly understood what Galen had said, however, because of the historical accidents of transmission of the old texts. Nowhere was this confusion greater than in the case of the heart and vessels, and even in the high renaissance when all the Galenic anatomical accounts were well understood we find strangely persistent ideas of cardiac function. For example, Massa is adamant from observation that the septum between the two ventricles of the heart is thick, dense, and without a cavity. Yet he does not altogether deny that a third cavity may be present in some hearts (he insists on the variability of the body), and he claims to have found such a cavity at a dissection in 1534 in the base of the heart at the border of the septum in "the biggest heart I have ever seen."⁴² He therefore considers that a third ventricle occasionally occurs in man,

and more often in larger animals (a belief he attributes wrongly to Galen). There were various other, pathological, appearances in the large heart of the dissected man.⁴³

Despite his belief that the septum was thick and dense, he nevertheless held that blood moved from the right to the left ventricle. As with older anatomists, he held too that the auricles were reservoirs of blood and spirit, able to receive and remit blood as the occasion arose. Some confusion over the function of the valves is evident here, and furthermore, we find that air came to the heart's right ventricle through the same vessel that sent blood to nourish the lung, that is, the arterial vein (pulmonary artery). He claimed that one of the three flaps of the valve of the aorta differs in construction, location, and function, allowing spirit into the arteries, but he also speaks of spirits entering the heart through this valve. His scheme of blood flow ensured an ebb and flow over the entire system, and he seems to have had little idea of the function of the valves. In another place he says that the auricles are continuous with the ventricles, and he derives the aorta from the left ventricle. The various elements of this odd scheme may be found in the traditional medieval anatomies with debased Galenism, fragments perhaps of unknown Greek sources, and a hint of Aristotle thoroughly mixed. It does, however, fit Massa's scheme of phlebotomy. Opening the *basilica* vein, he says, draws blood from the heart, and then from the liver, as we might expect from Galen's physiology. Nevertheless, both blood and spirits have an ebb and flow in the arteries and veins, principally between the heart and liver. There is also an important pathway from the heart to the brain, through the jugular veins and carotid arteries, and from the brain back down to the lower members. The flux and reflux occurs even in the finest branches of the vessels, and by its aid Massa is able to explain the Hippocratic account of sterility resulting from an incision of a vessel in the neck. He is also able to explain how blood, having undergone changes in the liver, heart, and brain, can carry the virtues of these organs back down to the testes, so that the semen has the virtues of all parts of the body—the Hippocratic theory of pangenesis.

Notes and references

- 1 See for example Corner, G W, The rise of medicine at Salerno in the twelfth century, *Annals of Medical History*, n s 3 no 1 (1931) 1–16.
- 2 Kristeller, P, The School of Salerno, *Bull Hist Med*, 17 (1945) 138–194. See Corner (1931) for a review of the earlier work of De Renzi and others.

- 3 Mieli, A, *La Science Arabe*, Leiden, 1966, p 222.
- 4 The name is recorded in medieval Byzantium, and it is not anyway clear how "Hunain" became "Joannitius." Nor is it clear why an Arabic translator of Greek should compile an introductory work in Greek (the early printed versions call it the book in Greek).
- 5 Corner, G W, *Early Medieval Anatomy*, Washington, 1927. *Anatomia Porci* is also included in the 1626 Junta (Venice) edition of the *Opera Omnia* of Galen as the pseudo-Galenic *Anatomia Parva*.
- 6 Corner, (1927) p 59.
- 7 Sarton, G, *Introduction to the History of Science*, vol 2, part 1, Washington, 1931, p 438. Sarton's numbering of the Salernitan anatomies differs from that of Sudhoff: see Sudhoff, K, *Die vierte Salernitaner Anatomie*, *Sudhoffs Archiv*, 20 (1923), 33–50.
- 8 Corner (1927) p 76.
- 9 Singer, C, and D, The origins of the medical school of Salerno in *Essays in the History of Medicine presented to Karl Sudhoff*, Oxford, 1924, pp 121–138.
- 10 Haskins, C, *Studies in the History of Medieval Science*, Harvard, 1924, p 132.
- 11 *Timaues*, 90a.
- 12 Koning, P, de, *Trois Traités d'Anatomie Arabes*, Leyden, 1903, p 179: "Ensuite il s'en détache, après cela, une branche qui se rend à la plus grande des deux oreilles du coeur; cette branche se divise en trois portions dont l'une entre dans la cavité droite des deux cavités du coeur et se rend de là au poulmon. Cette portion est la plus grande de ces [trois] portions et il en naît la veine nommée *veine arterieuse* parce q'elle ressemble en structure à une artère."
- 13 Constantine the African, *Operum Reliqua*, Basel, 1539, book 2, chapter 2: "Ubi furculata tandem ad cordis auriculam tendit majorem. Unde egressa in tres dividitur venas. Una major secedit in dextram concavitatem cordis et inde in pulmonem tendit. Ex hac exit vena que vocatur arteria."
- 14 Vincent of Beauvais, *Speculum Quadruplex*, book 28 (the edition of 1624 (Duaci) has been used here) and Bartholomaeus Anglicus, *De Proprietatibus Rerum*, book 5 (Argentinae, 1505).
- 15 Galen *Opera Omnia*, ed Kühn, Leipzig, 1821–33; 22 vols; vol 3, p 410.
- 16 *De Juvamentis Membrorum* book 7, chapter 1. The work may be found in the collected works of Galen of 1505 and 1515. Compare this passage with the translation of the original Greek work, *De Usu Partium*, by M T May, *Galen on the Usefulness of the Parts of the Body*, Cornell University Press, 1968, 2 vols; vol 1, p 278.
- 17 For Harvey's use of the term "clacks" see Harvey, W, *Lectures on the whole of Anatomy*, ed O'Malley et al, University of California Press, 1961, p 191. For his strong language in connection with the mitral valve see the Everyman edition of *De Motu Cordis: The Circulation of the Blood*, London, 1963; Franklin's translation, p 17.
- 18 Peter of Abano, *Conciliator controversiarum, quae inter Philosophos et Medicos versantur*, Venice, 1565. The writing of this book occupied several years, some of them spent in Paris, and was completed by 1303. See Jones, H W, The faculty of medicine at Paris, *Annals of Medical History*, third ser, 1, (1939) 1 29, and Thorndike, L, *A History of Magic and Experimental Science*, London, 1923, vol 2, p 876.
- 19 Peter of Abano (1565) p 60r.
- 20 In the *Theorica Planetarum*. Benjamin, F S and Toomer, G, *Campanus of Novara and Medieval Planetary Theory*, University of Wisconsin Press, 1971, p 307.
- 21 Peter of Abano (1565) p 69v.
- 22 Peter of Abano (1565) p 70v.
- 23 Thaddeus of Florence (Taddeo Alderotti), *Expositiones . . . in subtilissimum Joannitii Isagorum libellum*, Venice, 1527. See also Siraisi, N, Taddeo Alderotti and Bartolomeo da Varignana on the nature of medical learning, *Isis*, 68 (1977), 27–39.
- 24 The use of the *accessus* in medical writings of the middle ages does not seem to have caught the attention of historians. Its use in other disciplines is well described by Quain, E A, The medieval *accessus ad auctores*, *Traditio*, 3 (1945), 215–264.
- 25 On *De Sectis* see also Temkin, O, Studies on late Alexandrian medicine. 1 Alexandrian commentaries on Galen's *De Sectis ad Introducendos*, *Bull Hist Med*, 3 (1935), 405–430.
- 26 Bullough, V L, The medieval medical university at Paris, *Bull Hist Med*, 31 (1957), 197–211.
- 27 William of Saliceto, *Cirurgia*, Placentinae, 1476 (unpaginated). A facsimile of a MS of the anatomical section of this work has been produced by Caturegli, G, *L'anatomia di Guglielmo da Saliceto*, Pisa, 1969.
- 28 Mondino's text has been translated by Singer, C, in Ketham, J, *The Fasciculo di Medicina* (Venice, 1493), part 1, Florence, 1925.
- 29 Book 7, chapter 4.
- 30 Ketham (1925) p 83.
- 31 Book 7, chapter 2.
- 32 Galen (1968) vol 1, p 295.
- 33 The standard works on medical illustration in general are Choulant, L, *History and Bibliography of Anatomic Illustration*, ed Frank, M, New York, 1945 and Herrlinger, R, *History of Medical Illustration from Antiquity to 1000 AD*, London 1970.
- 34 There is a considerable literature on Leonardo. Useful works on his anatomy are: McMurich, J P, *Leonardo da Vinci the anatomist*, Baltimore, 1930; O'Malley, C D, and Saunders, J D de C M, *Leonardo da Vinci on the Human Body*, New York, 1952; Keele, K, Leonardo da Vinci's influence on renaissance anatomy, *Med Hist*, 8 (1964), 360–370.
- 35 Ketham (1925) p 83. Wallner, B, The middle English translation of Guy de Chauliac's anatomy, *Lunds Universitets Arsskrift*, N F Ard 1, 56 (5), 1964.

- 36 Gabriele de Zerbis, *Liber Anathomie Corporis Humani et Singulorum Membrorum illius*, Venice, 1502; Jacopo Berengario da Carpi, *Commentaria cum amplissimis additionibus super Anatomia Mundini*, Bologna, 1521; Nicolo Massa, *Anatomiae Liber Introductorius*, Venice, 1559 (first edn 1536). The shorter pre-Vesalian anatomies have been collected and translated by Lind, L R, *Studies in pre-Vesalian anatomy*, Philadelphia, 1975. The most serious omission from this collection, however, is the vast commentary by da Carpi on Mondino's anatomy. This is perhaps the most important document that illustrates the changes between medieval and renaissance anatomy.
- 37 De Zerbis (1502) p 65.
- 38 Reisman, D, *The Story of Medicine in the Middle Ages*, New York, 1935, p 184.
- 39 Thorndike, L, *Science and Thought in the Fifteenth Century*, New York, 1963, chapter 6.
- 40 Da Carpi (1521) p cliv verso.
- 41 Da Carpi (1521) p cliii verso.
- 42 Massa (1559) p 56 r.
- 43 See O'Malley, C D, Niccolo Massa, *Physis* (Firenze), 1969, 458–468.

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