

No other subject engaged Leonardo more than his work on the anatomy of the human body. It was the subject in which he argued most forcibly for the importance of independent observation allied to original thought. This process he called “experience”¹ of the world around him “gained through the senses” was his starting point for new understanding. Reason and contemplation brought to bear on the sensed experience allowed the development of a hypothesis. Experimental testing and mathematical proof then gave authority to that hypothesis, the veracity of which could be stated. This approach, proclaimed by Leonardo as essential for rational progress, presages the modern method of science.

This reliance upon dependent observation, throwing off the cloak of didactics, clearly brought him into conflict with some of the academics of the day. He can be heard to rail against his detractors who seem to be criticizing him for original thought; though the context may have been more general, the control on perceived wisdom by the physicians of the day would seem a likely target. Leonardo wrote:

Many will think that they can with reason blame me, alleging that my proofs are contrary to the authority of certain *men held in great reverence* by their inexperienced judgment, not considering that my works are the issue of simple and plain experience which is the true mistress. These rules enable you to know the true from the false—[The rules that he refers to are those that we would speak of as scientific method.]—and this induces men to look only for things that are possible and with due moderation—and they forbid you to use a cloak of ignorance, (allowing the enquirer to admit that he does not know the answer) which will bring about that you attain to no result and in despair abandon yourself to melancholy.

I am fully aware that the fact of my not being a man of letters may cause certain presumptuous persons to think that they may with reason blame me, alleging that I am a man without learning. Foolish folk! Do they not know that I might retort by saying, as did Marius² to the Roman Patricians, ‘They who adorn themselves in the labours of others will not permit me my own.’ They

will say that because I have no book learning, I cannot properly express what I desire to treat of—but they do not know that my subjects require for their exposition experience rather than the words of others. Experience has been the mistress of whoever has written well; and so as mistress I will cite her in all cases.³

Perhaps the melancholy he speaks of refers to his own state of mind in dealing with the obdurate academics that clearly were scoffing at his work. He was an original thinker prepared to think outside of the box, and his preparedness to challenge ancient accepted authority can be found in these words, which open the passage quoted above: “Consider now, O reader! What trust can we place in the ancients, who tried to define what the Soul and Life are—which are beyond proof—whereas those things which can at any time be clearly known and proved by experience remained for many centuries unknown or falsely understood.”⁴

The dominant academic force in anatomical teaching of the period (and for more than a century before and afterwards) was the work of the Greek physician Galen, who was born in Pergamum, on the seaboard of Asia Minor, in 129 A.D. Galen, who was physician to the gladiators, amongst other things, declaimed Hippocrates’ stance on the importance of knowledge of anatomy in the understanding of the human condition. Galen wrote, “He [Hippocrates] thought that one should have a precise understanding of the nature of the body, that this was the source of the whole theory of medicine.”⁵ As we shall see, Galen did not completely hold to that proclamation himself.

Galen’s anatomy was based upon the dissection of animals, principally monkeys; he argued that as a result of their external similarities, their internal form would mimic that of the human being. As a result, there were considerable inaccuracies in his descriptions. Despite maintaining the position

¹Experience is the term used quite specifically by Leonardo to distance his testable approach to understanding from that of the majority of academics, who were happy to quote the work of others.

²Marius’s speech to the Quirites in Sallust, *Bellum Iugurthinum*, ch. 85, §25.

³C.A. 119v.

⁴*Ibid.*

⁵*Quod optimus medicus sit quoque philosophus*. Khun, Karl Gottlieb. Leipzig reference I 54. Claudia Galeni Poera Omnia. Leipzig C. Cnobloch 1821–33 rpt. Hildesheim. Georg Olens 1964–5.

that anatomy had an important role, Galen's therapeutic approach to disease was based on the balance or imbalance between the four humors—blood, yellow and black bile, and phlegm—so the role of anatomy in the diagnosis of medical conditions was very limited. In both Galen's and Leonardo's time, knowledge of the superficial veins and arteries was important for the barbers who "let blood" from the sick, and knowledge of muscle, bones, and joints was important for the surgeons, who dealt mainly with trauma. Beyond these uses, however, there was little practical application for more advanced anatomy, other than demonstration to medical students of the structures that Galen described.

Galen was much more than just a physician, and he considered it impossible to be a doctor without a full knowledge and use of the canonical branches of philosophy (namely logic, physics, and ethics). This approach brings the disciplines of philosophy and medicine inextricably together. Galen wrote of this in the *De anatomicis administrationibus*. He said that there are applications for anatomy "that are more useful for philosophers than for physicians."⁶ He continued, "Of what use to aetiology, diagnosis and treatment [of disease] could a knowledge of the muscles of the tongue or of the muscles, nerves, arteries and veins that run through the heart and viscera if it was impossible to act upon them in any way?"⁷ Herein lay the context in which Leonardo was drawn so heavily into the challenge of understanding the human body. Not specifically to derive information that would be of use to the physicians and surgeons of the day but more to answer questions within the confines of Natural Philosophy.

Interestingly, as Andrea Carlino points out in his excellent book, *Books of the Body*,⁸ this epistemological approach discussed by Galen affected the reception of Vesalius's *de Fabrica* in the general medical world for several decades, with the continuation of the ritualisation of dissection for didactic ends and as a visual aid to the textbooks of the day, rather than developing the craft of dissection as a research tool, as Vesalius championed.

Leonardo's work and his ideas on "experiencing the truth" through dissection discussed in his manuscripts predated Vesalius's standard-setting *De Humani Corporis Fabrica* (1543) and others such as the *De Re Anatomica* of Realdo Colombo (1559) by a generation. Sadly, as Leonardo did not publish any of this work, there was no way that he could be recognized for the originality of his approach.

With this setting in mind, the observer can only marvel at the insightful questions that Leonardo asked of himself and the outstanding quality of dissection that was necessary to reveal aspects of previously unknown parts of anatomy.

These skills, allied to the originality and sheer beauty of the representation to be found in his drawings, make his work quite extraordinary. Also, although his anatomical work was known about by authorities of the time and is referenced with significance in Vasari's *Lives of the Great Artists and Sculptors*, there is no reference to it in the authoritative anatomical texts of his or the next generation. Vesalius produced *de Fabrica* whilst working in Padua.

The comparatively primitive work of the anatomist/physicians de Ketham and Berengario exemplifies the world of anatomy in Leonardo's time. It must be stated, however, that Berengario in his *Commentaria* corrected some aspects of Galen's work and was committed to carrying the specialty forward. He wrote, "We know how to carry out science by adding parts to other parts: and we are as children standing on the shoulders of giants: we are able to see much farther than antiquity could."⁹

Although it took time,¹⁰ it was in this setting that Vesalius's work was able to make such an enormous impact. Yet Leonardo had developed the inquisitive approach to anatomy decades earlier. His progress from a standing academic start, though disappointing to him, was enormous. The picture emerges, however, of a few other farsighted men who appreciated the relevance and importance of original thought. Again, Berengario wrote, "And in this discipline nothing is to be believed that is acquired either through the spoken voice or through writing: since what is required is seeing and touching."¹¹ In fact, he goes on to stress that Galen should not be followed "where seeing and touching [Leonardo's experience] are in opposition." Leonardo's attitude antedates these sentiments and indeed may have stimulated them. Berengario was an approximate contemporary of Leonardo, being born in 1460 and attending Bologna University. His *Commentaria* was not published until after Leonardo's death (1521), but Leonardo may well have known of Berengario's stance on anatomical exploration. Berengario was a considerable collector of art and had dealings with Raphael, so he is likely to have been aware of Leonardo's prowess in the arts world.

The importance of the subject to Leonardo is clear from the breadth and depth of his work as well as from the sheer volume of extant material. Bearing in mind that much has been lost, this body of his work is very substantial indeed and suggests a great deal of time spent looking and dissecting, in addition to the many hours of writing and drawing that his manuscripts reflect.

⁶Andrea Carlino, *Books of the Body*. (Chicago: University of Chicago Press, 1997), §4.

⁷Galen, *De anatomicis administrationibus*, KII 284 and 287.

⁸Andrea Carlino, *Books of the Body*, §6.

⁹Berengario da Carpi, *Commentaria*, fol. IIIv. A metaphor used famously by Isaac Newton.

¹⁰Masterful as Vesalius's work was, the lack of obvious practical application slowed its appreciation outside the major teaching institutions (Andrea Carlino).

¹¹Berengario da Carpi, *Commentaria*, fols. VIv and VIIr.

His study of anatomy spans three decades of his life. If, as seems most likely, he was first stimulated to learn anatomy for use in his artistic endeavors, what then drew him into the world of what effectively became a research scientist? His studies of proportion and the muscular and skeletal anatomy fit well with that of an artist struggling to achieve perfection in the representation of the human form in motion and at rest. His detailed analyses of the viscera and the cardiovascular and central nervous systems are something quite different.

A clue to this interest can be found in an interesting note on the earliest page of his extant anatomical notes. Dated as early as 1482 by some influential scholars and headed “Tree of vessels,” this drawing of a man standing with legs apart and arms partially outstretched looks as though it may have been drawn to help those who may wish to “let blood,” as the major arteries and veins are drawn in.¹² It also has a representation of some of the internal organs, namely the heart, liver, and kidneys. To the left side of the page is a note reminding him to “Cut through the middle of the heart, liver and lung and kidneys that you may entirely figure the tree of vessels.” These internal vital organs he refers to as “The Spiritual parts,” suggesting perhaps that their investigation linked more to philosophical enquiry than the practical.

Anatomy in the Time of Leonardo

The first records of dissection of the human body arise in Alexandria during the third century B.C. Surprisingly, from that time until the fourteenth century there is no reliable archival record of formal human dissection taking place, including in the work of Galen, whose anatomy (as pointed out earlier) was based on animal dissection.

In Leonardo’s time in the late fifteenth and early sixteenth centuries, dissection as practiced amongst physicians was largely in the form of autopsy to establish or confirm the cause of death. Interpretation of the findings was very limited by the teaching of the time, which was based upon the idea that the driving forces in the body were rooted in the relationship between the four elements of nature—earth, air, fire, and water—and the four humors of man—black bile (earth), blood (air), yellow bile (fire), and phlegm (water). The lack of equilibrium resulting from the predominance of one force over another gave rise to what Leonardo called the four dispositions of man: melancholy, choleric, sanguine, and phlegmatic.¹³ In this framework, the body was seen to be “opened” for inspection rather than to be systematically dissected. In the writings of Mundinus and Avicenna, the body was seen as three cavities: the abdomen, the thorax, and the skull. The surgeon anatomists considered the limbs separately,

with the purpose of structural repair. The first cavity to be opened would have been the abdomen because of the rapid putrefaction of the parts found therein after death. Also, for this reason, dissection tended to be exclusively a wintertime activity. Leonardo’s own commentary on dissection powerfully displays the distasteful nature of the task:

“And though you have love for such things you will perhaps be hindered by your stomach; and if that does not impede you, you will perhaps be impeded by the fear of living through the night hours in the company of quartered and flayed corpses fearful to behold. And if this does not impede you will lack the good draughtsmanship which appertains to such representation; and even if you have the skill in drawing it may not be accompanied by a knowledge of perspective; and if it were so accompanied, you may lack the methods of the geometrical demonstration and methods of calculating the forces and strength of the muscles; or perhaps you will lack patience so that you will not be diligent. Whether all these things were found in me or not, the 120 books composed by me will give their verdict yes or no. In these I have been impeded neither by avarice or negligence but only time. Farewell.”¹⁴

Several professional groups were interested in the body and its workings. At the head of the professional hierarchy were the physicians, who rated themselves on a par with the philosophers as part of the liberal arts. Thus they could not be seen to partake of manual occupations but worked within the academic boundaries of natural philosophy. Below them were the surgeons, barbers, and apothecaries, who worked at the bidding of the physician. In addition to these groups were the midwives, the empiricists, and, of course, the charlatans!

Furthermore, as practitioners of the liberal arts, architects were interested in the perspectival aspects of the human frame. Francesco de Giorgio and Alberti were influenced by the writings of the first century Roman architect, Vitruvius. His famed ten books on architecture were composed in the first century A.D. and were to architecture what Galen was to medicine. Leonardo was familiar with and significantly influenced by Vitruvius and by Alberti’s interpretation of Vitruvius. One of the manifestations of this influence was the various forms of imagery of the iconic Vitruvian man.¹⁵ For Vitruvius and his followers, the body was seen as a cultural entity. The standard layout of a church, which is based upon the head as the chancel, the extended arms as the side chapels, and the remainder of the body as the nave, can be found in di Giorgio’s manuscripts on architecture, a volume possessed by Leonardo. Leonardo’s own iconographic image of the Vitruvian man fits directly into this paradigm (Fig. 2.1).

The use of anatomical knowledge in the development of philosophical ideas about man’s place in the cosmos cannot be overstated. The question of how the human body was

¹²RL 12597 recto.

¹³RL 19037 verso.

¹⁴RL 19070 verso.

¹⁵There are numerous examples of Vitruvian forms relating man to the geometrical shapes of the square and the circle. The image by Leonardo da Vinci happens to be the most famous.

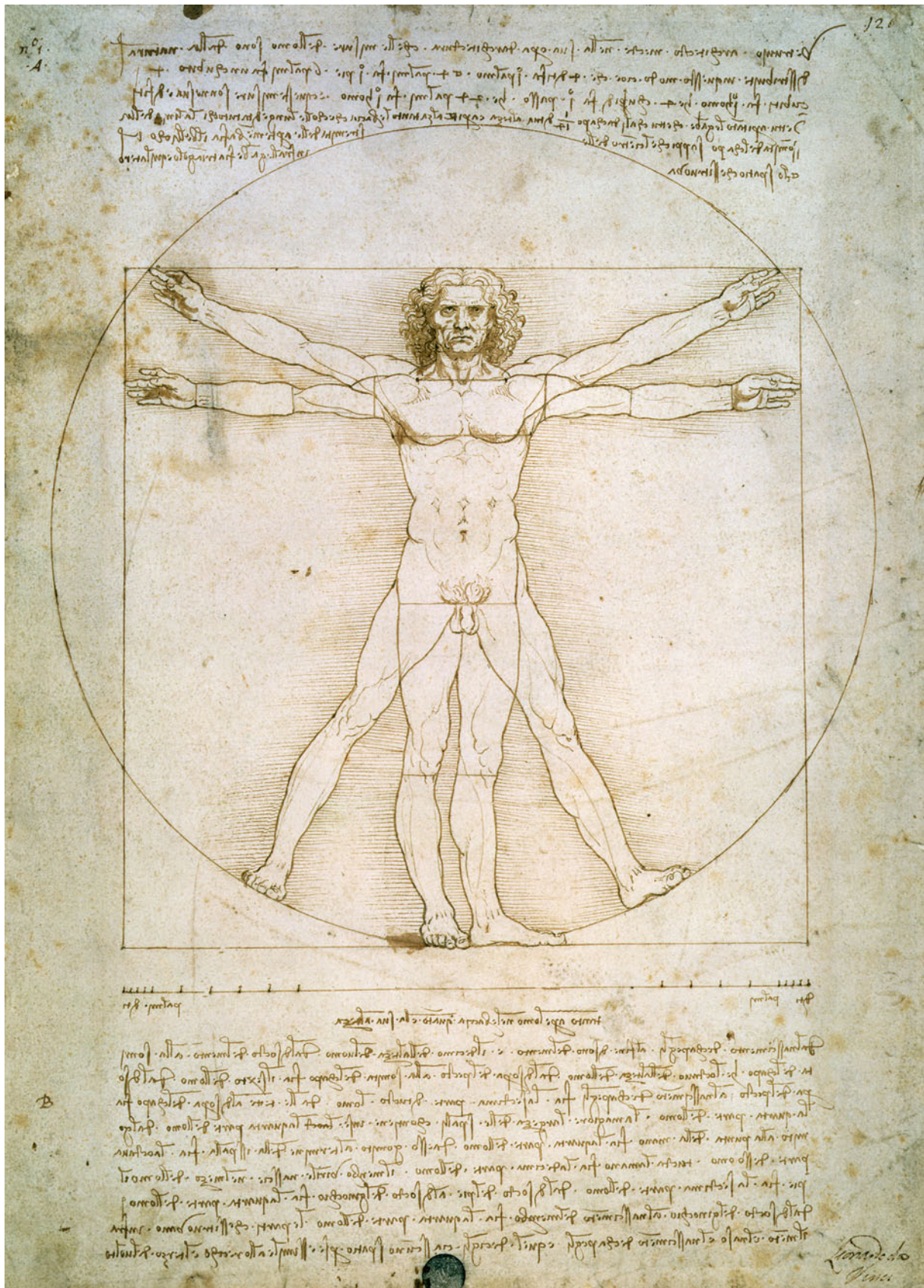


Fig. 2.1 Leonardo's Vitruvian man. BAL 4146. The Proportions of the human figure (after Vitruvius), c.1492 (pen & ink on paper), Vinci, Leonardo da (1452–1519)/Galleria dell' Accademia, Venice, Italy/The Bridgeman Art Library

made pertained as much to natural philosophy as to natural science. This positioning of anatomical knowledge within the sphere of philosophy continued to be influential upon Leonardo, as one would expect from his reading of the texts of the day. Indeed, Vesalius defines anatomical discipline in *de Fabrica* as belonging to natural philosophy.

Strict rules controlled access to human cadavers for dissection. To preserve anonymity, the unfortunate subject had to have been domiciled in an area distant from the place of dissection. He or she had to have been convicted of unpleasant crimes and not be a Catholic, but preferably of Jewish origin. The element of societal control was very important. Public dissections, which went on over several days, were highly ordered. In some cases, they were organized as the end phase of an execution. In such cases, the process was planned as two separate steps with significant ceremony. By such means was the sanctity of the human body managed and maintained.

Where Vesalius, and indeed Leonardo before him, broke with tradition was in their belief that the detailed structure of the human body should be studied for itself, independently of its relevance to the practice of medicine. Thus the study of anatomy as an independent scientific discipline began in the middle years of the sixteenth century. As a result of this new exploration of the anatomical universe of the human frame, there was an inevitable reevaluation of Galen's ideas and an improved record of observations on anatomy. This change was at first more subtle than might have been expected. In Berengario da Carpi's commentaries on the text of Mundinus,¹⁶ and also in Vesalius's *de Fabrica*,¹⁷ neither man was explicitly critical of his forebears, but utilized their experience from dissection as a means to point out differences in their developing knowledge base from that of Galen and Mundinus.

In the same period, philosophers were using anatomical insight to provide indisputable evidence of the supreme authority of the principles that inform man and nature. These questions largely revolved around the female form and the process of conception. This philosophical stance has reverberations in the words of Leonardo in his reference to the marvelous works of nature and man: "And would that it might please our creator that I were able to reveal the nature of man and his customs as I describe his figure!"¹⁸

The legitimacy of dissection in this period is often questioned. It has been suggested that the Vatican had banned dissection. Pope Bonifacio VIII issued a Papal Bull in 1299, declaring that there should be no separation of the parts of

the human body and no boiling of these separated parts. This has been taken as a prohibition of anatomical dissection, but in fact it was nothing of the kind. This Bull was declared in response to the attempts to preserve parts of the bodies of noblemen (and occasionally women) who died on the Crusades and whose relatives and friends did not want them buried in the unconsecrated ground of the Muslim homelands. The separation and boiling was to allow a degree of preservation of the tissues for repatriation of the parts for burial at home. Separation of the body into parts also allowed for several burial sites, allowing multiple opportunities for simultaneous prayer, thereby increasing the chance of the departed to pass from Purgatory and enter Heaven. In 1301, Cardinal Le Momier widened the Bull to "all desecration of the human body," including cremation, but this was nothing more than a commentary and had no legal status. An anatomist at the time of Mundinus comments that as a result of the Bull, dissection of humans should not be practiced because of the revulsion that it would cause. Nevertheless, Mundinus pressed on with his dissections just a few years later.

As Latin translations of the Arabic versions of Galenic texts became more available in the thirteenth and fourteenth centuries, factual verification of anatomical dissection was deemed necessary by the reading of the accepted texts. It was this "reading" by the Professor and the "demonstrating" of anatomy revealed by the "Prosector" that was the method of anatomical education in the time of Leonardo. This relationship is clearly depicted in "La lezione di anatomia" in the *Fasciculus Medicinae* of Johannes de' Ketham (Fig. 2.2).

Despite Berengario's words urging the anatomist to learn from his own experience, the same presentational relationship between Reader, Prosector, and Demonstrator is revealed in the frontispiece to his text *Isagoge Breves*.

It is from this teaching method that Vesalius really broke with tradition. In the frontispiece to his book *de Fabrica Humana Corporis*, he illustrates himself at the side of the corpse, personally carrying out the dissection and the demonstration of the parts. He has his quill pen and paper at his side to allow faithful recording of his findings as the dissection proceeds (Fig. 2.3). Here the paradigm has shifted very significantly: the Professor, or Reader, has become Prosector, Demonstrator, and Recorder, revealing the investigational approach to anatomy that put Vesalius apart from all of those between himself and Galen.

The principal texts of the time were the Canon of the Persian physician and philosopher Abd Allah Ibn Sina, known as Avicenna (c. 980–1037 A.D.) and, closer to home, the Italian professor of medicine, Mondino De' Luzzi (Mundinus). Leonardo was versed in both texts and had Mundinus in his personal library. He was quite familiar with at least parts of Galen's *De Usu Partium* through his later collaboration with Marcantonio della Torre. Avicenna was read and quoted widely at that time, and McMurich refers to

¹⁶A brief, early fourteenth century (1316) affirmation of Galenic traditional anatomy, flavored by the description of the dissection of two female bodies between January and March of 1315.

¹⁷This book was in many ways a commentary upon Galenic anatomy.

¹⁸Quaderni d'Anatomia I.2, recto. Royal Library Windsor.



Fig. 2.2 Johannes de' Ketham, The Dissection. ALG 178332. Illustration from *Fasciculus Medicinae* by Johannes de' Ketham (d.c.1490) 1493 (woodcut), Italian School (fifteenth century)/Biblioteca Civica, Padua, Italy/Alinari/The Bridgeman Art Library



Fig. 2.3 Frontispiece of *de Fabrica*. CH 466697. Frontispiece to *De Humani Corporis Fabrica Libri Septem* by Andreas Vesalius (1514–64), published by Johannes Oporinus, Basel, June 1543 (colour woodcut)

(see also 233019), Venetian School, (sixteenth century)/Private Collection/Photo © Christie's Images/The Bridgeman Art Library

this and other Arab contributions as the “keepers of the ‘Light’ through the dark ages.”¹⁹

That Leonardo was aware of the contents of Mundinus is clear, as he quotes from him in his notes. Leonardo broke new ground by being prosector, demonstrator, and recorder all in one person well in advance of Vesalius by conducting his own dissections and recording his observations, flavoured with his own interpretation. Both Leonardo and Vesalius recorded the sorts of instruments they used (Fig. 2.4). It is possible that later (1510–1512), Leonardo also recorded dissections carried out by Marcantonio della Torre, the young and brilliant professor of anatomy at Pavia University, and his students.

Anatomy for the Artist

The emergence of neoclassicism and humanism in the fifteenth century defined artistic direction in the Italian Renaissance. Bernard Berenson likened it to a human reawakening of the sense of personality, resulting in a boundless curiosity about all natural things.²⁰ The whole idea of art imitating nature was built upon the Greco-Roman tradition as exemplified in Pliny’s *Natural History*. Pliny described with admiration the massive leap forward made by sculptors and painters of that period. The power and grace of the human form hewn from marble and stone as seen in the newly excavated antiquities of Rome made a huge impression on the artists of the quattrocento. Unlike today, however, the antique (admirable as it was) was not seen necessarily as the ultimate in form, but rather as a starting point for betterment. In other words, the style and technique could be studied and copied to perfection, but then it was the challenge for the artist to take this realism to the ultimate. For this reason, Leonardo recommended that the student first draw from the antique before moving on to study nature. In short, says Berenson, “It (the renaissance) looked upon the antique as a short cut to knowledge.”²¹

For the artist to achieve the goal of absolute realism, it was perceived that an extensive general education would be necessary. Ghiberti suggested that the artist should be conversant with grammar, geometry, philosophy, medicine, astrology, optics, history, anatomy and arithmetic, as well as being an accomplished draughtsman.²²

The pursuit of ever more tangibly natural forms in commissioned works of art demanded the study of nature in depth. This development necessitated the use of human and animal

dissection, so it is not surprising to discover that commentators upon the Florentine studio curriculum of the fifteenth century often described this activity. The studios of the Pollaiuolo brothers and Andrea del Verrochio were known to have undertaken these activities. Vasari recalls the importance of anatomical knowledge to Raphael and Michelangelo as well as to Leonardo. It is known that Michelangelo was interested in anatomy and worked with the great anatomist Colombo in the mid 1500s,²³ but there is no record of his becoming interested in much other than the musculoskeletal system. Vasari speaks only of Leonardo as an “anatomist” who made great contributions to the fund of knowledge in this subject. He wrote, “Because of Leonardo we have a deeper knowledge of human anatomy and the anatomy of the horse” and he continued, saying that Leonardo’s fame would never be extinguished, “though this will rather be by word than by deed!” Thus he acknowledged Leonardo’s infuriating tendency not to finish things but also confirmed the massive legacy of his notebooks and manuscripts.²⁴

The frequency of dissection is more conjectural. It is known that studios possessed casts of human torsos and limbs, which would have been used on a regular basis. Indeed, Leonardo lists an inventory of artistic “blueprints,” amongst which there were likely such casts.²⁵

Leonardo’s Anatomical Work

The exact dating of all of Leonardo’s anatomical studies remains to be completed, but much of it is known with some certainty. From the extant record, it appears that there were periods of quite intense activity separated by periods of indus-

¹⁹J. Playfair McMurrich, *Leonardo da Vinci, the Anatomist*. (Baltimore, Williams & Wilkins [published for the Carnegie Institution of Washington], 1930), 8.

²⁰Hanna Kiel, ed., *The Bernard Berenson Treasury*. (New York, Simon and Schuster, 1962), 75–7.

²¹*Ibid.*, 64.

²²Martin Kemp, *The Marvellous Works of Nature and Man*. (Oxford: Oxford University Press, 2006), 18.

²³Colombo had been a surgeon in Padua before taking up the post of “Master of Anatomy and Surgery” in Pisa in 1544. He had been invited there by the Duke Cosimo. Colombo went to Rome to teach at the papal university, the Sapienza, initially in 1547 and permanently 1 year later. In a 1548 letter to Cosimo, he stated that his reason for leaving was “to pursue my dissections and supervise the painters.” He also referred to his intended collaboration with “the greatest painter in the world” (Michelangelo) on a proposed book of anatomy. As with Leonardo, however, the planned treatise on anatomy did not materialize. Colombo did produce *De re anatomica Libri XV*, which was published a few months after his death in 1559. Its sole illustration is the frontispiece, which features the presence of Michelangelo at the dissection table. There are further hints that Michelangelo’s involvement in anatomy was significant. Passarotti’s *Michelangelo Conducting an Anatomy Lesson* illustrates an array of artists gathered around the master. Included in the picture are Andrea del Sarto, sitting on a stool to the left of Michelangelo; Sebastien del Piombo, at his right; and Baccio Bandinelli, with his back to the viewer. Raphael is to be found facing forward, supporting the hand of the flayed corpse. The Accademia del Disegno in Florence, of which Michelangelo had been nominal head, recognized his knowledge of anatomy as a major contributing factor to the perfection of his art.

²⁴Vasari, Giorgio. *Lives of the Artists*. Volumes I & II. London: Penguin Classics, 1987.

²⁵Kemp, *Marvellous Works*, 17.

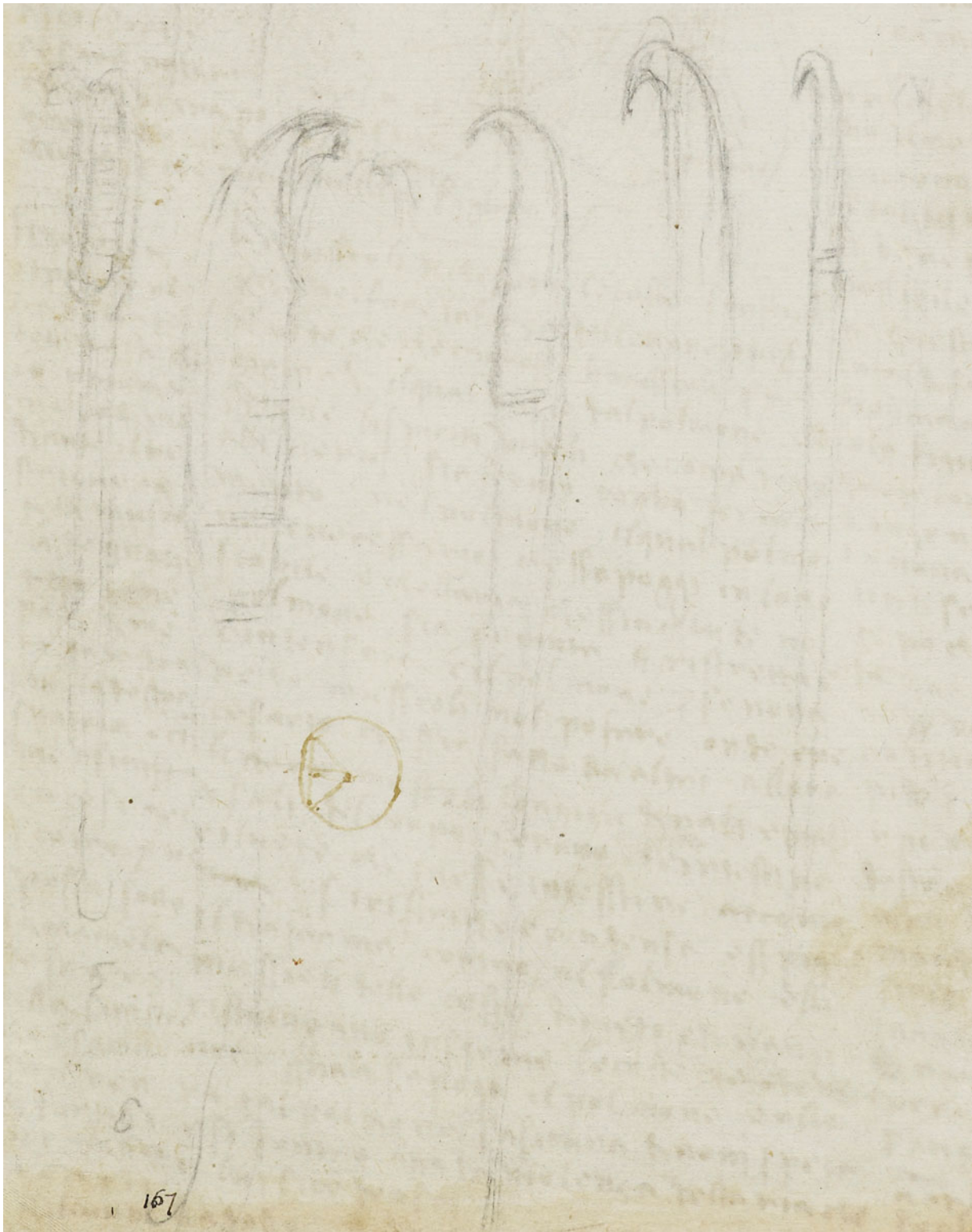
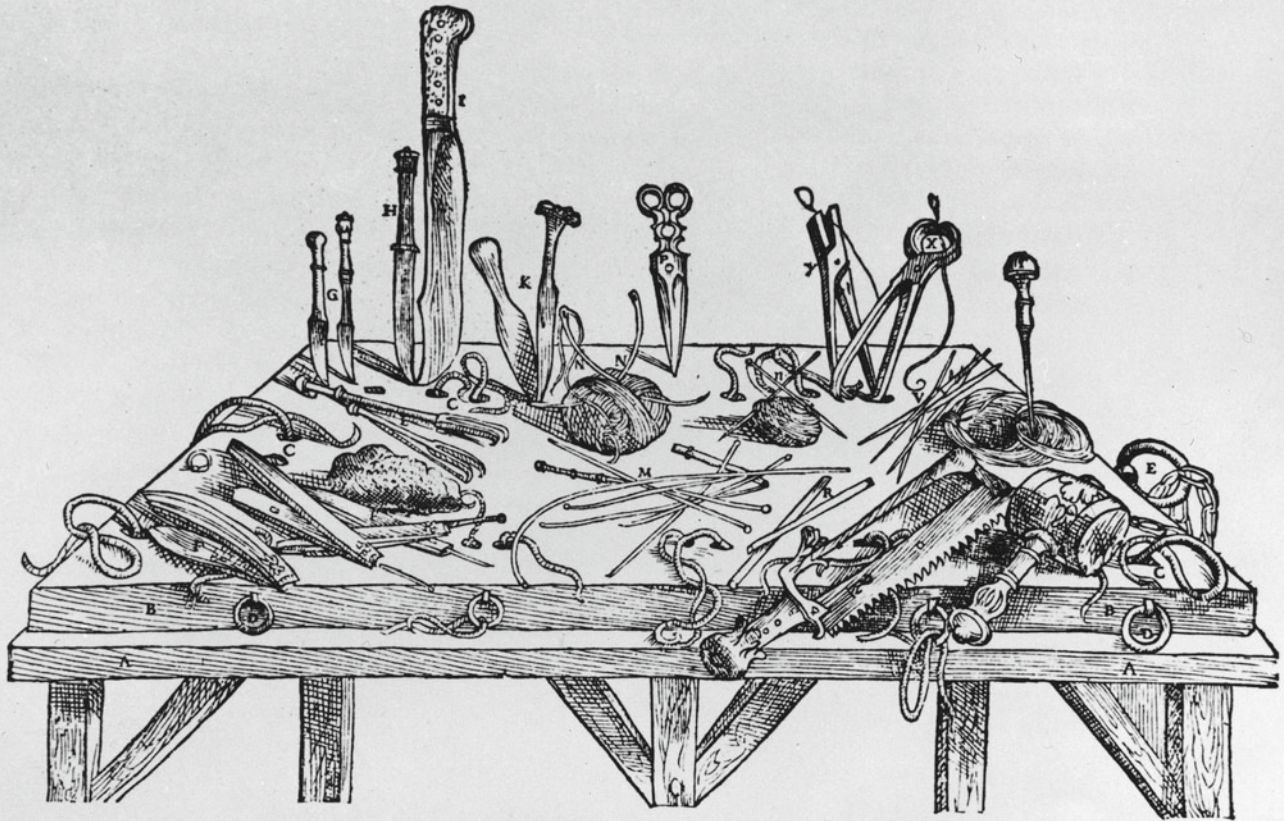


Fig. 2.4 (a) Sketches of the intestines, scalpels, and hooks for dissection, and notes. Detail from RL 19070 recto, Leonardo da Vinci, c.1508–10. Pen and ink and black chalk (Lent by Her Majesty The Queen. Royal Collection © Her Majesty Queen Elizabeth II). (b)

Vesalius's dissecting table with instruments displayed. FAB 45935. Illustration from *De Humani Corporis Fabrica* (b/w print), Andreas Vesalius (1514–64)/Fratelli Fabbri, Milan, Italy/The Bridgeman Art Library

DE HVMANI CORPORIS FABRICA LIBER II. 257
 DE INSTRVMENTIS, QVÆ SECTIONI-
 bus administrandis parari possunt. Caput VII.

ANATOMICORVM INSTRVMEN-
 TORVM DELINEATIO.



CHARACTERVM SEPTIMI CAPITIS FIGVRÆ INDEX.

PRÆSENTI figura mensæ cuidam incumbentem finximus asserem, quo in ut
 uorum sectionibus opportunè utimur, dein huic asseri omnia propemodum accōmodauimus, qui-
 bus in dissectionum administrationibus, adeoq; tota Anatome quis posset uti. Quo autem singu-
 la leuiori opera assequaris, huic etiam figuræ characteres, ac demum eorum indicem adhibere
 non grauatsum. Indicetur itaq;

- A, A* Mensa, cui reliqua omnia modo' seriatim indicanda supersternuntur.
B, B Asser uiuis sectionibus administrandis idoneus.
C, C Varia foramina, quibus laqueos pro animalis mole adhibemus, quū femora et brachia uincimus.
D, D Eiusmodi anuli, summis manibus pedibusq; ligandis adaptantur.
E Huic anulo maxilla superior, libera inferiori, catenula alligatur, ut caput immotum seruetur,
 ac interim neq; uox, neq; respiratio uinculorum occasione præpediantur.
F, F Diuersa nouacularum genera, quibus spongia accumbit.
G Cultelli ad earum speciem formati, quibus calami adaptantur.

Fig. 2.4 (continued)

try in other very disparate disciplines. How much of this is real and how much may be an impression created by the loss of material is impossible to know. It seems that the remaining notes can be divided into three fairly distinct periods. The relevance of the consideration of the anatomical studies in chronological episodes is that it allows emphasis upon Leonardo's intellectual and artistic development within this subspecialty of his work. Despite the clear influence of Hippocratic and Galenic thought on the functional aspects of the "soft or *spiritual* parts" throughout most of his work, there is an intensity of original observation and representation allied to exquisite dissection that is obvious from the first drawings of the skull. The wonderful realizations of the upper and lower limb muscles, bones, and joints and the superlative renderings of the complexities of the heart and other viscera attest to his independence of mind in observation of the true structure and relationship of the parts. It is in the later stages that his own interpretations of bodily function come to the fore.

The first period, from the early 1480's to 1495 in Milan, includes a very primitive and Galenic rendering of the circulation seen a drawing from about 1482,²⁶ and the Hippocratic notion of procreation is seen in Windsor 19097v, where the semen is depicted as being derived in a very fanciful way from the spinal cord. Also from this period is the wholly believable modern interpretation of the bony structure of the skull in drawings from 1489. How much knowledge gleaned from dissection was available to him at that time we do not know, but on the page of the "procreation" drawing, the penis is shown as having two channels, both of which appear to open into the urethral meatus, which is manifestly untrue. The second channel may be the dorsal vein of the penis, which Leonardo misconstrued.

The originality of the skull drawings of 1489 is so fundamentally different and superior to all other extant illustrations of the time that they are completely out of character with the age (Fig. 2.5). The lines of incision in the skull probably represent drawing summaries of the information gained from a series of dissections. They reveal the air spaces (the sinuses) and the complexities of the internal surface of the base of the skull that were not matched for centuries to come. They stand as completed demonstrations of virtuosity in artistic skill and insightful basic scientific questioning, yet they were produced within the early period. Within them are geometric lines placed in search of the *sensus communis*, a very Galenic idea of human function.

The second period of his anatomical record was created following his return to Milan from Florence, between 1506 and 1509. Whilst being grouped together by previous historians, this is a somewhat fragmentary period of Leonardo's life, with significant travelling between households in Milan and

Florence. It is probably during this period, whilst in Florence during the winter of 1507–1508 that he carefully documented a dissection that he carried out in the Santa Maria Novella. Leonardo had returned to Florence from Milan in an attempt to resolve the prolonged dispute between him and his brothers over his father's estate. Carmen Bambach dates this episode as 12 months later, in the winter of 1508.²⁷ According to Clark, however, quite accurate dating may be possible²⁸ because an outline of the passage to be found on the reverse side of the manuscript sheet describing the changes in the mesenteric arteries and veins in old age is also found on ff. 1, recto of Paris MS F,²⁹ and that is dated 12 September 1508.

Here, Leonardo describes his observation and conversation with an old man who died peacefully, claiming to have reached 100 years of age:

And this man, a few hours before his death, told me that he had passed one hundred years, and that he was conscious of no failure of body, except feebleness. And thus sitting upon a bed in the hospital of Santa Maria Nuovo at Florence, without any untoward movement or sign, he passed from this life.

And I made an anatomy to see the cause of a death so sweet, which I found to proceed from debility through lack of blood and deficiency of the artery which nourishes the heart and the lower members.³⁰

This very remarkable passage of writing reveals several things. First, it confirms that Leonardo undertook at least one human dissection. Second, it epitomizes his unceasingly enquiring mind; and third, it once again reveals his considerable powers of observation. This human autopsy report contains a description that constitutes the first report of the disease arteriosclerosis (hardening of the arteries). It also documents the intellectual progress that Leonardo is making from a purely didactic "Galenist" to a free-thinking academic. Information gleaned from the autopsy on the centenarian can be seen to inform much of his subsequent work.

This episode then marks the one definite human dissection by Leonardo. He variously claims to have dissected "more than ten human bodies...repeated twice over"³¹ including the young and the old! As described earlier, Antonio de Beatis in his diary reported that Leonardo described dissecting more than 30 bodies in his lifetime when the Cardinal of Aragon visited him in Amboise in October 1517.

²⁷Carmen C. Bambach, *Leonardo da Vinci, Master Draftsman* (New York Metropolitan Museum of Art Series). (New Haven: Yale University Press, 2003), 236.

²⁸Kenneth Clark, *The Drawings of Leonardo da Vinci in the Collection of Her Majesty the Queen at Windsor Castle*. (Vol. 3, Anatomical Drawings, Edition 2). (London: Phaidon, 1969), 13.

²⁹Paris Manuscript F folio 1.

³⁰RL 19027 verso.

³¹RL 19076 verso.

²⁶RL 12597 recto.

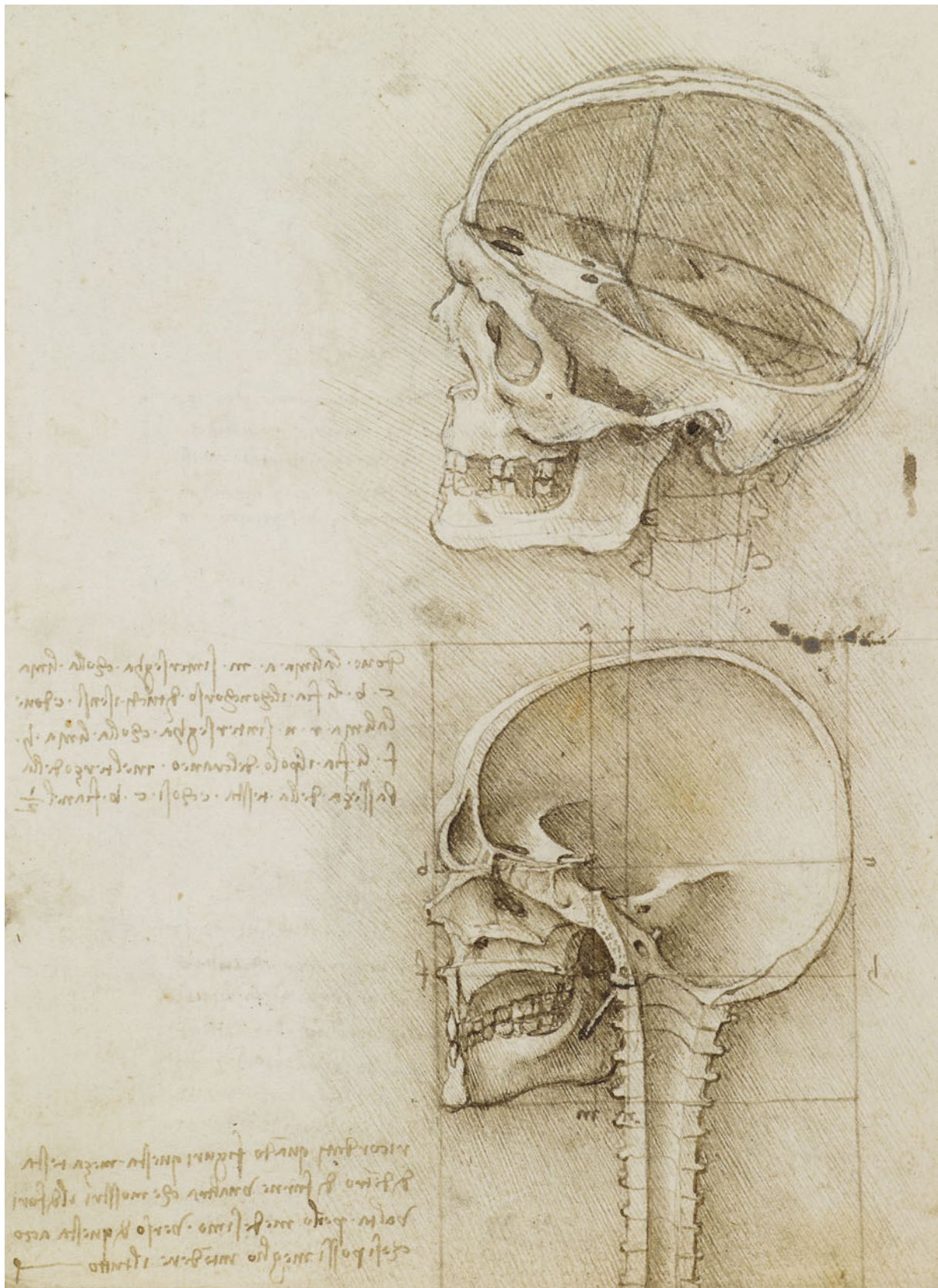


Fig. 2.5 Skull drawings carried out early in Leonardo's career. RL 19057 recto, The skull sectioned. Leonardo da Vinci., c. 1489. Pen and ink over black chalk (Lent by Her Majesty The Queen.Royal Collection © Her Majesty Queen Elizabeth II)

Places in which Leonardo probably either took part in or witnessed dissection were Santa Croce and Santa Maria Novella in Florence, where he may have participated in public demonstrations of anatomy; the University of Pavia, working alongside Marcantonio della Torre; and later, Santa Spirito in Rome, where he probably performed his last dissections, including his work on the heart. There is no record of this activity after Leonardo traveled to France at the invitation of King Francis I in 1516.

The instruments used for dissection were probably taken from surgical sets as well as being made up by the anatomist's assistants. One of Leonardo's last anatomical notes begins, "Definitions of the instruments." Under this heading, he writes a page of notes on the mechanical functions of the instruments. On the other side of the manuscript sheet on which he described the unpleasant nature of dissection and the skills that were involved, he made a sketch of some of the dissecting instruments that he used (Fig. 2.4a).

In the beginning of the third period, from 1510 to early 1513, Leonardo was in Milan. During this time he is thought to have been working with Marcantonio della Torre in Pavia. This potentially important liaison was short-lived, as Marcantonio died of the plague in 1511.

In 1513, the Swiss Guard invaded Milan. For a time, Leonardo boarded with the family of his long-term pupil, Francesco Melzi, in Vapprio d'Adda; he then moved to Rome at the invitation of Giuliano de' Medici, the brother of the Medici Pope.

The heart work was done during the period 1513–1516, covering the late Milanese period to the end of his stay in Rome. Many of the drawings of dissections of the ox heart seem to have been done during his stay in Vapprio, which is logical, as the displacement from his apartments in Milan and the dislocation of his engagement with the Sforza family during these troubled times would probably make it difficult for him to carry on a normal working life. Ox hearts would be easily accessible and allow Leonardo to continue some meaningful work whilst in domestic transition.

Within this period falls the production of his famous rendering of the female body, referred to by some as *The Great Lady* (Fig. 2.6). Close inspection of this drawing reveals an amalgam of observations and ideas. There appears to be ox anatomy, human foetal anatomy, and some adult human anatomy all blended together, giving evidence of the continuing Galenic influence of the cross-referencing of animal anatomy to the human. This drawing was probably produced for some type of formal use, as all of the major lines are pricked through for transfer of the image by the technique of "pouncing."³²

³²"Pouncing" is a technique whereby the drawing is dabbed with a muslin or other such cloth filled with carbon or silver dust, which passes through the holes and leaves behind an outline of the "traced" image.

In his last period of anatomy, during his stay in Rome, Leonardo produced his extraordinary work on the heart and other viscera. Although there are examples of work on the respiratory system in earlier years, some of the most impressive work, in which he discovered the bronchial arteries and correctly defined their function in supplying the bronchi rather than the lung parenchyma, was done in 1513.³³ On this page, he also described the nature of the supporting cartilages in the major airways.³⁴ He also produced extraordinary work on the muscle of the diaphragm and the intercostal muscles in the same period.³⁵ In addition he also records detailed work on the larynx, tongue, and palate.³⁶

Once Leonardo had left Rome (under what seems to have been difficult circumstances), the extant record and evidence of further anatomy ends. One wonders whether Leonardo may have worked on producing his anatomical treatise whilst the guest of Francis I in Amboise. He certainly had many or all of the manuscripts with him, as recorded by Antonio de Beatis, the secretary to Cardinal Louis of Aragon. By this time, Leonardo was partially paralysed by stroke and close to the end of his life.

The Intellectual Process

It is important to realize that Renaissance academic endeavor did not closely correspond to the methods of the natural sciences of today. Rhetoric and Aristotelian logic were the language of the academics of the day and may be reflected in Leonardo's analytical approach. Some authors have gone further and claim that they find unequivocal evidence of the use of the Renaissance analytical process, the "regressus demonstrativus" or "demonstrative regress." This rhetorical analysis utilizes an inference drawn from an observed effect to its proximate (closest, before or after) cause, which is then combined with a further inference about the proximate cause and the observed effect.³⁷ This analytical method is discussed by Aristotle in *Posterior Analytics*, in which he contrasts two sorts of syllogisms. He gives this example: "Heavenly bodies that are near the earth do not twinkle; the planets are near the earth; hence the planets do not twinkle." In this syllogism, the observed effect is "not twinkling" and the subject is "the planets." The middle term is being "near the earth," which is the proximate cause of the observed

³³Kenneth Clark catalogue of Windsor drawings. (RL 19071 recto).

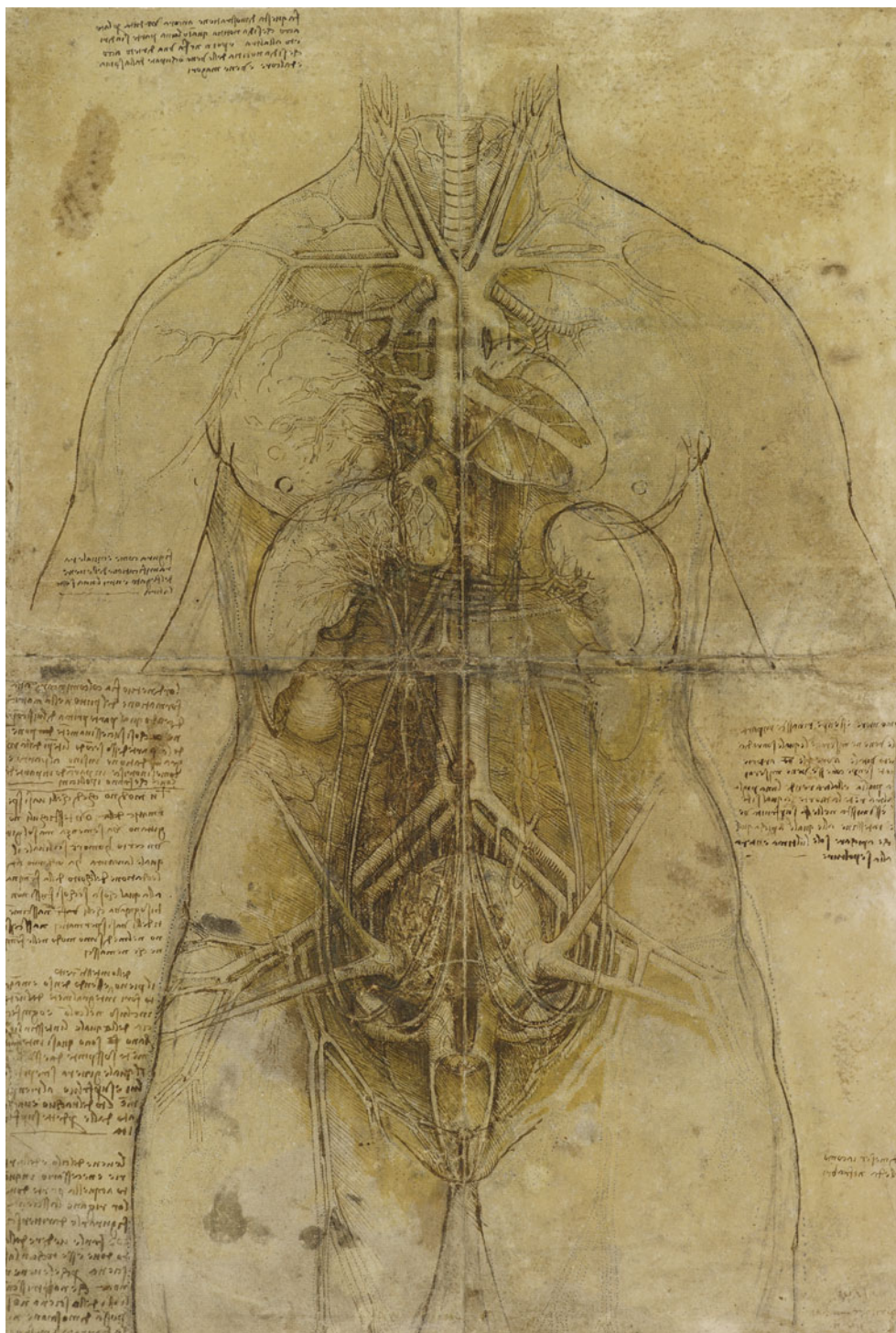
³⁴Ibid. RL 19072 recto.

³⁵Ibid. RL 19108 verso and RL 19109 recto.

³⁶Ibid. RL 19002 recto.

³⁷Zwijenberg, Robert. *The writings and drawings of Leonardo da Vinci. Order and chaos in early modern thought*. (Cambridge: Cambridge University Press, 1999), 151.

Fig. 2.6 Leonardo's composite drawing of the anatomy of a woman, showing the cardiovascular system and principal organs. RL 12281 recto, Leonardo da Vinci, c.1509–10. Black and red chalk, ink, yellow wash, finely pricked through (Lent by Her Majesty The Queen. Royal Collection © Her Majesty Queen Elizabeth II)



effect. By rearranging the terms, a demonstration of the fact is obtained in which the middle term expresses the effect rather than the cause. Thus, heavenly bodies that do not twinkle are near the earth; the planets do not twinkle; hence the planets are near the earth. When we come to discuss Leonardo's groundbreaking description of the true mechanism of aortic valve closure, this method will become evident to some extent.

Whilst there are signs of the use of these methods in Leonardo's workings on paper, he was clearly most comfortable with his observations of the interaction of proximate cause and effect in the natural world around him. These natural phenomena he adopted as his gold standard. The teleological approach used by Leonardo in his analysis is best seen in his description of the function of the aortic valve. In writing about the flow of blood through the atria and

ventricles of the heart, he wrote, "Nothing is superfluous and nothing is lacking in any species of animal or product of nature unless the defect comes from the means which produce it"³⁸; and again, "Although human ingenuity makes various inventions, corresponding by means of various machines to the same end, it will never discover any inventions more beautiful, more appropriate or more direct than nature because in her inventions nothing is lacking and nothing is superfluous."³⁹

Leonardo based much of his deductive reasoning on this belief that all structural forms were forged by the forces acting upon the structure in question. To him, it was therefore perfectly legitimate to describe the function of something by studying and understanding its form and the forces that shaped it. This argument was by no means new. It was described at length by Aristotle, whose work Leonardo studied, having translations of his writings in his personal library.

Leonardo's Book of Anatomy

This, my illustration of the human body shall be demonstrated to you, not otherwise than if you had a real man before you.⁴⁰

The Achilles heel for posthumous recognition in all of Leonardo's endeavors was the lack of any publication of his work during or after his lifetime. Leonardo clearly stated his intention to produce a book on anatomy, and indeed refers to the "many books produced by me." The books that he describes must surely reflect his copious manuscript notes, many of which remain available to us. It is possible that more substantive publications did exist, but their existence is very unlikely, as there is no corroborative evidence.

Leonardo's extensive use of notebooks and manuscripts probably arose from his experiences in the workshop of Verrochio. The use of the "common-place book" peaked in the Renaissance. This was a book where passages were collected and often indexed and themed. Tania Kovats described them thus in her opening remarks on a contemporary book on drawing: "They [the common-place books] sanctioned the selection of passages made significant by personal experience; they were personal anthologies, a forest of thinking governed by the objective selection of the compiler and as such represent to some extent what that individual's memory might look like."⁴¹

Leonardo set out his ambition for his book on anatomy on two separate occasions. On the first occasion, in 1489, he sounds more like the artist and anatomist rather than a scientist. He writes of portraying the conception and birth of a child and continues with descriptions of physiognomy and the emotional states that he wishes to represent. He relates the function of the eye to that of understanding perspective, and the ear to the hearing of music.⁴² Twenty years later, he again sets out his aspirations for his book on anatomy and begins with these words: "This my depiction of the human body will be shown to you just as though you had a real man before you. The reason is that if you wish to know thoroughly the parts of an anatomized man, you must either turn him or your eye so as to examine him from different aspects, from below, from above and from the sides, turning the subject around and investigating the origin of each member and in this way you will satisfy yourself as to your knowledge of the actual anatomy."⁴³

This description is more revealing of his intended objectives. He writes with the demanding eye of the artist, aspiring to achieve a true and lifelike representation of the human body. Schematic representations will not do. He states that because the process of dissection destroys some parts in the process of revealing others, at least 12 dissections are necessary to appreciate the human form: three for the veins and arteries; three for the ligaments, muscles, and cords; three for the bones and cartilages; and three for the membranes. In addition, he states that another three dissections of a woman are necessary to understand the mystery of the uterus and its foetus. His thorough approach is further underscored by his anger at those who try to take shortcuts to knowledge, and he rails at "abbreviators" of knowledge of any kind. He states that there can be no shortcut to a true appreciation and an understanding of the "marvel of artifice"⁴⁴ which is the human body: "The abbreviators of works do injury to knowledge and to love, for love of anything is the offspring of knowledge, love being more fervent in proportion as knowledge is more certain, and this certainty springs from a thorough knowledge of all those parts, which united, compose the whole.... Truly it is impatience, mother of folly, who praises brevity."⁴⁵

The three views that Leonardo speaks of refer to his architectural discipline, but as he progressed through the more complex anatomical forms he realized that these would not be enough and increased the number to six. Indeed, in his representation of the arm he employs an almost cinematographic approach. Superimposition of the drawings into a "flick book" format would almost produce the effect of the

³⁸RL 19063 verso.

³⁹RL 19115 recto.

⁴⁰RL 19009 recto.

⁴¹Tania Kovats, ed. *The Drawing Book: A Survey of Drawing: The Primary Means of Expression*. (London: Black Dog Publishing, 2007).

⁴²RL 19037 verso.

⁴³RL 19061 recto (1509–13).

⁴⁴Kemp, *The Marvellous Works*, 279.

⁴⁵RL 19084 recto.

viewer moving around the arm, or the arm rotating in front of the viewer. Leonardo refers to this effect in this passage: “If you wish to understand all the parts of an anatomised man, you turn him or your eye through all of the various positions...turning him around and searching for the origins of each member.”⁴⁶

Hence it can be seen that Leonardo’s plans were quite revolutionary when compared with what was available at the time and indeed with what was to later be heralded as the most important contribution to anatomical knowledge and study, namely *De Fabrica de Humana Corporis* by Vesalius. However, the very exhaustive scope of the proposed book almost certainly precluded the possibility of its ever being accomplished. He wrote in 1508:

Begin at Florence in the house of Piero di Braccio Martelli on the 22nd day of March 1508. This makes a collection without order, taken from many sheets which I have here copied hoping to arrange them later, each in its place according to the matter of which they treat. I believe that before I make an end to this I shall have to repeat the same things many times, for which O reader, do not blame me, for the subjects are many and the memory cannot retain them, and say, “This I do not need to write because I have written it before.” If I wished to avoid falling into this error, it would be necessary in every instance when I desired to copy, that I should read over all that had gone before so as not to repeat myself, and especially so since the intervals of time between one writing and the next are long!⁴⁷

Thus we find that an order of work is frequently lacking in Leonardo’s manuscripts and notebooks. That they were used as a paper laboratory of thought soon becomes very clear. Leonardo worked and reworked ideas incessantly and frequently over many years. Entries can be found on sheets years apart. How he kept track of it all, if he ever did, is a mystery. Perhaps this fact alone suggests that there was more order to it than we can now comprehend, with the separation and loss of material that is so evident. In codex Leicester he wrote, “I will not consider the demonstration here because I will reserve them for the ordered work; my concern now is to find cases and inventions, gathering them as they occur to me; then I shall have them in order, placing those of the same kind together; therefore you will not wonder or laugh at me, Reader, if here I make such great jumps from one subject to the other.”

One can find a note of optimism from Leonardo in his late anatomical studies. About 1507–1509, he wrote, “Have your books on anatomy bound,”⁴⁸ and later, “This winter of 1510 I believe that I will expedite all this anatomy.”⁴⁹ Sadly, we have no evidence that this optimism came to fruition. There is no magnum opus from him by which to place him in the

history of anatomy. The manuscripts and notebooks that we do have, however, reveal a giant intellect, not in any way daunted by the scale of the problems that presented to him but ready to tackle any and all keenly observed structures and phenomena with vigorous interrogation and abundant lateral thought. For that alone, his notes and deductions bear intense scrutiny through the scientific eyes of today.

Leonardo’s Writing

It is easy to focus on the beauty of Leonardo’s drawings, but it is also worth studying his writing style with care. He writes directly and often with beautiful simplicity but also uses imagery and metaphor quite frequently. Irma Richter wrote, “It was not only the beauty of nature but also the spirit at work beneath the world of appearance that fascinated him.” This passion for the representation of the truth of the beauty of nature can be heard in this passage on the formation of the child in the womb as the most perfect triumph of nature, something that manual human construction can never achieve:

Though human ingenuity may make various inventions answering by different machines to the same end, it will never devise an invention more beautiful, more simple, more direct than does Nature; because in her inventions nothing is lacking and nothing is superfluous. She needs no counterpoise when she creates limbs fitted for movement in the bodies of animals, but puts within them the soul of the body which forms them, that is the soul of the mother which first constructs within the womb the shape of man, and in due time awakens the soul that is to be its inhabitant.⁵⁰

His use of metaphor, which translates well into today’s world of medicine and surgery, in which new technologies are often introduced before being properly assessed, is beautifully shown in this fable about the butterfly:

The vain and wandering butterfly, not content with being able to fly at its ease through the air, overcome by the tempting flame of the candle, decided to fly into it; but its sportive impulse was the cause of a sudden fall, for its delicate wings were burnt in the flame. And the hapless butterfly having dropped, all scorched, at the foot of the candlestick, after much lamentation and repentance, dried tears from its swimming eyes, and raising its face exclaimed: O false light! How many must thou have miserably deceived in the past, like me; or if I must indeed see light so near, ought I not to have known the sun from the false glare of dirty tallow?⁵¹

Much of Leonardo’s notes is written with his left hand from right to left and in mirror image. Many reviewers in the past have thought that this was a device to protect the secrecy of his notes, but it is most likely that it was his natural way of writing. Recent study of left-handed people has shown that

⁴⁶RL 19016 recto.

⁴⁷Codex Arundel. B.M. 1r.

⁴⁸RL 19070 verso.

⁴⁹Ibid.

⁵⁰RL 19115 recto.

⁵¹C.A. 67r.

as many as 10 % may be able to write naturally in mirror image. Of course it may have suited him to conceal his thoughts from time to time, but there is no evidence that this was a strategy he adopted. There are sheets where he writes from left to right in a fully legible way. Some of these sheets are clearly for demonstration purposes.

Conclusions

We will probably never know in detail the reasons behind Leonardo's almost lifelong fascination with the structure of the human body. There seems no doubt that it was in the pursuit of the truth about its structure from the point of view of a natural philosopher and not as part of an explanatory process for use in medicine. His opinion of the medical profession can be felt in this passage: "Endeavor to preserve thy health in which thou wilt succeed the better the more thou guardest thyself from the physicians. For

their mixtures are a kind of alchemy on which there are no fewer books than there are remedies."⁵²

I will leave the last words on this topic to Martin Kemp and Leonardo himself. Kemp writes "To his already extensive range of studies in the late 1480s he added in 1489 his project for a treatise 'On the Human Body'. This was to be not so much an anatomical book as a far-reaching exposition of man's role in the natural order of things."⁵³

Leonardo wrote, "The Human race in its marvelous and varied works seems to reveal itself as a second nature in this world."⁵⁴

⁵²Part of a paraphrase from *Regimen Sanitatis* of Arnold of Villanova or one of the numerous modifications of that work, such as the tract of Ugo Benzo, Milan, 1481.

⁵³Kemp, *The Marvellous Works*, 106.

⁵⁴*B.L.* 151v.

The Heart of Leonardo

Foreword by HRH Prince Charles, The Prince of Wales
Wells, F.

2013, XXII, 256 p. 145 illus., 144 illus. in color.,

Hardcover

ISBN: 978-1-4471-4530-1