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GENERAL ASPECTS OF HISTORY AND PHILOSOPHY OF MEDICINE

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## The evolution of Vesalius's perspective on Galen's anatomy

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Early in his career, Vesalius had been trained as an orthodox Galenist, but gradually departed from traditional Galenic thought over the course of his medical training and academic career. Seeking to critically examine Galen's works, Vesalius initially turned to human dissection as a means of verification. In 1538, Vesalius published "Tabulæ Anatomicæ Sex", which continued several of Galen's mistakes. However, Vesalius recognized inconsistencies and errors with Galen's anatomy, particularly in the area of osteology, and realized that Galen was not infallible. At least as early as 1540, Vesalius was cognizant of many errors of Galenic human anatomy, and certainly by the time of the "De humani corporis fabrica" (1543) was convinced that Galen's errors were largely due to reliance on the dissections of animals. While demonstrating some of the errors of Galen's anatomy and thus undermining the misguided notion of Galen's infallibility, Vesalius only partially recognized the many errors introduced by applying animal anatomy to humans. He continued other errors by continuing to rely on Galenic physiology. Nevertheless, he highlighted the importance of observational studies based on dissection, which Galen had earlier championed. In so doing, Vesalius became a neo-Galenist in the sense that he epitomized Galen's practice of anatomy as an observational science, even when he derided the errors Galen had made by extrapolating animal anatomy to humans. More important than Vesalius's recognition (or lack of recognition) of any particular errors in the Galenic-Arabic canon was the impetus that Vesalius gave to shifting anatomy back from stagnant scholasticism to a vibrant observational science, and one finally focused on human dissections and comparative anatomy, rather than one based on animal dissections alone, or simply on scholastic studies of ancient texts.

**Keywords:** *anatomical illustration, anatomy, history of medicine, dissection, medieval, Renaissance, Galen, Vesalius*

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### Galen's anatomy in Medieval Europe

Galen of Pergamon (c. 130–c. 200) was the preeminent physician of the Roman Empire in the 2<sup>nd</sup> century, and arguably the most accomplished and prolific medical researcher of antiquity. His medical teachings, particularly concerning anatomy and physiology, dominated Western medical science for more than 1,300 years. However, because human dissection was not allowed in pagan Rome, Galen's anatomical works, ostensibly about human anatomy, were primarily based on dissections of monkeys, pigs, and oxen, along with the limited knowledge he could glean from treating the wounds of gladiators. Nevertheless, unaware of Galen's mistakes, physicians and the church took Galen's conception of human anatomy as dogma.

Because Galen's works were written in Greek, and because of the collapse of the Roman Empire in the West, the study of Galen declined in Western Europe during the Early Middle Ages, when very few Latin scholars could read Greek. Nevertheless, Galen continued to be studied in

the Eastern Roman (Byzantine) Empire, where Galen's extant Greek manuscripts were copied by Byzantine scholars. In the Abbasid historical period (Islamic Golden Age, after 750 CE), some of Galen's texts were translated into Arabic by Syrian Christian scholars. Some Arabic writers, such as Rhazes (Abū Bakr Muhammad ibn Zakariya ar-Rāzi; 854–925), considered Galen to be an important but not infallible source, and criticized some of Galen's conclusions [1]. In the 11th century, Latin translations of Islamic medical texts began to appear in the West and, from that time, Galenism took on a new, unquestioned authority. Galen's works on anatomy and medicine in Latin translation became the mainstay of the medieval physician's university curriculum, alongside Avicenna's (Ibn-Sīnā, full name Abū Alī al-Husayn ibn Abd Allāh ibn Al-Hasan ibn Ali ibn Sīnā; 980–1037) encyclopedic exposition of Galenic medicine, and The Canon of Medicine (1025). The fall of the Byzantine Empire (1453) was accompanied by an influx of Greek scholars and manuscripts to the West, which fostered comparisons between the original Greek texts of Galen and later Arabic translations and commentaries. During the Renaissance,

the Humanist intellectual movement sought to correct what had been an “age of Darkness” in the West after the fall of Rome by careful study and imitation of the great classical authors: in medicine the emphasis was on the resolution of apparent inconsistencies in Galen’s works through publication of new Latin translations from Arabic or preferably directly from Greek manuscripts, with the explicit intention of cleansing the works of Galen from transcription errors and Muslim influence imposed by Arabic scribes and authors. With the development of the printing press, and with the advent of new Latin translations of Galen’s works by German-born physician and scholar Johannes Winter von Andernach (also known by many variant names, including Johann Guenther von Andernach and Jean Guinter d’Andernach; ca 1505–1574) and others, Galen’s works were widely available in convenient volumes and were then further enshrined as dogma and tradition in 16<sup>th</sup> century Western Europe (fig. 1) [2–3].

The vanguard in the West that began to question Galen’s anatomy originated in northern Italy, and not coincidentally, this was where human dissection was introduced. The initial post-mortem dissections in the latter half of the 13<sup>th</sup> century were conducted in Bologna solely as a forensic process to gather evidence in legal cases. Subsequently, the first public or semi-public dissection occurred at the venerable medical school in Bologna around 1300 [4]. Even after dissection of human bodies became possible, anatomic illustrations were considered unnecessary given that the scholasticism of academics in medieval European universities served primarily to articulate and defend Galenic dogma. Until the middle of the 16<sup>th</sup> century, anatomy firmly remained a scholastic discipline based entirely on the reading of Latin translations from Arabic, rather than a science based on direct

observation. Any debates served simply and solely as an opportunity to practice the art of arguing or disputation. Discrepancies between anatomical dogma and a dissected body, when present and if noticed at all, were considered to be defects in the body at hand rather than a reflection of inaccuracies in Galenic teaching.

A small number of individuals – notably Italian physician-surgeon and anatomist Jacapo Berengario da Carpi (ca. 1460–ca. 1530) and later Flemish-born anatomist and physician Andreas Vesalius (the Latinized form of Andries van Wesel; 1514–1564) – sought corroboration of Galen’s teachings by direct observation of human dissections each had performed, rather than through comparative studies of ancient Arabic and Greek manuscripts as was then the norm [4–17]. In so doing, Vesalius came to understand that Galen had based his human anatomy primarily on dissections of animals and that, as a result, Galen’s work was flawed. This reinforced the need for and importance of human anatomical studies that were based on human dissection, rather than further scholastic studies of Galen’s texts.

Although he demonstrated some of the errors of Galen’s anatomy, and thus undermined the misguided notion of Galen’s infallibility, Vesalius only partially recognized the

many errors introduced by applying animal anatomy to humans. He continued other errors by relying on Galenic physiology. Still, he highlighted the importance of observational studies based on dissection, which Galen had earlier championed. Indeed, in “De anatomicis administrationibus” (On Anatomical Procedures), Galen had discounted value of anatomy learned only from the opportunistic examination of wounds, and had instead claimed that hands-on experience with dissection was essential for students and practitioners of medicine and anatomy [18].

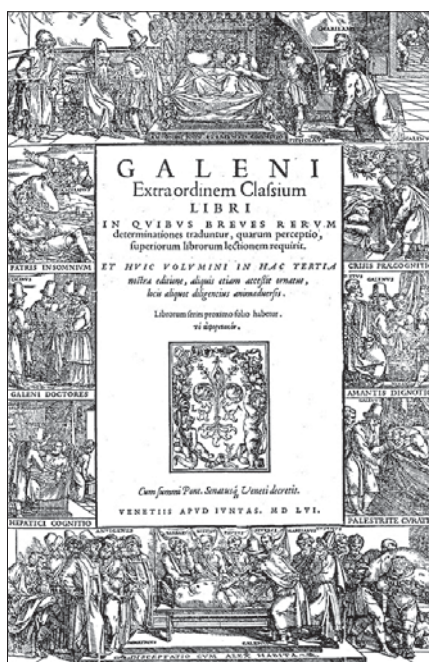


Fig. 1. Woodcut illustrations on the cover page of a mid-16<sup>th</sup> century Latin edition of Galen’s works [3].

This title page woodcut was recut in different 16<sup>th</sup>-century editions of Galen’s works. Courtesy of the Repositorio Institucional de la Universidad de Granada.

Early in his career, Vesalius had been trained as an orthodox Galenist and had edited some of Galen's texts at a time when anatomy and medicine were essentially limited to scholastic recitations or derivatives of Galen's works. Vesalius's departure from traditional Galenic thought happened gradually over the course of his medical training and academic career. It is possible to trace the evolution of Vesalius's thinking about Galen over the course of much of his career, from his own writings and from those who directly observed his teaching. For this purpose, Vesalius's medical career can be divided into three periods: medical training in Paris and Louvain (1528–1537), academic career in Padua (1537–1544), and imperial service (1544–1564).

#### **Vesalius's Medical Training in Paris and Louvain (1528–1537)**

After his undergraduate education at the Pedagogium Castre and later at the more progressive Collegium Trilingue of the University of Louvain (1528–1533), where he became accomplished in Latin and was at least exposed to rudimentary Greek and Hebrew, Vesalius was accepted for medical studies at the University of Paris. The University of Paris was then a very conservative institution, especially when compared with the more progressive universities in Italy. The medical faculty in Paris, including those whom Vesalius judged as being most influential during his training- Johannes Winter of Andernach and Jacobus Sylvius (Jacques du Bois of Amiens; 1478–1555) – focused their academic energies on scholastic studies of Galen's works. The medical students who were trained under this system, including Vesalius, naturally learned and accepted Galenic anatomy and physiology.

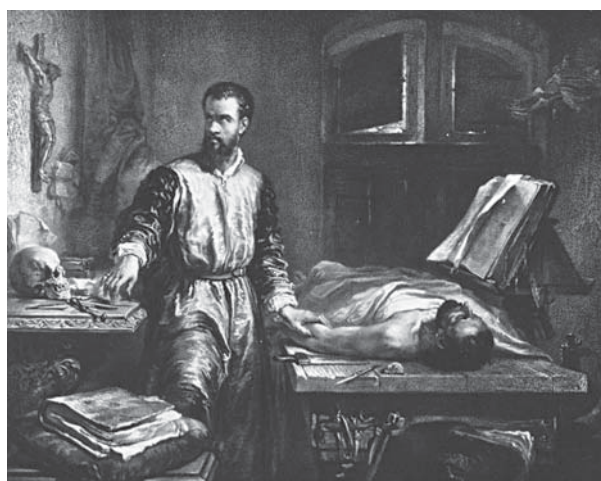
However, Vesalius became frustrated with the teaching of anatomy while a medical student in Paris (1533–1536), and subsequently in Louvain (1536–1537). Indeed, he reported that the anatomical teaching he received consisted merely of “the casual and superficial demonstration of a few organs presented to me to my fellow students in one or two public dissections by unskilled barbers” [9, p. 60]. Nevertheless, he gained experience in animal dissections and in osteology as a result of the bones and limbs

he stole from cemeteries and gibbets, for as he complained: “Those of us who wished to learn had to study all the more zealously since there was virtually no help to be had from our teachers in this part of medicine” [9, p. 60]. Also, even as a medical student, Vesalius's skill as a dissector was recognized, and he was provided opportunities to perform human dissections by Winter of Andernach in Paris.

In 1536 Vesalius was compelled to leave Paris after war broke out between the Holy Roman Empire and France. Vesalius completed his medical degree in Louvain, where he was again, because of his skill in dissection, allowed to perform human dissection.

#### **Vesalius in Padua (1537–1542)**

In December 1537 Vesalius was examined for his medical doctorate in Padua and the following day he was appointed to a lectureship in surgery and anatomy. Vesalius initiated a program of animal and human dissection, and also included various animal vivisection demonstrations [7–9, 13, 16, 19]. Within a week he had dissected his first human cadaver in Padua, but in so doing he broke with medieval tradition by serving simultaneously as lecturer, ostensor (demonstrator), and dissector (fig. 2). Vesalius encouraged his students to participate in hands-on direct observation of the structures and functions of the various parts of the body [13, 20]. Vesalius also soon introduced anatomical drawings and later detailed printed



**Fig. 2.** Lithograph (1848) of Andreas Vesalius standing before a dissecting table with a cadaver. By Edouard Hamman (1819–1888). Courtesy of the U.S. National Library of Medicine.

sheets as pedagogic aids to support his teaching. Extant notes and drawings of Vesalius's illustrations (Ms. 11,195 in the Austrian National Library, Vienna) made by Vitus Tritonius Athesinus, from those shown at a public anatomy performed by Vesalius at Padua in December 1537, show details that ultimately appeared in Vesalius's subsequent publications [21–23]. Vesalius's pioneering instructional techniques transformed anatomical teaching from a sterile scholasticism to a dynamic observational method.

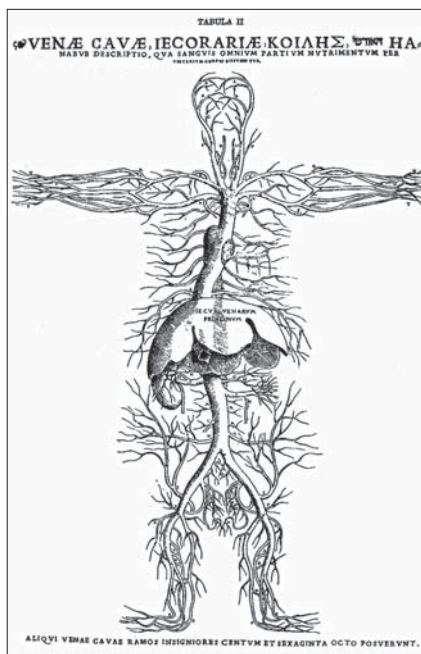
In 1538, Vesalius published what were later called the "Tabulæ Anatomicae Sex" (Six Anatomical Tables), a series of six "fugitive sheets" or broadsides for students that were essentially visual illustrations of Galen's anatomy that Vesalius used in his teaching [9, 11–12, 24]. Consequently, these continued several of Galen's mistakes, including showing the liver with five lobes (fig. 3). In other areas, though, Vesalius began to recognize inconsistencies and errors with Galen's anatomy, particularly in the area of osteology. Thus, Charles O'Malley (1907–1970) concluded in his authoritative biography of Vesalius that the "Tabulæ anatomicae" represent a transition period in Vesalius's career during which he "was no longer a complete Galenist and had come to realize through his own research and observation that Galen was not infallible" [9, p. 87].

Three Tabulæ (diagrams of the portal, caval and arterial systems) were drawn by Vesalius himself, while the others (illustrations of a skeleton standing in lifelike poses) were drawn by Flemish artist Jan Stefan van Calcar (c 1499–1546) from a human skeleton that Vesalius had constructed [11]. An additional diagram of the nervous system was not published then by Vesalius, though a pirated copy was published by others [12, 22–23]. The published illustrations were also soon plagiarized by printers in

Germany and France. Only two original full sets of these illustrations are known to exist, one in the Hunterian Collection at the University of Glasgow and the other at the Biblioteca Nazionale Marciana in Venice.

Late that year, Vesalius wrote "Epistola, docens venam axillarem dextri cubiti in dolore laterali secandam" (Letter, Teaching that in Cases of Pain in the Right Side, the Axillary Vein in the Right Elbow be Cut) commonly known as the Venesection Letter (1539), which he completed on January 1, 1539 [9, 25]. The classical Greek venesection procedure from Hippocrates, advocated by Galen, was to bleed the patient from a site near the location of the illness. However, the Muslim and medieval practice was to draw a smaller amount blood from a distant location. Vesalius generally supported Galen's view, but with qualifications that undermined the infallibility of Galen. Vesalius was nevertheless then clearly still in a large measure an orthodox Galenist: at one point, where Vesalius noted a discrepancy between Hippocrates and Galen, he said he was unwilling to use Hippocrates to supersede Galen's authority, "which I am afraid of disputing almost no less than if in our very sacred religion I were secretly to doubt the immortality of the soul"

[11, p. 83]. However, as O'Malley notes, "This statement ... was pro forma, and in fact Vesalius had little hesitation in expressing his doubts if his anatomical investigations warranted such heresy" [9, p. 96]. The lasting significance of this brief treatise is Vesalius's use of observations from human dissections to bolster his arguments, rather than simply appealing to authority through the selective reading of ancient texts. Consequently, even if flawed, this work helped to shift what evidence was considered salient to settle anatomical questions, and more specifically it championed observation and deduction over authority.



**Fig. 3.** Tabulæ II of Vesalius's "Tabulæ Anatomicae Sex" (1538). Note the 5-lobed liver, which is reminiscent of simian anatomy. The original text surrounding the figure has been removed. Courtesy of the Wellcome Library, London, UK.

### Vesalius's Public Anatomy in Bologna (1540)

In January 1540, around the time that Vesalius began work on the “*De humani corporis fabrica*” (*Fabrica*), he was invited to Bologna by the university students to perform a public anatomy. The anatomy, with 26 anatomical demonstrations by Vesalius presented to an audience of about 200 spectators, was held at the Church of San Francesco, in conjunction with a series of 25 lectures by the orthodox Galenic anatomist Matthæus Curtius (Matteo Corte or della Corte or Corti; c. 1474/5–1542/4) with. By this time, from his increasing number of human dissections [26], Vesalius had identified numerous errors in Galenic doctrine and had come to understand that Galen had based his anatomy on dissections of animals and not human cadavers [7, 27–28]. Consequently, in his demonstrations Vesalius openly challenged Galen's anatomy to the consternation of the orthodox Galenists among the faculty there.

In the late 1950s, Ruben Eriksson (1895–1962), Head Librarian at the Karolinska Institutets Bibliotek, discovered lecture notes recorded by a student who was present at this public anatomy at Bologna [20–21]. The notes were found in the Manuscript Collection at the Royal Library of Stockholm (Ms. Holm. X. 93), having been acquired by the library from a private owner in 1847, after which they had been neglected for more than a century. The notes were made by Baldasar Heseler (c. 1508/9–1567), a German medical student from a family of public officials and businessmen in Leignitz in Silesia (now Legnica in southwestern Poland), who had earlier studied theology under Martin Luther (1483–1546) at Wittenberg, Germany, before moving on to medical studies in Bologna.

The clash of the older authoritarian Curtius and the young brazen Vesalius showed a clear dichotomy between the traditional medieval anatomy, derived from Galen and sustained by rigid scholasticism, and the revolutionary Renaissance anatomy based on direct observation that was introduced and championed by Vesalius – a difference manifestly evident to the students present.

For example, on January 26<sup>th</sup>, 1540, Curtius lectured twice in opposition to Vesalius's views concerning venesection for pleurisy. Vesalius

refuted some of Curtius's scholastic arguments after his first lecture, and after the second sought to have Curtius actually examine the body being dissected so as to shift the arguments from rigid scholasticism to direct observation and inference. Curtius was contemptuous of dissection as he felt this served merely and solely to confirm Galen's teachings. Not surprisingly Curtius was unwilling to change his perspective, and instead emphasized the infallibility of Galen. The interaction deteriorated into mutual mockery: “When the lecture of Curtius was finished, Vesalius, who had been present and heard the refutation of his arguments, asked Curtius to accompany him to the anatomy. For he wanted to show him his theory was quite true. Therefore he brought Curtius to our two bodies. Now, he [Vesalius] said, excellentissime Domine [excellent Master], here we have our bodies. We shall see whether I have made an error. Now we want to look at this and we should in the meantime leave Galen, for I acknowledge that I have said, if it is permissible to say so, that here Galen is in the wrong, because he did not know the position of the vein without pair [azygous vein] in the human body, which is the same to-day just as it was in his time [referring here to attempts by some Galenists, including Sylvius, to explain any mistakes in Galen's works by claiming that human anatomy had itself changed since Galen's time]. Curtius answered smiling, for Vesalius, choleric as he was, was very excited: No, he [Curtius] said, Domine, we must not leave Galen, because he always well understood everything, and, consequently, we also follow him. Do you know how to interpret Hippocrates better than Galen did? Vesalius answered: I do not say so, but I show you here in these bodies the vein without pair, how it nourishes all the lower ribs, except the upper two ones, in which there is no pleurisy. ... Curtius replied: I am no anatomista [i.e., one who practices anatomy, here meant derogatorily as a dissector, which was in contrast to the medieval norm for a professor], but there can be also other veins nourishing the ribs and the muscles besides these. Where, please, Vesalius said, show them to me. Curtius said: Do you want to deny the ducts of Nature? Oh!, Vesalius said, you want to talk about things not visible and concealed. I, again, talk about what is visible [i.e., observable]. Curtius answered: Indeed, I always deal with what is most obvious.

Domine, you do not well understand Hippocrates and Galen concerning this. Vesalius replied: It is quite true, because I am not so old a man as you are. Thus, with much quarrel and scoffing they attacked each other, and in the meantime they accomplished nothing” [20, p. 273].

Vesalius tried to bring the discussion back to a professional level of disagreement without backing down, and Curtius similarly followed suit.

“Vesalius said: D[omine] Doctor, I beg Your Excellency not to think me so unskilled that I do not know and understand this. Smiling Curtius said: Domine, I did not say so, for I have said that you are excellent, but I have rejected the wrong explanation of Hippocrates implying that Galen should have erred in this. Vesalius replied: I acknowledge that I have said that Galen has erred in this, and this is evident here in these bodies, as also many other mistakes of his. ... When Curtius asked Vesalius not to be angry with him, Vesalius said: not at all, Domine. And thus Curtius left” [20, p. 273].

Vesalius later demonstrated the anatomy of the larynx and in particular the vocal cords on January 27<sup>th</sup>, 1540, using the larynx of an ox (because the larynxes of hanged human subjects are destroyed by the noose): “Then, he said, inside below the arytenoid cartilage there are the vocal cords[,] which are the proper instrument of the voice at each side consisting of a cartilaginous adipose membrane” [20, p. 285]. Curtius interjected at this point in Vesalius’s demonstration to argue with Vesalius’s characterization of the vocal cords, churlishly presenting Galen’s opinion that the vocal cords are composed of adipose tissue only and not cartilaginous tissue: “At this instant Curtius who too superstitiously observed the terms said: No, Domine [Master], because the vocal cords are composed of a substance of adipose membrane only and not of a cartilaginous one. Then Vesalius a little excited said: You don’t maintain, Domine, that cartilage is fat? Curtius said, that that was Galen’s opinion. Oh, Vesalius said, much is erroneously translated in Galen, where they ought to have written glottis, i.e. the vocal cords, they have put epiglottis, and vice versa where epiglottis, they have put glottis. Curtius answered [in the characteristic manner of a scholastic]: Oh, we certainly can have this from a Greek copy. Vesalius said: Also Greek manuscripts are corrupt in this point. But we

have one manuscript in the Dome of St. Marc in Venice, very old and very good, which now is translated, as you soon will see when it is printed. As it was nearly four o’clock in the evening, Curtius departed. Then Vesalius said: When we have understood the operations of the vocal cords, we may call them either Petrus, Paulus, Johannes [Peter, Paul, John] or whatever we want, for I will not fight about words. He blamed Curtius for being exceedingly superstitious about names.” [20, p. 285].

After Curtius’s interruption and subsequent departure, Vesalius continued with his demonstration. He emphasized the importance of direct observation, and encouraged the students to also study comparative anatomy, especially with readily available specimens from local butchers.

“When, he said, this divided membrane is pressed together by the muscles of the larynx into which the nervi reversivi [recurrent laryngeal nerves] are inserted, then there is formed a small fissure through which the air issues as through a narrow passage and a fine sound is effected, by which the speech and the voice are distinguished, and that is properly called the vocal cords. ... Finally, he showed us the ... muscles moving the larynx ... [and] how the larynx is both opened and shut by them to constitute the vocal cords etc. All this, he said, each of you, Domini, can see. Buy yourselves a larynx of an ox and you will see it all” [20, p. 285, 287].

### The “Fabrica” and “Epitome” (1543)

In 1543 Vesalius published his magnum opus, the magnificent “De humani corporis fabrica” (On the fabric of the human body), a folio volume comprised of seven “books” (chapters), now typically referred to simply as the *Fabrica* (fig. 4) [7, 9–11, 13, 16, 27–28]. The same year Vesalius also published a short abstract of the *Fabrica* for students, “De humani corporis fabrica librorum epitome,” or simple the *Epitome* [14].

The *Fabrica*, written when Vesalius was just 28, brought him international recognition and established him as the father of modern human anatomy. As Osler said in 1913 of Vesalius’s masterwork: “It is difficult to speak in terms of moderation of the ‘Fabrica’... The worth of a book, as of a man, must be judged by the results, and the ‘Fabrica’ thus judged is one of the great books of the world, and would come in any century

of volumes which embraced the richest harvest of the human mind. In medicine, it represents the full flower of the Renaissance” [10, p. 152].

Vesalius did not intend the *Fabrica* to be a standard text for students, or even a monograph for ordinary physicians and surgeons, but rather an enduring masterpiece suitable for an elite readership of wealthy, well educated, and powerful individuals [7]. Indeed, the *Fabrica* was meant to permanently and dramatically mark a major break with Galen’s anatomy by combining Vesalius’s newfound knowledge of human anatomy with a heretofore-never-achieved artistic excellence and realism of anatomical illustration (in contradistinction to earlier works based on Galen’s animal dissections that either were not illustrated or utilized very sparse and relatively crude illustrations on the frontispiece) (fig. 1). The *Fabrica* was remarkable, indeed revolutionary, for how it linked scientific exposition based on direct observation with a novel, sophisticated, and artful realism in scientific illustration [7]. Vesalius’s anatomical illustrations were executed with unprecedented skill, accuracy, elegance, and even beauty. Only in the case of a book like the *Fabrica*, intended to make such a brazen statement, would the author and printer suffer the tremendous effort and expense of commissioning specially cut initial letters and numerous large and detailed woodcut plates to be integrated with the text.

In his dedicatory preface to Holy Roman Emperor Charles V (1500–1558), Vesalius complained of the deification of Galen by anatomists and physicians: “But those who have followed Galen ... if they handed down anything worth reading, they took it straight from Galen... And so, with their teeth set, the principal followers of Galen put their trust in some kind of talking [scholastic argument], and relying upon the inertia of others in dissecting, they shamelessly abridge

Galen into elaborate compendia. They do not depart a hair’s breadth from him when following his sense; but to the front of their books they add writings of their own, stitched together completely from the opinions of Galen... The whole lot of them have placed their faith in him, with the result that you cannot find a doctor who has thought that even the slightest slip has ever been detected in the anatomical volumes of Galen, or could much less be found. ... [It] now becomes obvious to us from the reborn art of dissection, from diligent reading of the books of Galen, and from impeccable restoration in numerous places of [the text of] these books, that he himself never dissected the body of a man who had recently died. ... [H]e was misled by his [dissections of] apes... Nay, you may even find a great many things in his writings which he has not followed correctly in the apes; not to mention the fact that in the manifold and infinite difference between the organs of the human body and the body of apes, Galen noticed almost none, except in the fingers and in the bending of the knee. This difference he doubtless would have omitted too, if it had not been obvious to him without the dissection of man” [28, p. 135–136].

The *Fabrica* incorporated Vesalius’s original observations from his human dissections, and it was this hands-on experience that he credited with providing him the motivation to complete the *Fabrica*, and also with the authority to challenge Galen’s anatomy. In his dedication to Charles V, Vesalius noted that “This project would never have gone forward if when I was studying medicine at Paris I had not personally set my hand to Anatomy at a time when my fellow students and I had to content ourselves with a few internal parts being superficially displayed at one or two public dissections by the most ignorant barbers” [29]<sup>1</sup>.



**Fig. 4.** The striking and dramatic woodcut title-page illustration of the *Fabrica* (1543) shows Vesalius conducting a public dissection of a female cadaver in an open-air amphitheater, surrounded by a dense crowd of more than 70 students and onlookers. Courtesy of the Becker Medical Library at Washington University in St. Louis, Missouri, USA.

<sup>1</sup> See also: [9, p. 64] and [28, p. 134].



Despite Galen's anatomical errors from extrapolation of animal anatomy to humans, in the *Fabrica* Vesalius embraced Galen's hands-on approach to dissection as essential for both teachers and students, and – like Galen – Vesalius denounced: the vile ritual in the universities by which some perform dissections of the human body while others recite the anatomical information. While the latter in their egregious conceit squawk like jackdaws from their lofty professorial chairs things they have never done but only memorize from the books of others or see written down, the former are so ignorant of languages that they are unable to explain dissections to an audience and they butcher the things they are meant to demonstrate, following the instructions of a physician who in a haughty manner navigates out of a manual alone matters he has never subjected to dissection by hand. And as everything is being thus wrongly taught in the universities and as days pass in silly questions, fewer things are placed before the spectators in all that confusion than a butcher in a market could teach a doctor [29].

Knowing his audience was composed largely of orthodox Galenists, Vesalius was cautious to moderate his criticisms of Galen, even if this was pro forma, while still noting with some optimism and pride that he was acquiring disciples: “I have in no wise [way] set out to reprimand the false doctrines of Galen, easily the chief of the professors of dissection; and much less would I wish to be considered disloyal and too little respectful of authority toward that author of all good things right at the beginning of my work. For I am not unaware of how much disturbance the doctors – far less than the adherents of Aristotle – raise when they observe that Galen deviated more than two hundred times from the correct description of anatomy alone, as I now exhibit in the schools, while they examine sharply the dissected particles with the greatest zeal in defending him. Although these men, led by the love of truth, gradually grow milder and put a little more trust in their rational faculties and their eyes – by no means ineffectual eyes and brains – than to the writings of Galen, they are now writing hither and thither to their friends about these truly paradoxical things which have neither been borrowed from the attempts of others or buttressed by congeries of authorities so sedulously and they have been urging their

friends to learn some true anatomy so eagerly and amicably, that there is hope of its being fostered in all our Universities as it once was practiced at Alexandria” [28, p. 136, 137].

More important than Vesalius's recognition (or lack of recognition) of any particular errors in the Galenic-Arabic canon was the impetus that the *Fabrica* gave to shifting anatomy back from stagnant scholasticism to a vibrant observational science, and one finally focused on human dissections and comparative anatomy, rather than one based on animal dissections alone, or simply on scholastic studies of ancient texts.

### Vesalius in Imperial Service

In 1543, even before the initial print run of the *Fabrica* was completed, Vesalius headed north from Basel with a presentation copy for Charles V. Charles immediately enlisted Vesalius in his service as a royal physician, and subsequently Vesalius spent most of his time as a military physician in a succession of campaigns with the emperor. Vesalius traveled with the court, treating injuries from battles and tournaments. During this period, he spent much of his remaining time defending himself against continuing attacks by orthodox Galenists, including his former teacher Sylvius who bitterly denounced Vesalius. In 1544, in a fit of anger supposedly due to the attacks by his opponents, Vesalius burned his notes on Galen before leaving Padua [15], though he probably also realized that his scientific career had largely ended upon entering imperial service.

In 1546 Vesalius wrote “*Epistola rationem modumque propinandi radicis Chynæ decocti,*” commonly known as the Letter on the China Root [15]. Ostensibly an appraisal of a popular, albeit ineffective, treatment for gout, syphilis, and urinary tract stones, this work was actually a polemic against Galenism and a reply to his critics, particularly Sylvius. Sylvius in his “*Ordo et ordinis ratio in legendis Hippocratis et Galeni libris*” (The order and the rationale of the order in reading the books of Hippocrates and Galen, 1539) had claimed that Galen was infallible and that Galen's “*De usu partium Humani corporis*” (On the Usefulness of the Parts of the Body) was divine, and consequently Sylvius considered it impossible to make significant advances in knowledge of anatomy [23]. When Vesalius called attention to Galen's mistakes, Sylvius demanded

that he recant, and when Vesalius nevertheless persisted, Sylvius sought to undermine him with the Emperor, threatened to denounce him publicly, and called him a “madman.” Vesalius remained unapologetic and was convinced of the validity of his own observations. Vesalius noted that he had lectured in Padua three times on Galen’s osteology “before I dared call attention to his mistakes” [9, p. 111]. At the same time Vesalius was bitter over the reception his work had received: “They ought to be grateful to me as the first who has dared to attack man’s false opinions, to lay bare the extraordinary frauds of the Greeks, and to provide our contemporaries with an unusual opportunity for searching out the truth. Such, however, is not the case, and because of Galen’s authority you will find many who, having glanced at my efforts only superficially and without investigation of the cadaver, still maintain what Galen wrote is wholly correct” [9, p. 218].

Vesalius published a second folio edition of the *Fabrica* in 1555; this incorporated stylistic and factual changes to the text, along with changes to the figures. Sometime after this Vesalius planned a third edition of the *Fabrica*, but it was never published. With the emperor’s abdication the following year, Vesalius entered the service of his son Philip II (1527–1598), who became King of Spain, while Charles’s brother Ferdinand I (1503–1564) became Holy Roman Emperor.

In February 1561, Vesalius was given a copy of “*Observationes anatomicæ*” (*Observations of Anatomy*, 1561), written by Italian physician and anatomist Gabriele Falloppio (Fallopian; 1523–1562) (fig. 5); this contained some respectful additions and corrections to the *Fabrica*. Before the end of the year Vesalius composed a cordial reply, “*Anatomicarum Gabrielis Fallopii observationum examen*” (*Anatomical analysis of observations of Gabriele Fallopius*), generally referred to as the *Examen* [17]. Vesalius largely accepted the contributions of Fallopian and

hailed him as a worthy successor to himself, even though in the end Vesalius outlived the younger Fallopian. Vesalius’ reply to Fallopian was published posthumously in May 1564, a month after Vesalius’ death on the Greek island of Zante (now Zakynthos), and a year and a half after the death of Fallopian.

### Examples of Vesalius’s changing perspective on Galen’s Anatomy

**1. Venous fibers.** In the Venesection Letter (1539), Vesalius recorded a disagreement he had with Curtius in 1538. This concerned the existence of purported “fibers” in the veins, which Vesalius claimed to see in accordance with his interpretation of Hippocrates and Galen [9, 25]. In the humoral doctrine, tissues were supposedly endowed with variously oriented fibers, which served to attract and retain nourishment and expel any excess; Vesalius alleged that these fibers were present in veins as well. In both editions of the *Fabrica* (1543, 1555), Vesalius illustrated diagrammatically the interleaved fibers, but on the instigation of Fallopian, Vesalius finally abandoned the idea of venous fibers, with chagrin, in the *Examen* (1564) [9, 11, 13, 16–17, 25]: “I recall

how sharp the controversy once was over these matters with Matteo Corti in Bologna, when I declared that fibres of the veins were perceptible in dissection of bodies, and so provided Corti and his followers, who had some time previously published their conclusions, no little opportunity for attacking the fibres. For when I separated the substance of the veins in search of the fibres, I dissected it raw and boiled, and, by Hercules, to tell the truth, the fibres had come from the imagination of our authors [i.e., Galen]. Finally, when I had come to have serious doubts and



Fig. 5. Italian professor of anatomy and surgery Gabriele Falloppio Mutinensis (Gabriele Falloppio of Modena, or Fallopian; (1523 – October 9, 1562)<sup>2</sup>. Courtesy of the U.S. National Library of Medicine.

<sup>2</sup> The years given in the figure (1551–1563) give the years of his appointment in Padua, although he died near the end of 1562.

rejected the whole matter as a vulgar opinion ... our dispute over what vein ought to be opened in venesection was so much “goat’s wool” [9, p. 95].

**2. The interventricular septum of the heart.**

In “De Facultatibus Naturalibus” (On the Natural Faculties), Galen had claimed that there are perforations in the interventricular septum of the heart through which blood passes from the right to the left ventricle [30, p. 321].

In the *Fabrica* (1543), Vesalius recognized that there are no visible passageways for blood to flow across the interventricular septum, but he did not refute the existence of invisible passageways, largely because he was still operating under the framework of Galenic physiology: “None of these small grooves (at least as far as I can see) penetrates from the right to the left ventricle so that we are compelled to admire the genius of the Master Builder of all things, by which the blood can penetrate from the right ventricle to the left one, through gaps invisible to the eye” [13, 31].

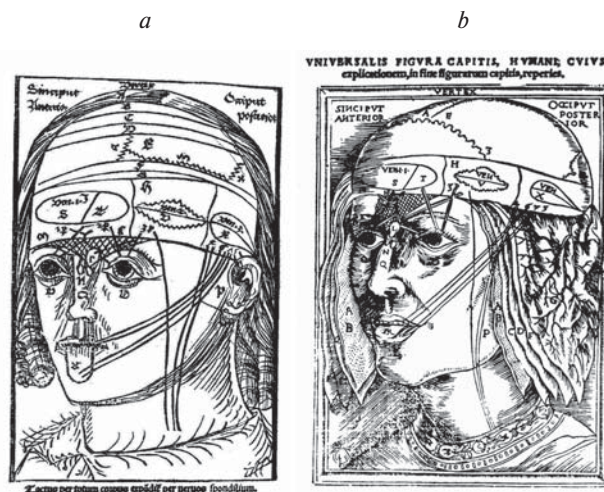
By the second edition of the *Fabrica* (1555), Vesalius was increasingly skeptical of these purported passageways, although he still did not unequivocally deny their existence: “I have not found any gaps in the septum between the two ventricles. Yet, these little channels have been described by anatomists who have decided that the blood flows from the right to the left ventricle. Personally, I have my strongest doubts as to the function of the heart in this respect” [16, 31].

**3. The rete mirabile.** In certain ungulate animals, Galen had noted and described the rete mirabile (Latin: “wonderful net”), a division of the internal carotid arteries into a meshwork of small arterial branches near the base of the hypothalamus, which subsequently reunited and continued again as the internal carotid artery to supply the cerebral hemispheres [32–33]: In his monograph “De Usu Partium Corporis Humani” (On the Usefulness of the Parts of the Body), Galen wrote, “It is not a simple network but [looks] as if you had taken several fisherman’s nets and superimposed them” [34]. Galen erroneously believed that this structure was present as well in humans, and that it served as an important linkage between the body and the mind, with similarities to the putative role of the pineal body in the similarly imaginative Cartesian physiology of the early 17<sup>th</sup> century [33, 35]. Naturally this mythical human anatomical structure was included in

medieval and Renaissance teaching on human anatomy (fig. 6).

In his “Commentaria cum amplissimis additionibus super anatomia Mundini” (Commentary, with extensive additions on the anatomy of Mundinus, 1521), Berengario expressed his frustration and general failure at finding the rete mirabile described by Galen, and moreover expressed doubts about its very existence [35]. In his “Isogogæ Breves” (A Short Introduction to Anatomy, 1523), Berengario discussed “the marvelous net according to common opinion,” and courageously admitted that he was unable to find it in humans, despite many human dissections. He, therefore, doubted its existence in humans, a statement that was certainly brazen for its time [5].

However, ignoring Berengario and instead following Galen, Vesalius initially accepted Galen’s ideas concerning the rete mirabile in humans, which Vesalius called the “mirabilis plexus reticularis” (wonderful plexus network). In Tabula III of the “Tabulæ Anatomicæ Sex” (1538), Vesalius himself had drawn a diagram



**Fig. 6.** 16th-century pre-Vesalian depictions of the rete mirabili (shown schematically in both as a cross-hatched area above the nose).

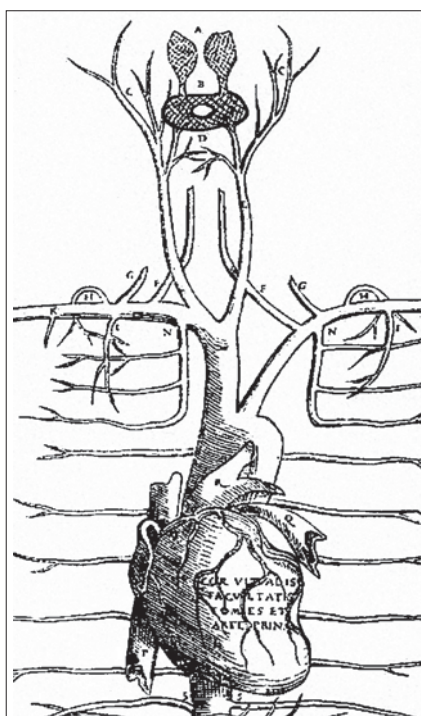
*a:* From *Antropologium de ho[mi]nis dignitate, natura, et p[ro]p[ri]etate, de elementis, partibus et me[m]bris humani corporis* (Leipzig: Wolfgang Stöckel, 1501), by German physician Magnus Hundt (1449–1519).  
*b:* From *Anatomia, hoc est, corporis humani dissectionis pars prior, in quo singular quae ad caput spectant recensentur membra, atque singulae partes, singulis suis ad vivum commodissime expressis figuris, deliniantur* (Marburg [Marburg]: Eucharius Ceruicorus, 1537) by German anatomist Johann Dryander (1500–1560). Courtesy of the U.S. National Library of Medicine.

showing the rete mirabile in humans (fig. 7). This diagram supported the Galenic doctrine that in humans the rete mirabile was located in a purported plexiform termination of the carotid arteries and that the life spirit (*spiritus vitalis*) of Galenic physiology is transformed into the animal spirit (*spiritus animalis*) before being distributed from the brain along the nerves to the body, as if through pipes. Two years later, in Bologna, Vesalius demonstrated the rete mirabile to the audience, apparently using the sheep's head he had dissected for comparison with human anatomy.

On the evening of January 22<sup>nd</sup>, 1540, Vesalius first showed the rete mirabile, at which time he had brought the head of a sheep to illustrate various structures and make them easier to appreciate on the human cadaver.

“[Eventually, he showed us the network of winding arteries around the rete mirabile in which the *spiritus animales* are produced, transmitted there from the heart as *spiritus vitales*. And I saw particularly those which run in coils around the base of the cranium, which are called rete mirabile. He did not say that the *spiritus animales* are produced in the substance of the bone or in the rete mirabile, but in the network of arteries” [20, p. 221].

Six days later, on January 28<sup>th</sup>, 1540, Vesalius had again dissected the head from one of the human cadavers and also dissected the head of a sheep to show to the students. “At last he [Vesalius] showed us the rete mirabile, situated higher up in the middle of the cranium near where the arteries ascend, and



**Fig. 7.** The rete mirabile at the base of the brain as imagined and illustrated in *Tabulæ III* of Vesalius's *Tabulæ Anatomicae Sex* (1538)

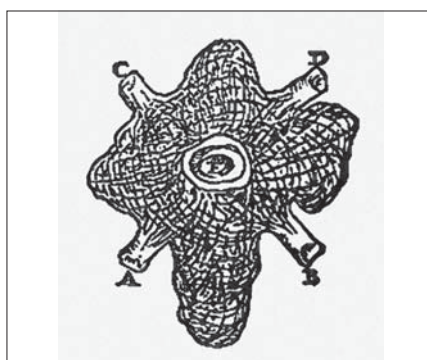
[i.e., the hatched ring at the top of the figure, labeled “B”] “wherein the vital spirit is elaborated into the animal spirit.” Also shown is a variant aortic arch that is more typical of simian species than humans. Courtesy of the Wellcome Library, London, UK.

forming the plexus in which the *spiritus animales* are produced out of the *spiritus vitales* transferred there [Heseler does not state whether this was shown on the sheep's head, but this of necessity must be the case]. And it was a reddish, fine, netlike web of arteries lying above the bones, which I afterwards touched with my hands, as I did with the whole head” [20, p. 290–291].

It was not long after this that Vesalius began work on the *Fabrica* (1543), and at least by the time of its publication he fully reversed himself, categorically denied the existence of the rete mirabile in humans, and castigated himself for his prior failure to recognize this error in Galen's works [13, 35–36]. Although Vesalius provided an illustration of the rete mirabile in the *Fabrica* (1543), he showed this out of anatomical context with other structures of the human body (fig. 8).

“Here I must speak plainly and without any concealment about Galen's reticular plexus [rete mirabile], because I have no doubts about the arrangement of the cerebral vessels observed by me; we know that Galen was deceived through dissection of the brain of the ox, not the brain of man, so that he described the vessels of the ox rather than those of man” [35, p. 767].

“How much has been attributed to Galen, easily leader of the professors of dissection, by those physicians and anatomists who have followed him, and often against reason! In confirmation there is that blessed and wonderful plexus reticularis which that man everywhere inculcates in



**Fig. 8.** The rete mirabile as imagined and illustrated in the *Fabrica* (1543). Courtesy of the Wellcome Library, London, UK.

his books. There is nothing of which physicians speak more often. They have never seen it (for it is almost non-existent in the human body), yet they describe it from Galen's teaching. Indeed, I myself cannot wonder enough at my own stupidity and too great trust in the writings of Galen and other anatomists; yes, I who so much labored in my love for Galen that I never undertook to dissect a human head in public without that of a lamb or ox at hand, so as to supply what I could in no way find in that of man, and to impress it on the spectators, lest I be charged with failure to find that plexus so universally familiar by name. For the [internal carotid] arteries quite fail to produce such a 'plexus reticularis' as that which Galen recounts!" [36, p. 57].

### Conclusion

Seeking to examine critically Galen's works, Vesalius initially turned to human dissection as a means of verification. In some cases, Vesalius initially misinterpreted human anatomy from the perspective of Galen's teachings, which had been based on the dissections of animals (e.g., the purported existence of the rete mirabile in humans), even though Vesalius eventually came to recognize, with chagrin, his own errors. In other cases, Vesalius was unable to divorce himself fully from Galenic doctrine and Galenic physiology, and continued to misinterpret anatomical findings from a Galenic perspective, even when his own observations showed results incommensurable with Galen (e.g., the purported pathways for blood through the interventricular septum, or the role of the pituitary in evacuating phlegm from the brain). In still other cases, Vesalius never recognized the differences between Galenic and human anatomy, even when he must have dissected some human structures many times (e.g., the branching pattern of the human aortic arch).

Vesalius was an admirer of Galen, but at least as early as 1540 Vesalius was cognizant of many errors of Galenic human anatomy, and certainly

by the time of the *Fabrica* (1543) was convinced that Galen's errors stemmed largely from Galen's reliance on the dissections of animals. Vesalius championed a return to observational anatomy over the stagnant scholasticism that had become entrenched in medieval medical schools. In so doing, Vesalius became a neo-Galenist in the sense that he epitomized Galen's practice of anatomy as an observational science, even when he derided the errors Galen had made by extrapolating animal anatomy to humans. Unlike Galen, though, Vesalius championed the idea that human anatomy must be acquired by dissection of human bodies.

Of course, Vesalius's heterodoxy threatened both the intellectual framework (i.e., paradigm, in a Kuhnian sense) [37] and the professional reputations of conservative, orthodox Galenists, such as Curtius and Sylvius. As in most scientific revolutions, practitioners under the prevailing paradigm (scholastic Galenism) remained unconvinced of the merits of a new paradigm (observational human anatomy based on the dissection of human cadavers), even in the face of clear

evidence of failures of the traditional framework and greater explanatory and predictive power of the new one. The result was a bitter struggle, with the heavily invested orthodox group diminishing slowly by attrition, rather than by scientific conversion. Nevertheless, Vesalius succeeded in promulgating a new approach to the study of human anatomy and acquired his own disciples. He shifted the problems or issues that were considered salient, and the studies that would be considered legitimate in addressing them (i.e., human dissection rather than scholastic study of ancient texts).

Even as he began to disparage Galen's anatomical errors, Vesalius nevertheless adopted some of Galen's classic physiological demonstrations; specifically, the ligation (and subsequent release) of the recurrent laryngeal nerves of a pig to demonstrate its role in generating the pig's squeal



Fig. 9. A large historiated initial Q from the preface of the *Fabrica* (1543) by Vesalius.

Courtesy of the Becker Medical Library of Washington University in St. Louis, Missouri, USA.

(fig. 9) [3, 8, 13, 16]. Vesalius envisioned dissection and vivisection as complementary investigational and teaching approaches that elucidated the structure and function of the body. While Vesalius was openly critical of Galen's anatomy, all evidence suggests that Vesalius remained an admirer of Galen's physiology [8, 13, 38]. Although Berengario da Carpi gave a firsthand account of a vivisection earlier (1521), Vesalius was nevertheless the first

to provide a detailed and systematic description of the use of vivisection as described by Galen in his "De Anatomicis Administrationibus" (on Anatomical Procedures) [13, 38–40]. While it is clear that Vesalius improved on Galen's anatomy, the same cannot be said about Vesalius in terms of Galen's physiology, even though Vesalius discarded a key structure of Galenic physiology, the rete mirabile [33].

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Received: 16.06.14

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**The name of the article for quotation:** *The evolution of Vesalius's perspective on Galen's anatomy. Istorija meditsiny (History of Medicine). 2015. Vol. 2. № 1. P. 17–32.*