On the innovative genius of Andreas Vesalius

Brinkman, R.J.C.

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Chapter 1

Introduction
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Andreas Vesalius (1515 - 1564) is generally considered to be the founding father of modern human anatomy. To commemorate his 500th birthday, some of the most striking anatomical and physiological aspects of Vesalius' major work *De Humani Corporis Fabrica Libri Septem (De Fabrica)* are presented and discussed in this thesis. These aspects were revolutionary in his time and through his dissections and publications, Vesalius initiated the end of more than 13 centuries of Galen's influence on anatomical and physiological knowledge. The evolution of this influence has previously been reported by Lanska [1]. Following is an annotated summary of his report.

Galen's anatomy and physiology in Medieval and early Renaissance Europe

Galen of Pergamon (Aelius or Claudius Galenus; c. 130–c. 200) was the preeminent physician and most prolific medical researcher of the Roman Empire in the 2nd century. After his studies in Asia Minor, he moved to Rome at age 31, to become the physician to emperor Marcus Aurelius and his successors [2]. Galen was a true experimentalist who always wanted to test everything for himself and trust no authority, until he had done so [2]. Because dissections of human corpses were not allowed in Rome in his era, however, Galen's works on human anatomy were primarily based on the dissections of monkeys, pigs, and oxen, and his occasionally treating extensive wounds of gladiators [1]. Still, his thoughts on human anatomy were accepted without reserve as no one was aware of possible differences between animal and human anatomy. In Roman times, and in the Arab Middle Ages alike, Galen's ideas were even given priority over those of Hippocrates [3].

After the collapse of the Roman Empire in the West, the study of anatomy and physiology ceased to exist in Western Europe [1,2]. As such, the study of Galen's Greek records declined during the Early Middle Ages, when very few Latin scholars could read Greek. Still, his works continued to be studied in the Eastern Roman (Byzantine) Empire, where the 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. Subsequently, some Islamic writers considered Galen to be an important, but not infallible source. Among the most famous, the Persian scholar Rhazes (Abū Bakr Muhammad ibn Zakariya ar-Rāzī; 854–925) studied 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 Galenism took on a new, unquestioned authority. Scholasticism flourished in the thirteenth and fourteenth centuries and consisted of the study and discussion of Arab knowledge generally without adding to it by observation or experiment [2]. The Roman Catholic church supported Galenic theory as the anatomical and medical dogma and these Latin translations became the mainstay of the medieval physician's university curriculum, along with Avicenna's (Persian scholar Ibn-Sīnā, full name Abū Alī al-Husayn ibn Abd Allāh ibn Al-Hasan ibn Ali ibn Sīnā; 980–1037) encyclopaedic exposition of Galenic medicine *The Canon of Medicine* (1025)[1].
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The fall of the Byzantine Empire (1453) was accompanied by an influx of Greek scholars and manuscripts to the West. This influx 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 [1]. In medicine the emphasis was on the resolution of apparent inconsistencies in Galen’s works. New Latin translations were published of the Arabic translations or, preferably, the original Greek manuscripts. These translations were intended to rid the extant translations of Galen’s works from transcription errors and Islamic influences. Such a “new” Latin translation of Galen’s works was presented by German-born physician Johannes Winter von Andernach (Johann Guenther von Andernach, or Jean Guinter d’Andernach; ca 1505–1574). With the development of the printing press, this and other “new” translations became widely available in convenient volumes and were then further enshrined as dogma and tradition in 16th century Western Europe. Consequently, anatomy firmly remained a scholastic discipline based entirely on the reading of Latin translations from Arabic rather than a science based on direct observation, until the middle of the 16th century. Any debate simply and solely served as an opportunity to practice the art of arguing or disputation.

The vanguard in the West that began to question Galen’s anatomy originated in northern Italy, where the practice of dissection of human corpses was introduced in the latter half of the 13th century. The initial dissections 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 medical school in Bologna around 1300 [1]. Unlike his predecessors, the Bolognese professor of anatomy Mondinus (Mondino de’ Luzzi; 1275-1326) actually dissected the human body personally, rather than turning it over to menials [2]. In 1316, Mondinus published his scarcely illustrated Anathomia corporis humani that incorporated many of his own observations and a discussion of anatomical and physiological principles to surgical practice [4]. Anatomic illustrations were still considered unnecessary given that the scholasticism of academics in medieval European universities served primarily to articulate and defend Galenic authority. Possible discrepancies that were noticed between the dissected body and anatomical dogma were considered to be defects in that body, rather than inaccuracies in Galenic theory.

Like Vesalius after him, the Italian physician-surgeon and anatomist Jacapo Berengario da Carpi (ca. 1460–ca. 1530) sought corroboration of Galen’s theories by direct observation of human dissections rather than through comparative studies of ancient Arabic and Greek manuscripts [1]. Still, Andreas Vesalius (1515 – 1564) was the first to understand that Galen’s work was flawed because Galen had based his human anatomy primarily on dissections of animals. He highlighted the importance of observational studies based on human dissection, just as Galen had claimed that hands-on experience with animal dissection was essential for students and practitioners of
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Figure 1.1: Andreas Vesalius as portrait in his major work *De Humani Corporis Fabrica Libri Septem*. The cadaver arm is alleged to intentionally appear large to emphasise the importance of its dissection. As his trademark, Vesalius routinely began his public dissections with the forearm and hand.
Andreas Vesalius

Andreas Vesalius Bruxellensis (Figure 1.1) was born as Andreas van Wesel, allegedly on the last day of 1514 or in the early morning of January 1, 1515 [9]. According to a horoscope cast by the Milanese physician and mathematician Jerome Cardan (1501 – 1576) with whom Vesalius corresponded, the birth occurred at a quarter to six on the morning of December 31st, 1514, according to the then prevailing Julian calendar (Figure 1.2) [10]. Because the calendar year in Roman Catholic Europe ran from March 25th (the feast of the Incarnation of Jesus) to March 24th [11, 12], both December 31st and January 1st of the Julian calendar would have been reckoned to the year 1514 (see also chapter 11). In this thesis, however, the current Gregorian calendar that was introduced in 1582 was followed. At the time of the introduction of this “new style” calendar, all “old style” Julian dates shifted 10 days forward. Hence, December 31st and January 1st of 1514 of the Julian calendar are January 10th and 11th of 1515 according to our current calendar. It is proper, therefore, to celebrate Vesalius’ 500th anniversary at January 10th or 11th of 2015. This was the main reason to quote 1515 as Vesalius’ year of birth in this series on his innovations in anatomy and physiology.

Andreas was the descendant of a family of skilled physicians that for at least four generations had a lasting relationship with the rulers of the House of Habsburg (Figure 1.3) [6, 7, 14-16]. Vesalius’ father Andries was the illegitimate child of the third known generation of physicians, which prohibited him from becoming a royal physician himself. Instead, he became the pharmacist to Margaret of Austria and to her nephew King Charles V, who was to become Emperor. Andries and his wife had one daughter and three sons, of which Andreas was the middle. Andreas grew up next to the Galgenberg (Montague de la Potence, or Gallow’s Hill) in Brussels and very likely played there among the bones of the convicted scattered on the grounds. At an early age he began to dissect small animals such as mice, rats, moles and, on occasion, even a dog or cat [6].

After grammar school in Brussels, he took his Matriculate in Louvain, in 1530. Subsequently, he was taught the Literae Humaniores and learned Latin, Greek and possibly some Hebrew. In September 1533, he started his three years of medical study in Paris. Here, he was taught and trained in the theories of Galen [1]. In Vesalius’ time, such teaching was still done by a professor seated high in the chair in the Mediaeval tradition, while a barber-surgeon would perform the possible dissections of dogs, pigs and, sometimes, human corpses. One of the few exceptions to that rule was Jacobus Sylvius (Jacques Dubois; 1478-1555) who taught a three-year course of medicine in the de Tréguier in Paris. Sylvius was an ardent Galenist but he dissected himself. Like Galen, he predominately dissected animals as he had no human corpses at his
Figure 1.2: Chart (or ‘geniture’) casted by the Milanese physician, mathematician, and astrologer Girolamo Cardano (1501-1576), indicating the relative positions of various planets (called aspects) at the time of birth of Andreas Vesalius [13]. It indicates 30 December 1514, 17:45 post meridiem as the date and time of birth. This is accepted to correspond with 05:45 in the morning of December 31st, 1514 (according to the Julian calendar) [8].
disposal. Still, he may have brought the arm or a leg of an executed convict to his demonstrations [6].

While in Paris, Vesalius had to go to the Cemetery of the Innocents to collect the remaining human bones for their study of osteology [14, 17]. It was also in Paris that he felt the urgent need of the resurrection of the science of anatomy to the height of the Alexandrian medical period “lest I should fall below the level of my forebears, doctors of not unknown fame” (quote on p. 1361) [18]. Vesalius dissected under the guidance of Sylvius whom, Vesalius felt, “can never be praised too highly” (quote on p. lii) [17]. As a result, his knowledge of old languages and anatomy and his abilities as a dissector were clear even when he still was a student. In his Institutiones Anatomicae, an essay on Galen’s anatomical teachings, Vesalius’ professor of medicine Johann Winter von Andernach (1505 - 1574) praised his student as “by Hercules a young man of great promise, who, besides an extra-ordinary knowledge of medicine, also shows an experience in both classical languages and is skilful in dissecting bodies” (quote on p. 71) [19]. Consequently, the last of the three dissections that took place during his three years in Paris was performed by Vesalius himself three days before he had to leave.

Vesalius had to flee from Paris before he could take his Bachelors in Medicine after four years of study, because of hostilities that broke out between his king Charles V and the French king Francis I. Thus, he returned to Louvain still a Candidate in Medicine, in 1536. There, he repeated his osteology manoeuver by stealing no less than a complete skeleton from the local Gallow’s Hill [14]. Once more, he smuggled the skeleton into town and into his quarters and reconstructed it [6, 17]. He was to restore many more human skeletons, one of which is still present at the Institute of Anatomy of the Basel University. In Louvain, Vesalius once again had the opportunity to perform public dissections on human corpses. His entering a dispute with some theologians over the proper location of bloodletting made him a suspect of anti-catholic thoughts and ideals and, consequently, he felt he had to leave Louvain and go to Italy for a better future. However, before leaving for Italy he published his Paraphrases of the Persian scholar Rhazes’ ninth book for King Al-Mansor (see also chapter 6).

In the spring and summer of 1537, Vesalius stayed in Venice. It is likely that he met the Flemish artist Jan Steven van Calcar (approx. 1499 – 1546) for the first time in that period. Van Calcar would later make some of the anatomical drawings for Vesalius’ Tabulae Anatomicae Sex and De Fabrica (see also chapter 2) [20](p.121) [21](p. 82). In the autumn, Vesalius went to Padua where he took his Medical Doctorate ‘magna cum laude’ on December 5th, 1537 [8]. The day after, he assumed his activities as second professor of surgery: a complete public practical course on anatomy to illustrate the theoretical course given by another professor [22]. Soon, he was appointed senior professor of surgery and of anatomy. Initially, Vesalius followed the teachings of Galen [14, 15].
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To back-up his course, Vesalius published six anatomical drawings, *Tabulae Anatomicae Six* in the spring of 1538. Three of these drawings had been prepared by Vesalius, whereas the other three were done by van Calcar. Like his teachings, these drawings were still done in Galenic tradition with a five-lobed liver [1]. He would prepare two more publications before his *De Fabrica*: a fully revised reprint of Günther’s *Institutiones Anatomicae* (1538) and *Epistola, docens venam axillarem dextri cubiti in dolore laterali secandam* (*Epistola de Vena Secanda*, or bloodletting letter, 1539). In January of 1540, Vesalius gave a public course on anatomy in the old and renowned university at Bologna at the urgent request of the medical students. This course was followed by the German Baldasar Heseler, who left us an eyewitness report and notes of both the theoretical lectures in full Galenic tradition by the Bolognese professor Mattheus Curtius, and the dissections by Vesalius [22]. Vesalius, by that time, had become far less Galenic in his opinions and Heseler recorded some emotional debates between Curtius and Vesalius.

Vesalius remained to teach in Padua until the end of 1542. By then, he had finished his opus magnus: *De Fabrica*. As he wished to market this work predominately in Central Europe, he choose to have it printed in Basel. After having the woodblocks and proof sheets packed and delivered to Milan for transport over the Alps, Vesalius left Padua to oversee the printing and publishing of his work in Basel. On the way there, he spent some time in Ferrara, in the north of Italy. Here he visited the anatomist Canano who, like Vesalius, was only 27 years of age. Canano showed Vesalius five of his drawings of the muscles of the hand (see also chapter 2).

According to its colophon, *De Fabrica* was completed in June 1543. Since the binding of the whole edition must have taken several weeks, the book must have been for sale at the beginning of August. *De Fabrica* was dedicated to Charles V, by then the Habsburg Emperor of Western Europe to whom Vesalius’ father was the imperial pharmacist. The dedication was made in Padua, Italy and dated August 1, 1542. Simultaneously with *De Fabrica*, Vesalius had his *De Humani Corporis Fabrica Librorum Epitome* (*Epitome*) printed and published in Basel. Its fourteen pages of text and nine folio-sized *Tabulae* were meant to be a less expensive “pathway through these books [De Fabrica] and an index to the things demonstrated in them” (quote on p. liv) [17], as well as a ‘trailer’ to *De Fabrica*. It was dedicated to Prince Philip, the son of Charles V, already on August 13, 1542, while Vesalius was still in Venice. It was first marketed on August 9, 1543, and was repeatedly reprinted and instantly translated in German. Immediately following the publication of *De Fabrica* and the *Epitome*, Vesalius went to Mainz where Charles V was staying for some days. He offered the Emperor a copy of *De Fabrica* printed on vellum along with a copy on vellum of the *Epitome* for the Emperors’ son Philip [16]. At this occasion, Charles V asked Vesalius to become his court physician. Vesalius then shortly joined Charles as military surgeon on one of the Emperor’s campaigns but soon returned to Italy.
Back in Padua at the end of 1543, Vesalius found his former assistant and protégé Realdo Colombo of Cremona (approx. 1515 – 1559) to have turned against him and his teachings (see also chapter 3). To publicly clear his name and prove his being right on his teachings, Vesalius performed two additional public dissections in January 1544. After this, he fell into a depression during which he burned all his additional manuscripts in the presence of some friends, and he left Padua for good. After a stop-over in Pisa, Vesalius returned to Charles V. After Charles had finished another field campaign, this time in France, Vesalius travelled back to Brussels with him. There, Vesalius got married to Anna van Hamme and set up a family and a profitable practice. In the fifteen years he lived in Brussels and spent time abroad with Charles on field campaigns and diplomacy travels, Vesalius publicly turned against his former Parisian teachers Sylvius and Winter von Andernach in the *Epistola rationem mod-unde propinandi radicis Chynae decocti* (*Epistola Chynae*, or China-root letter, 1546), in an attempt to explain that he had not intended to collect Galen’s flaws but only had been interested in the (anatomical) truth [14, 15]. Additionally, Vesalius prepared a second edition of the *De Fabrica* that was published in 1555. Although fully revised by Vesalius, it hardly contained important scientific changes.

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**Figure 1.3**: Andreas Vesalius was a descendant of a family of skilled physicians and an apothecary that for generations had an exceptional, lasting relationship with the Habsburg and Burgundy royal houses. A → B : A lend his services to B (after Lindeboom) [7].
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In 1556, Charles V abdicated by resigning the imperial dignity and Vesalius passed into the service of Charles’ son Philip, who initially held his court in Brussels. As of 1559, Vesalius lived in Spain as Philip moved there. Not being able to perform any anatomical dissections [23], Vesalius was kept to his surgical practice. In 1561, he received a copy of Gabriele Fallopius’ *Observationes Anatomicae*. Although Fallopius (1523 – 1562) clearly and repeatedly honoured Vesalius for his anatomical genius in his book, he also entered some points of disagreement. Within two weeks, Vesalius finished an extensive reaction to be delivered to Fallopius in Padua. When this reaction finally arrived in Padua in the autumn of 1562, however, Fallopius had died. In 1564, Vesalius had his reaction published in Venice under the title *Anatomicarum Gabrieles Fallopii Observationum Examen*.

For reasons unknown, Vesalius went on pilgrimage to the Holy Land in 1564. He made a stop-over at Venice and it is said that, after his departure, the Senate of the town decided to reappoint him in Padua at a high salary. This message would have reached him in Cyprus, during his pilgrimage. On his return from the Holy Land, Vesalius’ ship sailed in heavy storms and Vesalius is said to have come ashore and die at the isle of Zacynthos (Zanthe), probably on October 15, 1564.

In all, Andreas Vesalius was a Renaissance man or *uomo universal*, performing anatomy, surgery, teaching, philology, arts, philosophy, and fine prose [24]. He is “the first modern anatomist to place his study on a firm foundation of observation” (quote on p. xvii) [24], the results of which are to be found in his masterpiece *De Humani Corporis Fabrica Libri Septem*.

*De Humani Corporis Fabrica Libri Septem*

Vesalius is rightfully seen as the father of modern anatomy [25, 26]. His *De Fabrica* has long been, and is still being, recognized as the work that brought anatomy and, consequently, surgery into the new era of scientific reasoning [25]. Such was the immediate influence and impact of the work that it made Canano from Ferrara decided to not publish any more of his own work [27-29].

Still, *De Fabrica* was one work out of many. Prior to Vesalius, the Italians Mondino de’ Luzzi (1275-1326), Jacopo Berengario da Capri (ca. 1460-1530), Alessandro Achillini (1463-1512), Giogio Valla (1447-1500) and Niccolo Massa (? – 1569) had already published anatomical observations (p. 96) [4, 21, 30]. Berengario’s medical drawings published in 1521 in his *Isagogae breves* are considered the first in the modern sense [25, 31]. After Vesalius, Realdo Colombo (1516-1559) planned to publish together with Michelangelo a work on anatomy that would outshine Vesalius’ *De Fabrica*. The plan stranded because of the old age of the artist [32][p.72] [33, 34]. Instead Colombo published his *De re anatomica libri XV* in 1559, 16 years after the first print of *De Fabrica* [35].
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Like *De Fabrica*, the *De dissectione partium corporis libri tres* that Charles Estienne published in Paris in 1545, was a combination of text and illustrations. Estienne and Vesalius prepared their works ignorant of the work of one another. Like Vesalius, Estienne contradicted some of Galen's observations even though he did not do his own dissections and illustrations but had them made by a barber-surgeon. His *De dissectione*, however, hardly attracted any interest as it did not reach the quality of Vesalius' *De Fabrica* [21, 26]. Gabriele Fallopio (1523-1562) was to follow with his original work *Observations anatomicae* in 1561 [4], while the 42 copper plates by Bartholomeus Eustachius (15??-1574) were completed around 1564. They were only published in 1714, in the *Tabulae anatomicae* by Lancisius [25].

Vesalius sought to show the structure of the human body as correctly as possible. He took great pains to illustrate the text by fine drawings and, in 1546, acknowledged to have contracted various artists for this without, however, mentioning their name (p. 186)[14, 15] (p. 121)[20]. Vesalius warned nevertheless, that the illustrations do not make personal inspection superfluous: "it was never my intention that students should rely on these [illustrations] without ever dissecting cadavers" (quote on p. lvi) [17]. Still, these illustrations rather than the text, got all attention in the majority of commentaries on his work [21, 25, 36]. In Vesalius' time this may have been explained by the novelty of illustrating anatomical texts whereas, a century later, medical doctors may have been so proud of their own medical advancements that they preferred to regard the work of their predecessors as outdated [8] (p. 12). In our era, the neglect of Vesalius' text may have resulted from difficulty of handling his Latin language [24, 25, 36, 37]. Although many editions, revisions, adaptations, and facsimiles of this work appeared over the centuries, remarkably it has never before now been translated (except for fragments) into a modern language other than Russian (Moscow, 1950–1954). The English translation presented by Richardson and Carman between 1998 and 2009 supplies a modern, accessible version of this monumental work for the first time. Since, the study of the unique combination of Vesalius’ text and illustrations in all seven books of *De Fabrica* has become readily available.

Our studies proved that the illustrations and the text cannot be fully appreciated without each other. The text, for example, stresses that some parts of the illustrations intentionally zoomed in on details to draw extra attention to them [21]. Likewise, only from the text can be learned that Vesalius intentionally illustrated the rectus abdominis muscle in accordance with the opinion of Galen while he was fully aware, and explained in the text, that Galen had been wrong (Figure 1.4) [38]. We found the text on the muscles of the hand and forearm could not have been fully understood had it not been for the many Tabulae accompanying it, and vice versa (see also chapter 2).

Commemorating Vesalius’ 500th anniversary, chapters 2 through 5 report on Vesalius’ innovative observations on the upper extremity. In chapter 6 and 7, his observations on the superficial fascial system are presented, whereas chapters 8 and 9 focus on his innovative considerations of voice production and the pulmonary system. The
influence of Vesalius’ role in the acceptance of the concept of animal cognition is presented in chapter 10. Of lighter calibre is chapter 11 in which his links to the, then fairly new, game of tennis are presented. In chapter 12, I discuss the general role that Vesalius’ character played in the history of anatomy.

Figure 1.4: One of Vesalius’ famous muscle-men (Tabula V) portrayed in Book II of De Fabrica - On the ligaments and muscles. In it, Vesalius intentionally illustrated the rectus abdominis muscle in accordance with the opinion of Galen. Only from the accompanying text can be learned that Vesalius was fully aware that Galen had been wrong: ‘the line r terminates the fleshy part of the upright muscle; in man this is the last part of its insertion, as can be seen in Table IV at symbol n. The interval from r to s here marks the tendon or membrane or fleshless part of the upright muscle in the simian abdomen’ (quote on p. 37-38) [38]. The paradox between Tabula V and accompanying text may, alternatively or additionally, be explained in case the Tabula had been prepared in the period that Vesalius was still heavily influenced by Galenic theory.
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