An Overview of Anatomy

Danny Huang

Physiology/Honors

Introduction

I have been fortunate enough to take a class called "History of Medicine" with the Honors Program. The class as a whole was lucky enough to travel to England, Italy, and Scotland over three weeks to learn about how medicine evolved and progressed throughout Europe. One of our guides in England was Berwyn Kinsey. Berwyn Kinsey can only be described as the modern-day renaissance man and human encyclopedia all bundled up together with a Welsh accent. He led the class around London showing the historical impact the city had on medicine, not just in Europe, but around the world. However, Berwyn's best attribute as a guide was his ability not to spew historical facts during his tours, but his ability to tell a story and demonstrate how medical ideas percolated into every aspect of society especially in areas that one would not expect.

We had the privilege of visiting was King's Gordon Museum of Pathology, the largest medical museum in the UK, which is reserved for medical students and researchers. The museum was a wondrous experience for me. In every corner of the museum were neatly arranged and cataloged anatomical specimens displaying innumerable pathological cases. Among the collection, I spent the most amount of time in an area dedicated to famous murder cases. Displayed, were actual artifacts from these murders from the murder weapons to a bludgeoned skull. More importantly, UK law and order adapted and progressed as a result of these cases. Upon leaving the museum, I reflected upon Berwyn's notion of how we should examine things beyond their face value. After looking at the anatomical specimens, I asked myself, what can we gather from the study of anatomy?

If one types into Google, "fun facts about the human body," over 340 million results instantaneously appear. You might learn from websites like *allthatisinteresting.com* that the human body contains over 100,000 miles of blood vessels or that humans produce enough saliva to fill two Olympic size pools during their lifetime (Serena, 2018). While these facts may seem trivial and useless, they are rooted in the study of anatomy. I imagine the majority of the population might think that the investigation or the subject of anatomy is quite dry, but I would argue a deeper dive into the history of anatomy reveals anatomy has played a central role in how humans understand and navigate the world.

Ancient Studies

Today, we know the fine interworkings of the human body allows us to function as a well-oiled machine. Twenty-five thousand years ago, there was no such conception nor the mental prowess nor technology to investigate such ideas, but our fascination with our bodily form is as ancient as the cave-dwelling art. Ancient art depicts hunting scenes and interactions with animals but also the rudimentary understanding of the human form most notably in depictions of injuries sustained by the hunters (Persaud, 1984). Beyond what they saw in their daily lives, prehistoric paintings also hint at the notion that our ancestors were able to manipulate the human form. For example, in Aventignan, France, two hundred thirty- one ancient paintings of human hands were found in a cave. One hundred fourteen of them displayed some variation in the hand position. They were contorted in a fashion in which a finger or multiple fingers were not visible, although it remains a mystery for the reasoning, many argue that these drawings were done deliberately. So to believe that the study of anatomy is a relatively modern concept is wrong. (Figure 1)

As civilization progressed, so did our understanding of anatomy and our ability to use it as an extension to surmise the world around us. For example, in Mesopotamia, notions of the supernatural governed Babylonian civilization and their understanding of the human body (Persaud, 1984). In the absence of studying human anatomy prohibited by strict moral codes, Mesopotamian tablets speak of diseases that we today are familiar with: gonorrhea, scabies, night blindness, and strokes (Ackerknecht, 2016). The Mesopotamians believed that disease was the direct result of sin caused by a perceived notion of uncleanliness or ungodliness. Such trespassing from godliness was caused by a multitude of taboos, resulting in the belief that the Gods themselves rescinding their protection, allowing demons to enter and injure such individuals. The Mesopotamians resorted to alleviate such ailments by first understanding the origins of sins, dream interpretation, astrology, and even hepatoscopy, the study of the liver from sacrificial animals.

While Mesopotamia did not trifle in the exploration of the human body, the Egyptians welcomed it with open arms. For the ancient Egyptians, the universe was in a constant flux of natural cycles, from the rising and setting of the sun to rain and drought. This conception of cycles meant life on Earth was also met with its complement: death (Taylor, 2001). However, the Egyptians did not believe that one's cessation of life on Earth meant a total resolution, but instead another step into "another existence," the afterlife (Persaud, Loukas, & Tubbs, 2014). The Egyptians viewed a duality between the body and soul, as the human was comprised of both physical and non-physical parts known as Ka (physical features) and Ba (soul). It was understood that after death, the Ba would leave the body and be guided to the underworld by the sun during the night and return to the body (Ka) during the day. To ensure the cyclical pattern would endure, it was vital the physical body be preserved in its most life-like form. In order for this to happen, anatomy would play a crucial role. (Figure 2)

According to Persaud and his colleagues our modern understanding on the process of mummification relies on the written record of Herodotus, a Greek historian, who visited Egypt in the fifth century B.C. Immediately after death, the body was placed at the house of purification where the embalmer's job began. First, the clothing was removed, and the body was then placed on a wooden board. This was the beginning of a 70-day process. Next, the brain was extracted via the nostrils with a probe. Once completed, the internal organs except the kidneys were removed, and the abdominal cavity was then filled with palm wine and spices. Each organ is then individually treated with natron for 40 days and placed back into the body before burial. The body cavity was "filled with temporary stuffing in order to accelerate the dehydration process and to preserve the external features" (pg. 12). Halfway through the 70-day process, the temporary wrappings were removed, and the abdomen was sutured. The rest of the body was treated with a combination of cedar oil, cumin, wax, natron, and gum. The cranial cavity, along with the cheeks and orbits were plugged with linen and eyes were drawn over the closed eyelids. Finally, the body was lacquered with resin and adorned with jewelry and bandaged in a preset manner.

These tasks rested in the hands of embalmers. While it was the embalmer's job to practically prepared the body for the afterlife, they coincidentally developed techniques that modern medical procedures would later use. Ancient Egyptian embalmers christen the process known as trans-sphenoidal access to the cranial vault, a method used only again in 20th-century medicine to remove pituitary tumors. Embalmers were not only to engage in the understanding of the human body, but physicians would also investigate the human body, along with the theme of understanding conditions. In 1862, Edwin Smith purchased a fifteen-foot papyrus dating back to the 17th century BC (Murkherjee, 2010). This papyrus belonged to an Egyptian physician by the name of Imhotep. The artifact was a stark contrast to the Mesopotamian ideas that came before it, as the papyrus was not filled with "magic and religion but the absence of magic and religion" (Mukherjee, 2010, p. 40). The Smith Papyrus described 48 medical cases with clear descriptions of the prognosis and diagnosis of the diseases as well as the prescribed treatment for each ailment including the first written case of breast cancer. It is described as "having bulging masses on the breast... spread over his breast... no granulation, contains no fluid, give rise to no liquid discharge" (p. 40).

Hauntingly of the 48 medical cases, the treatment options always followed, except for breast cancer, which Imhotep stated: "there is none" (p. 41). The Smith Papyrus is one of many believed to belong to Imhotep. Another known as the Ebers papyrus similar in the style of medical rigor as the Smith Papyrus is the first to make connections of the cardiovascular system, implying a relationship between the pulse and the heart. In the papyrus also describes albeit wrong, anatomical processes that occurred within the body (Persaud, Loukas, & Tubbs, 2014). Both mummification and these papyruses show the duality of anatomy in Egyptian society, one dedicated to the eternal afterlife, another to help extend life in the present.

The Greeks

The ancient Greeks displayed an excellent understanding in the fields of humanities and science. Today, we owe them a great deal of gratitude. Modern medicine is built upon the ideas that the ancient Greek developed. No longer did the Greeks believed that disease was a supernatural occurrence and treated as such, but rather illnesses need to be examined from "a rational, naturalistic, and scientific point of view" (Ackerknecht, 2016, p. 36) However, such transformative ideas did not arise suddenly, but rather slowly. In the early Greek history, religious medicine was still the placeholder, while minuscule changes did occur, it was not until monumental shifts occurred when Hippocrates and his contemporaries would collectively write and rewrite the *Corpus Hippocraticum.* The *Corpus Hippocraticum* was comprised of 60 treatises that on the causes, prevention, and treatment of sickness (Jackson, 2014) (Figure 3). Among the 60 treaties rest Hippocrates most transformative idea: humors. In total, there were four humors: black bile, blood, yellow bile, and phlegm that corresponded with the natural elements of earth, air, fire, and water. Each humor had distinct attributes and characteristics. Among Hippocrates's followers was the Claudius Galen, who brought humoral medicine to its zenith (Lagley, 2002). (Figure 4)

Galenic medicine was predicated on the idea of balance of the humors. Disturbances were caused by a multitude of reasons ranging from gluttony, sleep patterns to the unpredictable nature of the climate. Galenic physicians diagnosed which humor was out of place and tried to balance and restore equilibrium within the individual. In order to accurately assess the patient, the physicians would systematically gather the details of the disease by carefully examining all angles of the patient's life and surroundings.

Galenic medicine is predicated on the study of anatomy beginning with his tenure working as a surgeon to the Roman gladiators. He would observe various anatomical observations based on the injuries sustained by the gladiators. Beyond the visible grotesque injuries, Galen would also perform dissections, but because of Roman law that prohibited human dissections, Galen would reach for the next best options: a wide range of animals. Galen would use apes, monkeys, dogs, and pigs even believing that pigs and humans had similar organ systems. While Galen did contribute to the anatomical findings such as identifying the various landmarks of the skull, it is widely considered that his work is riddled with anatomical mistakes (Ackerknecht, 2016). For example, he believed that heart transported some blood to the brain, where the blood would be transfused into an "animal spirit" that were distributed to the wider body (p.58). However, Galen's works would not be challenged until the 16th century by the anatomist, Vesalius.

Prior to Galen's anatomical findings, two Greeks would precede him in exploring the human body, more importantly, correctly. Plato once hypothesized that the body entrapped the soul and that only death could free it; two Greek anatomists would investigate this notion. Herophilus and his younger contemporary, Erasistratus were at the forefront of anatomical discoveries, performing systematic dissection of the human body (Bay & Bay, 2010). However, their window of opportunity opened and closed in a matter of 30 to 40 years as dissection would become taboo for the next 1800 years. During this period of investigation, Herophilus would help differentiate and determine various aspects of the body. In the nervous system, it is believed he was one of the first to understand the distinction from blood vessels and nerve, but also to elaborate on the notion that the nerves conveyed neural impulses. This idea would not be elaborated further until Charles Bell and Francois Magendie in 1831 who discerned that the dorsal spinal roots mediated sensation and ventral roots dictated motor functions. However, Herophilus and Erasistratus already noted the distinction. Herophilus is also credited with naming the meninges and the ventricles while refuting Aristotle's long-standing notion that the brain was a "cooling chamber," but rather the "seat of intellect." Beyond the nervous system, Herophilus and Erasistratus work stretched to other areas of the body as well from the digestive system to the individual components of the eyes. Herophilus's life was not only marked by his diligent work and his discoveries but the dangers of forward and progressive thinking.

Herophilus was labeled as a butcher by future Greek physicians and intellects like Galen. They accused Herophilus of performing on live patients. As a result, Galen and his work would determine the history of medicine and anatomy during the Middle Ages and early modern times.

The Middle Ages

The Middle Ages could be described as a period of stagnation. During the Middle Ages, it was medieval custom to compile and interpret existing knowledge, and along the Catholic Church ban on dissection detesting the sanctity of the human body, Galenic medicine would hold sway of Europe over for the next 1300 years (Persaud, Loukas, & Tubbs, 2014). Because of Galen's monopoly, it was to be understood that Galen's anatomical works and studies were the only sources needed to understand human structure and function (Ackerknecht, 2016). More importantly, notions of studying anatomy were seen as paganistic and was thoroughly frowned upon. Because of such indifference to exploration, the study of anatomy would grind to a complete halt until the birth of European universities.

As Europe transformed and shifted in societal values, the expansion of trades and territories, and the formation of self- sustaining, the notion of exploration was not limited to just land and sea conquests, but new knowledge itself. A paradigm shift would occur in how humans would come to understand ourselves within the cosmos. People began to explore "religion, the occult, mysticism, and astrology," but how humans were under the "magical influence of the planets" (Persaud, Loukas, & Tubbs, 2014, p. 50-51). The inquiry for new knowledge would come in the place of universities. The study of anatomy at these universities under the approval of church and state would be revived. In total, eighty universities would be formed with the University of Bologna as its most revered.

Persaud and his coauthors state that among those to have gained tutelage in the College of Medicine at the University of Bologna Mondino de Liuzzi may be their most famous pupil. Born during the most opportune time and to the family of both high esteem and wealth, Mondino de Liuzzi would not waste his opportunity to influence the trajectory of anatomy. Born during the late Middle Ages, the Catholic Church during this period allowed for the dissection of executed criminals. As a result, he had ample opportunities in dissect and create the Anathomia, his dissection guide. Mondino de Liuzzi's family was a well-connected one which lead to his admission into the University of Bologna in the first place. Upon graduation, using his familial connection, he worked his way into serving as the Ambassador of Bologna. As a result of such political clout, he lobbied for anatomy to be finally included in the medical curriculum, mainly his manual, Anathomia. Through Anathomia, entrance into the medical curriculum, a paramount rationalization is formed; that "humans were superior to all other creatures because of their intellect, reasoning ability, tool-making abilities, and upright stature," a notion that is still firmly believed today. Charles Darwin, the father of natural selection, stated "I fully … subscribe to the judgment of those writers who maintain that of all the differences between man and the lower animals the moral sense or conscience is by far the most important" (Ayala, 2010). Modern science also helps confirm the judgment that humans possess a higher intellectual ability as superior pattern processing of our brains give us unparalleled superiority unmatched by any other species (Mattson, 2014).

The 15th century would provide a turning point in the advancement of technology that assisted in the rapid delivery of information. Johannes Gutenberg's printing press would revolutionize how information could be dispersed and made widely available to the masses (Jackson, 2014). By accelerating the ability to produce books, a printing evolution began. While the original goal of the printing press was efficiency, there were other considerable advantages occur. First, the ability to mass produce books led to a smaller illiterate population and secondly the printing press introduced the newly literate masses to ancient literature that would in-turn, inspire a transformation in the scientific method leading to a newer and broader understanding of the world.

Renaissance

Anatomy would be at a crossroad in the 15th century. The study of anatomy would experience an explosion of appreciation and exploration that previous centuries had been shuttered from. The human form would be at the forefront of art, but also the first steps of modern medicine would begin to take place.

The Renaissance is described as the period between the 15th to 17th century in Western Europe in which intellects from all subject matters would engage in the pivotal shift from medieval sensibilities to a renewed look at ancient humanistic philosophies. Art, itself, would look to recreate the structural forms of the human body exhibited in classical art. In the pantheon of great Renaissance artist stand three individuals: Leonardo da Vinci, Michelangelo Buonarroti, and Raffaello Sanzio de Urbino (Persaud, Loukas, & Tubbs, 2014). These three would push for the return of the traditional perceptions and depictions of the human form. To return to such roots, these Italian masters would use anatomical studies as both direction and inspiration for their art. As a result of the renewed naturalistic view, the study of anatomy would become a requisite for these masters. For Leonardo da Vinci and his contemporaries, they initially turned their attention to surface anatomy but, gradually, a shift began. The artists started to investigate underneath the skin, to uncover the internal structures (Jackson, 2014).

Leonardo da Vinci is considered the most celebrated anatomical artist, not only for the mastery of the artwork itself but also for his ability to try to understand the human form and its relation to function. He saw painting as a scientific activity, where every effect such as light and shade should resemble and represent the nature around him. He also believed that studying the superficial layers of the human body was not sufficient, but to evoke both emotion and drama of his human subjects in his paintings and sculptures, he yearned to understand how an "individual's appearance from moment to moment was related to the works of the mind" (Clayton, 2012).

Such yearning would lead to his direct engagement in dissections. He performs his dissections in both Florence and Rome, during the night, in secret, and armed only with a knife and bone chisel. Between 1507 and 1513, Leonardo da Vinci would perform dissections on 30 individuals. However, it was during 1510-11 where da Vinci made the most ground on his understanding of anatomy. During this period, he would partner with Marcantonio Della Torre, an anatomy professor at the University of Pavia. Della Torre would provide da Vinci with the human material required, and during the winter, he would dissect over 20 bodies. Armed with these rudimentary tools and under the guise of the dark, da Vinci would meticulously uncover new information about the human body.

He unearthed the mysteries of the cardiovascular system, understanding and depicting the different heart valves and their functions. He even understood and noticed arteriosclerosis in his cadavers, in his drawings, he noticed the subtle differences between the blood vessels of older individuals and those of a younger person. True to his notion of form and function, his observation of arteriosclerosis would lead to his initial interest in fluid dynamics (Persaud, Loukas, & Tubbs, 2014) (Figure 5). What makes his work even more challenging and miraculous is the fact that he performed such dissections with material that was not chilled, embalmed, or fixed. However, his research was halted in 1511, when the city of Milan was under military turmoil, da Vinci fled without any of his treasured materials.

However, unfettered, he would still ponder the human form and instead of human resources, he would use animals to study. Most notably was his work with ox hearts, whose comparative anatomy is similar to that of humans (Clayton, 2012). With the ox hearts, he wrote in great detail about the intricacies of the ventricle and atria structures; beyond just the physical structure, but the meticulous minute by minute detail of the heart's movement. So, fascinated by the heart, he created a glass model of the aortic valve in which he pumped water that was mixed with grass seeds to study the swirling of fluid during the widening of the aortic valve. Through this model, he understood that "these vortices were crucial in the closing of the heart." His findings would be confirmed in the 20th century.

Perhaps the most tragic aspect of Leonardo da Vinci's work was that he failed to publish his research. As a result, in 1519, when he passed, his work was left to Francesco Melzi, his assistant. Because of this, his work was forgotten until the 17th century, when the last 150 surviving pages of his work was combined with another album that contained more artistic drawings (Clayton, 2012). However, while his work could have been the quintessential basis of modern anatomy, another man would take this mantle, Andrea Vesalius.

Such introduction of dissections in the European educational system, a dramatic shift began as the dissection of the human body would contest the dominant theory of Gaelic medicine, and Andrea Vesalius would reluctantly lead the charge. Vesalius, a devote follower, of Galen medicine would, through his dissections, tear down Galen's notions of anatomy and medicine. However, his work is not without controversy. Because of the inability to preserve the human bodies over an extended period, medical schools only allowed to cadavers during the winter months, in order to slow the process of decomposition. However, Vesalius, eager to understand more about the human body, he would resort to grave robbing. Vesalius conducted his work in Paris, at the Hospital Dieu and near to the hospital was the Cemetery of the Innocent (Mukherjee, 2010). This cemetery would become his convenience store. While unsettling as it may be, beginning in the 1530s, Vesalius began his production of beautifully illustrated and educational texts that included anatomical structures and discussion on the works of Galen (Mequita, Junior, & Ferrerira, 2015). However, through his investigation, he began to realize how incorrect Galen was. Through his observations, Vesalius began to argue the inaccuracies of Galen's findings. Vesalius would collect his observations and notes and published the *De Humane Corporis Fabrica* or just *Fabrica*, a seven-volume overview of anatomy (Figure 6). *Fabrica* contained and argued many of Galen's original works including the idea of the "animal spirit" and presented counterarguments of a different version of the circulatory system. However, his works were not without contentions as many of his peers shunned his work as they were ardent supporters of Galen medicine, which lead to the demise in his academic ventures. Although he would not know this, his work would be instrumental in future works (Jackson, 2014).

The study of anatomy during this period as a lens to further understand something that occurred on a much larger scale: the beginning of the scientific revolution. Before the Renaissance, western culture subscribed to the ideas of Aristotle of how humans were oriented in the cosmos. Aristotle believed that the universe was neatly packaged and organized into its distinct parts. Like the four humors of the body, the universe adheres to the same principle, with four elements and four seasons. Aristotle also believed that the Earth was the center of the universe and that the Sun and the planets rotated around the Earth, giving rise to the geocentric theory. However, during the Renaissance, upheaval in these Aristotelian beliefs would occur and be examined just like Galen's theory of anatomy. These notions were attacked and dissected with the same pragmatism (Jackson, 2014).

At the same time, Vesalius would publish the *Fabrica*, Nicolaus Copernicus would propose a radical idea that would radically alter our standing in the universe. He would write *De revoltionibus erbium coelestium* (On the Revolutions of the Heavenly Spheres) which introduced the idea that planets revolved around the Sun instead. Like Vesalius, it was ridiculed and deemed preposterous. Galileo Galilei only confirmed his findings. Author Mark Jackson believes that the very notion to examine and meticulously assessment of classical thinking would be the catalyst for the scientific revolution of the 20th century: a period marked with the use of empirical data and research from experimentation to explain the universe and the rapid advancement of technology.

Theology and Science

While the likes of Vesalius and Galileo pushed the frontiers of our understandings of our physical self and world during this era, lesser known of such Michael Servetus, a Spanish physician, and theologian, tell a cautionary tale reminiscent of Herophilus, in the pursuit of knowledge (Jackson, 2014). Servetus was a prolific writer in both fields of theology and science. Both ambitious and radical, his ideas were often ridiculed. For example, after observing the night sky, he wrote about the effects of astrology on one's health (Britannica, 2018). Although mocked for such proclamation, he would still become Vienne's archbishop's personal physician. As a physician, he would also inquire about human anatomy; however much of his work was imbued with religious mysticism. Like Vesalius, he would rebuke Galen's approach to medicine.

However, unlike Vesalius, he would not be celebrated, but instead vilified for his findings. In his findings, he would be the first to record the correct process of pulmonary circulation (Stefanadis, Karamanou, & Androutsos, 2009). While correct, he would try to correlate his conclusions to his theological work known as the *Chistianismi Restitutio*, a critical misstep on his part. Servetus believed that the human vascular system could answer fundamental questions such as the movement of the stars and the essence of the human spirit; “from respiration to inspiration. This spark was the soul.” He further contended that the human soul was “a spark of the Spirit of God” (Caattermole, 1997). Such proclamation was seen as open defiance to the Holy Trinity and the incarnation of Christ and was seen as heresy among both the Catholic and Protestant Churches.

As a result, he was arrested, tried, and burned at the stake along with the majority of his work in 1553. Michael Servetus is not just a cautionary tale, but also one that highlights defiance and intolerance. Like his Renaissance contemporaries, he pushed the preset boundaries with the intention of seeking knowledge and truth. His work can be characteristically marked by his defiance in an era in which stringent religious conventions are absolute statutes (Cattlermole, 1997). He should be recognized for his provocation in the face of such dogma and willingness to stand behind one’s work. His defiance is also marked with intolerance which highlights the inherent dangers of challenging the preconceived notions, even at the risk of one’s own life.

Michael Servetus’s execution would have rippling effects in the Protestant Church. John Calvin, a theologian, lead the French Protestant Reformation, a movement that would migrate and be indoctrinated in other areas of Europe and North America (Bouwsma, 2018). John Calvin would also oversee the trial of Michael Servetus. Calvin, himself, pushed Servetus to accept the Christian doctrines; however, Servetus was steadfast in his convictions. As a result, Calvin saw no choice, but to convict Servetus. However, in the aftermath, Calvin’s actions were criticized, it was seen that his uncompassionate actions were the due to root out any disagreeing opinions. It was also seen as an unwise political move to a reformation church to participate in acts of execution.

Rise of Science

After Michael Servetus untimely death, another man would unknowingly continue where he left off. This man would be William Harvey. Harvey, an Englishman, would receive his medical degree from the University of Padua in Italy. Upon graduation, he would return home to England and have an illustrious career as a medical lecturer and a personal physician to the royal family; his career was marked with the monumental discovery of understanding the circulation of the blood (Ribatti, 2009). However, his crowning achievement is his secular approach to science and experimentation. Unlike the Egyptians and Servetus who saw anatomy as an extension to the afterlife or a tool to argue and discern religious doctrine, William Harvey empirically saw anatomy as its own secular endeavor. At the time of his experimentation, physicians long held the belief that the lungs powered the movement of the blood throughout the body. Harvey, on the other hand, observed something differently in animals. He saw that during that during the systole, the contraction of the heart ejected the blood. He hypothesized that the amount of blood being pumped out at any moment was too much to entirely be absorbed by the body (See Figure 7). He showed that valves in the veins permitted blood flow in one direction towards the heart and proved that blood circulates, throughout the body and return, to the heart. In his manuscript, *De Motu Cordis*, he clearly writes the passage of blood that any modern anatomist would understand:

> "It has been shown by reason and experiment that blood by the beat of the ventricles flows through the lungs and heart and is pumped to the whole body. There it passes

through pores in the flesh into the veins through which it returns from the periphery everywhere to the centre, from the smaller veins into the larger ones, finally coming to the vena cava and right atrium."

Harvey also tackled the widely held belief that blood was regularly formed from the intake of food. It was believed that through digestion, food would disintegrate into the formation of blood to be used primarily as fuel for tissue and the sole purpose of the heart was to act as a furnace. Again, he was able to scientifically show that the volume of food ingested daily did not equal the volume of blood within the body. Today, William Harvey's discoveries are often heralded as the most significant single-handed discovery in physiology and medicine. While that may be true, there is something else that should be recognized in his discoveries.

Again, we must look at the implications of Galen. For the more than 1,500 years Galen's model remained relevant, due to the lack of experimentation and the trust of experimentation to explain the natural world. Along the with distrust was the reluctance to let go of old truths for new ones in the face of overwhelming evidence, that is why William Harvey is so impressive. William Harvey's work is heralded a paradigm shift – the beginning of the scientific method. serves as a crossroad of a paradigm shift in how humans seek to gain knowledge in the natural world. Essentially without the scientific method, science does not exist as we know it today. This skepticism of new knowledge is not antiquated; modern history tells us that old habits die hard.

Climate change presents the perfect foil to examine this idea. For more than a quarter of a century, scientists have been warning the public and government about the rise in global temperatures. A recently mandated Climate Assessment from the current Administration showed that not only is the planet getting warmer, but it is also reaching a critical point, and remedial effects in future can help change the damage already caused by climate change. In the presence of such data, history would tell us to wisely consider these reports not as warnings, but as absolute trues, where logically, we should seek ways to alleviate our carbon footprints. However, the Environmental Protection Agency has acted against the advice of the report by rolling back restriction on oil, gas and coal emissions (Christensen & Nedelman, 2018).

Age of Enlightenment

When William Harvey passed away in 1657, a new era of thinking began, one that he helped usher in: the age of enlightenment. From the late 17th century through the 18th century, the period would be reminiscent of the renaissance as its goal remain the same; the full pursuit of knowledge. No longer were theological and occult ideas used to explain the natural world, but rather a clear secular scientific approach, where “reason replaced revelation” was implemented (Jackson, 2014, p. 85). Jackson also argues that while Harvey served as a prelude to this era, a multitude of other reasons help propel this era into existence. First, humans were not bound to borders, as people were able to travel more efficiently and safely cross land and sea. With physical boundaries become more blurred, boundaries of social class were also being muddled, as upward social mobility becoming a possibility as global markets providing opportunities for all walks of life. With opportunity came urbanization and with increasing literacy rates, ideas and knowledge were no longer private affairs, but could be widely disseminated among the masses. The science of anatomy would benefit from such factors.

If one is to discuss anatomy during the Enlightenment period, the Hunter brothers William and John, are inextricably linked to it (Persaud, Loukas, & Tubbs, 2014). William Hunter, the eldest, began his education at Glasgow University and after apprenticeships and changes in job positions, William Hunter would finally settle in London in 1746 with the opening of his school: The Great Windmill Street School. At this time, John Hunter who was ten years younger than William would also join him, working and gaining tutelage under him. The Great Windmill Street School was a massive success both scholastically and financially. Before the opening of his school, the majority of anatomical lessons were held at universities. Even at these universities, opportunities for medical students to experience practical anatomy were limited. As a result, medical doctors' exposure to identifying and treating pathological conditions was constrained. As a result, many would procure outside lessons from private anatomy lectures and apprenticeships. However, the Company of Barber-Surgeons, who oversaw practices of surgeons in London eliminated private anatomy lectures through strict regulations. However, in 1745, the Company of Barber-Surgeons disbanded and as their stranglehold on anatomical practices loosened, the Great Windmill Street School would open and a fill a necessary void.

At the Great Windmill Street School, William Harvey would reform longstanding anatomy practices. While dissections remained a constant practice, he would begin to preserve specimens. William and his brother would facilitate and preserve a wide range of specimens through dissection, highlighting pathological oddities and diseases used for comparative anatomy. Along with his own specimens, he would also purchase pieces from sellers, and soon he amassed an extensive collection and formed a museum one that would be recognized not only for its quantity but also the quality of materials. Along with his collection of specimens, he also acquired fossils, minerals, shells, coins, and painting as well as creating a library with 10,000 literary works. Soon, William Hunter's school became the most reputable and respected private anatomy school to learn medicine and would teach some individuals who would become highly distinguished in the field of medicine and anatomy. While bright minds would congregate at his school, his museum would also become a status symbol and generated interest from the most unlikely of crowds: the general public.

William Hunter's museum would soon garner the attention of the science world. His collection was not just a collection of pieces, but in many ways, an extension of himself. Much of his collection was procured because he had a vested interest in them, including his rare coin collection and his love of reading. One of his contemporaries remarked that Hunter had "the most magnificent treasure of Greek and Latin books" (p.145). Such attention would become veneration, as respected dignitaries and esteemed company would clamor to enter his museum. As his collection grew in size and status, William Hunter's income from teaching was not sufficient to handle the new influx of interest, and in order to sustain the museum, he would wisely invest into the market, buying and selling East India Company stocks. However, interest in his museum did not just come from the elite, but the general population. For much of history, the study of anatomy remained on the periphery of the general public's interest. Until his museum, the study of anatomy was the focus of the intellectual elite or resided in the chambers of anatomical theaters.

While his ambitions lead to great success, it was at a tremendous personal cost. John William, his youngest brother, would become his most bitter rival. John followed in the footsteps of his older brother and followed him to the Great Windmill Street School. At the school, William taught John anatomy, and, soon, John began to not only help dissect, but also teach at the school. Like his brother, he showed great anatomical skills, however, unlike his brother, John would investigate other life forms, such as birds, fishes, and insects. He believed that through examination of other species, we could come to understand human form and function better and treat diseases accordingly. John and William Hunter harmoniously worked together for ten years until the publication of William Hunter's book, *The Anatomy of the Human Gravid Uterus* (Figure 8).

In the publication, William Hunter acknowledges John for the help that he provided during the dissection but does not give any credit to John for any of the discoveries in the publication. John, himself, was offended by the recognition, proclaiming that he not only performed the dissections, but that he also discovered the structures that William credits as his own. The quarrel between the two did not remain private, and soon the dispute would become public with each writing distasteful pieces to the Royal Society. This dispute would mark the end of their relationship both as coworkers and as family.

Following the split between the two, John's life work and legacy would be immortalized with the creation of the Hunterian Museum, one that would rival his brother's. When the Royal College of Surgeons inherited a collection of 14,000 specimens in 1799, John Hunter took it upon himself to restore and look after the collection, spending roughly 70,000 pounds, the majority of his net worth, to do so. Upon death, he requested the collection would be formed into a museum, one that the British Parliament and Royal College of Surgeons would honor. As for William, upon his death, he did not bequeath John any portion of his will instead bequeathing his estate to his extended family.

While the Hunter's familial dispute may be muddled with personal pettiness, a singular theme remained clear of both the brothers and the age of Enlightenment; a fervor for knowledge. While William Hunter may have achieved fame or fortune from his museum, he remained steadfast in his approach to understanding anatomy, never soiled by either. Even by John's admission, "William's attachment to money arose for prudence, and not from a love of it, or a love to be rich" (p. 150). John's quest for scientific understanding should also not be underestimated, as he pushed for the use of scientific rigor to answer questions regarding the natural world. A principle he would instill into his students, like Edward Jenner, the father of vaccination.

As the world moved towards the 19th century and into the Industrial Revolution, the study of anatomy would take giant steps to modernize as well. Until then the study of anatomy faced two issues: the procurement of bodies and the preservation of the cadavers. Prior to the 19th century, anatomists attained bodies from the executed criminals or relied on their ingenuity. However, by the 19th century, the number of executions were dramatically reduced, and this coupled with the lack of refrigeration, and an increase of medical schools resulted in bodies being in short supply. As such, a business opportunity arose: body-snatching. Grave robbers or "resurrectionist" were men that were paid for robbing graves and delivering the bodies to, however, was in need. As a lucrative market formed, much of the medical community turned a blind eye to these acts as they saw as a necessary evil. Such negligence and desecration of the dead would lead to extreme outcomes and reform ("Body Snatching Around the World", 2014).

While most resurrectionists would use graves and cemeteries for bodies, one duo took a unique angle. William Burke and William Hare, two Irishmen, who called Scotland their home. Formed an effective partnership after meeting though fellow acquaintances (Johnson, 2018). In December 1827 at Hare's own boarding house, their partnership began when one of Hare's tenants passed away. Burke and Hare took the body and placed it into a coffin and delivered it to Edinburgh University to a Dr. Robert Knox who paid seven pounds and ten shillings for the body. This would be their first offense of many to come. Following this, the pair realized the profit they could make, but instead of stealing only directly from the dead, they would resort to more deadly measures to fill their wallets.

Along with their common-law wives, the pair would attract fifteen unsuspecting travelers to Hare's boarding house, where they would intoxicate the individual and suffocate them leaving no signs of struggle. Afterward, they would again deliver the bodies to Dr. Robert Knox, who rewarded them handsomely. However, the pair's luck would eventually run out, when they were caught and discovered in 1831 (Ghosh, 2015). The pair would eventually turn and testify against each other. Hare was released and eventually disappeared with no records of his whereabouts, while Burke met a more unfortunate and ironic twist. He was hung in front of a crowd of 25,000, and his body was then donated to medical science, where his death mask and his skeleton can still be found at the Surgeon's Hall in Edinburgh (Figure 9). The two's crimes reached the collect conscience as a society would seek reform to end the graverobbing trade with the Anatomy Act of 1832, which helped regulate and grant access to cadavers via a legal donation system (Johnson, 2018).

While the legal donation system did help alleviate some issues facing the anatomy community, they still faced a constant pressure- nature itself. The preservation of the cadaver was vital for such a limited resource. From the mummification to performing dissections only during the winter months, a variety of methods had been used to prolong the natural state of the bodies. However, during the 18th and 19th century, we see real advancement in embalming methods (Brenner, 2014). For example, the 1770s, John Hunter began using spirits to preserve soft tissue specimens, while some anatomist used pure alcohol, mercury, or a concoction of chemicals to various degrees of success of preservation, however in 1869, formaldehyde would revolutionize embalming and preservation methods. A German chemist, August Wilhelm von Hofmann, would discover the chemical and to this day, formaldehyde remains a constant fixture in the preservation of human cadavers. Formaldehyde has three primary qualities that make it a perfect chemical; it is bactericidal, fungicidal and insecticidal. Secondly, the chemical has antiseptic properties that delay the process of decomposition dramatically. However, formaldehyde does have its drawbacks: it coagulates blood, can dehydrate tissues and can have an unpleasant scent. Regardless of the drawbacks, state-of-the-art anatomy labs still rely on it and use it to some degree.

The Civil War

Preservation of human bodies would take on a different meaning during the Civil War where modern embalming practices can trace its root too. The American Civil War resulted directly in the death of 2.5% of the population at the time. For more perspective, it would equivalent to 7 million individuals today ("The Civil War by the Numbers," 2018). Resulting from the carnage, embalming practice arose for sentimental values allowing loved ones to pay their final respects. Before the Civil War, a Frenchman Jean Gannal published *Histoire des Embaumements*, a book about embalming and it becomes popular in America. As America divided and fought amongst themselves, Americans put pen and paper into action with many trying outdated techniques to preserve bodies as they made their way home (Walsh, 2018.) Field embalmings were regularly performed next to the battlefield by nonprofessionals with a range of success. As a result, the government began issuing licenses to trained embalmers who could advertise their services. By the end of the war, of the 600,000 causalities, 40,000 would receive some array of embalming, including Abraham Lincoln upon his assassination. After his death, Abraham Lincoln's body would embark on a three-week tour around the country and for many, this was the first exposure to an embalmed body. His funeral tour and the practice of embalming became a national sensation, a practice we still practice today. In modern times, death is still a lucrative business where a single funeral can cost up to $8,000 with embalming included (Walsh, 2018).

Photography

The industrial revolution and the Civil War give birth to another form of technology that will help shape modern anatomy: photography (Devine, 2017). The Civil War was the first war to be photographed, in essence creating a whole new discipline with no shortage of material. Photography does what no painting or drawing can do: accurately portray reality without any subjective perspective. It allowed the masses to see the brutality of the war unfiltered, images of daily lives, showcasing the soldiers who fought it and the sacrifices they made; this had wide-reaching impacts on the perception of the war. Secondly, the same realism depicting the devastation of war also illustrated the toll that war took on the human body. For the first time in history, wounds and pathological cases could be quickly recorded and examined without the requirement of prolonged artist renditions and anatomical dissections. By the end of the Civil War, the Army Medical Museum published 109 photographs that were to be included in an eight-volume set known as *Photographs of Surgical Cases of Specimens*, which showcased the efforts wartime physicians took to understand and treat war-ravaged bodies (Figure 10). Today, photos still illuminate the heartbreaking nature of the war on both the soldiers and the civilians involved; but it also highlights the compassionate nature of humans when human suffering is great. As such, photography has the power to shape our conscious awareness of conflict and suffering.

The majority of discoveries of anatomical features were discovered from cadavers. As our anatomical knowledge grew so did our surgical prowess. However, to achieve such rapid advancements, humans would use despicable methods to attain them While human suffering was apparent during the Civil War, there must be acknowledgment for a reason for the conflict. Perhaps the most singular and foremost reason was for the abolishment of slavery ("Causes of the Civil War," n.d.). Slaves were not just vessel for manual labor, but also human experimentation. During the 19th century, the South pushed to modernize their medical school system as there was an apparent need for medical students to gain experience with anatomical specimens. However, when they were unable to secure them, they would look to patients in the hospital wards, preying on the poor and those that were enslaved, with the majority of cadavers coming from the slave population as they had no protection from the law (Savitt, 1962).

Dr. James Marion Sims was widely considered the "father of gynecology" as he was the first to treat vesicovaginal fistula, a deadly complication resulting from childbirth (Wall, 2006). However, not until the 20th century, methods in which he took to make this discovery surfaced. Between 1845 and 1849, Dr. Sims would perform surgical experiments on slave women. For example, one slave by the name Anarcha endured over 30 surgical attempts in order to fix her condition, without the use of any local anesthetic (Figure 11). However, there needs to be some context to his medical experimentation. First, the majority of the cases that he saw were as a result of slave owners had calling upon his expertise to examine the slave's condition. Secondly, the use of anesthesia was not prevalent as it was a relatively new tool, one that was not fully understood. These rebuttals are not a defense for the actions of Dr. James Sim, but rather show the precarious nature of medicine within the context of history. Dr. James Marion Sims is not an isolated case where the disadvantage were exploited.

We can look to the 20th century to see that these types of actions still occurring — for example, the Tuskegee experiment that was conducted in 1932 where the United States government wanted to see the effects of syphilis. The study included 600 black men, 399 with syphilis and 201 without the disease. What was supposed to last only for six months, lasted for more than 40 years. The study was only discovered in 1972 after the Associated Press released a story about it and the public demanded an investigation. A panel unearthed shocking details of the trial. First, the participants of the study were not fully aware of the purpose of the study, and many did not give their informed consent. Secondly, the men were not given any treatment or medical care even the introduction of penicillin in 1947 could adequately treat the disease ("U.S. Public Health Service Syphilis Study at Tuskegee", 2015).

Modern Era

As the world entered the 20th century, many of the standard fixtures in the study of anatomy are in flux. For example, the most critical chemical used the preservation of cadavers, formaldehyde. Faces strong opposition as it is seen as an outdated and dangerous chemical. For example, the European Union has a board known as the Biocidal Products Directive that oversees the usage of biocidal products and the effects on humans, animals, and the environment. There is a push from the board to collect more data about the usage and the safety of formaldehyde and its effects. In the United States, there is a lack of regulations; embalming fluids are exempt for regulations stated by the Federal Insecticide, Fungicide, and Rodenticide Act or FIFRA. While some of the tools may be subject to examination, the very idea of dissection faces scrutiny (Brenner, 2014).

Opponents of anatomy have many valid reasons to oppose dissections. Dissections can still be seen as an ethical dilemma, a financial burden, unsafe, and lack of awareness to people's sensitivities and religious beliefs. There is a growing notion that dissection is an outdated and barbaric way of learning anatomy and that there are more safe and practical manners to learn with the usage of new technology

The introduction of technology to aid students have slowly entered into the curriculum. Many methods range from using basic plastic models, animal models to screen based simulations (Kurt, Yurdakul, & Atac, 2013). Rapid advancements in the technology have allowed to computer-assisted systems to help guide and teach students and among the most advanced is the Anatomage Table. The Anatomage Table is a system that is pre-set with 3-D gross and regional anatomy of both sexes and a library collection of 120 pathological examples. However, the unique feature is the ability for medical schools to incorporate and integrate details depending on their curriculum. For example, professors can download radiographs and surgical cases to help explain the subject material better ("Anatomage Table", 2018). Another method has to enhance the student's experience is the inclusion of prosections, in which certain aspects of the body is isolated and dissected by a trained anatomist, rather than by students (Topp, 2004). Topp also argues that while technology may help aid, it should not be a replacement of actual dissections. Proponents argue that the only correct way to learn anatomy is through dissections. Participation in the dissections also serves as an essential link to the acquisition of clinical skills. However, more importantly, there is a case to be made that visual representation of anatomy via a screen is not the same experience that is allowed from hands-on exploration

While anatomy serves a practical purpose as the discipline of science of medicine, anatomy has informed many parts of society and culture. Once again, art has looked to anatomy for inspiration in the most literal sense with the creation of plastination. Dr. Gunther von Hagens created a technique that uses oil and water to remove the unwanted tissues and to use polymerized materials to harden and isolate the wanted tissue. Dr. von Hagen's work could be found in his exhibit: Body Worlds (Figure 12). However, his work has been criticized for the source of material. Like the resurrectionists, it is unclear as to how Dr. von Hagen's received his cadavers. He states that Chinese medical schools supply him with cadavers to plastinate, however NPR who first reported on this could not find the proper documents that show Dr. von Hagen legally and ethically obtained the bodies (Ulaby, 2006). Anatomy can also be found in the backdrop of American pop culture with medical dramas such as Grey's Anatomy, an homage to *Gray's Anatomy,* a classic anatomical textbook of the 20th century. These medical dramas rely heavily on fictitious medical cases to drive the story's narrative, there is an unintended consequence when these audience members turn into patients, they tend to have unrealistic notions of hospitals and doctors (Serrone et al., 2018).

The history of anatomy is long detailed, and complex. It is just impossible to discuss every significant anatomical discovery; but what can be done, is what Berwyn Kinsey imparted in the very beginning of my J-term class: history deserves examination from every angle, not just for its face value. The history of anatomy can be used as this type of foil as it shows how religion, societal expectations, and cultural phenomenon that coincided with the discovery and the understanding of the human body.

Figures

Figure 1: Cave Drawings in Gargas, Aventignan dating back 27,000 years.
Office of Tourism of France, (2018). *Prehistoric Caves of Gargas, Aventignan* [digital image]. Retrieved from https://www.tourisme-stgaudens.com/visit/prehistoric-caves-of-gargas-aventignan-2184

Figure 2: King Tutankhamun's sarcophagus and burial chamber
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Figure 3: Galen's writing about properties of a medicinal herb in *Corpus Hippocraticum.*
U.S. National Library of Medicine. *De Virtute Cemtaureae* [digital image]. Retrieved from https://www.nlm.nih.gov/exhibition/odysseyofknowledge/greekmedicine.html

Figure 4: Portrait of Galen

National Library of Medicine. *Lithograph of Galen of Pergamum* [digital image]. Retrieved from https://www.britannica.com/biography/Galen-of-Pergamum/media/223895/136663

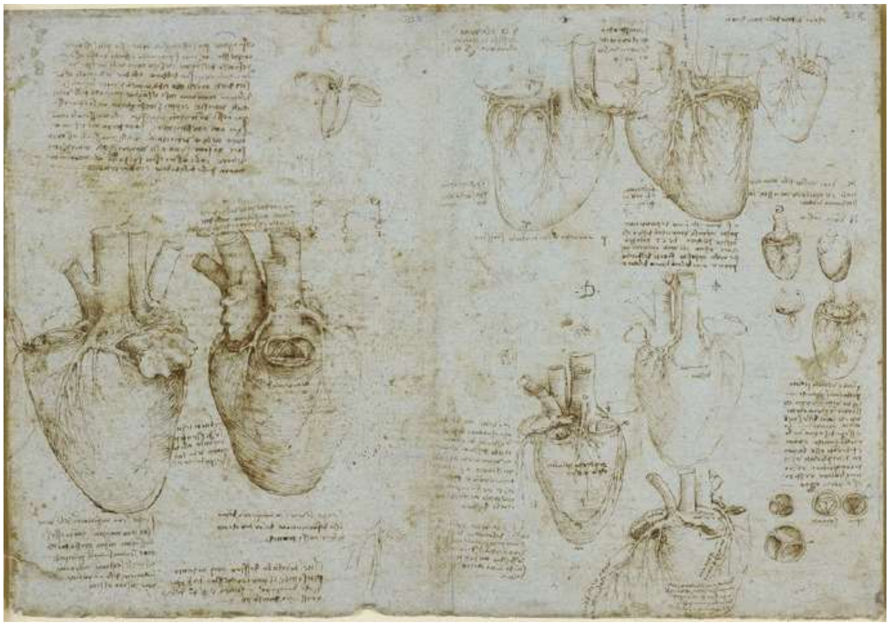

Figure 5: Leonardo da Vinci's notes and drawing of coronary vessels and valves
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Figure 6: Vesalius's anatomical drawings from *De Humani Corporis Fabrica*
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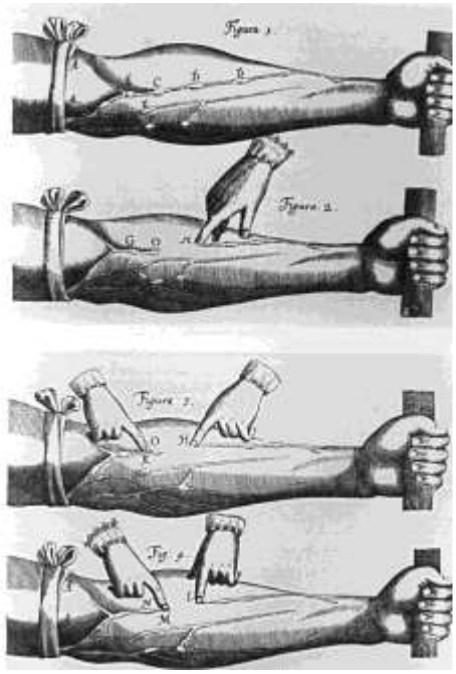

Figure 7: Illustration of William Harvey's circulation experiment from his *On the Circulation of the Blood*
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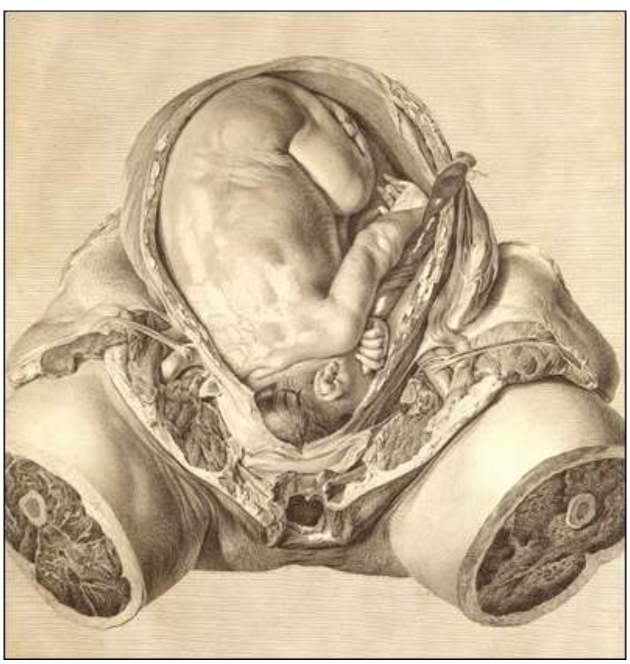

Figure 8: Late Pregnancy Drawing from William Hunter's *The Anatomy of the Human Gravid Uterus*
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Figure 9: William Burke’s Death Mask
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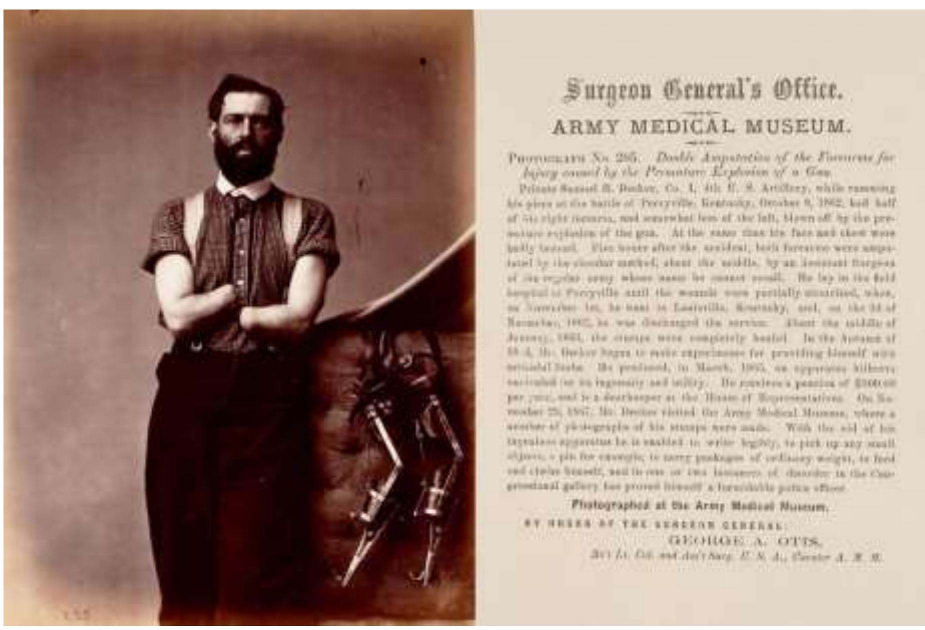

Figure 10: Photography of Private Samuel Decker. Alongside him are his prostheses after losing his hands in an artillery accident.
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Figure 11: Illustration by Robert Thom depicting Dr. J. Sims and Anarcha
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Figure 12: Plastinated human throwing a javelin and the human's complete skeletal and arterial system.
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