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Medical Illustration

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Senior Thesis

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"When people ask me what I do for a living I tell them, 'I am a medical illustrator'. This response often elicits a look of confusion, along with the question, 'You're a what?'" This is the response often received by medical illustrator Monique Guilderson, after being asked the standard "What do you do for a living?" question. I think this one statement does an excellent job of summarizing the general public perception of the field. In fact, I myself would have responded the same way just a few years ago, but since I first came to realize that this is actually a career, I have become very interested. Looking back now, it seems very odd to me that I, along with many others I am sure, could remain completely oblivious to the existence of this career because examples of its products can be seen virtually everywhere. From the colorful images in biology text books, to the detailed pictures on posters often found on doctors' office walls, to the clever animations often used to explain scientific concepts in educational videos. Indeed, medical illustration is but one category within the larger field of scientific illustration, but my focus has been on this category specifically because I find it the most intriguing. To me, the balls and rods used to illustrate molecules in chemistry just aren't as exciting to look at as elaborate drawings of the human body for medicine and biology. For those individuals who are unfamiliar with the field, as I was before doing this research, it is helpful to look at the history of medical illustration in order to fully understand where it stands in the modern world. Several guiding principles about the craft can be learned from its historical journey, and, after discovering these principles, I was able to use them to create some of my own illustrations, which I will describe later.

As long as humans have mortal bodies that they must carry through life, the need for medical doctors will persist. Likewise, as long as medical doctors are mortal humans and eventually need to be replaced, the need to educate new doctors will also persist. Perhaps the most important tool in medical education, or any form of education, is the visual picture. As the saying goes, "A picture is worth a thousand words." Pictures can work together with the written text to illustrate processes, functions, and structures much more efficiently than either could do by themselves. Medical illustration is an important tool in medical education, and, as history shows, the early evolution of medical illustration closely correlated with the early evolution of mankind's growing medical knowledge. The history of medical illustration is a story of how individuals slowly acquired and united skills in science and in art to produce images that advanced both fields.

The earliest evidence of medical illustration can be seen on Paleolithic cave drawings. Unlike modern medical illustrations, these crude pictures primarily emphasized practical ways to kill animals during hunts rather than ways to heal humans during medical treatments. With the Paleolithic era preceding the invention of farming, hunting was the primary concern of the time, serving as a primary means of obtaining food. These early people found that knowledge of animal anatomy could be beneficial for successfully killing the animals they hunted. For example, animals were depicted with spears piercing their most vulnerable body areas or with their vital organs drawn to indicate the areas to target during hunts (Figure 1) (Delaflor).

Figure 1 – Ancient cave drawing from Spain depicting the heart in an elephant (Delafor).

As time progressed and civilizations arose, religion also became a dominant emphasis in human art. The ancient Egyptians exhibited an interest in human anatomy in their art, but religion remained the dominant focus. ***The Book of the Dead*** was an ancient Egyptian book filled with spells and illustrations helpful to the dead souls on their afterlife journey. To accompany the text, pictures were made of dead bodies with Anubis, the Egyptian god of mummification, removing their organs or performing other ceremonial procedures (Figure 2) (Deurer). Certain proportions were closely obeyed in the drawings of the bodies, even to the extent of using a grid pattern, which can still be seen today in some of the unfinished Egyptian works (Getlein, 128-129). Though the human portrayals weren't completely accurate, they were very precise and systematic. It is evident that Egyptians had certain knowledge of human anatomy and worked with that knowledge when working with the dead (***Field of Medical Illustration***). However, the purpose behind the elaborate illustrations that accompanied the dead was primarily religious, as their intentions seemed to be more focused on pictorially portraying the ritualistic practices rather than on faithfully portraying the human anatomy for educational purposes.

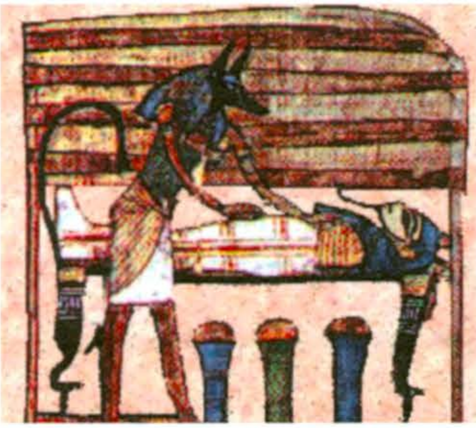

Figure 2 – Anubis preparing a dead body for the afterlife (Deurer).

Religion remained closely tied to human concepts of medicine until the era of the ancient Greeks. Though no medical illustrations from the ancient Greeks have survived, their contribution to medicine was still important, especially that of Hippocrates (460 BC-377 BC), the "Father of Medicine." In medical history, Hippocrates played a notable role for initiating the separation between religion and medicine. He believed that illnesses had a physical explanation rather than a superstitious one (Delvey) and pushed for the study of the human body based on "observation rather than divination" (Delaflor). Though his observations were limited to surface anatomy, his successors continued his work and also made considerable contributions. One of these was Aristotle, the "Father of Biological Science" (Delaflor). He began dissecting animals to get a better understanding of their anatomy, and he made several assumptions about human anatomy based on these animals since human dissections were not yet seen as an acceptable practice (Loechel). A collection of the work of Hippocrates and his successors was recorded in the ***Hippocratic corpus*** (Sharp).

Following the ancient Greeks, the Hellenistic era ushered in new learning opportunities for the curious minds, particularly in Alexandria. Herophilus (330 BC-260 BC) took a monumental step in anatomy studies by doing studies with human dissections. Alexandria became the only city of the era, and for a while to come, to allow human dissection research (***Herophilus Biography***). Inspired by the ***Hippocratic corpus***, which was kept at Alexandria's library (Sharp), Herophilus published his own book, ***On Anatomy***, containing descriptions based on his observations in actual human bodies. He also performed many of his dissections with public viewers and founded a medical school in Alexandria (***Herophilus Biography***). His work gave him the title the "Father of Anatomy." ***On Anatomy*** had references to several illustrations, but unfortunately none of the illustrations from the book have survived. Erasistratus, Herophilus' successor, continued his work (Delaflor).

After the Roman conquest of Alexandria, human dissection once again became a forbidden practice. Despite this limitation, a notable Roman figure still contributed to the medical cause. Claudius Galen (129 AD-209 AD) wrote hundreds of books on medicine and anatomy. His knowledge was based on his reading of the Alexandrian works as well as his own animal dissections (Sharp). Religious ideas played a key role in his reasoning, and this persuaded the church to embrace his work (Delaflor). In fact, his work became the key medical and anatomy tool throughout the Middle Ages (***Galen of Pergamum***), despite the fact that he abandoned two of the key achievements of his predecessors: the separation of religion and medicine and the idea of basing human anatomy knowledge on actual human dissections.

It is not known whether Galen included illustrations in his original writings (if he did they did not survive), but those who preserved and copied his work for the next several centuries added their own illustrations. Initially, his work and that of Herophilus were preserved through the Arabs, who translated it into Arabic. Later, in the Middle Ages, Galen's text gained popularity with the rest of Europe, and it was retranslated from Arabic into other European languages (***Islamic Medical Manuscripts***). It became the universal European tool for university medical education (***Galen of Pergamum***). Even after human dissections became acceptable again for educational purposes, anything found that did not agree with Galen's descriptions was dismissed as an abnormality. The accompanying illustrations of the text provided by both the Muslims and the other Europeans had a common quality of flatness (for the techniques of shading and perspective had not yet been perfected), and it was often obvious that the illustrators did not actually observe the anatomical

Figure 3 – This illustration was drawing based on text descriptions only (***Islamic Medical Manuscripts***).

parts that they sought to portray (Figure 3). Instead, they were based entirely on the artists' reading and understanding of Galen's text (Delaflor).

It was not until the Renaissance that Galen's work was challenged. New advances in both science and art came together to fuel new breakthroughs. In art, new techniques in perspective allowed for greater accuracy, and new shading techniques, called chiaroscuro, allowed for greater realism (***Renaissance Man***). In science, intellectual attitudes changed from being rigidly grounded in tradition to favoring tested theories through observation. Furthermore, the printing press and woodcut engravings allowed for easy text and image duplication to further spread new knowledge (Sharp). The new medical breakthroughs did not happen overnight though. The skills in science and art were often present in separate people, with few individuals possessing them both. On top of that, anatomical studies were still an unpleasant undertaking, as preservatives had not yet been invented (Loechel). Individuals who both were willing to face these conditions and also possessed the needed balance of skills in science and art were hard to come by, but the Renaissance saw the arrival of a man who fit this description excellently. He was a highly motivated man with interests in a surprisingly wide variety of fields, most of which he taught himself to master. This "self-taught Genius" was Leonardo Da Vinci (***Leonardo-Da-Vinci-Biography.com***).

Leonardo Da Vinci (1452-1519 AD) is famous for exhibiting a wide range of outstanding talents, including those in art and science. After learning perspective techniques from Verocchio, perfecting chiaroscuro (***Renaissance Man***), and dissecting more than 30 cadavers (Loechel), Da Vinci created over 750 anatomical illustrations that clearly stood out for their time, highly contrasting the previous flat, inaccurate illustrations of the Middle Ages (Figure 4). Da Vinci's works were truly revolutionary, but unfortunately they were not published (Sharp). After

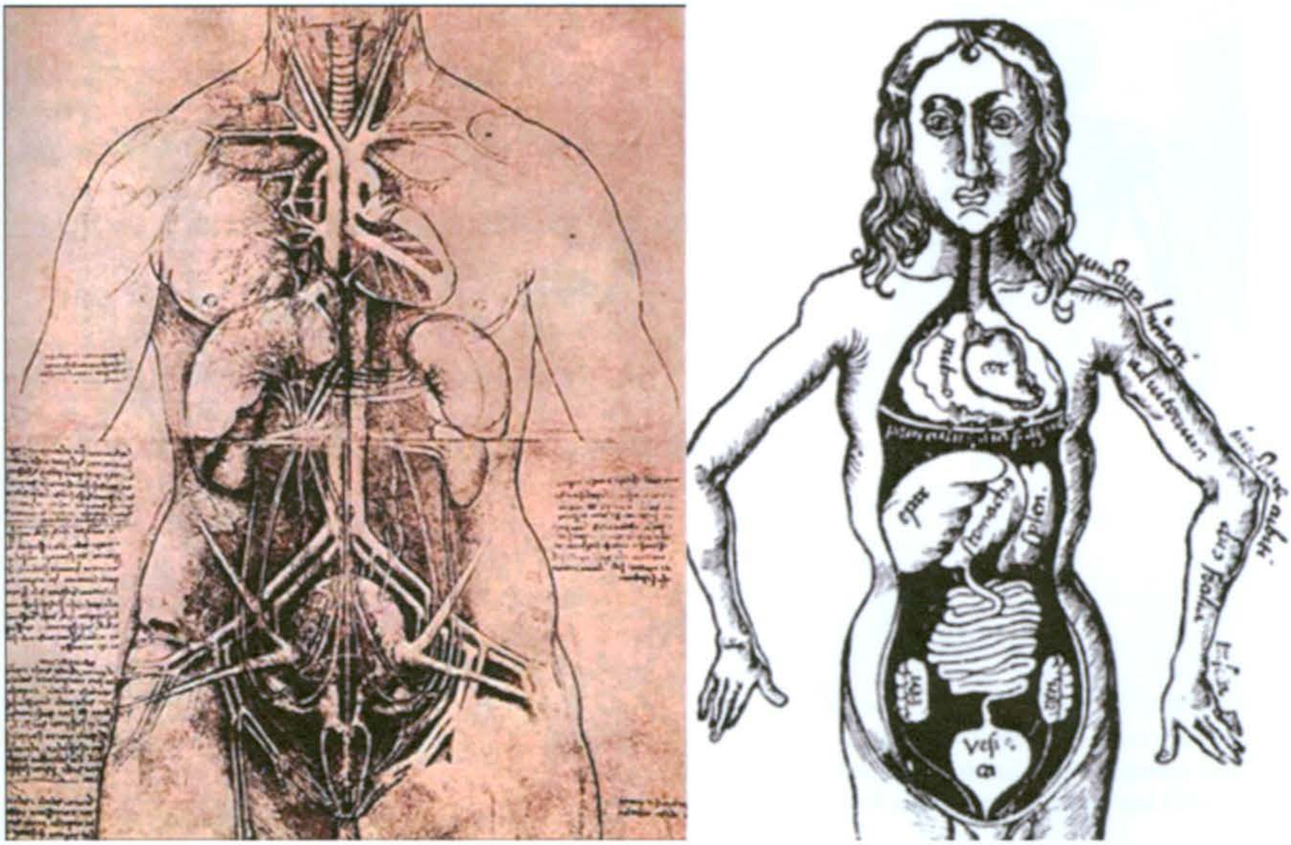

Figure 4 – Da Vinci's "The Great Lady" on left (***Leonardo-Da-Vinic-Biography.com***) as compared to a typical medieval medical illustration on right (Delafor).

his death, these works were lost for hundreds of years. Therefore, despite the fact that his work radically breathed new life into medical illustration, it ironically had no influence on the medical publications of others, at least not directly. Curiously, work arose soon after Da Vinci that closely matched his in both accuracy and artistic beauty. These works were commissioned by Andreas Vesalius, who, some believe, saw and was influenced by Da Vinci's work before it was lost (Delaflor). It is not known whether this claim is actually true, but one thing is for sure: Because his work was actually published, it was Vesalius' work that directly influenced medical illustrators for centuries to follow.

Andreas Vesalius (1514-1564 AD) was a professor who made the bold move to go beyond the common practice of his profession. Rather than just reading Galen's descriptions while an assistant did the dissections, he got down off the podium and did the dissections himself. He began making charts to help the students learn the anatomy, and, while doing so, he found errors in Galen's work. This led him to publish his own work accompanied with elaborate illustrations, ***De Humani: Corporis Fabrica*** (***Understanding Evolution***). Though he was a brilliant anatomist, he was not an artist, so he commissioned artists, such as Joannes van Calcar, to produce the illustrations while he supervised closely (Delaflor). This commissioning is an example of scientists and artists collaborating to produce illustrations that exhibit both scientific accuracy and aesthetic beauty. Since few individuals at this time possessed both talents (Da Vinci was a rare exception), this form of collaboration became the norm for the next several centuries (***Understanding Evolution***). In fact, the publication of ***De Humani: Corporis Fabrica*** greatly influenced the majority of the medical works in the period to follow. The illustrations found in

Figure 5 – Typical Vesalius drawing featuring a detailed free standing body with an elaborate background (Sharp).

Figure 6 – Works by Valverde de Amusco (left) and Eustachi (right). Typical of the post-Vesalius era, closely following Vesalius' style (***Historical Anatomies on the Web***).

the book reflected those of Da Vinci in their artistic beauty, employing the devices of chiaroscuro and perspective (Figure 5) (Sharp).

From 1543 to the 1800s, a large number of medical illustrative works were published, all either highly inspired by or directly plagiarizing Vesalius' work (Figure 6) (Sharp). There were a few contributions that stood out during this era. Bernard Siegfried Albinus (1697-1770) collaborated with the artist Jan Wandelaar (16) to create illustrations based on elaborate survey mechanisms rather than just eye-balling his subjects (Sharp). Govard Bidloo (1649-1713) used copperplates (rather than the previously used wooden ones) to create larger, more detailed, and more realistic medical works (***Govard Bidloo***). He broke away from the Vesalius tradition of posing the subjects in landscapes and focused more on the natural lab setting.

Figure 7 – The Gross Clinic (1875) by Thomas Eakins (Kimball).

Some artists of the era worked alone, rather than in collaboration with scientists. A passion for realism was exemplified in portraits of public dissections observed by the artists. Though anatomical truthfulness was important to these artists (Kimball), it was not intended for educational purposes as typical medical illustrations are. They merely used it along with the rest of the scene to stress a sense of realism that they hoped to achieve in their work (Kren and Marx), making them more of artist statements than educational tools. These artists were seeking to bring realism to an entirely new level. Rather than portraying a perfected version of reality as was common in the Renaissance, these artists were portraying the ugly side of reality. Examples of these unpleasantly realistic portrayals can especially be seen in the work of Rembrandt Van Rijn (Kren and Marx) and Thomas Eakins (Kimball) (Figure 7).

At the end of this post-Vesalius Era came a significant turning point that affected not only medical illustration but all forms of art, the invention of photography. Invented in 1835 and rising to popularity by the end of the 19th century, photography could realistically capture in seconds what could take hours for an artist to realistically capture, and often the camera did a better job. This put pressure on artists to add something more to their work than realism. New styles of art arose as a result, such as impressionism, which moved beyond the emphasis on realistic portrayals to make the art more interesting (Wardhana). What did this mean for medical illustrators? It would seem that the need for medical illustrators was approaching its end. Why would a scientist want to collaborate with an artist to portray his findings and methods if he could just take a picture with a camera? Despite this seemingly logical reasoning, one more great medical illustrator, Max Brödel, rose to the scene and set the standards for what a modern medical illustrator should be. He showed that a medical artist can still add something to his work that a camera cannot. He is known as the "Father of Modern Medical Illustration" (Loechel).

Max Brödel came to America from Germany in the 1890s and became an employee at the Johns Hopkins Hospital as a medical illustrator. Brödel differed from the typical commissioned artist because he sought an actual understanding of what he was portraying. Already possessing the artistic skills, Brödel also wanted to know the science behind the subjects. He worked closely with his doctor colleagues to grasp as much of their knowledge as he could. Brödel then

Figure 8 – Max Brödel's portrayal of a tumor on the brain stem (Crosby and Cody).

took his learning even further by doing some of his own studies and research. The resulting illustrations were remarkable (Figure 8). Brödel perfected new illustration techniques that gave his subjects a great life-like, photographic quality, but at the same time it was better than a photograph. He, the artist, knew and understood the concepts that he was seeking to portray, so he was able to be selective in what was emphasized in the image in order to efficiently highlight the concepts. Photographs did not, and still do not, have this selective ability, and therefore could not bring conceptual emphasis to the images they produced (Crosby and Cody).

In this way, Max Brödel was able to find his place in the changing world of the early 1900s as a medical illustrator. Later in his career, he even started the first school of medical illustration at Johns Hopkins in order to provide training for future medical illustrators. He heavily stressed the need for medical illustrators to possess the skills and knowledge both in art and in science. He was the first key figure to possess both of these since Da Vinci, and he ushered in the new movement for all medical illustrators to do the same. He once wrote, "…the only way to plan a picture is to leave the paper and pencil alone until the mind has grasped the meaning of the object. I blundered when I relied on faithful copying alone. Copying a medical object is not medical illustrating. The camera copies well, and often better, than the eye and hand … in medical drawing full comprehension must precede execution." (Crosby and Cody)

The educational contributions of Max Brödel have carried medical illustration to modern times. Medical illustrators are trained to seek the appropriate balance between complexity and conciseness in their work to communicate their message, so that they too can be useful even in the presence of photography. Knowing what to leave out is often just as or more important than knowing what to put in. In 1945, the Association of Medical Illustrators was established, which laid out the accreditation standards for schools that offer medical illustration programs. Today there are five accredited graduate programs in the U.S. dedicated to the study of medical illustration, including the one that Brödel established at Johns Hopkins University. Though technology continues to improve, the need for medical illustrators still exists. Rather than taking the jobs of medical illustrators, technology has provided more tools and possibilities for the artists to use in their work. Computer modeling has made possible the production of images that are not only three-dimensional, but also exhibit motion, to better illustrate the functional processes of certain human structures.

The purpose of medical illustration has also diversified. It has moved beyond being merely an educational tool, and has taken on other roles, such as providing visual aids in legal cases, designing medical prosthetics, digitally aging missing children in photos for posters, and aiding in advertisements (Hodges, 416-428). The world of medical illustration is still evolving as it has been for the past 3000 years, and it will continue to evolve as long as new technologies and discoveries are made in medical science.

Among these advances in technology, the role of an illustrator is constantly being challenged, just as it was with the invention of photography. One innovation in particular has arisen to bring all new possibilities to the study of anatomy. In 1975, a German anatomist and educator Gunther von Hagens invented a groundbreaking technique called Plastination. Plastination is a method of preserving human bodily structures by removing the waters and fats from within the cells and replacing them with polymers. This process removes the degrading enzymes from within the cells and creates an unlivable environment for bacterial and fungal colonization, resulting in durable, long-lasting specimens that can replace cadaver dissections in anatomy courses. Samples of von Hogans' models have been displayed worldwide in various "Body Worlds" exhibitions (***Gunther van Hagens' Body Worlds***). In a sense, this procedure has taken photography into the third dimension. Anatomy students can now study and examine body parts from all angles without needing to be present in an unpleasant cadaver lab. What does this new innovation mean for modern medical illustrators? This type of visualization is more a product of strategic preservation than illustration, and the resulting items are very useful educational tools. Why does the need for medical illustrators persist in the light of this new technology? The answer to this question is probably the same as reason why the need for medical illustrators persisted after the invention of photography. Because Plastination is basically photography in the third dimension, it carries with it some of the same problems that photography held. Though Plastination does an amazing job of presenting what is there to be seen in a specimen, it cannot make sense of the subject or interpret it for the student. Whether in two dimensions or three dimensions, the illustrator will always have a place to make visualizations that have a clear message and a purpose.

The information concerning history and evolution of medical illustration, resulting from this research, has given me a better idea of where the practice stands in the modern world for application in my own work. The pursuit was experimented with and perfected for thousands of years, and lessons were learned along the way about what works and what does not work. It should be noted that the primary purpose of medical illustrations is to educate the viewers, and history has shown us that some techniques do a better job at that than others. The lessons learned by these historic illustrators are as applicable today as they ever were, thus it was important for me to take note of them before attempting to create my own illustrations. Based on what I have seen from history, and particularly what was laid out by Max Brödel, I believe that there are three key guiding principles that are the foundation on which the modern practice of medical illustration rests.

First, direct observation is very important for making a useful illustration. An illustrator cannot hope to accurately portray the structure of a human liver until he first observes the liver with his own two eyes. Details are easily lost in translation, so the only reliable source of information is the object itself. The illustrators of Medieval times gave us excellent examples of what can happen when images are drawn based only on what others have observed and written down. This type of illustration proceeded for hundreds of years, and it is evident in the fanciful images produced that they were more a product of the imagination than actual fact. In today's terms, it may seem silly to even suggest that one would create an illustration solely off of text descriptions because other images are so readily available for reference, but the principle still applies. Though today's abundant stock of images may be a much more reliable reference than the text descriptions laid down hundreds of years ago, in truth, these images still cannot substitute for direct observation. Images can come in the form of photographs or other illustrations. Beyond the fact that referencing these could lead to outright plagiarism through copying the photograph or illustration that someone else created, they are also only telling part of the story. Relying solely on either of these to create new illustrations is just as dangerous as relying just on text, because just like the text, these images are simply translations of the information, and much of it is left out or unclear. A photograph only reveals the object based on the light reflecting off of it at a certain angle. It provides a very limited perspective of the object, much less than is needed to create a quality, informative illustration. Other illustrations only reveal what the illustrators see as important based on the message that they wanted to convey. Illustrations based on preexisting illustrations are pointless and of no use, because the illustrator cannot accurately portray anything new in the newer illustration. A new illustration is only justifiable if there is a new message to convey, and the new information for the message can only be collected directly from the object itself.

Second, the integration of scientific knowledge with artistic capabilities should be employed when making illustrations. That is to say, the final product should be both scientifically correct in the message that it is conveying and skillfully created so that the message is effectively conveyed. A well rendered drawing is useless as an educational tool if it portrays incorrect information. Likewise, a scientifically correct sketch is just as useless for education if it is sloppily thrown together in a jumbled mess. Both qualities of the illustration must be taken into account, and it is up to the illustrator to put both into the work. It is one thing to look at the object before illustrating it, but it is another thing to look at and understand the object before illustrating it. This can be, and often is, accomplished by teamwork between an illustrator and a scientist, but in the end, it is up to the illustrator to possess both the skill and the knowledge to create the illustration. Though the illustrator cannot give his artistic skill to the scientist, the scientist must give his knowledge to the illustrator before the rendering can begin. The scientist is the source of the information that the illustrator must learn and understand thoroughly. History provides many examples of these collaborations between scientists and artists, but there were also artists that worked alone, such as Da Vinci and Brödel, because they already knew the information they wanted to communicate.

Third, the purpose of an illustration is to inform, teach, or convey a message, not to depict an exact replica of the object. This is the principle that Max Brödel really brought to light, and it really ties together the other two principles already discussed. The need to convey a message is the reason why photographs cannot replace the need for illustrators and why photographs cannot serve as the sole reference source for an illustrator. The illustrator must observe the object himself and fully understand the science behind the message that he is seeking to convey, so he can strategically design the illustration to most effectively convey that message. Some details in the object may need to be exaggerated and others may need to be toned down, or even eliminated. For example, an illustration depicting the paths of veins and arteries throughout the body need not depict all of the fatty tissue that lies under the skin. Not only would this waste time with unnecessary details for the illustrator, but it would also be distracting, perhaps even confusing, for the viewer. A balance must be reached between detail and simplicity. The illustration must be detailed enough so that the viewer can clearly tell what he is looking at, but at the same time, it must be simple enough so that the purpose of the image is not clouded by unneeded clutter.

With these three principles in mind, I set out to try my own hand at medical illustration. Given my location, human subjects were not readily available, so I had to look to other subjects to find illustration opportunities. I found my opportunity in the anatomy and physiology lab. I knew from having taken the class the previous year that the lab offered many great opportunities to observe biological specimens very closely, to the point of dissecting them and indentifying their parts. Most notably among these specimens were the cats, which we dissected and then indentified the muscles. That assignment was both the most challenging and the most interesting part of the lab for me. Several weeks were spent learning and studying nearly one hundred different muscles of that cat, leading up to the big final exam, which covered them all. One of the biggest struggles with this particular lab was not necessarily the cats themselves, but the lab books, which served as our only reference to identify the dozens of muscles. The problem with the lab book was that it was illustrated only with photographs. These photographs were scattered over eight to ten pages of the book, showing different views and sections of the skinned cat. With these serving as our only tools, the identification of the cat muscles often meant several hours of flipping through pages, straining to see tiny muscles in four by four inch photographs, and trying to match them with those found on the actual cats.

I saw this as a great chance to make use of illustration techniques that I had been studying, so I seized the opportunity. I became a teacher's assistant for Dr. Hensley in the anatomy lab, and with that I had all of the tools I needed to create the illustrations. I had the cats of the students to refer to for direct observation, I had Dr. Hensley to refer to for any questions of accuracy that I had, and I had a clear purpose for creating the illustrations: To illustrate the muscles of the cats for easy and convenient reference and study for the students taking the anatomy and physiology lab.

Before beginning the cat illustrations, I practiced with a few smaller illustrations to get experience and figure out what worked best. One of these smaller projects was an illustration of a sheep brain (Figure 9), which I was also able to directly observe in the lab. When I felt that I had practiced enough, I began the cat muscle anatomy project. In all, I spent about five weeks working on the project, and I had a great time doing it. I made sure to apply the key principles that I learned through my previous research, most notably the three I listed above. I based the illustrations on direct observations, I integrated scientific knowledge with artistic considerations, and I designed the portrayals to best convey the intended message. I spent three of the five weeks in the anatomy lab closely observing the cat specimens, making several sketches and putting them together to build the overall cat. By strategically taking advantage of the bilateral symmetry of the cat, I found that I could illustrate every muscle needed for the test in just two cat images, one showing a dorsal (back side) view of the overall cat and the other showing a ventral (belly side) view of the overall cat. In the final two weeks of the project, I worked in the graphic design lab, where I transferred my pieced-together-sketches to a clean sheet of vellum, on which I traced the muscle outlines in India ink and detailed the striations with graphite (the muscle striations are helpful in identifying some of the muscles, so I included them as a necessary detail). Finally, I scanned the large cat drawings in sections into a computer, where I put the pieces back together, added color, and added the appropriate labels to all of the muscles using Adobe Photoshop. The final result was two cat illustrations that clearly depicted every muscle needed for the anatomy and physiology test (Figures 10 and 11). Finally, I printed two three by two foot posters of these cats (one of each view) to hang in the anatomy

Figure 9 – My personal drawing of the midsagittal section of a sheep brain.

lab for the convenience of all future anatomy and physiology students at OBU. These posters serve as practical applications of the techniques and principles that I acquired in my research of medical illustration, with the intent of fulfilling the purpose of the practice, to aid in the education of others through the use of visual representations.

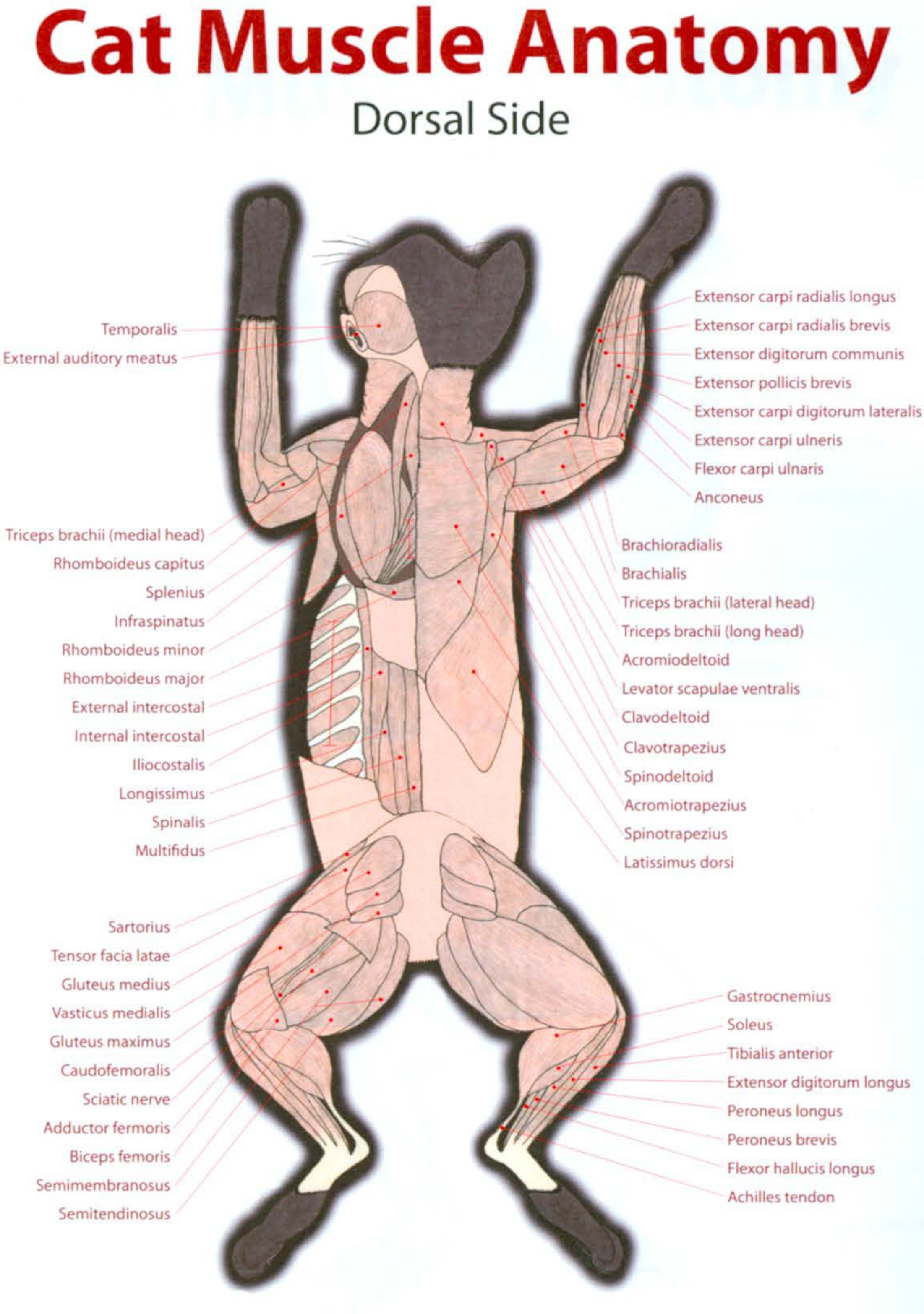

Figure 10 –One of two of my own illustration of the cat muscle anatomy, specifically the dorsal side.

Cat Muscle Anatomy

Ventral Side

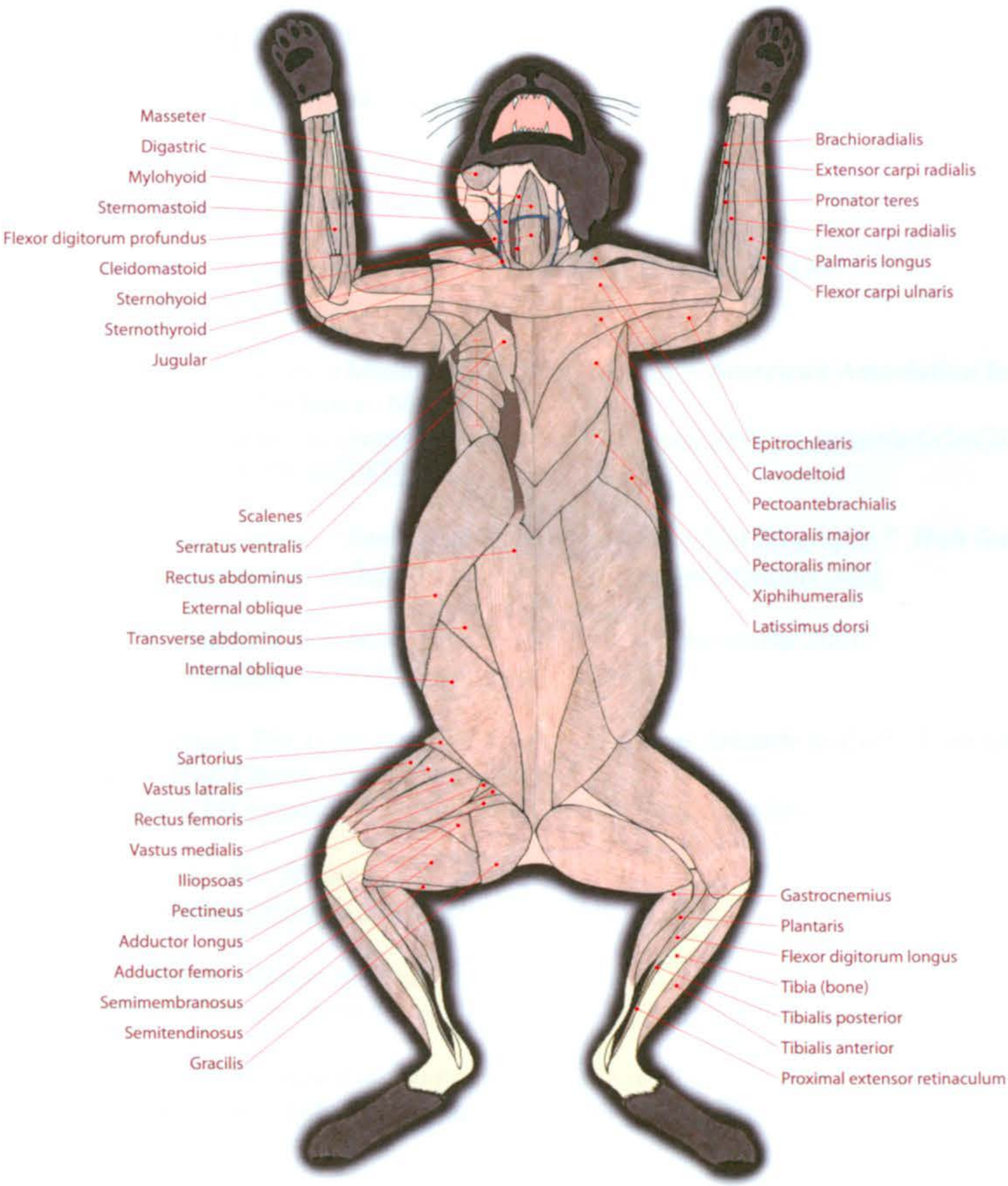

Figure 11 – The other view of the cat muscle anatomy, the ventral side.

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