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The Evolution and Influence of Art in Scientific Illustration

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by

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For my grandparents
Vito and Vita

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INTRODUCTION

The worlds of science and art are often thought of as separate. I wanted my senior project to prove this idea as wrong; they had to overlap and find a common ground of interest. For me, this project was about melding my two passions and proving them compatible with one another. Throughout the history of art the most famous and closely related work to science that first comes to mind is *The Anatomy Lesson of Dr. Nicholaes Tulp* by Rembrandt in 1632. The painting, as the title suggests, depicts an anatomy lesson of the muscles in the cadaver's arm. Scientific discovery here is displayed through dissection and observation as a way of learning and understanding the world that surrounds us. The painting shows the awe Rembrandt had towards the world of science. The painting is very much an appreciation of scientific discovery. It is an artistic evaluation of a scientific setting, which in this case is the dissection of a body to teach anatomy. Rembrandt himself partakes in the scientific discovery by creating the painting and observing the dissection, but he is not involved in the learning process the students are part of as they surround the cadaver. Rembrandt was not contributing to the advancement of science. The piece was an admiration of the world of science; it was not truly part of the scientific world.

Of course, when trying to think of works that evaluate the relationship between art and science in an art historical setting, we immediately think of painting or sculpture but forget about the artistic aspects that exist within scientific illustrations. Art and science rely upon each other more than we originally realize, for they both are dependent on observation of the world that surrounds us. This relationship is clarified when examining scientific illustrations. Scientific illustration's history reveals a slow culminating interest in the artistic and aesthetic aspects of observation. By the Renaissance, there is an interest in understanding the body and nature not only for scientific advancement, but for the sake of art, or beauty, as well.

The respect for the art form of scientific illustration was rare until Ernst Haeckel began publishing in the mid-19th century. However, it should be noted that Leonardo da Vinci and Andreas Vesalius had already published their illustrations in the Renaissance. Leonardo's illustrations were particularly artistically inclined due to his own interest in studying the human anatomy to assist him to create anatomically correct paintings. Haeckel, however, changed the outlook upon scientific illustration from its early histories into something that on its own is both romantic and sublime. His work was based on his belief that there are artistic elements that exist within nature, and therefore logically exist within science. The rise of scientific illustration's usage based primarily upon the new technologies that enabled images to circulate with ease. With photography's invention in 1839 and its ability to portray reality with advancement of technology through time, the questions asked then become: Is scientific illustration no longer important? What is more accurate? Are there still artistic aspects in scientific photographs?

Regardless of whether the medium of photograph or by the artist's hand is used, nature is seen to unite both art and science. Blossfeldt and Haeckel's interest in their nature's forms and structures both translate in a scientific and artistic manner. However, this again is only made possible with careful observation. Science and art overlap in their interest in organic design and structural detail, both of which are clearly articulated in scientific illustration. Haeckel stands out as one of the main people to bring science into the realm of art. Blossfeldt, on the other hand, is an artist who brought a scientific interest into his own art. Examining scientific illustration's history and these two artists allows us to evaluate the relationship between science and art.

CHAPTER I: THE HISTORY OF SCIENTIFIC ILLUSTRATION

Today, with the media, textbooks, and other products, we are surrounded by visual representations. It is easy to take for granted the power of images have in our society, especially when thinking of the educational purposes of images and illustrations. It is difficult to imagine taking science courses without illustrations or a textbook containing images. Illustrations create simpler ways of understanding the basic concepts behind the science. For instance, when studying mitosis the nuclear division that produces two genetically identical nuclei, conveying the division and distribution of genetic information through words alone becomes complicated. Scientific illustration introduces another structure of understanding, along with the written explanation within a textbook or similar source.

Biology textbooks, like *Campbell Biology* (10^{th} Edition), now introduce the cell's genetic replication process and division through a number of computer-produced illustrations and corresponding photographs. Although photographs present the cell in its most realistic form, it is difficult to differentiate chromosomes, centrioles, and other structures throughout the phases of mitosis. Even to the eye, the jumble of genetic material is tough to distinguish one from another. Illustrations allow for a clear depiction of what is occurring within the cell, especially with the chromosomes (Fig. 1). An illustration can remove all of the confusion that a photograph or real life visualizations may provide, and display the key concepts of mitosis. Illustrations created either with the computer or by hand create a visually distinct image of the complicated mess seen in real life.

Illustrations continue to clarify scientific reasoning regardless of whether a photograph is provided. They are a way for a general audience to examine, understand, and learn new information taught in lectures or texts. Similar to texts, illustrations ultimately introduce laypeople to another technique for learning and digesting information, just as writing does. To completely comprehend the development of an embryo for an exam, one might re-write one's notes or re-draw the illustrations of the development. Both learning techniques have a similar effect on how they aid one to understand the development. Furthermore, illustrations help us visually comprehend what is occurring without having to look under a microscope. Illustrations are observations, but also interpretations of observations, meaning that they can simplify an observation in order for the viewer to comprehend a process or view. As Brian S. Baigrie put it in 1996, "scientific images are not translations of a given meaning nor visual appetizers to make some epistemic entrée more appealing, but a complex of insights that emerges from, and during, the very process of observation and modeling."[1] Baigrie here refers mostly to scientific illustrations that from the Renaissance until today. They are essential and relevant for science, since they present a way to learn about the nature of things that surround us. Before our culture became so consumed and involved with images in science, the very early histories of scientific illustration show that there was very little understanding for their use or necessity; scientific illustration was mostly disregarded until the about the 15th century.

Science and art are tightly intertwined with one another in many aspects, especially with scientific illustration. The history of scientific and medical illustration

[1] Host Bredekamp, Vera Dünkel, and Birgit Schneider, *The Technical Image: A History of Styles and Scientific Imagery* (Chicago: Univeristy of Chicago Press, 2015), 36.

exemplifies the relationship between the two. Art incorporates choices of beauty and aesthetics expressed through a visual form. Art is also defined through its creation, which involves observations skills of the artists to then translate to a visually expressive form. Art often does not express actual form of an object, but can simplify or even exaggerate its features. In illustrations, science relies upon artful aesthetics to clarify certain points and command an understanding of science. Scientific illustrations also provide an image when one is not able to examine the species in real life. At the same time, this does not mean that all scientific illustration involves art. When examining the history of scientific illustration this become overwhelmingly clear; however, the popularization of scientific illustration slowly builds upon the incorporation of art into scientific illustration.

This chapter examines the growing importance and interest in scientific illustration through out the ages, and its impact upon the scientific community. These illustrations developed dramatically from the 13th century to the late 18th century. The evolution of science naturally became more complicated in each century with the evolution of technologies and anatomical investigations, and so did the depictions of illustrations. Moreover, this chapter traces the history of scientific illustration in order to understand how artistic interests became involved in science. During the medieval ages (400-1400 A.D.), the use of scientific illustration was sparse. Illustrations within science texts were thought of as an ineffective way to communicate science and the functions of the body. The more scientific knowledge gained by the general public and scientific community, the more relevant illustration became. What is understood as scientific illustration broadens in definition as well, for these illustrations become inclusive of anatomy, microorganisms, animals, and plants. Nonetheless scientific illustration is defined by the use of scientifically informed observation to create an accurate depiction of the object or subject. It is defined by the ability to illustrate the hard-to-observe phenomena or by its abilities to present structures and details with clarity as a description of a subject. Illustrations become more accurate and scientific with the increased interest in observation as a learning tool within the Renaissance. After the Renaissance, observation continues to play a key role when depicting the microscopic and the natural world. The importance of scientific illustration increases because it visually translated the knowledge obtained from visual experience and experimentation. This, however, is barely recognized during or before the medieval ages.

Knowledge of medicine from the medieval world and ancient worlds carried over into the first medical schools that began in the early 15th century. The ancient world primarily documented observations of the body or experiments in their writings, not in illustrations. Hippocrates and Galen constitute the basis of ancient medicine as it existed up to the medieval period. Hippocrates (460 BC – 370 BC) devised the humoral theory that proclaimed the four humors of the human body: black bile, blood, yellow bile, and phlegm. Having all four humors balanced is what maintained a healthy body. His theories of humoral pathology provided explanations for mental diseases and physical diseases, explaining, for example, that epilepsy was due to the abnormal amounts of phlegm in the brain. However, all of this information was only posited through written documents. Observations were only put into writing and were typically expanded upon other physicians, like Galen.

Galen (129 – 201 A.D.) built upon Hippocrates's idea of the humors. In his anatomical texts, Galen described the purpose, form, and function for many biological structures. He did this by conducting dissections on animals, particularly pigs. Galen theorized that the human heart had four valves. In reality, only mammals similar to pigs did, while humans only had two.[2] His writings discouraged any atheistic scientific beliefs, and praised the complexities of God's skills as a creator. All of his writings were firmly based upon observation. He promoted the idea of learning about the anatomy through writings and actual experience.[3] His text on anatomy, however, did not include any illustrations. The manuscripts that he wrote on anatomy were meant for other scientists, especially for those conducting surgeries. His writings were not praised until the 16th century, when his manuscripts had been translated into Latin. His works, however, were translated into Arabic in the 800s and built upon with visual forms.

Galen's work was commented upon all over the world. Early in the 13th century, an Islamic physician by the name of Ibn al-Nafis (1213-1288 A.D.) created a visual documentation based upon Galen's writings. In his manuscript, Ibn al-Nafis depicted an image of the heart and veins in the human body that proved Galen's theory about a cluster of veins incorrect.[4] His illustrations became a way to point out problems with Galen's theories. The illustration in Ibn al-Nafis' manuscript contains a two-dimensional image that documents the layout of the veins and a few organs similar to those seen in figure. The simple depiction gives a general and basic idea of the location of these veins and organs. The text surrounds and in some cases is written over organs or veins as if writing the text was a secondary thought. In this way, the text is secondary to the illustration. For Ibn al-Nafis, the illustration is his argument, not the text; the text only provides secondary information to the reader. This illustration created a simplified view

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[2] Louis N. Magner, *A History of the Life Sciences*, 3rd ed. (New York: M. Dekker, 2002), 60.
[3] Magner, *A History of the Life*, 58.
[4] Ibid, 73.

of the body with only the organs and veins that were relevant for Ibn al-Nafis' argument against Galen's theories. The image, however, remains inaccurate and confusing due to the layout of the organs and text.

Even though Ibn al-Nafis' illustration created a clear argument, it was not widely shared due to his anti-Galenic views. Their manuscript form also did not help with the circulation of these illustrations, meaning that it was mostly only shared within the scientific community.[5] Moreover, since all of these texts were hand written manuscripts, this knowledge was very expensive. Only manuscripts were produced during the middle ages, since printing was not invented until the mid-fifteenth century. Without printing, manuscripts were copied by hand by a scribe. This process ultimately limited the circulation of images. The scientists themselves created the original images and texts of the manuscripts. Manuscripts that contained illustrations were typically debased since scribes who were copying them had little knowledge of scientific depictions. The language was altered, as well, with the creation of each copy. For these reasons, it was hardly worthwhile to create a text with images. With the onset of printing in the mid-fifteenth century, the debasing of illustrations was no longer a problem, and images circulated more freely as well.

In the 14th century, human anatomy was typically taught with illustrations that were based upon Galen's writings or other past anatomical writings.[6] Similarly, lectures and manuscripts still followed the teachings of ancient texts. Observation as a way of learning was emphasized through human dissections in anatomy lessons. In the early 1300s in Bologna, Italy, teachers began to demonstrate dissections to students and

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[5] Magner, *A History of the Life*, 58.
[6] Julie Anderson et al., *The Art of Medicine: Over 2,000 Years of Images and Imagination* (London: University of Chicago Press, 2011), 22.

colleagues. Medical schools in other parts of Europe were slow to follow Italy's example.[7] As the interest in human anatomy grew, the use of illustration as a form of teaching in lectures dwindled, and instead dissections dominated the classrooms. Although illustrations had lost their importance in the medical lectures, they were still seen in manuscripts from the twelfth to fifteenth century. These illustrations, however, were not of primary importance; the texts of the manuscripts were.

The illustrations in manuscripts between the 12th and 15th century represented the simple ideas of medicine that many of the ancient texts discussed. Medical manuscripts contained illustrations that were similar to the illustrations discussed in classes. These illustrations were typically not aesthetically pleasing; instead, their sole purpose was to illustrate the locations of inner bodily structures (Fig. 3). This illustration from the 13th century depicts various systems of the body and organs that are comparable to the Islamic illustration examined earlier. Many of illustrations of the human body popularly presented the body in a squatting position that appears similar to a frog-like stance we saw in Ibn al-Nafis' illustration (Fig. 2). This stance is still seen in the Ashmole Manuscript, but the man looks slightly more erect (Fig. 3). There is a clearer focus on the veins, arteries, and organs in the 13th century seen in illustration both in Ibn al-Nafis and the Ashmole Manuscript. Most importantly, like many illustrations of this time, it is depicted as a line drawing in color with no dimensional modeling or space. Here, the illustration has evolved somewhat, since the text surrounds the body in a more organized fashion. Illustrations like these were produced through the collaboration of the artist and the scientist. This illustration, like many others of its time, presents a more symbolic

[7] Britain and Germany did not use human cadavers to teach human anatomy until the mid-sixteenth century. Anderson et al., *The Art of Medicine,* 20.

representation of the inside of the body. These depictions were not meant to guide the reader through a dissection like the words. Nor do they mean to depict the realistic appearance of an organ while one was dissecting. Illustrations provide a supplementary and secondary view; they were not to be relied upon without text.

As the knowledge of the human anatomy grew and became more complex in the 15th century, illustrating science became more relevant. The slow realization of the importance of illustrations was in part due to the fact that dissections were not done frequently enough until the end of the 15th century.[8] The limited supply of cadavers stunted the amount learned about the human anatomy. In 1482, this all changed when Pope Sixtus IV announced that the cadaver of an executed criminal could be dissected if he was given a proper Christian burial afterward.[9] Padua University was one of the universities to utilize this new availability of cadavers. It presented dissections for both the public and academics through out the 16th century. The dissections were meant to provide a greater understanding of the human anatomy. At this time, the curriculum of medical universities still consisted of the classic texts of the ancients, few of which included illustrations, even though the printing press was well established throughout Europe by 1500. This conservatism limited the possibility of new scientific discoveries. However, the use of illustrations as a way to discuss discoveries of the body slowly became increasingly important, as dissections became a more prominent way of learning. Since the body was so complex, documenting discoveries by writing alone became more

[8] Cadavers were in high demand due to the interest in laypeople, scientist, and artists to participate and watch dissections. Gallows and families swayed with the prospect of a free funeral regularly supplied the bodies for dissections. Sanjib Kumar Ghosh, "Human Cadaveric Dissection: a Historical Account from Ancient Greece to the Modern Era," *Anatomy & Cell Biology* 48, no. 3 (September 2015), accessed April 29, 2016. doi: 10.5115/acb.2015.48.3.153.
[9] Anderson et al., *The Art of Medicine*, 18.

complicated and difficult to achieve. Illustrations presented an easier way to explain the complexities of the body. Due to this, by the 16th century illustrations had become centrally important in published medical texts.

The popularization of anatomical images can be attributed in part to the fact that these dissections were open to anyone who was interested. Observation as a way of learning was on the rise, and naturally, the interest of using illustrations to explain anatomy grew as well. The increasing interest in observation ultimately leads to more accurate and artistic illustrations within the 16th century. At this time, an overlap between the world of artist and the scientist began to occur. A few artists like Leonardo were establishing a new interest in scientific illustration. Their visions of the human body changed the appearance of scientific illustration. Following from the rise of naturalism during the Renaissance, there was an increased interest in depicting the body realistically, and at a slightly later point in Northern Europe, group portraits of doctors and students gathered for anatomical lessons were becoming popular, though the emphasis was on teaching of anatomy and not anatomy itself. For artists in the Renaissance, observation became key to creating a naturalistic rendering of the body. During this time, theorists sand artists insisted that artists needed to have a mastery of the human body's motion and emotions.[10] The quest for knowledge of the body's muscular and skeletal mechanisms, along with the emotional expressions, united anatomy and art. The Renaissance artists' demands for realism were mostly satisfied through their own attendance at dissections. Artists like Leonardo da Vinci were increasingly dedicated to the portrayal of the natural and realistic body, and knowing its exterior alone was not sufficient; the muscular and

[10] Martin Kemp and Marina Wallace, *Spectacular Bodies: The Art and Science of the Human Body From Leonardo to Now* (London: Hayward Gallery, 2000), 12.

inner structures of the body were of great interest. Artists were especially concerned with the proportions of the human body in order to create the "perfect" male and female body. Major and minor artists alike drew from experiencing dissections, typically with the intentions of publishing their drawings.[11]

Leonardo da Vinci's illustrations were the first to truly represent this new scientific awakening of the 16th century caused by the emphasis on dissection and therefore deeper observation. He took a great interest in the anatomical structures of both the human and animal body, as learned through dissection, which he qualified through the practice of careful illustration. His illustrations recognized the heart as a muscular organ; this study of the heart was very advanced for his time. Due to all of the dissections conducted, there was a shift away from the old anatomical interest in just the organs, as we saw with Ibn al-Nafis' drawings, and movement towards anatomical drawings that included representations of the muscles (Fig. 2 and 4). The shading and sheer amount of detail that Leonardo provides with ink starkly contrasts with the simplistic medieval illustrations (Fig. 4). The human body becomes three dimensional in these illustrations with the interest in shading, lighting, and natural contours of the body. The stark outline and even tonal color of the body and its organs gave Ibn al-Nafis' illustrations a flattened appearance. The use of shading within Leonardo's figure allows the "outline" of the body to blend into the rest of the body's figure and create a three-dimensional appearance. The bones even become an object of interest within scientific illustration as we see with Leonardo's sketches. Leonardo's figures also lack the frog like structure seen in Ibn al-Nafis' illustrations; now, instead, the body was shown in an upright manner. Leonardo's

[11] Mimi Cazort, Monique Kornell, and K.B. Roberts, *The Ingenious Machine of Nature: Four Centuries of Art and Anatomy* (Ottawa: National Gallery of Canada, 1996), 17.

sketches provided multiple viewpoints of the body, when originally there was only a flat two-dimensional form to examine. These viewpoints helped to maximize information of the anatomical illustration. His drawings also chose to focus on particular parts of the body, such as the musculature and bone of the shoulder and arm (Fig. 4). The drawings as a whole are well rendered and easy to understand. Letters on each body structure indicate the organization of his depictions with the text that surrounds them.

Leonard did not intend to publish these illustrations, even though they are so detailed and easy to understand. They were made as his own personal study. These illustrations communicate Leonardo's own approach to science and anatomy through observation. He was focused on understanding the body through describing and depicting its forms. Leonardo has become well known for his anatomical drawings; however, he never published any books and instead spent a majority of his time drawing in his notebooks. These illustrations were published later after his death in 1519. Illustrations after Leonardo show the growing connection between art and science. His evaluations of the body provided a perspectival and three-dimensional view, he gave an artistic and scientific view of the body. Illustrations served as a learning tool for the advancement of artists' and scientists' knowledge.

By the sixteenth century, the use of scientific illustrations as a tool of communication was becoming increasingly popular in Europe.[12] Drawing with ink and pen was no longer the ideal choice for creating illustrations. Woodblock print consisted of the artist carving the wooden surface so that only the design remains; the carved-away areas did not carry ink. Woodblocks were ideal for printing books because both the

[12] For most people in the 15th and 16th century, the only access to printed books or paintings was through the displays in churches or palaces.

illustration and text could coexist on the page. The woodblock print, however, fell out of fashion because it was tedious and difficult to use.[13] On the other hand, engravings were easier to make. For an engraving, the artist inscribes the lines of their image on a metal plate of either copper or steel, which can then produce a relief. The ink is held in the areas that the artist inscribed, and is released under the pressure of the press to create a design on the paper. The whole process of creating the metal plate was rather arduous. Later in the 16th century, etchings replaced the engraving process. To create an etching, a metal plate is covered in an acid-resistant varnish. A needle is then used to draw onto the plate, and finally the plate is dipped in acid to further expose the lines that the artist etched. As anatomists and artists became more confident in illustrations and their techniques, text became less important and took a secondary place to illustrations.[14] Prints were created on cloth or paper depending on their purposes; for books, they were typically printed on paper.

Leonardo's illustrative successor was Andreas Vesalius (1514-1564), a Belgian anatomist, whose anatomical ideas were influenced by Galenic teachings, although he would not agree with all of them. Early on in his academic career, Vesalius taught surgery at Padua University. Vesalius, unlike Leonardo, published his works. This was only possible because of the printing process that developed during the sixteenth century. Vesalius exploited the printing press for its true power, and it ultimately further allowed science and art to become intertwined when he published his book *De humani corporis fabrica* (*On the Fabric of the Human Body*) in 1543. The book contained a written analysis of the body and detailed anatomical drawings, which he reproduced via both

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[13] Woodcuts became more sophisticated towards the beginning of the 19th century, reviving their use.
[14] K.B. Roberts and J.D.W. Tomlinson, *The Fabric of the Body: European Traditions of Anatomical Illustrations* (Oxford: Clarendon Press, 1992), 53.

engravings and woodcuts. Vesalius' book depicted bodies in muscular and skeletal form. His anatomical book, *De humani corporis fabrica*, was the first to focus more upon the illustration than the text. In doing so, Vesalius' book received harsh criticism, since many critics feared that the illustrations would come to be substituted for participation in dissections.[15] The scientific community also censured him for pointing out that Galen's descriptions were flawed. Yet, despite his disagreements with Galen, Vesalius still based his illustrations on Galenic knowledge. Vesalius believed that Galen never dissected the human body, which therefore led to Galen's errors of the description of the human body. It is important to note that Veaslius' illustrations mirrored the increased interest in experiential learning, observing anatomy directly. This interest in illustration is derived from observing dissections. Even though many anatomists were shocked by Vesalius' blunt anti-Galenic views, it was hard for them to ignore how amazingly detailed his illustrations were.

There is a clear influence of Renaissance artists in Vesalius' anatomy book. When comparing depiction of the male anatomy by Vesalius (Fig. 5) to any of Michelangelo's nude men in the Sistine chapel, the similarities in the interest and depiction of musculature of the male form between the two are easily seen. In fact, Vesalius' male figure stands in the popular idealized contrapposto form familiar from the Renaissance.[16] Interestingly, Vesalius' figures are not always portrayed against a white background; instead, his figure is shown on a cliff side with a town receding into the background. The background of the flayed man depicts the landscapes of northern Italy. The landscape is depicted perspectivally, allowing the artist to show his artistic skills. Both the pose and

[15] Magner, *A History of the Life*, 86.
[16] The contrapposto means counterpose in Italian. In art history, the term is used to describe a figure that leans its full weight on one leg and the other leg is more relaxed usually with a bent knee.

the landscape correlate to the art done within the Renaissance period. The pose is immediately comparable to the sculpture of David by Michelangelo from 1501 (Fig. 6). The legs of the flayed man are in the same position as David's legs. The illustrator must have been very aware of the art and popular ideas of the Renaissance art because both the contrapposto pose and perspectival view are depicted in the scientific illustration. This growing awareness of the artistry and has nothing to do with accuracy; it has to do with appealing to the visual culture of the Renaissance. And yet the illustration still clearly communicates its purpose of examining the musculature of the male body.

The interest in the natural world through observation truly began to take off in the Renaissance; however, scientists and artists were not only interested in representing the human body. Albrecht Dürer's (1471-1528) work greatly influenced many biological illustrations.[17] Dürer was influenced by Leonardo's illustrations that he saw on his journeys to Italy. Dürer conducted many studies of plants and animals. He is best known for his drawings, paintings, woodcuts, and engravings. He devoted much of his time to publishing his works via the process of woodcuts. His interest relied upon the developing ideas of naturalism. Dürer famously illustrated *Adam and Eve* in 1504 (Fig. 7). The focus of the image is set upon the bodies of Adam and Eve in the Garden of Eden. He engraved the ideal and proportional body adored in the Renaissance, which exaggerated the musculature of both the male and female bodies. Eve stands in contrapposto, and the plants that surround Adam and Eve are rendered in exquisite detail. The detail enables the viewers to differentiate between what Adam and Eve are each holding. The tree branch Adam holds is from the Tree of Life, where as Eve's branch is from the forbidden Tree of

[17] Brain J. Ford, *Images of Science: A History of Scientific Illustration* (New York: Oxford University Press, 1993), 89.

Knowledge. Every plant and animal is depicted with tremendous detail, such detail would later be found in his botanical studies.

Dürer's great curiosity about natural history led him to create detailed renderings of flowers and animals (Fig. 8). In the *Eight Studies of Wild Flowers,* he used watercolor to render the plants in their most vivid and colorful form. The plants are not labeled and do not contain any text within the illustration. Instead, the viewer is left to marvel at their beauty. They do not appear to be organized in any way, but are laid out organically along the page. The flowers, like the engraving of Adam and Eve, are rendered with exquisite amounts of detail. They appear three-dimensional due to all of the attention Dürer gave to every aspect of the plant, especially the leaves. Dürer's illustrations of plants stimulated a new interest in plants, and ultimately botany. Some were not as impressed with scientific illustrations, such as Hieronymus Bock (1498-1554), a German botanist, who originally thought that illustrations distracted from the text.[18] He eventually agreed that scientific illustrations were necessary and useful to examine when the actual plant was unavailable.[19] Like Bock, the scientific community realized the importance of scientific images, which not only included anatomy, but also depictions of the natural world.

Through out the 15th and 16th century there was an increased interest in the contents of the world, and therefore the knowledge of the natural world. The New World stimulated these interests, and led to the examination of the hidden and unfamiliar. Scientists were sent on trips to the new world to collect and study these new species, and there was therefore an increased circulation of illustrations that depicted the newly discovered environment and animals of New World. The 17th century ushered in the great

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[18] Dickenson, *Drawn from Life: Science, 84.*
[19] Ibid, 90.

age of colonial expansion and European explorers were enthusiastically collecting animal and plant specimens, instruments, and furniture from around the world. These collected objects were often organized into systems now known as cabinets of curiosities (Fig. 9). The cabinets of curiosities were hugely popular through the 16th and 17th centuries. They usually included specimens, drawings, and illustrations of many different disciplines (Fig. 10). Objects portrayed the specific interest in the natural and artificial world, and ultimately explored the boundaries of art and nature. These collections typically belonged to the upper class since they were able to collect what the world had to offer. The interest in the New World stimulated an increase in all types of illustration. Botany went through a revival during this period. In 1570 Philip II of Spain sent his physician, Francisco Hernández, to Mexico in hopes of gathering new information about the new world.[20] Hernández's work was later published in 1649 as *Plantarum, Animalium et Mineralium Mexicanorum*. The book contained woodcuts of the earliest surviving views explorations of the New World.

Similar to Hernández, Nehemiah Grew produced another book in 1682 called *The Anatomy of Vegetables begun*. This book helped revive an interest in the science of botany outside of herbal plants. The book included a study of "The Anatomy of Plants", "The Anatomy of Roots", "The Comparative Anatomy of Trunks", "The Anatomy of Leaves", and "Flowers, Fruits, and Seeds". Grew also investigated a range of different plant species under the microscope, most of his illustrations were reproductions of the cell walls of different types of plants (Fig. 11). This image shows his interest in the geometrical structures of the plant's structure. Each layer of the cell wall is depicted and has a very linear structure. He noted that the vascular tissue of plants had a tubular nature.

[20] Ford, *Images of Science: A History*, 83.

He also speculated that plants contained sexual organs.[21] So many scientific discoveries were being made with the microscope, meaning that illustrations like these portrayed the new interest in the world hidden from the natural eye.

Scientific illustration becomes more prominent with the development of the microscope in the 1590s. The world of the microscope opened up a whole new world for the scientist.[22] Moreover, the whole body was still becoming more complicated than scientists had previously realized. The only way to fully represent what was seen under the microscope without using it was with an illustration of the object under the microscope. This was Robert Hooke's purpose later in the seventeenth century. The New World of the Americas and the new world presented under the microscope dominated scientific interests until the 19th century. These two worlds expanded the outlook of science, especially in new studies of not only the body, but also of nature.

During the age of Enlightenment (1650-1701), there was a new demand for having knowledge published and available for all. The publishing of books had evolved since the printing press was created. Illustrations were achieving a new form of accuracy, thanks to the microscope. In 1665, Robert Hooke published his book *Micrographia*, a series of engravings. It was the first major publication of The Royal Society.[23] Hooke published the book with the intention of producing it for the public, and therefore mirrored the democratic ideals of the age of Enlightenment. Along with each illustration, a detailed text was provided for the reader. The illustrations are placed intermittently in

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[21] Magner, *A History of the Life*, 145.
[22] The microscope developed an interest in the worlds hidden from our eyes. Microscopes became quite common within the middle-class Victorian homes.[22] The microscope was so heavily used in the 17th century, that it lost its full emphasis and interest by the 18th century. The microscope was further improved in the beginning of the 19th century, reviving its interest to the public. Ford, *Images of Science: A History*, 194.
[23] The Royal Society is a fellowship of scientists and one of the oldest scientific academies that is still in existence today.

Hooke's writing. Hooke investigated everyday objects under the microscope, making his ideas easily accessible to the public: woven cloth, fish scales, feathers, sponges, the sting of a bee, the eye of a fly, and human hair.[24] One of the more famous drawings within the book was a 16-inch-long engraving of the flea (Fig. 12). The flea is depicted in exquisite detail, the type of detail one can only see under a microscope. The hairs on the legs and toward the body remind the viewer of the new levels of detail the microscope could now provide. The outer shell of the flea and its layers are also given great thought due to the amount of shading they each have, giving the figure a three-dimensional appearance. Hooke, here, transformed the flea's appearance by how he made the typically unappealing flea an object of interest through the details shown of the mouth and flea's body, thanks to the microscope. The body parts of the flea are also labeled with capital letters, showing that Hooke most likely discussed each of them in detail and referred back upon certain structures. It is important to note that they were not all engraved by the author himself; this, however, was not atypical. Hooke utilized and exploited the microscope to reveal the unseen and show what has been hidden in our everyday lives.

Moreover, accurate illustrations provided unprecedented access of knowledge to the poorly educated. The illustrations also provided a way to connect to the public, especially since Hooke studied conventional objects under the microscope. Although the book was written about everyday objects and for a general audience, Hooke was sure to include his scientific speculations and evaluations. He included his speculations on the nature of light, the relationship between respiration and combustion, and the origin of

[24] Jennifer B. Lee and Miriam Mandelbaum, *Seeing is Believing: 700 Years of Scientific and Medical Illustration* (New York: New York Public Library, 1999), 55.

fossils.[25] He also notably was the first to coin the term "cell" in this book (Fig. 13). Hooke observed the cell structure of cork and described it as a honeycomb.[26] He also famously described and depicted a fly's eye. Overall, Hooke's illustration was a process of seeing and representing, which for him constituted understanding. Hooke elevated illustration as a way of learning and comprehending an object in a new perspective.[27]

Depictions of the natural world were now more easily produced due to the developments in illustration techniques. The relief process, revived in the 18th century, perfected woodblock printing. An English engraver, Thomas Bewick, perfected and created a new technique engraving tools on hard wood, like boxwood. The technique entailed carving against the grain to cut away nonprinting surfaces, allowing for the creation of fine details. The new techniques offered by Bewick produced a boom in the quantity of illustrated books, magazines, and newspapers that were published towards the end of the 18th century.[28] Only wood engravings could be surrounded by text. This method of illustrating scientific writings lasted until photomechanical processes allowed for a more direct printing process.

Printing processes continued to expand; Lithography was later invented in 1798, and by the end of the 19th century became the first process to print multiple colors at once. Other processes were able to create a multicolored print by superimposing many printing blocks. To create a lithograph, a grease pencil is used to draw the design on stone or plate; the ink then sticks to the grease pencil, but wipes right off the stone with a damp cloth. This process does not allow the image to be surrounded by text. Lithographs,

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[25] Magner, *A History of the Life*, 175.
[26] Ibid, 175.
[27] Victoria Dickenson, *Drawn from Life: Science and Art in the Portrayl of the New World* (Toronto: University of Toronto Press, 1998), 231.
[28] Lee and Mandelbaum, *Seeing is Believing: 700 Years*, 58.

however, were still useful when the page only needed to contain an image. With each development in printing, illustration became more useful in terms of learning, observation, and teaching.

The use of scientific illustration was on the rise du to the variety of printing techniques that allowed for easier usage and circulation of illustrations and texts. As we move forward in the history of scientific illustration, it became evident that the images became more aesthetically pleasing and their makers became more aware of the artistic aspects surrounding science. These scientific illustrations, however, remain more in tune with science than they do with the artistic realm. Yet artistic skills helped to portray the object or subject accurately and thereby also making the image easy to understand. Images become more accurate with the increased attention of observing the natural world. By the 19th century, printing techniques become even easier to use especially with the new ability to print easily in color thanks to lithography. The combination of heightened observation, new and improved printing techniques, and a growing interest in aesthetic appearance all built upon scientific illustration's newfound ability as a communicative tool in the 19th century. Increasingly, more medical books were published with illustrations in the early 19th century. Many thought that artists and biologists needed to be educated in anatomy, and therefore needed to also have a basic skill set of drawing and observation.[29] Art and science work together in scientific illustration to produce meaning and knowledge world that surrounds us. Ernst Haeckel, a naturalist and biologist, was the one of the first to make the artistic treatment of material a priority in his illustrations.

[29] Bredekamp, Dünkel, and Schneider, *The Technical Image: A History*, 42.

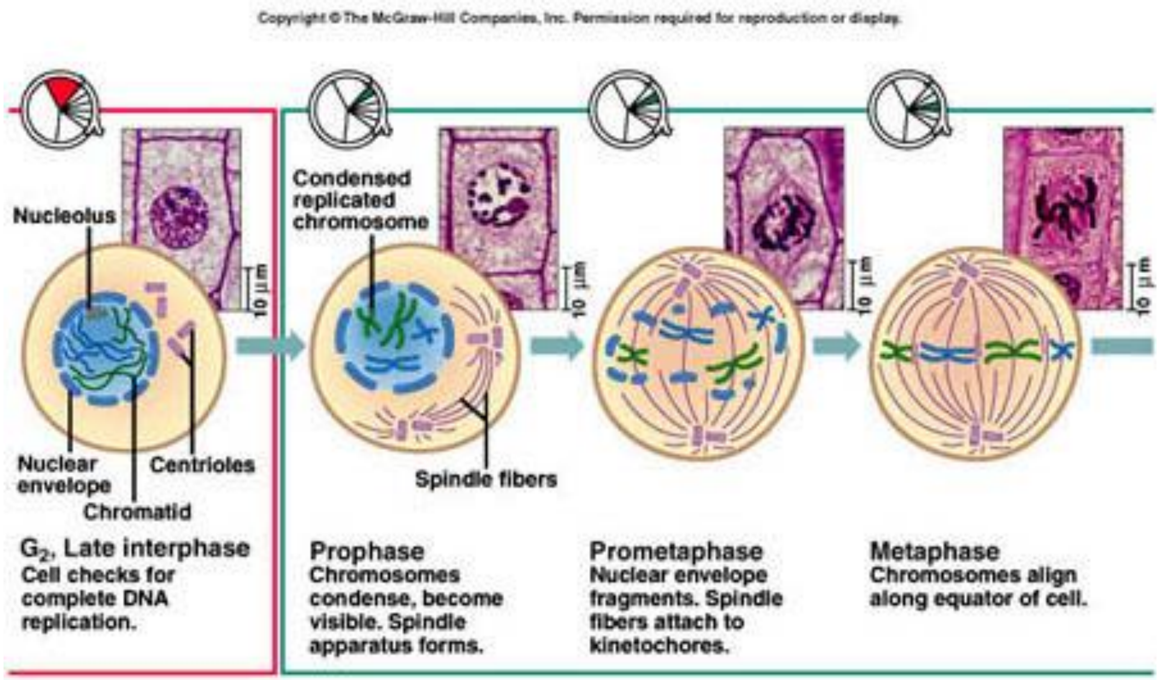

Figure 1. Partial Illustration of Mitosis Phases, McGraw-Hill Companies, Inc., c. 2000 (Note that this image is missing the last two stages – anaphase and telophase).

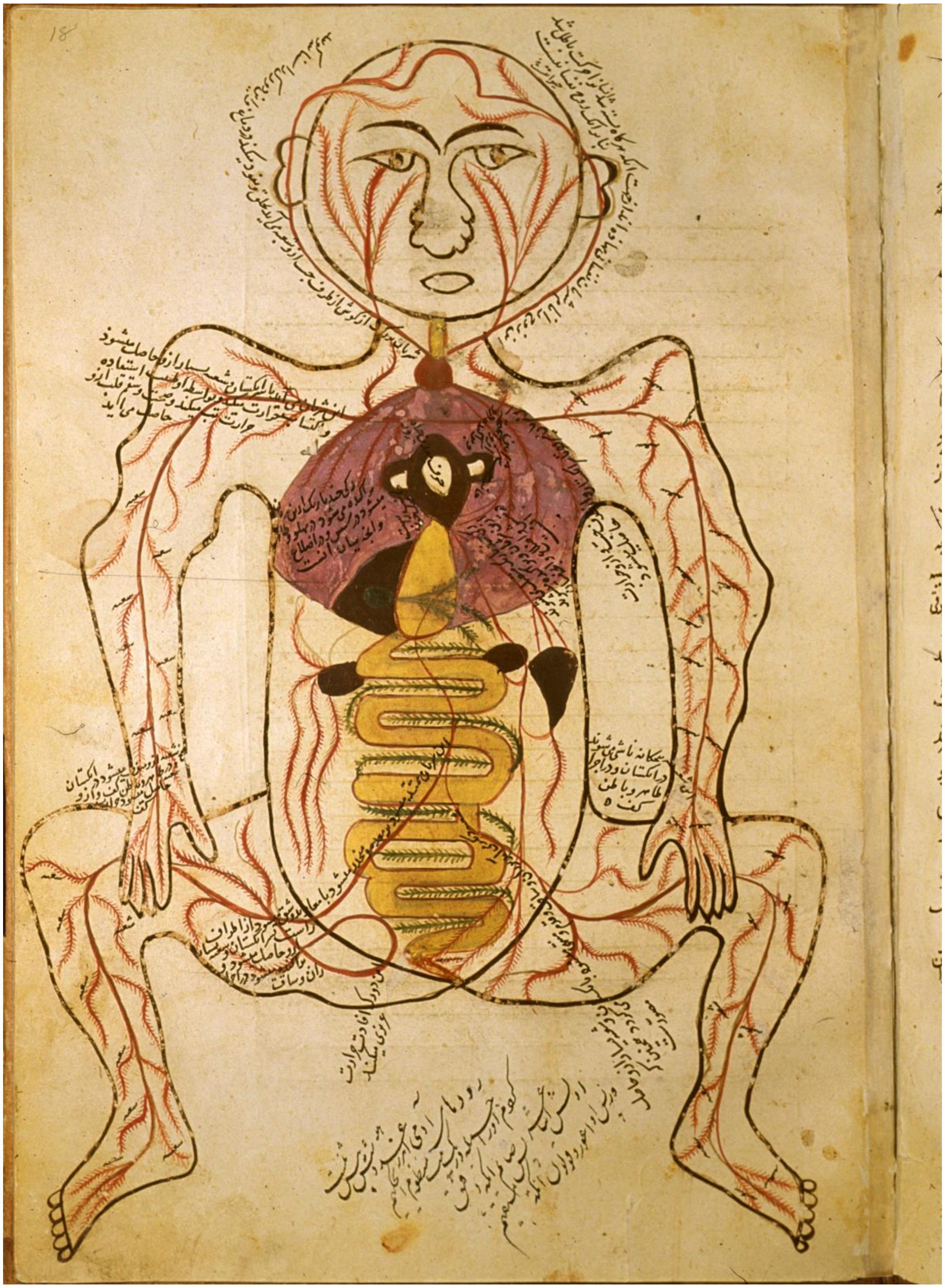

Figure 2. This manuscript is representative of what illustrations looked like within the Islamic Golden Age. Ibn-al-Nafis' illustrations were very similar to these. Artist unknown, 13th century, pen and ink.

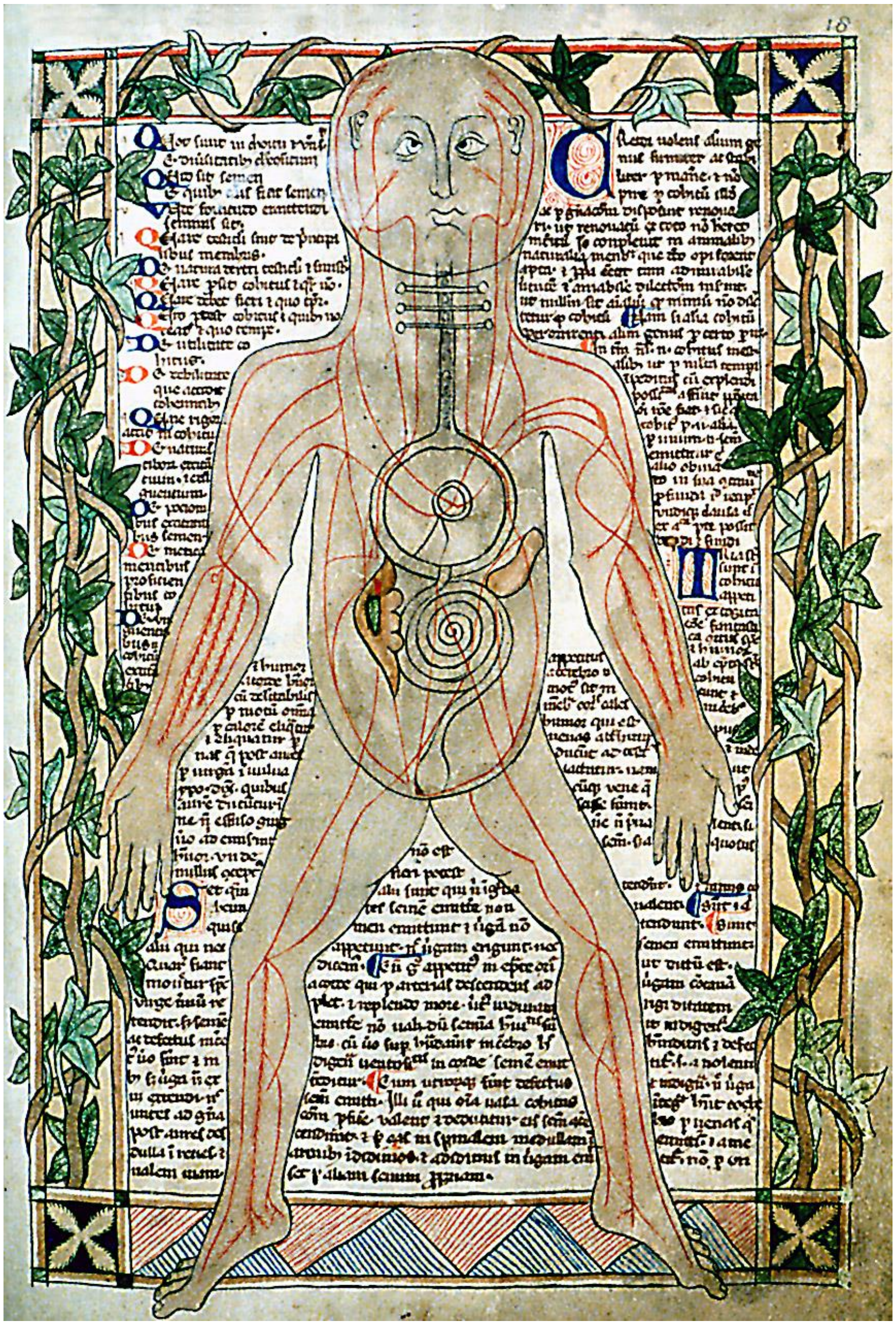

Figure 3. The arterial figure of folio 19, *Ashmole Manuscript*, 13th century. Colored manuscript drawing on vellum, 26.8 x 19.1 cm.

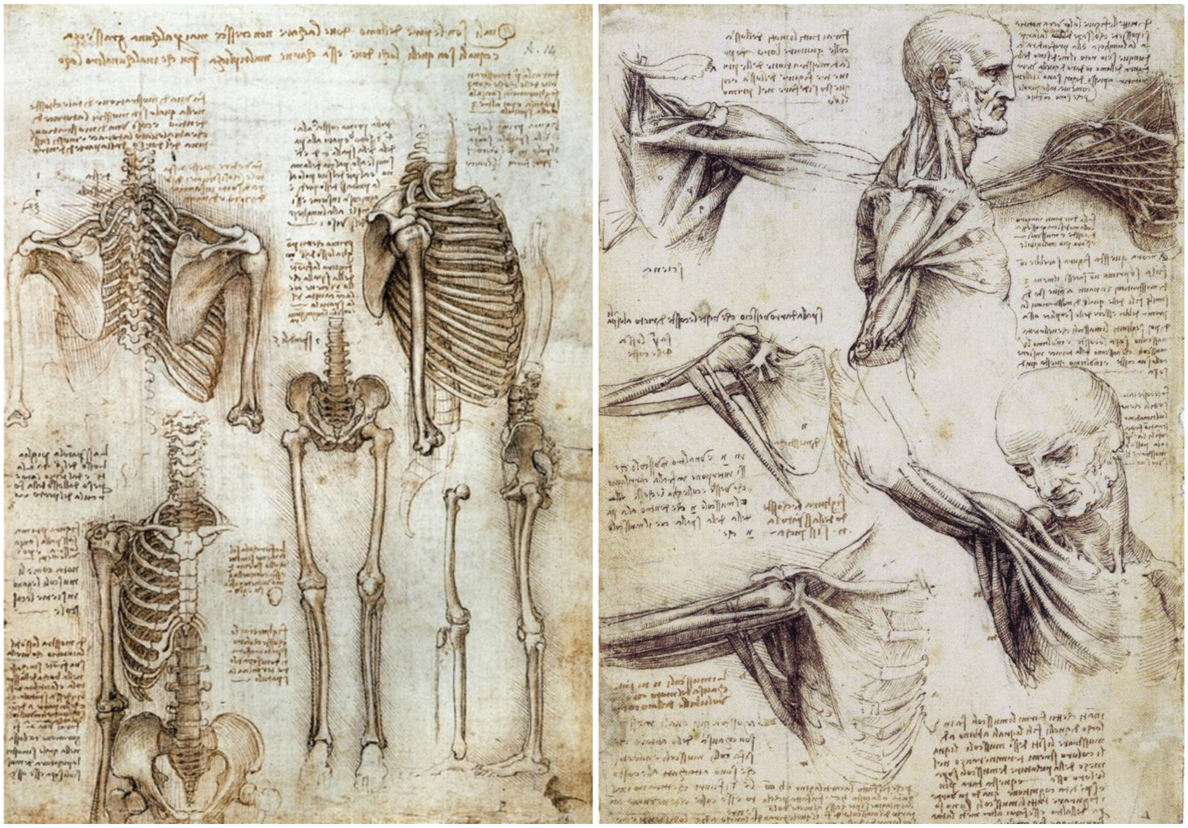

Figure 4. Leonardo da Vinci, Human Body Sketches, c. 1510, pen, brown ink and wash over black chalk, (*The Ingenious Machines of Nature* pg 107)

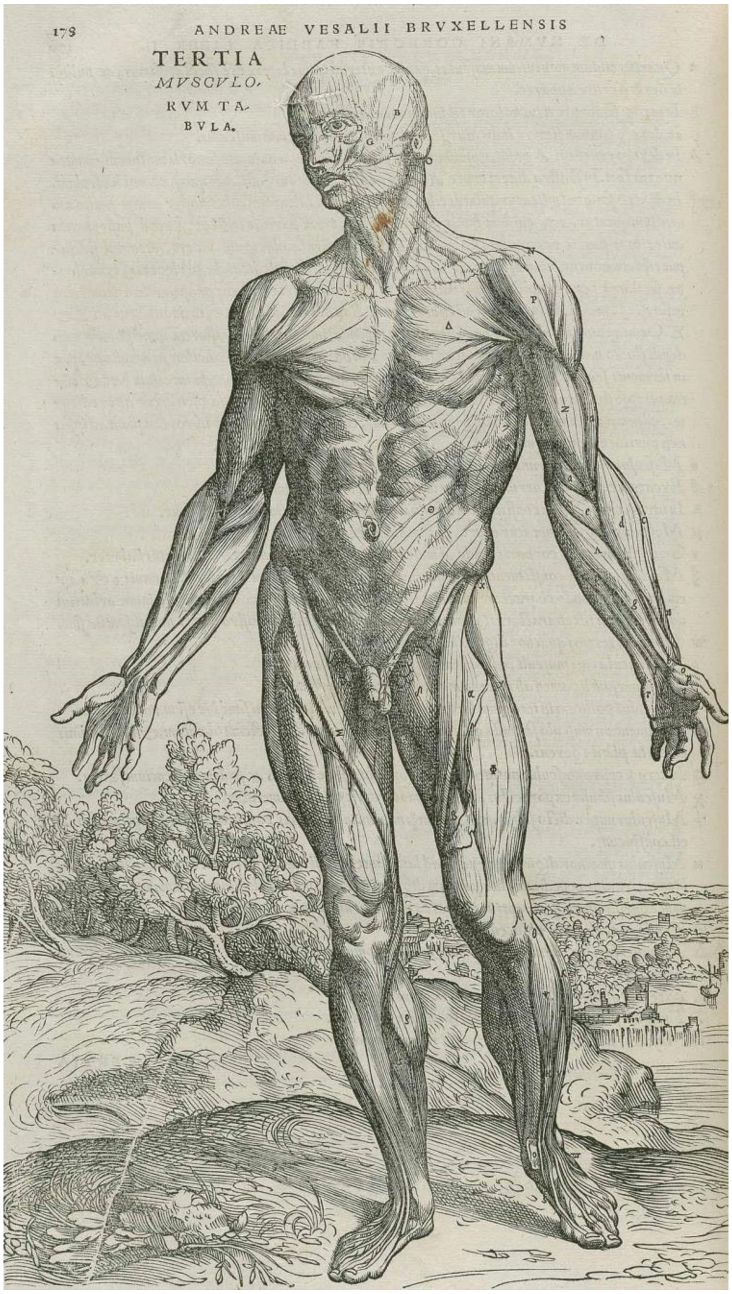

Figure 5. Andreas Veaslius, *De humani corporis fabrica*, Prima musculorum tabula, 1543, woodcut.

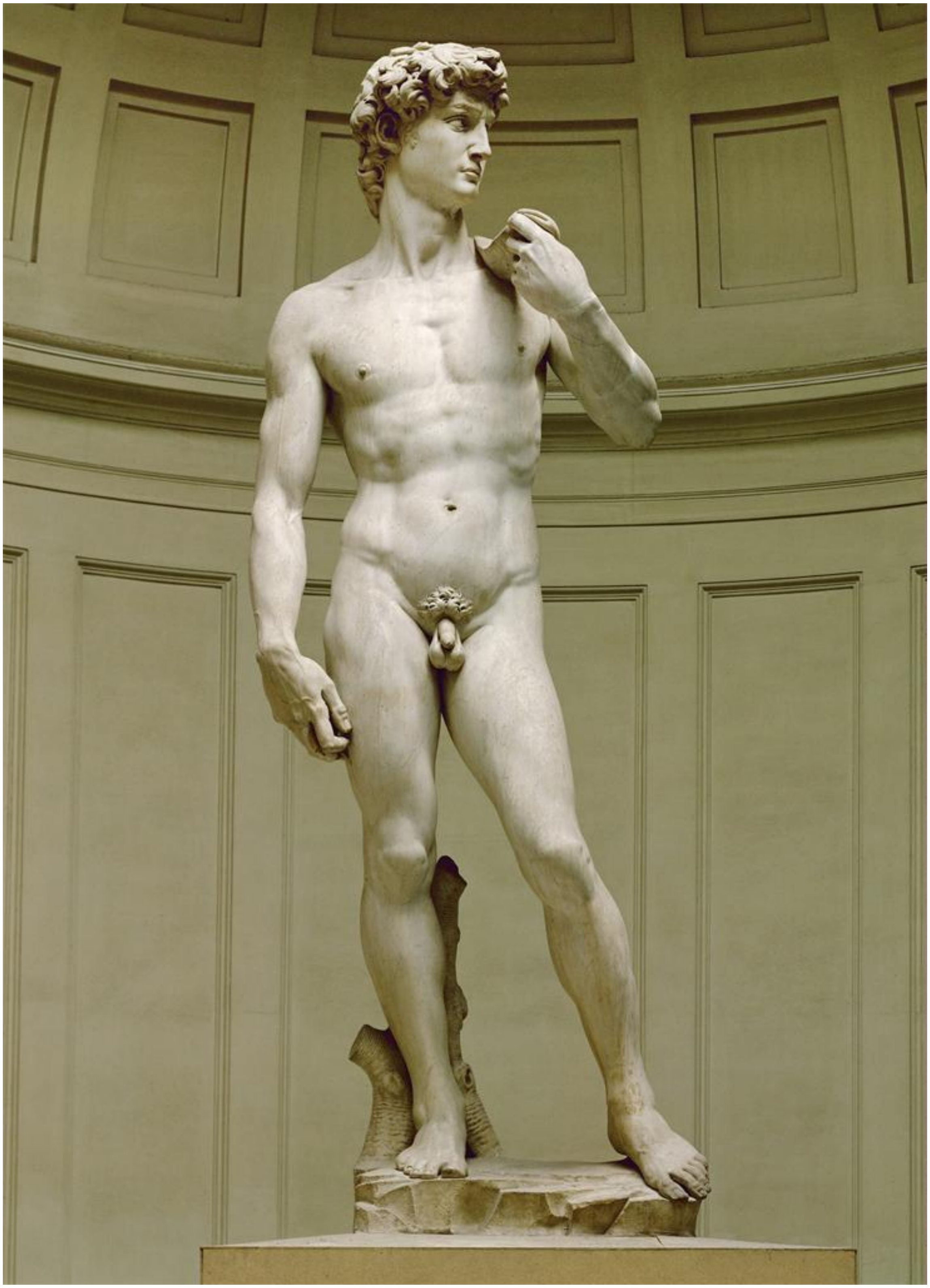

Figure 6. Michelangelo, *David*, 1501-1504, marble.

Figure 7. Albrecht Dürer, *Adam and Eve*, 1504, engraving.

Figure 8. Albretch Dürer, *Eight Studies of Wild Flowers*, 16th century, watercolor on paper.

Figure 9. Ferrante Imperato, *Dell'Historia Naturale,* 1599. Naples. Engraving. The museum of Ferrante Imperato.

Figure 10. Frans II Franken, *An Art of Curio Collection*, 1620-1625, oil on panel.

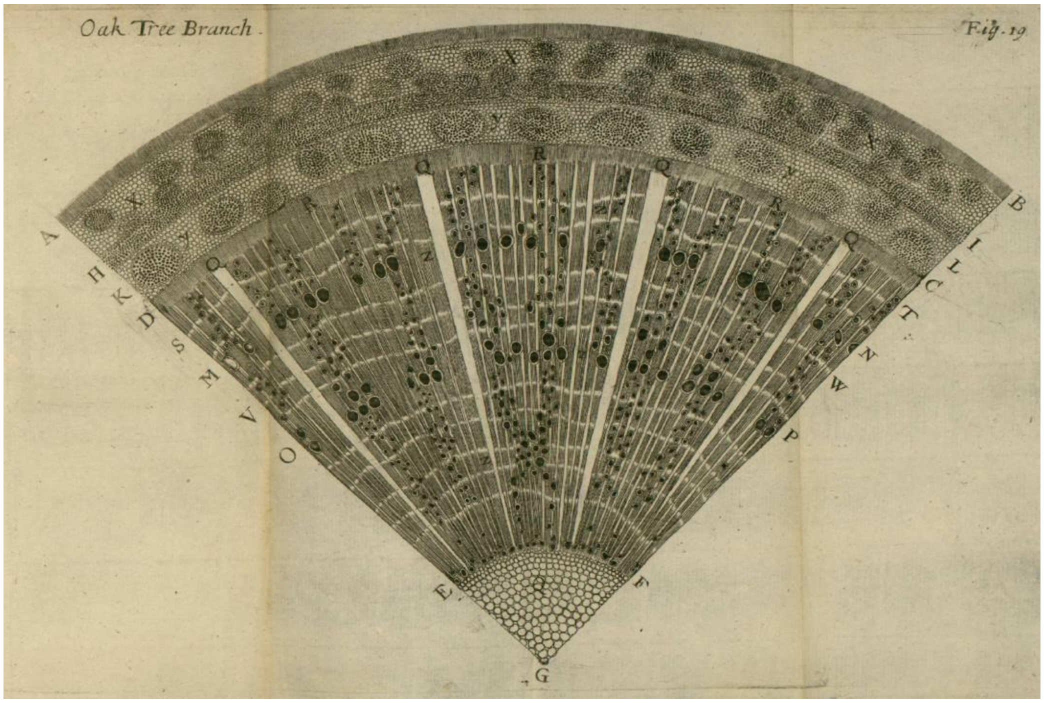

Figure 11. Nehemiah Grew, *The Anatomy of Plants*, 1682.

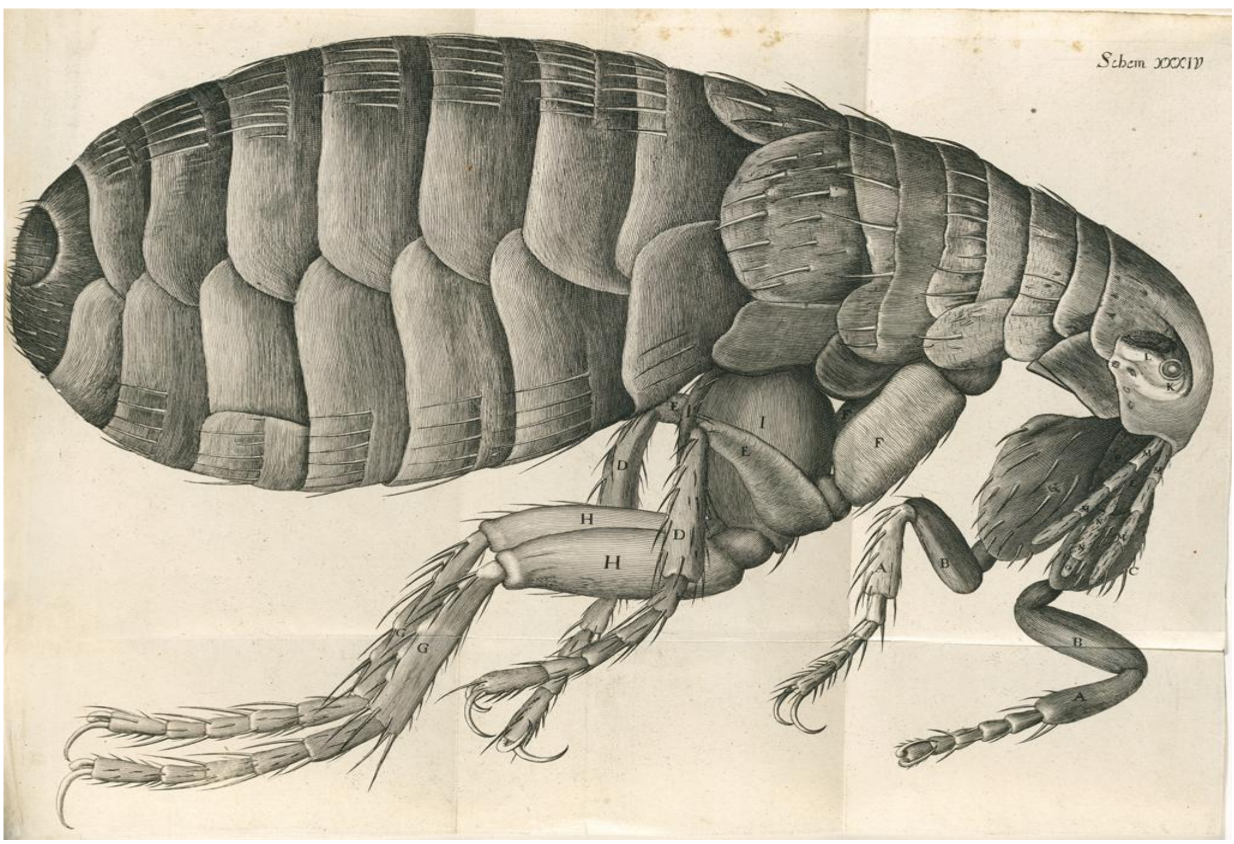

Figure 12. Robert Hooke, Flea, *Micrographia*, 1665, Engraving, 323 x 435 mm.

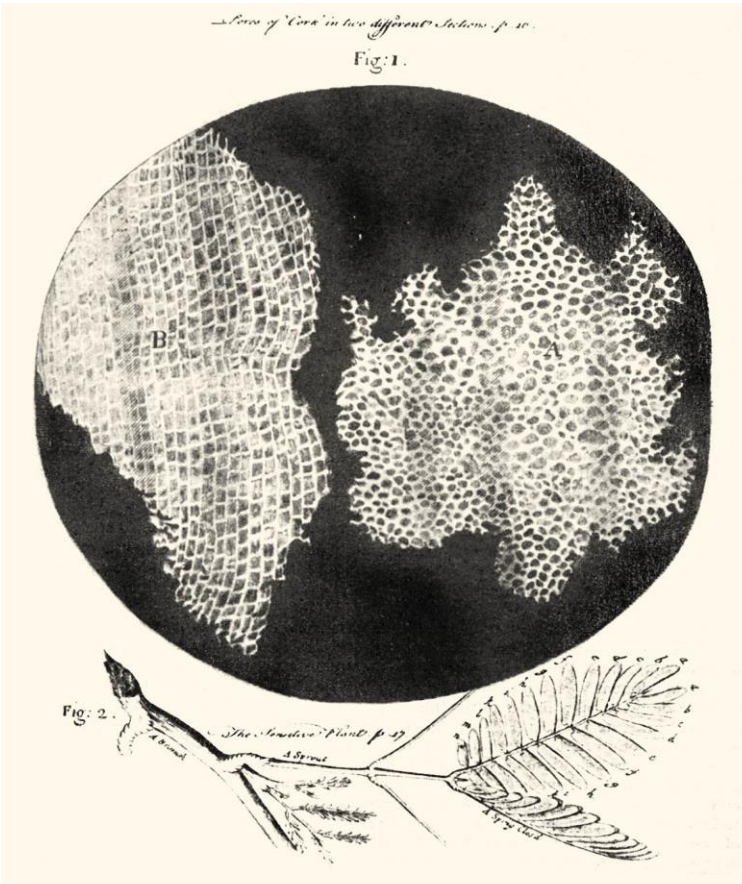

Figure 13. Robert Hooke, Cork Cell Structure and Sprig of a Plant, *Micrographia*, 1665.

CHAPTER II: ERNST HAECKEL

An exotic array of geometrical forms is displayed on Plate XIV of *Die Radiolarien*, published in 1862 (Fig. 1). No context is given for the illustrations other than the numbers and Latin terms at the bottom of the page. The six forms are laid out in a pentagon format; all of the figures are strongly outlined, and each is shaded in to give the three-dimensional appearance. Each of the individual forms is circular with stem-like objects protruding from its crevices. These protruding structures have a similar appearance to tree branches, especially the forms labeled 3, 5, and 6. The two forms at the bottom of the plate immediately catch the viewer's attention due to their vibrant colors. One of the forms contains a yellow center, while the other is blue in the center and surrounded by the same bright yellow color seen in the other colored form. The other forms that lack color share more similarities to a sea urchin. These objects' sponge-like structures are rigidly geometrical, in the way that every protruding branch appears equidistant from one another. Due to the layout and the structure of the objects portrayed, one can say that the artist was enchanted by nature and geometry. Overall, these forms evoke nature through their sponge and branch-like structures. Even though they are reminiscent of nature, they still have an aura of mystery in their abstract geometrical appearances. Ernst Haeckel (1834-1919), the creator of the illustration, began to redefine scientific illustrations with this acute focus on nature's symmetries and organic beauty. Haeckel was a German scientist, biologist, and Naturalist who wrote and illustrated *Die Radiolarian*. His illustrations came to shape modern views on scientific illustration, as shown by the fact that some of his illustrations were produced in science textbooks until the end of the 20th century.

To the 19th-century viewer, these abstract, hollow, skeletal-like structures elicited wonderment and awe, for no one had seen structures like these. The structures could induce a reaction that was as aesthetic as scientific. The causal viewer was not used to these microscopic views of life forms, and therefore understood the image through its form and structure. Due to this form of evaluation, the viewer could approach the illustration as an object of structural beauty. Haeckel's innovativeness as an illustrator allowed him to pay as much attention to aesthetic form as to biological functions that led modern viewers to accept scientific illustration as an art in its own right. His specific view of nature captivates the viewer, in that his illustrations are so definitive in the amount of detail they provide. Haeckel's attention to both the biological functions and aesthetic form of nature and translation of this attention into his illustrations were extremely innovative. Haeckel's innovation perhaps is what would later attract viewers and artists in the 20th century and allow for a more general acceptation of scientific illustration as an art form.

Radiolarians are single-celled marine organisms with a complex cell body. These microscopically sized organisms can sometimes reach a few millimeters in size. Radiolarians are recognized by their unique mineral skeletal structures that are typically perfectly symmetrical and geometrical. They are found throughout the ocean, whether it is on the ocean floor or shore. When Haeckel began to evaluate these life forms, there were only fifty known to the scientific world. Haeckel himself described 4,000 out of 5,000 species of radiolarians, though he was not the first to discover them. His professor, Johannes Müller, had studied radiolarians and introduced Haeckel to the world of marine organisms.[30] Most of the species cannot be seen without the help of a microscope. Without any background knowledge, a viewer's casual encounter with the illustration was almost certainly rooted in artistic and formal analysis. For the 19th-century casual viewer, the objects portrayed might have been anything from an imagined geometric abstraction to a factual observation of the natural world. Then, as now, Haeckel's illustrations led their viewers into a realm of artistic imagination that was based upon scientific fact, created out of Haeckel's consideration of form, symmetry, and structure of nature.

Haeckel's illustrations would ultimately be regarded as the high point of scientific illustration in the mid-19th century. Technology, artistic training, romantic taste, scientific knowledge and ambition were brought together by Haeckel, ultimately allowing him to create great illustrations. His admiration for the geometry and design of nature brought together art and science in such a way that it made his discoveries accessible to the public. Haeckel's work is an example of what scientific illustration was capable of, when combining popular tastes drawn from Realism, Romanticism, and possibly even symbolism, along with the new optical and printing technologies of the mid-19th century. Furthermore, Haeckel's own use of illustration as an argument for evolutionary theory helped to further cement the relationship between these two seemingly contrasting worlds. The understanding of his beliefs and therefore visual argument is first established through bibliographical information derived from Robert J. Richard and Olaf Breidbach's writing on Haeckel's life. In this chapter, we will see how art and science become involved in the 19th-century scientific world through Haeckel's struggle to conduct research in Italy and the publications that followed this experience. More importantly, his

[30] He later dedicated *Die Radiolarien* to Müller.

struggle reveals how he stands out among his peer scientific illustrators in the ways he popularized scientific illustration through his use of art. The illustrations of radiolarians were a new demonstration of the union of two contrasting fields of practice.

In 1862, Haeckel when published this plate in his first book of scientific illustrations, *Die Radiolarien,* his illustrations were put on the map; it was the beginning of his rise to fame. Darwin himself admired Haeckel's work and praised his understanding of evolutionary principles. Scientific illustrations like these opened a window into a new and mysterious world that few knew existed. In 1805, the notion that the ocean's depths were covered in ice and that therefore nothing lived in its depths was very common.[31] It was understood, however, that the shores of the oceans contained life forms: the plentitude of life that lined its wider waters led to oceanic metaphors, fantasies, myths and poetry. It was not until the expansion of the telegraph from New York to London in 1859, which was attempted by laying a cable across the ocean, that creatures of the ocean floor were discovered.[32] This discovery was nearly as awe inspiring as landing on the moon was in the 20th century.[33]

[31]*Proteus: A Nineteenth Century Vision,* directed by David Lebrun, Night Fire Films, 2004, accessed May 1, 2016, https:www.youtube.com/watch?v=S0hX0Yx7Nk0.
[32] Samuel Morse and Alfred Vail created the telegraph in the 1844. The ability of rapid communication took the world by storm, and soon there were demands to be able to communicate as easily across the ocean by the late 1850s. In 1859, the first attempt to lay a cable across the ocean from New York to London began. During the first attempt, the wire that the placed among the ocean floor snapped and was then brought up for repair from the ocean floor; the wire was teeming with unknown marine organisms. The popular that the ocean floor contained no living creatures was shattered. Tools were then created to measure and map out the ocean floor. Some artists took this map of the ocean floor as a parallel to the unconscious world. The clash of the two worlds began to meet when these organisms of the ocean floor were discovered.
Continuously more expeditions were created to uncover the mysteries of the oceans. In 1872, the Royal Society conducted its own voyage to survey the ocean's life forms name the HMS *Challenger*. Haeckel joined the expedition in which he wound up discovering and documenting 3,000 species of radiolarians. (Due to this expedition, he concluded that God is everywhere.) Haeckel committed himself to this work on the *Challenger* for fifteen years.
[33] *Proteus: A Nineteenth Century*.

In the midst of this new discovery, Haeckel was pursuing a career in medicine at the insistence of his father. Meanwhile, Haeckel fantasized about exploring nature in the same way Johann Wolfgang von Goethe had. Haeckel was a child of Romanticism and grew up admiring Goethe, a German philosopher and poet. For Goethe, morphology had aesthetic roots. Goethe explored nature by indicating its phenomenological values. According to Goethe aesthetic and artistic judgment complemented scientific understanding.[34] Haeckel's attachment to Goethe's ideologies is evident in his quoting of Goethe in the concluding chapter of *Generelle Morphologie* from 1866 as he discusses nature:

> There is in nature an eternal life, becoming, and movement. She alters herself eternally, and is never still. She has no conception of stasis and can only curse it. She is strong, her step is measured, her laws unalterable, She has thought and constantly reflects—but not as human being, but as nature. She appears to everyone in a particular form. She hides herself in a thousands names and terms, and is always the same. [35]

Goethe's idea of nature foreshadows some of Darwin's ideas of evolution, in how "She" constantly is changing forms. For Goethe aesthetic judgment complimented scientific understanding, and Haeckel would mix this ideology with that of Darwin's ideas of evolution.[36] The quote itself is romantic in how it references nature's greatness in her ability to change eternally. Romanticism placed a high value on emotional feeling as part of the aesthetic experience, and Romantic artists were interested in provoking experiences of awe, terror, and danger known as sublime. This was often achieved

[34] Robert J. Richards, *The Tragic Sense of Life: Ernst Haeckel and the Struggle over Evolutionary Thought* (Chicago: University of Chicago Press, 2008), 111.
[35] Ernst Haeckel, *Generelle Morphologie der Organismen*, 2 vols. from Johann Wolfgang von Goethe. Quoted in Richards, *Tragic Sense of Life*, 111.
[36] Robert J. Richards, "The Foundation of Ernst Haeckel's Evolutionary Project in Morphology, Aesthetics, and Tragedy," in *The Many Faces of Evolution in Europe, c. 1860-1914*, ed. Patrick Dessen and Mary Kemperiuk (Leuven: Peeters, 2005), 23, accessed May 1, 2016, http://home.uchicago.edu/~rjr6/articles/Netherlands.doc.

through depictions of nature. The sublime can also be defined as the element of infinity, making us feel overwhelmed by the immensity art or nature. Haeckel drew upon the sublime in dealing with the infinite variety of things in nature, which were then being gradually revealed through scientific study.

With these interests in romanticism and nature, he did not take much of an interest in classes that included dissections of the human anatomy.[37] Haeckel did not take interest in his university classes until he took courses with the professors Rudolf Virchow (1821-1902) and Albert von Kölliker (1817-1905) at the University of Wüzburg, while pursuing of his medical degree.[38] These classes stimulated his interest in scientific illustration. During his time in university, illustrations had already been recognized for their importance in teaching scientific methods. Drawing courses were even provided outside of the regular course load.

Kölliker's classes in 1853 brought out some of Haeckel's interest in art. Kölliker did comparative work in marine biology. In his classes, he was known to use drawings to illustrate the natural disposition of organic creatures.[39] In Haeckel's lecture notes, there are illustrations of the basic structures of the organism with typical descriptions. In these illustrations, Haeckel singled out layers of tissues and color-coded them in order to organize and understand each individual layer's purpose (Fig. 2). Professor Virchow, who specialized in diseased cell physiology, also had an effect on Haeckel's interest in scientific illustrations. Haeckel's notes from Virchow's class include intricate colorful forms that are neatly outlined and explained within his notes.[40] In embryology and other

[37] Olaf Breidbach, *Visions of Nature: The Art and Science of Ersnt Haeckel* (Munich: Prestel, 2006), 289. .
[38] Breidbach, *Visions of Nature: The Art and Science, 289.*
[39] Ibid, 78.
[40] Ibid, 82.

classes, students were trained to recognize, draw, and label unknown objects.[41] Drawing was now recognized as a form of learning. Copying and redrawing the shapes seen on the blackboard were processes used to solidify understandings and memorize scientific specimens. Mainly through Kölliker, Haeckel came to the basic understanding of how images could produce clear and accurate observations of scientific organisms.

He also attended Johannes Müller's lectures on comparative anatomy and physiology. Haeckel wrote to his parents about his new favorite science, comparative anatomy.[42] Haeckel and Müller became very close and in the summer of 1854, when they traveled together with Müller's son and another student to Heligoland, an island in northern Germany where Müller introduced Haeckel to marine biology.[43] Haeckel's interest in marine life blossomed, and due to this trip, he decided he would become a naturalist and zoologist.[44] Haeckel followed in Müller's footsteps when he found a variety of radiolaria the late 1850s in Italy.

In 1858, Haeckel graduated from medical school. In March of 1858, Carl Gegenbaur, who Haeckel knew from Wüzburg as an independent lecturer, invited Haeckel and other young scientists to Jena for the celebration of the three hundredth anniversary of the university.[45] Haeckel was then encouraged to join Gegenbaur on an expedition to Italy. In the end, Gegenbaur was unable to go and Haeckel proceeded alone

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[41] Nick Hopwood, *Haeckel's Embryos: Images, Evolution, and Fraud* (Chicago: University of Chicago Press, 2015), 35.

[42] Ernst Haeckel, "The Most Charming Creatures," in *Art Forms in Nature: The Prints of Ernst Haeckel* (Munich: Prestel, 1998), 8.

[43] Müller taught Haeckel techniques to capture plankton with fine gauze. Müller coined the term 'radiolaria' and had done extensive research on the organisms until a tragedy occurred on a fishing trip. Müller took a trip to the coast of Norway with two students in 1855. Their boat was shipwrecked as they were on their way back from Christiansand. Müller and one student made it safely back to shore, but his other student was not so lucky and drowned. This experience ruined the oceanic world for Müller. His work on radiolaria from then on was very limited.

[44] Haeckel, "The Most Charming Creatures," in *Art Forms from the Ocean*, 8.

[45] Richards, *The Tragic Sense of Life*, 53; Haeckel, *Art Forms from the Ocean*, 13.

to Italy the following year. Haeckel left with the hopes of getting a teaching position in Jena when he returned with his biological research.[46] He planned to make some stops before reaching Naples to study art, and to perhaps even gain a new outlook on life.[47] Haeckel's interest in philosophers and their own adventures stirred his interest in international travel. Within the 18th and 19th centuries, Germans became deeply interested in Italy's literature, visual arts, and music. This growing interest was related to German's perception of Italy as a place for escaping; Italy had a mythological status within German culture. The increase in travel occurred with the interest of written representations of journeys.[48] Goethe, for example, had gone on a similar trip to Italy in the late 1780s. Haeckel closely followed Goethe's philosophies, especially those that had to do with nature.[49]

In January of 1859, he first travelled to Genoa, and then briefly stopped in Florence to purchase a microscope with water immersion lenses.[50] Next, he left for Rome, where he spent five weeks enjoying its art and history. He studied all the great artists of the Italian Renaissance, though the religious paintings became overwhelming for his liberal protestant views.[51] At the end of March, he traveled to Naples to begin his biological research without realizing that he had chosen a bad time of year to begin. He felt uncomfortable in the foreign city, and thought of the people as rude. Yet, he stayed for six months in hope of finding interesting information on the topic that had been

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46 Breidbach, *Visions of Nature: The Art and Science, 280.*
47 Richards, *The Tragic Sense of Life*, 53.
48 Hachmeister, *Italy in the German Literary Imagination: Goethe's "Italian Journey" and Its Reception by Eichendorff, Platen, and Heine* (Rochester, NY: Camden House, 2002), 1.
49 Haeckel credited a majority of his work to both Goethe's and Darwin's ideologies.
50 Haeckel, *Art Forms From the Ocean,* 13; He purchased the microscope from a well-known physicist and microscope maker, Giovanni Battista Amici. The microscope allowed for a magnification of up to 1,000 times. The water immersion lens would later help with Haeckel's analysis of small marine organisms like Radiolarian.
51 Haeckel, "The Most Charming Creatures," in *Art Forms from the Ocean*, 13.

recommended to him by Johannes Müller. Haeckel began to despair when he was unable to procure and discover an anatomically interesting species of echinoderm—starfish. However, having recently realized his distaste towards the medical world, Haeckel immediately took advantage of his surroundings and examined the world of art. His failure to find live marine specimens further distanced him from the scientific world. With the loss of hope in his scientific research, he turned to the beautiful Italian island, Ischia, in late June. It was here that he befriended a German poet and painter by the name of Herman Allmers. His vacillation between science and art now led him to pursue art in a serious fashion.

The divide between the two worlds became increasingly apparent for Haeckel. For him, science was a world of rigid rules and systems, while the art world remained a dark world of mystery.[52] Haeckel and Allmers became friends within weeks of knowing one another. Their friendship gave Haeckel relief from the frustrations of his research. Together on Ischia, they hiked and examined the beauty of nature by painting or sketching. While traveling with Allmers along the beautiful coasts of Italy, Haeckel found that he adored landscape paintings. In August, they sailed to Capri to continue their bohemian lifestyle. However at this point Haeckel's father intervened, forcing Haeckel to leave Messina in September to resume his biological research in Italy.

Although he had begun his research again, Haeckel continued to vacillate between choosing to pursue either the world of art or science. He was deeply conflicted with the choice until 1860 when he recognized that he could practice both at the same time.

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[52] Haeckel was greatly influenced by the Romantics since he grew up surrounded by this art form. The Romantics stressed the emotional and psychological aspects of art.

During this time, he wrote a letter to Allmers about his decision to favor biology but at the same time still have an artistic existence.

> Despite its unbroken monotony life is anything but boring owing to Nature's inexhaustible richness which, time and again, produces ever-new, beautiful and fascinating forms that provide new material to speculate and ponder over, to draw and describe. Indeed, this is just the right sort of work for me because, in addition to the scientific element, it involves artistic matters to a large degree. At the same time I have once again completely reconciled myself to my dear science in loyalty which shall, throughout my life, take the highest priority and which I had seriously begun to doubt owing to your artistic aesthetic influences.[53]

Haeckel came to understand the involvement of art in science through nature's riches, which for him were the details and intricacies of nature. Through art, he sought to exploit the beauty of science in its most natural forms, which he considered artistic. With his science background, Haeckel fully explored the differences between species. This vision became clear with his first encounter with radiolarians in Messina. Haeckel's meticulous attention to the natural forms gave life to the artistic aspects of scientific illustration. These forms that Haeckel observed and recreated were not just representations of real life; their intricate symmetries were a form of nature's beauty and godliness, which in turn related to art. Haeckel shared the common Romantic view that God represented his divine hand and artistry through his own creations, which included nature. It was a romantic idea that by studying nature one was also studies God's work, and therefore painting and analyzing nature for its forms became a meditative process.

In Messina, he was able to classify 120 new species of radiolaria. This classification was only possible according to the specific characteristics and composition of the radiolarian's skeleton.[54] The artistic geometrical elements of the radiolarian's skeleton linked Haeckel's interest to scientific taxonomies by how they showed the

[53] Breidbach, *Visions of Nature: The Art and Science*, 289.
[54] Haeckel, "The Most Charming Creatures," in *Art Forms from the Ocean*, 9.

progress of evolution and genetic variation. Furthermore looking, he was able to understand the natural aesthetics with his trained scientific eye. Examining organisms closely under the microscope for Haeckel becomes a way of learning and acquiring knowledge. He developed a way of looking at nature through his admiration for their symmetries and intricacies of design.

When first examining the illustrations in *Die Radiolarien*, the viewer is left unaware of what they are examining without consulting the book's text. Haeckel relates the romantic interest of the hidden and unconscious world to that of the scientific with captivatingly alien illustrations in *Die Radiolarien*. In his illustrations, Haeckel identifies the artistic aspects, their forms, and organic symmetries of the radiolarian. In doing so, he takes every care to illustrate the various forms with precision (Fig. 3). He composed the whole plate to magnify certain aspects of the radiolarian's form. The readers barely notice the numbers that label each radiolarian because of his thoughtful organization of the plate. He used green and bright yellow to have the reader immediately notice the largest of the cluster of radiolarians at the bottom of the plate. Significantly, he labeled this radiolarian "number one". From there, the eye naturally follows in an upward motion to examine the rest of the plate. The bottom corners of the plate display only a few elements of the radiolarian's geometrical structure. He shows his interest in their intricate features and forms when he depicts only fragments of their form in the bottom corners of the plate where he uses the structure to ornament the ends of the page. These fragmentary ornamentations ultimately limit the viewer's eye to the contained space of the plate. The colors of the radiolarian also magnify the differences in each structure within the radiolarian.

Another plate in *Die Radiolarien* establishes Haeckel's interest in the structure and design of the radiolarian. For differently shaped radiolarians, Haeckel organizes and designs the plate differently. Plate VII is formatted differently from plate XXII (Fig. 3) by how it guides the viewer's eye along the plate in a circular motion (Fig. 4). Whereas plate XXII highlights the pointed and stemmed forms of the radiolarian within the squared plane in which it is presented. Plate VII forces the viewer to notice the circular aspects of the geometry of this set of radiolarians. It does this by placing the radiolarian labeled number one in the center. This central radiolarian radiates out to the circling radiolarians by the web-like lines that stem out from its surface. These radiating webs allow the viewer's eye to proceed in a circular motion. This circular motion emphasizes the circular symmetries of the radiolarian. All of these details and organizations of the radiolarians express his artistic interests in their organic symmetries. The colored radiolarians again highlight the different structures within the radiolarian. While these illustrations focus on form, they also express Haeckel's interest in Darwin's evolutionary theory published within the *Origin of Species* in 1859. Darwin himself recognized *Die Radiolarian* as great feat, admired Haeckel for his work, and praised Haeckel's understanding of his own theories by saying: "[they] were the most magnificent works which I have ever seen, and I am proud to possess a copy from the author."[55] Haeckel produced his own interpretation on Darwin's theory of evolution by focusing on the two important causes of evolution: adaptation and heredity. The perfectly geometrical shapes of the radiolarian outlined his ideas of both adaptation and heredity. Depicting the forms

[55] Richards, "The Foundation of Ernst," in *The Many Faces of Evolution*, 1. Quoted from Charles Darwin to Ernst Haeckel (3 March 1864), in Correspondence of Ernst Haeckel, in Haeckel Papers, Institut für Geschichte der Medizin und der Naturwissenschaften, Ernst-Haeckel-Haus, Friedrich-Schiller-Universität, Jena.

in such much detail allowed him to create a scientific analysis and understand the artistic aspects of the symmetries of nature through the radiolarian.

Haeckel's inventiveness as a scientific illustrator becomes evident when comparing his works to that of his peers. Other scientific illustrations were not quite as detailed as Haeckel's. Thomas Henry Huxley, a marine naturalist and assistant surgeon, voyaged on the H.M.S. Rattlesnake to survey New Guinea and Australia in 1846. One of his sketches on the trip included a radiolarian (Fig. 5). The Royal Society published *The Oceanic Hydrozoa* in 1851 about his voyage on the H.M.S. Rattlesnake from 1846 to 1851; however, this image of the radiolarian was not published until 1899.[56] Huxley's radiolarian is small and not as precisely detailed as Haeckel's radiolarians. In Huxley's illustration, each structure of the radiolarian is identifiable; however, there is nothing intriguing or pleasing about Huxley's illustration. The radiolarian seems quite ordinary without the magnified interest that Haeckel provides in his detailed depiction of the symmetries and design of the radiolarian. In comparison to Haeckel's plates of radiolarians, Huxley's radiolarian appears quite flat. Haeckel magnifies all the radiolarian's geometry, while Huxley remains distant and uninterested in the radiolarian's form as he depicts it from a distance. Haeckel was clearly devoted to rousing an interest in the marine world within the public realm than Huxley, whose illustrations took on a more bland and scientific format. Huxley's images were primarily focused upon the scientific analysis of what he observed. He was against any idealizing or generalization of science. His strict ideas of science and the rules that surround its depiction translate right into Huxley's illustration of the radiolarian. He presents it how he observed it, with no adjustments to its structure. Haeckel on the other hand idealized and exemplified the

[56] Philip Ritterbush, *The Art of Organic Forms* (Washington: Smithsonian Institution Press, 1968), 61.

beauty of the organic structure of radiolarians in order to popularize marine science, but also to show the way he saw them to the rest of the world.

Haeckel uses art and nature's formal beauty to build a visual argument and create an understanding of science for the public. His illustrations were visual representations of evolution. In *Die Radiolarian* he was able to show the different forms of one species, and through this how they related to evolution. His use of illustration, however, also created a controversy among scientists. Although the artistic use of color and the way he broke down structures were optically appealing to non-specialist viewers, scientists found faults in his arguments. Creating an argument using visual mediums became increasingly important in this period, given that it was the only way to portray any microscopic observations or marine organisms. Illustrations drew readers to the text and gave a more enriched experience and understanding due to the images. His illustrations were clear in the arguments (usually of evolution) that they provided. The sales of his books did not decrease, but idealization of form and structure of organisms ultimately brought him trouble from his own peers.

The controversy started rather early in Haeckel's career when he published *Natürliche Schöpfungsgeschichte* (*The Natural History of Creation*) in 1868. The book focused on the developmental history of the human. The book contained images of embryos at various stages of development, and they demonstrated an aspect of Haeckel's biogenetic law. The biogentic law states that when developing from an embryo to an adult, animals go through stages in which they resemble their ancestors and therefore provide evidence of evolutionary descent. The illustrations emphasizing the biogenetic law were more striking than the abstract expressions like that of the radiolarian. These woodcuts of embryos were about human development; this directness is therefore more striking then examining a microscopic creature, which is not related to the viewer. The problem arose when Haeckel was accused of oversimplifying one of the earliest stages of embryo development of a dog, chicken, and turtle by using the same image (Fig. 6). Haeckel's counter argument was that embryos at such early stages were hardly differentiable, meaning that it was ultimately unnecessary to draw illustrations for each of the three animals. He even clearly stated this within the text of next edition of his book: "It is all the same whether we describe the embryo of a dog, chicken, turtle, or any of the other higher vertebrates. For embryos … at the represented stage certainly cannot be distinguished."[57] However, stating this in the 2nd edition of the book did not change the fact that Haeckel had used the same woodblock print for each one. The mere fact that he did this haunted the rest of his career, even though the simplification of the embryo prints was to communicate their resemblances, and therefore prove the biogentic law. By placing the three different species beside one another, he was further able to establish a comparison for his visual argument. In using his illustrations as an argument, he first documented what was actually in nature, in order to then interpret how one should look at what was observed.[58]

Depictions of the embryo set a perfect example of why illustrations are so useful in understanding the composition and meaning of the embryo. Embryology requires a visual medium. Using words to explain the process of embryonic development does not fully convey what is occurring. With drawings, one can easily label and highlight the changes occurring in each stage. At that time in the 19th century, embryos were too rare,

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[57] Richards, *The Tragic Sense of Life*, 279. Quote from Ernst Haeckel, *Natürliche Schöpfunfsfeschichte* (Berlin: Georg Reimer, 1868), 249.
[58] Breidbach, *Visions of Nature: The Art and Science,* 133.

translucent, and delicate to preserve. Fresh material to examine was not always available. The development of the embryo was much easier to understand when looking at an image, instead of through wordy explanations. In order to clearly communicate his argument even further he used the drawing traditions that surrounded him in the classroom.

Haeckel grew up in this tradition of simplifying embryos and schematizing them in his drawings creating embryonic images that were heavily influenced by the lectures he attended in medical school.[59] In medical school, the simplification of an organism was very common in order to show specific aspects of the organism's structure, like the cell walls. The teachings of medical school are reflected in of the dog, chicken, and turtle of figure 6. Many of the illustrations in the book were not as simplified or idealized as those in figure 6, however, they were still thought of as controversial. In figure 7, he used a very similar schema of generalization, but the top images that represented a dog and human embryo respectively had slight differentiations in the size of their embryonic sack and position of what might become a paw or hand. These slight differentiations were still not completely "true" to the appearance of these embryos, and were still therefore controversial. His drawings were problematic partially because of the artistic choices he made when developing this conceptual map of the embryo. For example, he emphasized schematics, using a simple type of line drawing, which was typically used to hypothesize structures that were not yet understood or seen. Line drawings consisted of narrow lines that vary in density in width to create a tonal and shaded image. This schema was widely accepted in classrooms, but in print the line drawing schema posed a problem for the

[59] Nick Hopwood, *Haeckel's Embryos: Images, Evolution, and Fraud* (Chicago: University of Chicago Press, 2015), 56.

scientific world. The second printing of the book gained even more popularity due to the controversy surrounding the book.[60]

As Haeckel increased in popularity, he would make use of the new printing techniques of the 19th century in order to allow a wider circulation of his books. In *Die Radiolarien*, Haeckel used copper plates as his printing method of choice, while Huxley, his peer, most likely was using wood block printing. The copperplate had the ability to be used several hundred times to create the same print. New methods of production included cheaper and better printing techniques, which allowed for an expansion within the print market. Lithography, invented in 1796, was another new printing process based on drawing upon stone with a grease pencil. This major innovation allowed for the ease shading and application of color enabling it to became the main color printing technique towards the second half of the 19th century. By 1875, color lithography (chromolithography) was cheaper than copper printing and in wide usage. Haeckel did not start using lithographs until 1874, and when he did, he had an artist translate his drawings into lithographs. However, not all of the prints in his books produced after this time were lithographs; he still used other printing techniques. The ease and swiftness of the new and improved printing methods, allowed images to circulate more easily, and therefore stimulated interest in graphic works. Part of the reason Haeckel's illustrations differed from other scientific illustrations was due his use of new printing techniques like lithography.

Huxley and Haeckel used different printing techniques and therefore achieved very different illustrations regardless of their individual artistic skills. Huxley focused on his discoveries within on his voyage aboard the H.M.S Rattlesnake Challenger, where he

[60] Hopwood, *Haeckel's Embryos: Images, Evolution*, 122.

also observed the radiolarian. In 1859, Huxley published *The Oceanic Hydrozoa*, which focused on the alluring species of jellyfish called the medusa, yet his medusa does not stir any amazement (Fig. 8). Huxley's medusa representation was of the order siphonophore called the *agalma*.[61] Here, the entirety of the medusa is seen in the center of the page with its individual structures surrounding it. There are no colored illustrations within the book, and at that, there are very few illustrations distributed through out the book. The image itself almost appears as a watercolor, due to the lightness of depiction. There is a purely scientific interest in illustration of this medusa, since it is portrayed colorless to show the medusa's transparency. This correlates to the actual weight and appearance of the medusa. There is no use of color to differentiate certain aspects of the medusa, as Haeckel had done in his depictions of radiolarians in *Die Radiolarien*. Some species of siphonophorae are known to illuminate fluorescently when provoked; however, Huxley does not use color to depict this provocation. Instead, he focused more upon the generic facts of the species as he did with the depiction of the radiolarian. *The Oceanic Hydrozoa* was ultimately meant for only the scientific reader. Haeckel, on the other hand, would have used vibrant colors to entice the reader and portray the aesthetic beauty of a different medusa's form and structure.

Meanwhile, Haeckel was using illustration to produce a vivid argument of the beautiful in the scientific. Haeckel made his vision of art and nature more emphatically clear when he published his book *Kuntsformen der Natur* (*Art Forms in Nature*) in a series of ten installments with ten plates each between 1899 and 1904. The book depicted a variety of different species, from radiolarians to medusa. The hundreds of plates

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[61]Alagma is the genus of the siphonophorae and is the Greek word for ornaments.

became a summation of his work throughout his life and his view on nature.[62] Importantly, they were scientific illustrations that made use of ideals of beauty to present Haeckel's view on nature. Nature is symmetrical and organized and to Haeckel this showed the unity of all living things. Haeckel made use of lithography to reproduce his illustrations in color and vividly present they geometrical and organized nature he observed. The book itself contains more illustration than text, and texts are only used to give more information on the lithographs when needed. The amount of detail and artistic attention Haeckel provided toward each illustration, ultimately maximized supported his vision of nature.

His argument for the beauties and symmetries of nature relied upon illustrations. *Art Forms in Nature* was meant to explain the mechanics of evolution through the various symmetries found in animals like the medusa. The illustrations seamlessly incorporated romantic ideas and scientific interests (Fig. 9). The illustration contains an image of the medusa Haeckel named *Desmonemna annasethe*, after his deceased wife Anna Sethe. The sentimental gesture to his deceased wife creates a romantic and emotionally charged illustration. There is no environmental background for the medusa, showing his interest is purely in its organic symmetries. The background also makes the viewer focus on the medusa for its unique design. By drawing attention to nature's organic symmetries, he was yet again able to relate science and art. The bright blues and reds of the medusa perfectly describe its natural coloration. Haeckel depicts the medusa in exquisite detail to make sure that viewer understands the level of ornamentation that this species of medusa displays. The tentacles are idealized in the way they whimsically undulate over one

[62] The lithograph-artist Adolf Giltsch assisted with the creation of the lithograph plates by translating Haeckel's drawings to the lithographic stone.

another. Realistically the tentacles of a medusa are more randomly and messily arranged. They do not curve like this naturally; Haeckel had done this for the sake for the aesthetic and beauty of the line that it creates. Haeckel also depicts the medusa with an interest veering towards romanticism and the sublime. His illustrations remind his viewer how much surrounds us in the world. There are many small intricate details that are not immediately noticed, and they make the world appear infinite and therefore sublime. His illustrations take the viewer beyond the normal realm of scientific illustration's rational and objective purposes and into the realm of the imaginative. This combination of imagination and reason is an aspect of the sublime, which Haeckel seems to express in his illustrations.[63]

Through the comparison of these illustrations by Haeckel and Huxley, it is easy to see how Haeckel creates an argument about the natural symmetries of life. Haeckel's interest in the beauty of the marine world is made clear through the articulate detail he provides for his illustration of the medusa. He persuades the viewer that marine animals are art forms within themselves, due to how naturally symmetrical and wondrous they appear. This relates back to how Haeckel perceives nature. "What nature is, is visible on its surface. The plastic form that this visibility of nature assumes is therefore more than the illustration of a text. It bears within itself the knowledge that the text then merely explicates."[64] The beauty of nature was easily visible for Haeckel, since nature reveals itself through its forms. Nature does not hide its symmetry, and Haeckel makes sure that this is clear. So in order to understand nature, it takes a certain understanding of its

[63] This idea of the sublime comes from Kant's *Critique of Judgment*. He defines two notions of the sublime: the mathematically sublime and dynamically sublime. The mathematically sublime is experienced when one cannot estimate the magnitude of vastness in an aesthetic sense, but can be formed in a mathematical sense.
[64] Haeckel, "The Most Charming Creatures," in *Art Forms from the Ocean,* 18.

beauty. Haeckel accentuates this beauty in illustration in order to come to an understanding of the beauty that nature presents and the argument that it portrays.

Overall, Haeckel is easily distinguishable from the tradition of scientific illustration that we have evaluated in the past chapter. For one, his illustrations have an immense amount of detail and are produced with an exquisite quality. The use of color and form is incomparable to other scientific illustrations like those of Huxley. The subject matter itself explored a whole new area of science that was only just being discovered. Depictions of marine organisms under the microscope were not in high circulation until Haeckel came onto the scene. Haeckel was depicting unknown forms, and in this, his interest of evaluating their forms and artistic intricacies became a part of his illustration and evaluations of species like radiolarian and medusa. Haeckel managed to capture not only the elegance of these creatures, but captivate the viewer in by rendering their naturally beautiful forms through his artistic illustrations.

While Haeckel was interested in the morphology of organisms, we have seen that at the same time their aesthetic forms captivated him. Through his interest in bringing science and art together by the way of scientific illustration, he proved how important illustrations were not only as a learning tool, but a way to stimulate interest in the sciences through aesthetic interest.[65] Scientific illustrations were not simply images of anatomy or nature. He used illustration to form an argument about science, just as text could. Through visual elements, he was able to communicate both ideas of evolution and

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[65] In 1899, *Die Welträthsel* (*The Riddles of the Universe*) was published and later translated into 20 other languages in 1912. Over 40,000 copies were sold within its first year of release in Germany alone. It sold more than *The Origin of Species* had in 1859, which only sold 39,000 copies in six English editions. This book discussed Haeckel's specific philosophies and evolutionary ideas. The book was published much later in Haeckel's carrier, but it shows the popularization of his ideas through his books commercial consumption by the public. Haeckel was illustration and philosophies were already well known by 1899.

biogentics. In these illustrations, Haeckel created a beautiful image of science, allowing him to champion the realms of both science and art. In a way, Haeckel broke down the wall of fact that surrounded scientific illustration by how he involved artistic aspects within his illustrations. Technologies were rapidly developing, and at the same time, Haeckel's interest in nature's aesthetics and organic design became increasingly clear accessible to the public. The marine and microscopic worlds that Haeckel illustrated became more familiar with the evolution of new technologies. Many of his illustrations were based on studying an organism under a light microscope. The light microscope used a combination of light and lenses to magnify the samples under the microscope. Haeckel had been using a light microscope, whose scope of resolution was limited to 0.25 micrometers. The light microscope during the 19th century was the primary way of viewing microscopic organisms at the highest magnifications. In 1931, the electron microscope was invented and along with it came a new resolution allowing for a clearer imaging within the cell that had not been possible before. The electron microscope allowed for a resolution of 0.2 nanometers. New structures, like the Golgi complex, within the cell were glimpsed for the first time.

With the invention of the electron microscope, it was discovered that radiolarians were not quite as "exaggerated" as Haeckel made them appear. He accentuated the aspects that he found intriguing with each species of radiolarian, which typically was the regularity of the geometry (Fig. 10). The illustration on the left is Haeckel's, which is contrasted with the photographic image of a radiolarian seen under an electron microscope. The aspects that he "exaggerated" highlighted the unique geometric characteristics of the radiolarian ultimately make them more aesthetically appealing.

Although the geometry of the radiolarian is evident when looking at an electron microscope image, the forms do not appear as smooth and ideal as they appear in Haeckel's illustration. Haeckel's illustration, however, still resembles a radiolarian despite its idealized features. Haeckel's radiolarian lacks the same number of branches seen within the microscopic photograph of the radiolarian. Haeckel's illustration, however, reveals each layer of the radiolarian's geometry, while the photograph only shows the radiolarian's outer surface. Yet, the photograph is able to accurately and realistically portray this one view of the radiolarian, where as the illustration shows more information, but with a biased interest in the symmetry of the radiolarian. Microscopes came a long way from the first illustrations depicted in the 17th century by Robert Hooke. For Haeckel, there was a true culmination of ideas, interest, and technology at the time that he began his illustrations.

Haeckel's illustration became inspiration for Symbolist and Art Nouveau artists, designers, and architects at the end of the century. Artists of Art Nouveau, flourishing from the late-19th to early-20th century, drew upon geometric and organic forms. Haeckel's illustrations from *Kunstformen der Natur* in 1899 influenced many of the artists within the Art Nouveau movement. Specifically, René Binet imposed the design of the organic forms onto his huge triple triumphal archway for the entrance of the Universal Exposition of Paris 1900 (Fig. 11). The archway was based upon Haeckel's illustrations from *Kunstformen der Natur*. Thousands of red and blue cabochons and light bulbs lined the archway's crevices.[66] At night, the whole archway sparkled with a dream-

[66] Victor Arwas, *Art Nouveau: The French Aesthetic* (London: Andreas Papadakis, 2002), 60, Google Books.

like effect. The influences of Haeckel's illustrations are seen in intricate ornamentation of each arch that seems to resemble the structures of radiolarians.

The interest in design in the Art Nouveau movement relates itself to the work of Blossfeldt, since his teaching revolved around design, based on the structures present in natural forms; however, his photographs were an outgrowth of Art Nouveau and were considered a part of the New Objectivity movement. The increase in technology surrounding photography showed how microphotographs were now able to show what Haeckel had graphically depicted. By the 1928, Karl Blossfeldt published a series of photographs in his first publication called *Art Forms in Nature*. In the next chapter, Haeckel's influence on the interest in nature's designs and symmetries will be explored through Karl Blossfeldt's interests shown through his photographs. Technologies continued to evolve and photography was becoming the best way to portray scientific information.

CHAPTER II FIGURES

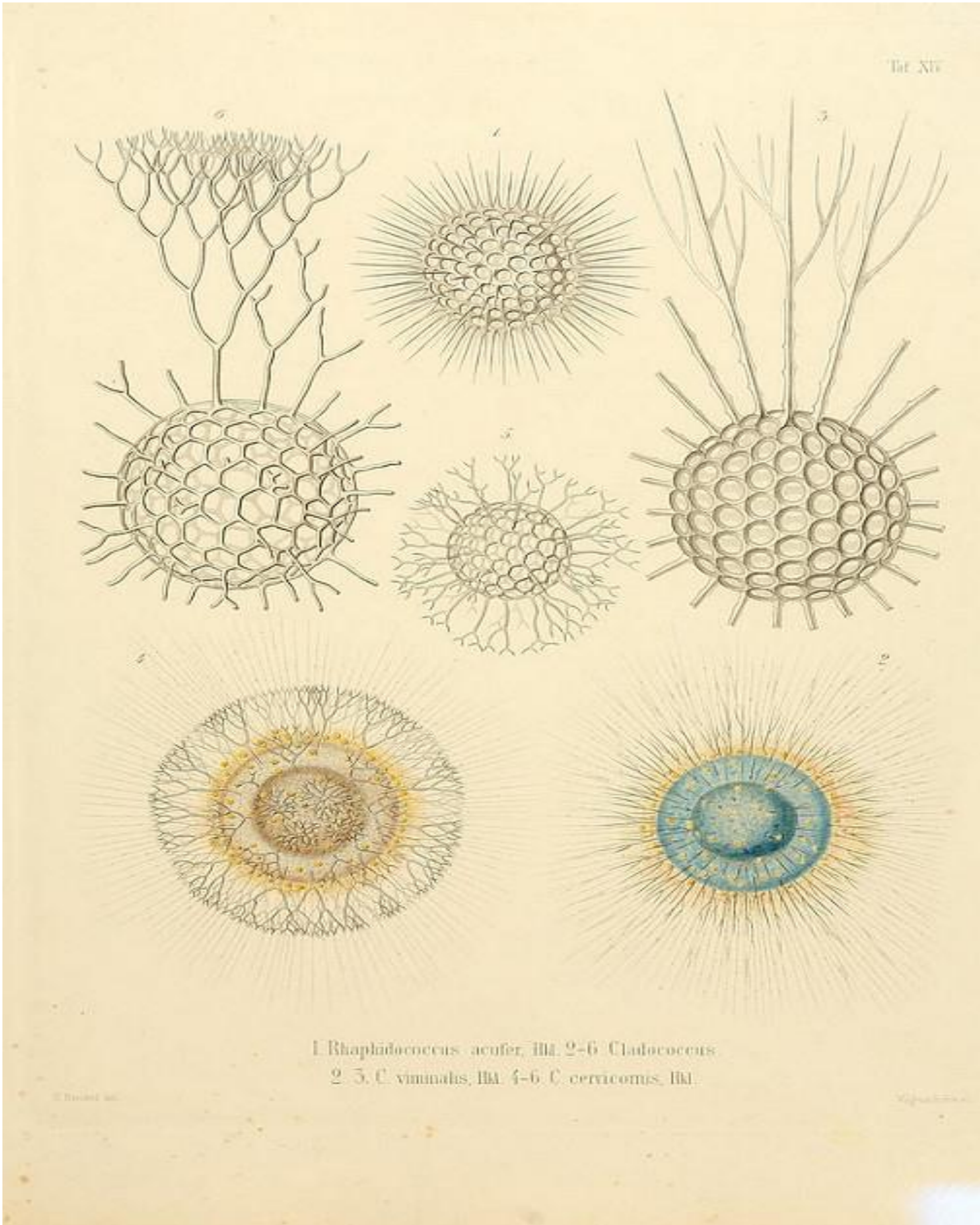

Figure 1. Ernst Haeckel, Radiolarians, *Die Radiolarien*, 1862, copper plate.

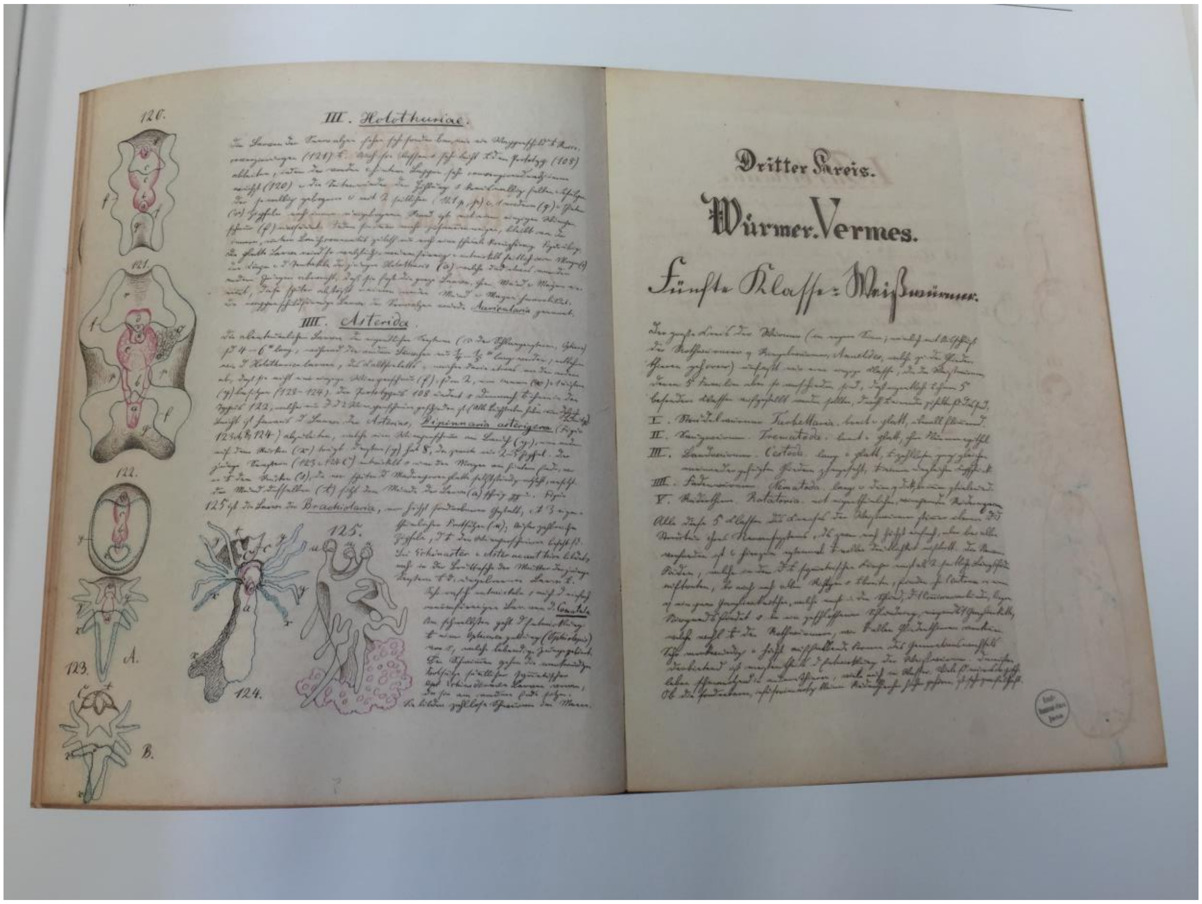

Figure 2. Ernst Haeckel, Illustrated notes taken in Kölliker’s lectures, 1853.

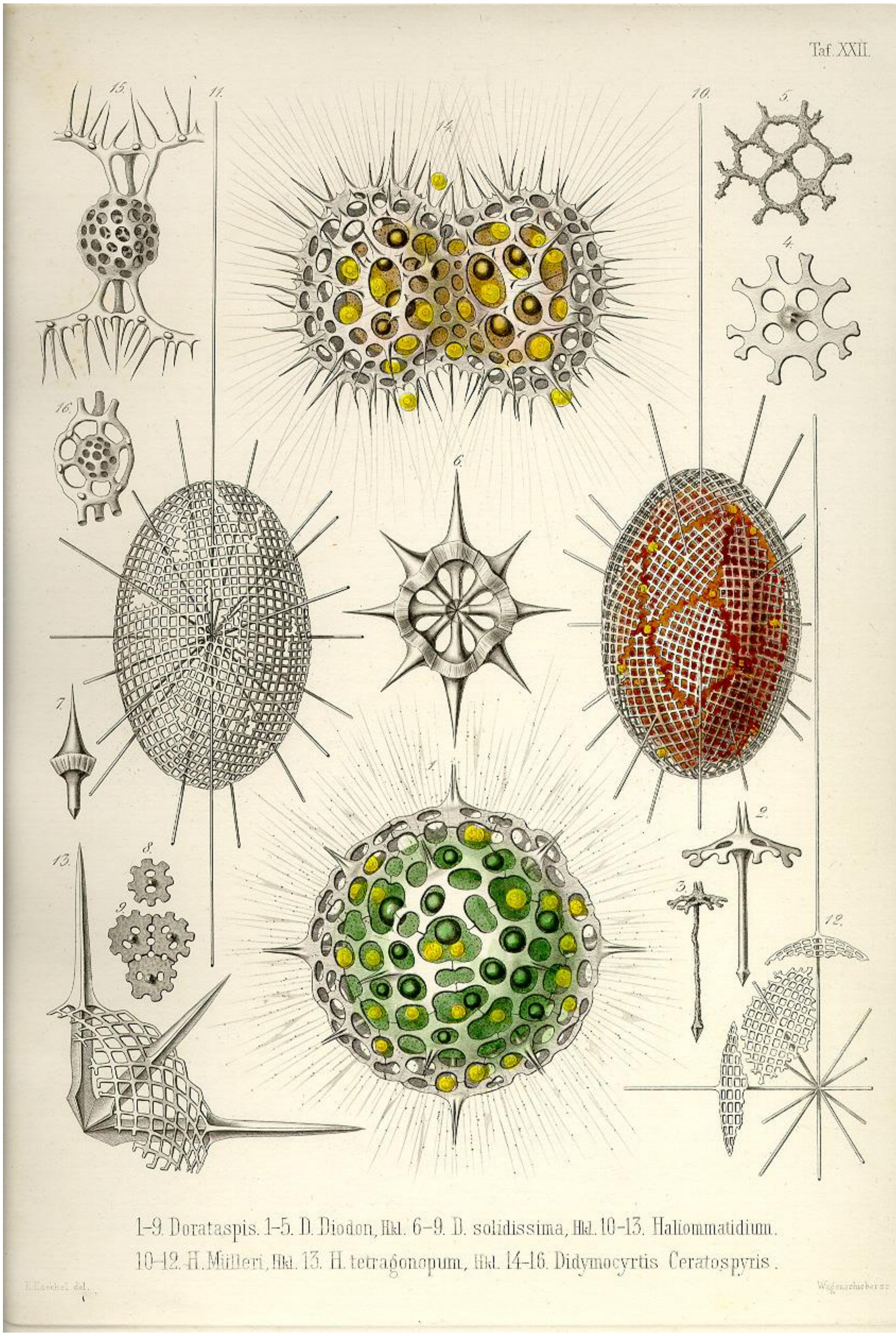

Figure 3. Ernst Haeckel, Radiolarians, Plate XXII, *Die Radiolarien*, 1862, copper plate.

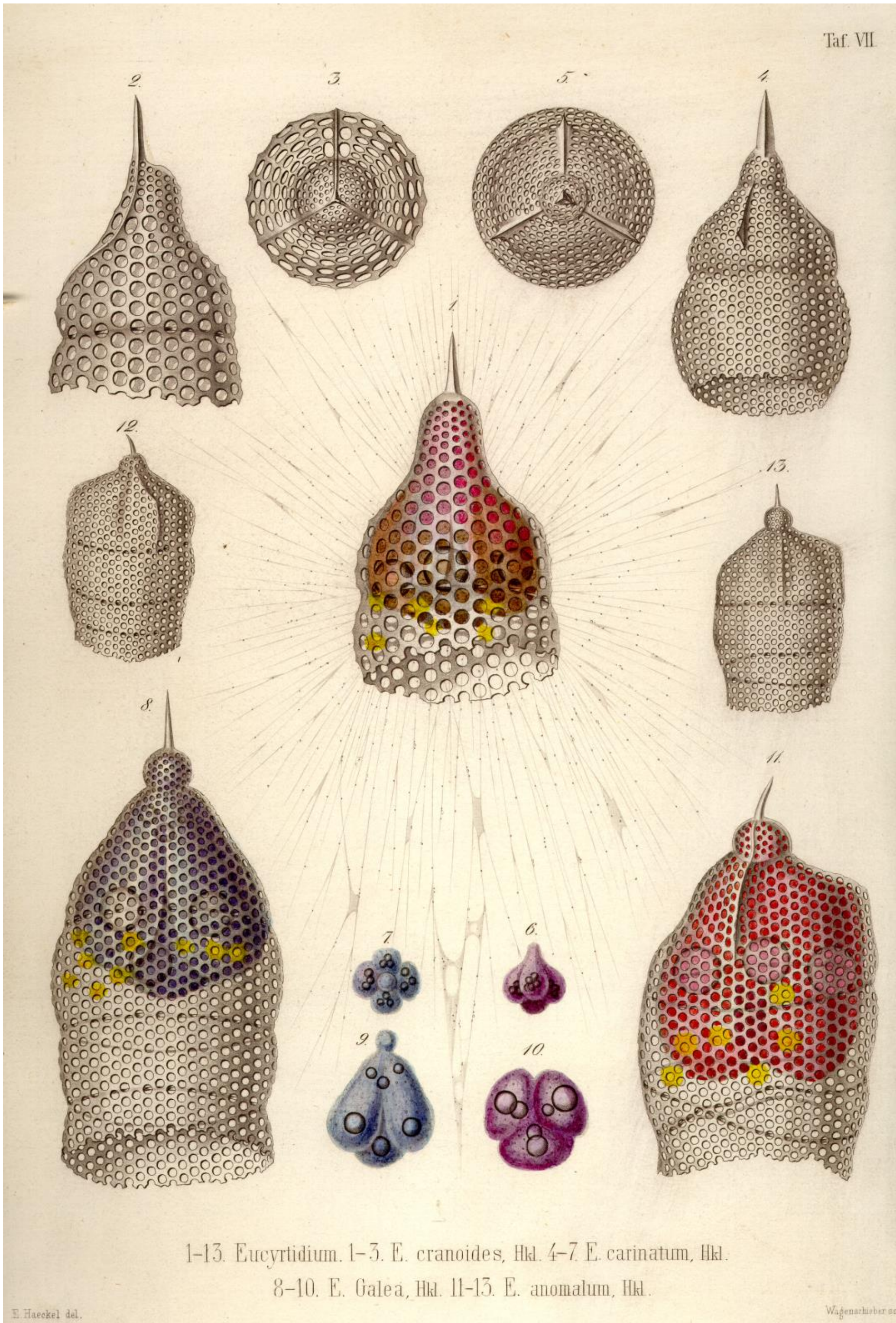

Figure 4. Ernst Haeckel, Radiolarians, Plate VII, *Die Radiolarien*, 1862, copper plate.

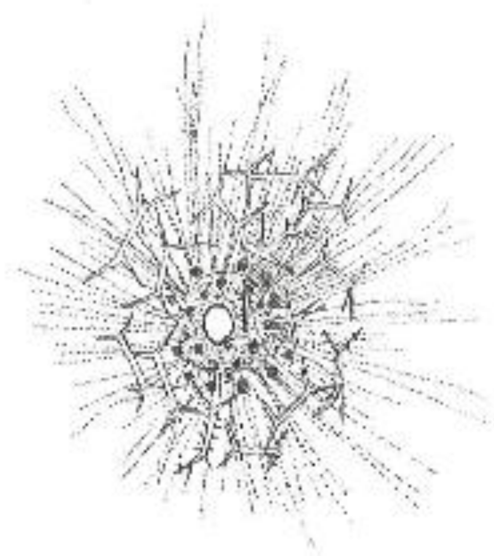

Figure 5. Huxley, "Zoological Notes and Observations Made on Board H.M.S. Ratttlesnake During the Years 1846-1850," *Scientific Memoirs*, 1899.

Fig. 9. Fig. 10. Fig. 11.

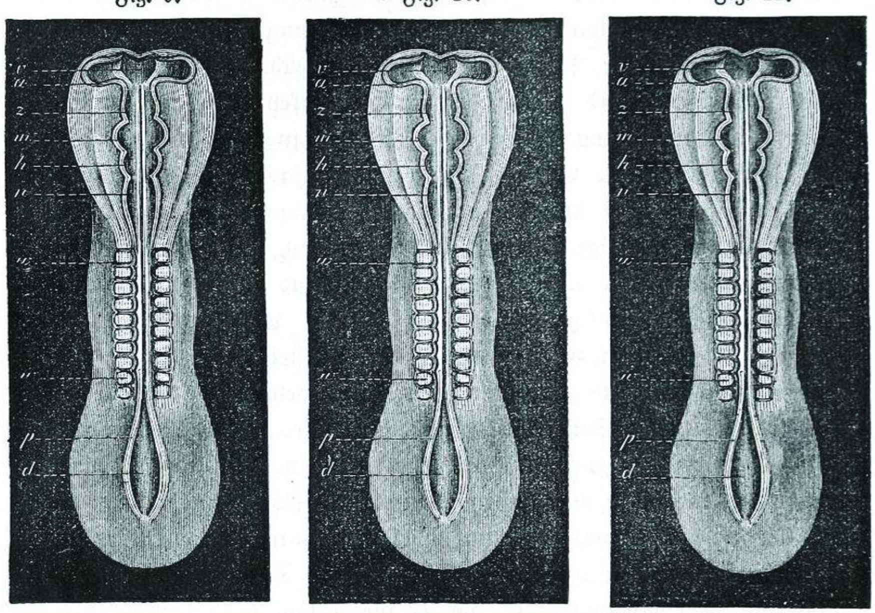

Fig. 9. Embryo des Hundes. Fig. 10. Embryo des Huhns. Fig. 11. Embryo der Schildkröte. Alle drei Embryonen sind genau aus demselben Entwickelungsstadium genommen, in dem soeben die fünf Hirnblasen angelegt sind. Die Buchstaben bedeuten in allen drei Figuren dasselbe: *v* Vorderhirn. *z* Zwischenhirn. *m* Mittelhirn. *h* Hinterhirn. *n* Nachhirn. *p* Rückenmark. *a* Augenblasen. *w* Urwirbel. *d* Rückenstrang oder Chorda.

Figure 6. Ernst Haeckel, Embryo's of a dog, chicken, and turtle at the sandal stage, *Natürliche Schöfungsgeschichte*, 1868, wood block print.

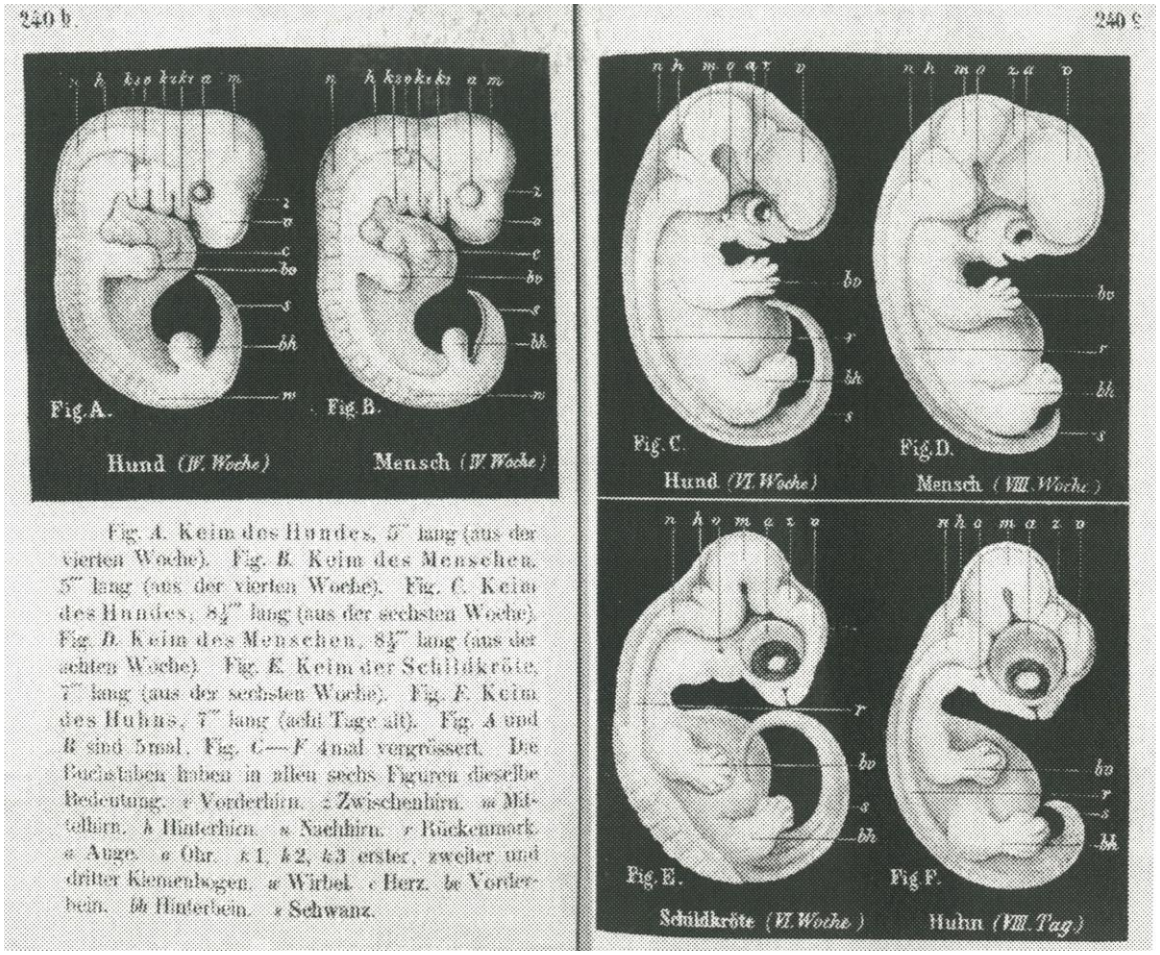

Figure 7. On the top left is the depiction of dog embryos at two different stages of development (four and six weeks respectively). On the top right is the depiction of human embryos except at four and 8 weeks of development. The bottom row compares a turtle and chicken embryo (at six and eight weeks respectively).
Ernst Haeckel, Embryos, *Natürliche Schöfungsgeschichte*, 1868, wood block print.

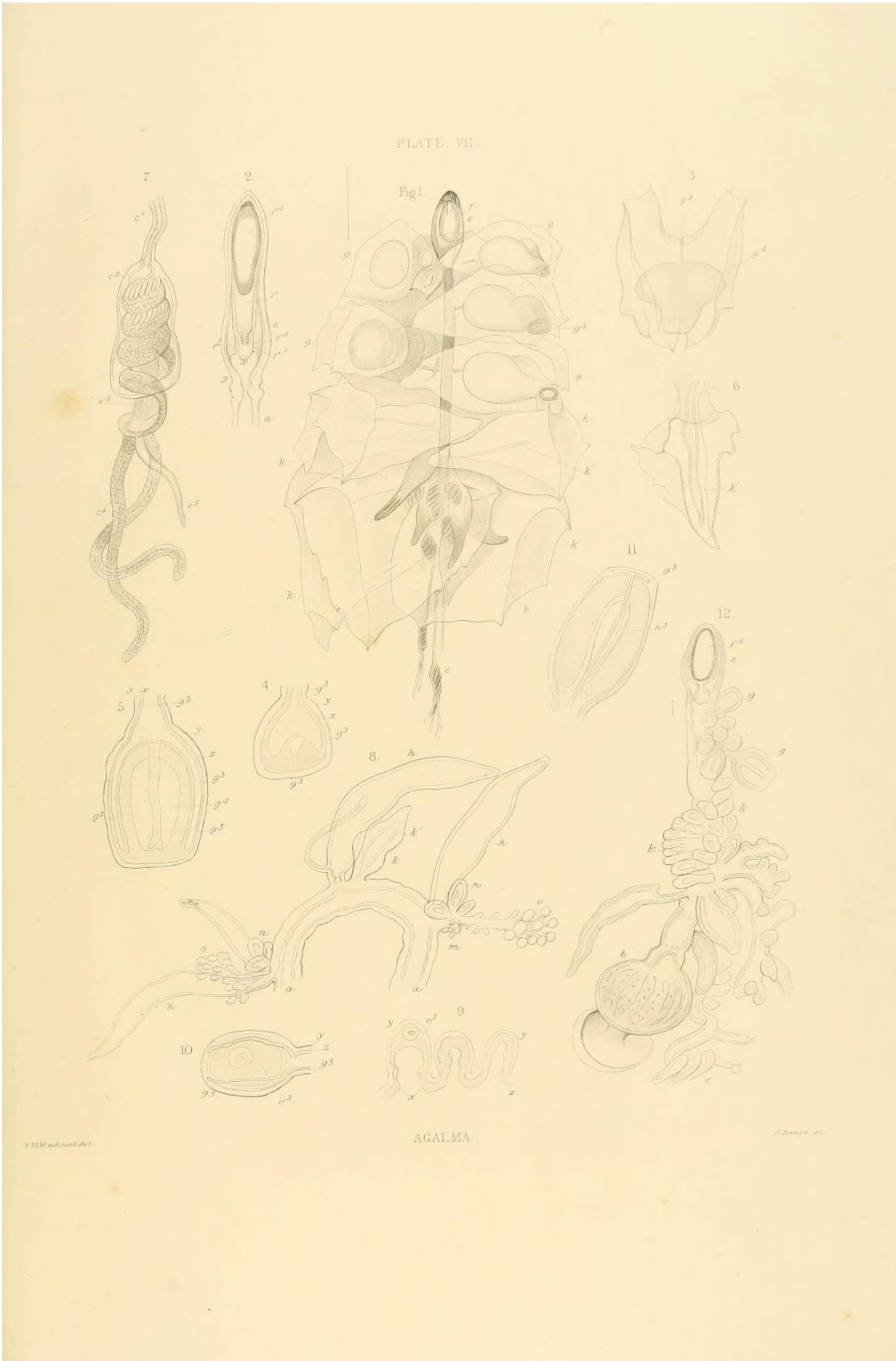

Figure 8. Huxley, “Agalma,” *The Oceanic Hydrozoa,* 1859, wood block print.

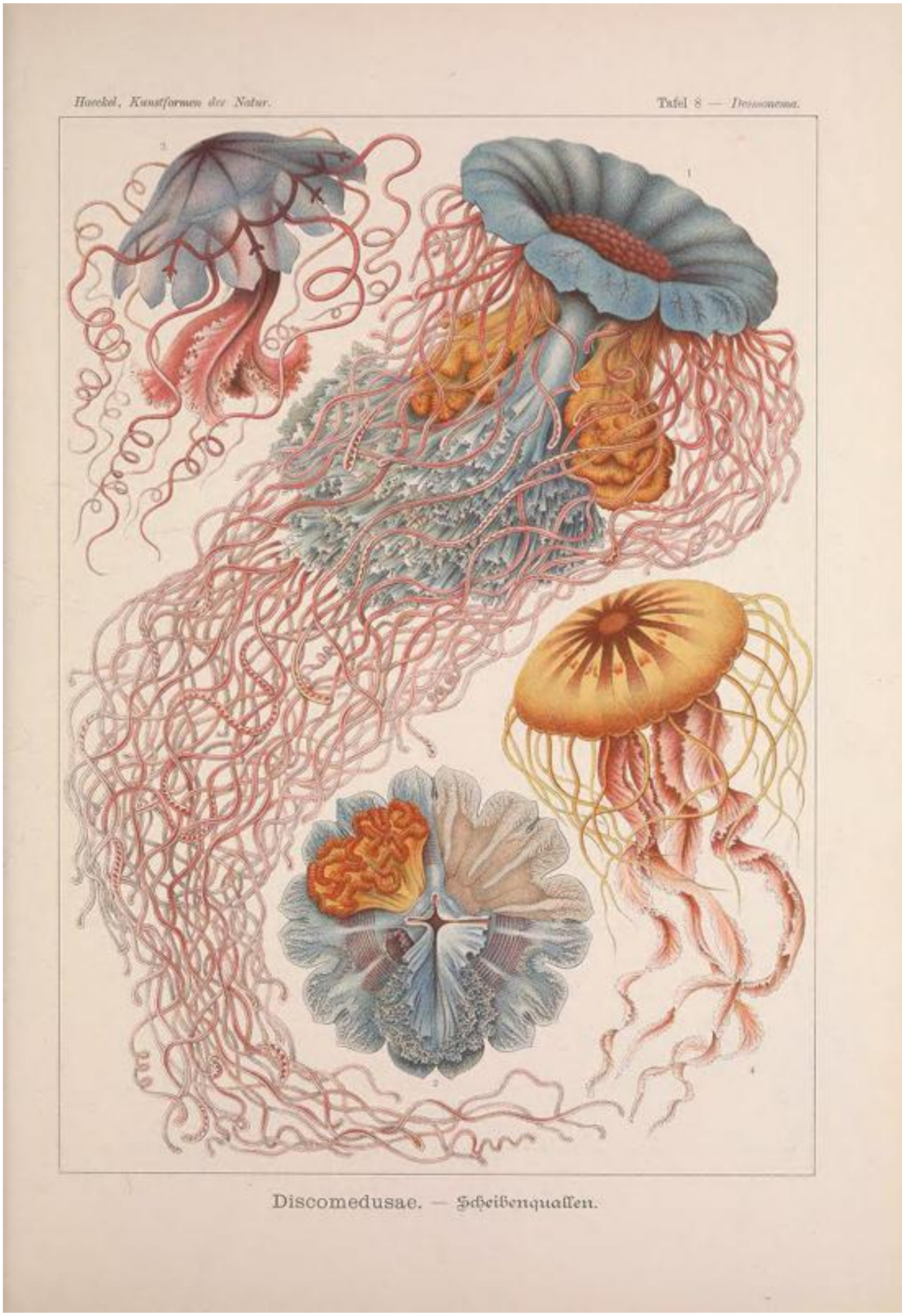

Figure 9. Ernst Haeckel, “Discomedusa,” *Kunstformen der Natur*, 1899, lithograph.

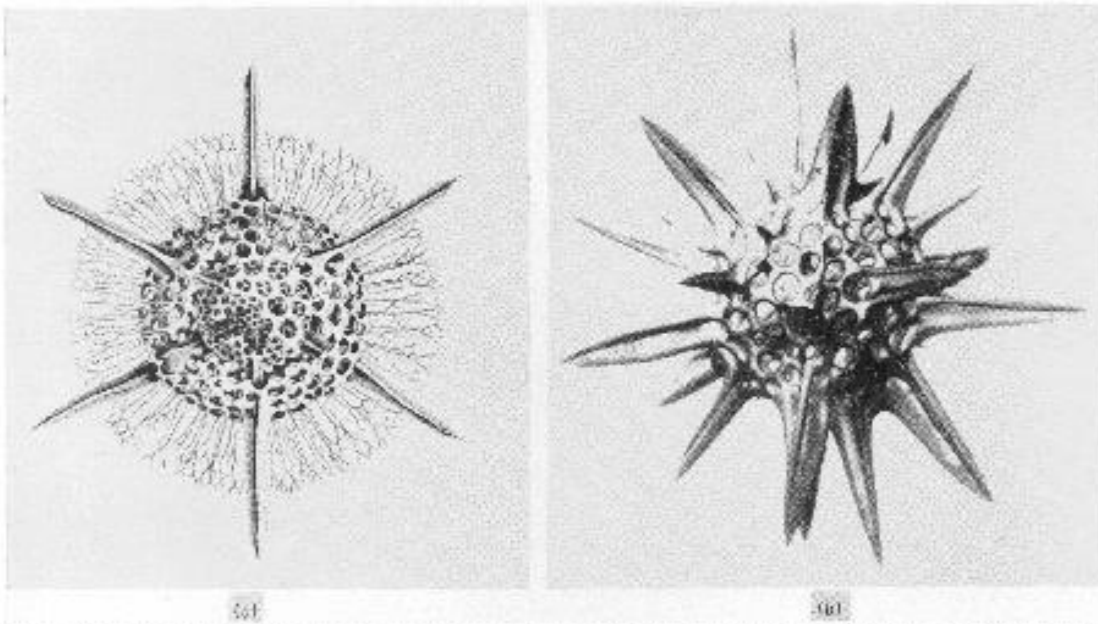

Fig. 5. (a) The exaggerated regularity attributed to radiolaria by Ernst Haeckel (Die Radiolarien, 1562) contrasted (b) with the objective portrayal of the scanning electron microscope (U.S. Geological Survey). (Photo: Smithsonian Institution, Washington, D.C.)

Figure 10. L: Ernst Haeckel, *Die Radiolarien*, 1862, copper plate; R: Radiolarian, Smithosian Institute, Washington (D.C), photograph from scanning electron microscope.

Figure 11. René Binet, Triple Triumphal Archway, Universal Exposition of Paris, 1900.

CHAPTER III: KARL BLOSSFELDT

In the very beginnings of photography's history, photography shared an affinity with science. Photography was founded upon chemical experimentation. Scientists were already acclimated to the using other objects—the telescope and microscope—to enhance their visions of the natural world, and when photography came into being it added to the world of technological advancement within science. With the invention of photography in 1839, there was an immediate interest in the scientific world in using it as a tool for empirical observation. Photography attracted scientists because of its ability to clearly and realistically render the subject of photograph. Photography was thought of as a form of documentation, a way to replicate truly what the eyes saw. It represented the old idea that "seeing is believing," and was believed to portray the world realistically and truly.[67] At the same time, it was said to enhance what was truly seen, in the way that it captured the light and shadows that were not easily noticed by the naked eye. Photography built upon the pre-existing scientific interest in optical technologies like microscopes and telescopes. In this sense, photography was a natural continuation of this empirical recording and observation for scientists. Photography became a way to further question, probe, and document the surrounding natural world.

William Henry Fox Talbot, one of the inventors of photography, expressed an interest in photography's ability to perfectly reproduce empirical observations. Talbot was the inventor of the calotype and used this processes to take various photographs of plants. A calotype is a negative process produced on paper that creates a soft rendering of

[67] Normand Overney and Gregor Overney, "The History of Photomicrography," *Micscape Magazine Index*, March 2011, 3, accessed May 2, 2016, http://www.microscopy-uk.org.uk/mag/artmar10/history_photomicrography_ed3.pdf.

the subject or object portrayed. Using light-sensitive paper and silver iodide Talbot was able to produce a permanent image on paper. Many of his first calotypes were of leaf outlines. One of his calotypes shows the outline of the Buckler fern from 1839 (Fig. 1). Although the details in each leaf are not entirely visible, the general form the fern is understood. Talbot also created photomicrographs by using the solar microscope, such as a magnified photograph of a lantern fly's wing (Fig. 2). This photograph is from a year later and reveals a great deal more detail of the object's structure seen through the wing's intricate patterns. He produced many other similar photographs of using the solar microscope to depict lace, dragonfly wings, and cross sectional areas of plant stems. The images of cross-sectional areas became evidence for the intricacies of plant structure and the microscopic structure that had only been seen previously in scientific illustration. All of his micrographs were under 20x magnification.[68]

While Talbot's photographs exhibited mainly focused on the object's structure, other scientists were using photography to illustrate the actions of an experiment. Henri-Victor Regnault, a French physicist and Royal Society member, created a series of calotypes depicting acoustic experiments. Regnault was in the first generation of photographers with Talbot. The *Acoustic Experiment* from 1850 depicts a man dressed in a suit and top hat holding an empty metal cylinder at the edge of a bowl (Fig. 3). The image shows the man conducting an experiment, yet as viewers our senses are immediately limited by the act of looking at the photograph. We cannot hear the sound created by the instrument that the man holds. By looking at the image, however, the viewer does gain an understanding how the man is conducting his experiment. Regnault shows photography's ability to illustrate what may be difficult to explain in words. The

[68] Overney and Overney, "The History of Photomicrography," 2.

exact positioning and angle of that the cylinder sits over the bowl can be easily referenced by the viewer who might conduct the experiment themselves.[69] Regnault and Talbot showed how photography and science were interested in one another. Science had already had a strong relationship with photography when Karl Blossfeldt published his series of photographs of manicured plants in 1928.

The original *Art Forms in Nature* (*Urfromen der Kunst*) was printed in a forest green hard cover book with its title and a small plant outline in golden ink. The book contained 120 photogravure prints each sized at about 8 by 10 inches. Photogravure was a popular printing process used from the mid-19th century well into the 20th century. Blossfeldt's photographs, created with a homemade camera, became popular practically overnight. The scientifically exact photographs in *Art Forms in Nature* captured the unseen details in the already familiar world of nature, but that were difficult to see. No contextual background is provided for the viewer who examines Blossfeldt's photographs, only a philosophically abstract introduction is given by Karl Nierendorf. In the table of contents, each specimen is identified by its Latin names, its normal non-taxonomical name, and its magnification.[70] The photographs are printed on every other page, meaning that the left page is blank and the right page has the photograph. This format emphasizes each photograph allowing the viewer to spend time to process each image. Only a close examination does the viewer understand that they are looking at an object of nature. The first page of *Art Forms in Nature* shows a photograph a young shoot of a winter horsetail, *equisetum hiemale*, enlarged 25 times (Fig. 4). The closely cropped

[69] Laurie Dahlberg, *Victor Regnault and the Advance of Photography: The Art of Avoiding Errors* (Princeton, NJ: Princeton University Press, 2005), 29.
[70] A magnification of 25 times of a water droplet can reveal an entire ecosystem of diatoms, bacteria, zooplankton etc. This level of magnification gives a significant amount of detail in the plants that Blossfeldt was examining.

black-and-white image depicts the head of the horsetail and its blossoming cup segments that extended from it. The black and white allows viewers to restrict their focus to the lines and structure of the winter horsetail.

At the same time, this restricted view disorients the viewer. Blossfeldt sets up an interesting view of the winter horsetail, as there is nothing particularly special about this plant until it is enlarged. Normally, the winter horsetail looks like a reed when examining by the naked eye; however, in a magnified photograph the plant's form becomes abstracted beyond recognition, especially for a normal layperson. Botanists, however, tend to comprehend various aspects of a plant's forms because of their interest in the minute physiology of plant structures. The highly magnified and carefully cropped photograph of the abstracted plant creates intriguing sculptural and even architectural forms. These newly created forms add new characteristics to the botanical form of the plant. The plant itself, in both its design and structure, becomes comparable to a variety of skyscrapers, in particular the Empire State Building. The building has a larger base topped by smaller and narrower structures as the building grows taller. The spire at the top of the Empire State Building looks like the top of the winter horsetail. Blossfeldt then continues by further evaluating the winter horsetail in its various forms.

The next two of photographs are also of the winter horsetail, but each shows a different section of the horsetail's structure, for example part of the root enlarged eight times (Fig. 5). Yet again, the blossoming cup segments reveal the plant's structure, which is graphically transformed into ridges and lines, except in this photograph there are multiple sprouting forms branching off from the same stem. At the very top of the root, the cups carefully curve over, making them appear as if they might be hollow on the inside. The photograph organically shows the branching out of these blossoming cup segments. This ties back into photography's great appeal to scientists. Photography has the ability to easily render the natural world in a precise and realistic way.

Another photograph, which depicts a cross-sectional area of the winter horsetail's stem enlarged 30 times, even more clearly depicts the scientific use of photography (Fig. 6). The cross-section reveals that each ridge is created by the underlying arch-like structure between the inner and outer surfaces of the plant. This amount of detail and interest in every aspect of the plant produces both a botanical and artistic outlook on nature through the plant's design. The photograph focuses on the fluting structure of the plant, not unlike that seen on Roman columns. The black and white gives a simplified view of the design of the horsetail's form. The cross-section of the horsetail looks like a piece of red licorice or a series of arches.

These systematically organized images all build upon one another and create a complex form of observation about the plant's structure. When compiled together, these images create a complete taxonomic view of the winter horsetail. The series of photographs appear as if they are creating an argument based upon their structural functions. However, as readers continue through the book, they find even more plant forms. There is no textual component or diagrammatic labeling, as one might expect since all of the photographs in the book stress the natural botanical and architectural forms of plants. This hints at the aesthetic interests that the photographs were produced for. Anyone could create enlarged photographs of winter horsetails; however, Blossfeldt's contributed his distinct observational skills, highlighting the plant's structure and beauty through careful composition. The enlarged photographs of manicured plants showed the hidden architectural structures of the plant in realistic lighting. As we recall, scientific illustrations examined nature not in just its basic elemental appearance, but also provided a magnified look at its structure. Blossfeldt's photographs naturally pick up on these aspects of scientific illustration. By their magnified examination of many different aspects of one plant form, his photographs reveal themselves to have botanical and taxonomical interests. However, there is also an artistic interest evident within the composition and the design aspects of the plant's structure. These photographs present the unseen within the ordinary things of in everyday nature.

These photographs from Blossfeldt's *Art Forms in Nature* were not meant to expand upon scientific knowledge and understanding of plant forms. Instead, the photographs were created with the purpose of teaching and identifying design in nature in a studio or a classroom, not for publishing. By the time *Art Forms in Nature* was published, Blossfeldt was 63 and would only live for four more years. The book consisted of a collection of the photographs he made for his students in his arts and crafts classes. His photographs were meant to exploit nature's design structures so that students could easily translate these design elements into their own architectural and graphic drawings, but they also demonstrated photograph's power to reveal the unknown. His book shared success similar to Haeckel's *Art Forms in Nature*, which coincidentally had some influence over Karl Blossfeldt's thinking about ornamentation in nature. Haeckel's scientifically precise observations fully translated to Blossfeldt's interest in the intricacies of nature's design. Blossfeldt's photographs were not just influenced by scientific illustration, but expanded possibilities of seeing art in nature.

As we shall see, Karl Blossfeldt was a key figure in establishing this new and progressive connection in the art world with scientific interests. His photographs were considered a modern view on everyday life. In fact, Blossfeldt's inspection of nature fascinated artists within the Surrealist and New Objectivity movements. Still, Blossfeldt had not intended to create a work of art. It was his awareness of the architectural structure of plants that made his focus artistic and not just an objective replication of plants intended for the botanist. This chapter ultimately examines Blossfeldt's photographic art in relation to his botanical interests. Finally, the comparison of Blossfeldt and Haeckel's work reveals the newfound interest in art forms and the scientific illustration, which can be traced back to the beginnings of scientific illustration. Blossfeldt and Haeckel, however, came from completely different backgrounds, which allowed Blossfeldt to work differently from Haeckel, despite their shared interests in design.

The design of plant forms always intrigued Blossfeldt. From a young age, Blossfeldt intertwined his interest of art and plant structure since he was trained in the creation of sculpture. Many decorative motifs of architecture and sculpture involved decorative plant motifs, especially iron works. While serving an apprenticeship (1881-1883) in sculpture and modeling, he studied decorative motifs of architecture, particularly the ornamentation of iron gates and iron casting, at the iron foundry of Mägdesprung. As he studied different forms of art, he would also try photography.

Although Blossfeldt was well versed in drawing and sculpture, he never received any formal training in photography; it was an interest that he pursued on his own. Some of his first photographs were taken in his home village in Schielo, Germany.[71] He was an enthusiastic amateur when it came to photography and the camera in general.

[71] Hans-Christian Adam and Karl Blossfeldt, *Karl Blossfeldt: 1865*-1932 (Köln: Taschen, 1999), 20.

Photography became an outlet for Blossfeldt's interest in plants as it was used as another way to clearly illustrate the intricacies of nature. While Blossfeldt did not consider himself a photographer or a botanist, he would only think of photography as showing his strong interest in the design and ornamentation of microscopic aspects within plant forms. In 1890, he received a grant to study at Kungstewrbreschule, where he would meet an influential professor by the name of Moritz Meurer. Here he was able to explore his both the interests in nature and photography with Meurer's teachings.

Blossfeldt's scholarship allowed him to study as an aspiring professor with Professor Meurer and four other artists in Italy, North Africa, and Greece.[72] Meurer, the professor of ornament and design, led the trip while also researching a way to create plant reproductions as instructional works for his students via the use of photography. In effect, Meurer was attempting to change the system of teaching students about plants through dried specimens. He began experimenting with photography, utilizing in particular photographic herbaria (homemade albums illustrated with collected photographs of plants) as another prospective teaching method. Although Blossfeldt had previously tried photography, Meurer's interest in it as an alternative teaching tool piqued Blossfeldt's interest in the medium. Meurer also directed Blossfeldt toward natural philosophers like Haeckel, Goethe, and Semper. Meurer clearly influenced Blossfeldt's way of thinking about art and nature, especially when Blossfeldt later published his book named after Haeckel's own *Art Forms in Nature*. However, Blossfeldt would not publish his book until much later in his career.

[72] Karl Blossfeldt, Georges Batialle, and Gert Mattenklot, *Art Froms in Nature: The Complete Edition* (Munich: Schirmer Art Books, 1999), 28.

Towards the end of the 1898, Blossfeldt began teaching in the Department of Plant Modeling at Kunstgewerbliche Lehranstalt (the Institute of the Royal Arts and Crafts Museum) in Berlin, where he created his photographs of plants.[73] Blossfeldt taught here for the next 31 years, teaching modeling and drawing based upon plant samples and his photographs, becoming a Professor Emeritus in 1930.[74] His photographs were all made with teaching purposes in mind and therefore have a consistent, stylized appearance. As seen earlier, the three photographs of the winter horsetail have the same blank background and low contrast tonality (Fig. 4,5,6). His interest was in showing certain magnified aspects of plants that were only visible to his students after long and tedious examination. He did not consider these photographs as artistic in themselves.

Already familiar with the photographic process, Blossfeldt began to expand upon his experience and Meurer's teachings. He built his own cameras, which enabled him to create productions that were enlarged 3 to 15 times and occasionally at higher magnifications in later photos. Enlarging these specimens allowed Blossfeldt to examine the architecture of plants. The photographs have a mundane essence about them due to Blossfeldt's interest in the everyday plant. He frequently made trips by bicycle or train just to gather plants.[75] Blossfeldt never purchased plants from a florist; instead, he gathered his "proletarian plants" from "proletarian places."[76] Fully bloomed flowery subjects are barely present in Blossfeldt's work. Unlike Haeckel, who had been interested in depicting nature for wide audiences for the sake of teaching them about science,

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[73] Adam and Blossfeldt, *Karl Blossfeldt: 1865*-1932, 331.
[74] The Institute of Royal Arts and Crafts in Berlin was renamed as the College of Fine Arts (Hochschule für bildende Künste) in Berlin in 1921. Blossfeldt worked at the same establishment for 31 years. The school's focus was more upon the decorative arts than anything else.
[75] Adam and Blossfeldt, *Karl Blossfeldt: 1865*-1932, 32.
[76] Ibid.

Blossfeldt was interested in teaching art to mostly beginning art students, and he therefore never intended to publish them.

Blossfeldt strongly believed “that the best human art was modeled on forms preexisting in nature.”[77] With this strong belief, he created photographs that expressed this ideology to his students, showing a diligence in collecting various natural specimens that made interesting sources for arts and crafts designs.[78] The photographs reveal an interest in line and unfamiliar shapes of nature that could be seen by means of a keen examination of nature, such as the photograph of the speckled stem of the ostrich fern, *Matteucia struthiopteris*, curling into itself (Fig. 7). The monochrome background allows for the viewer to question whether the image is of a fern or an industrial object. The striking lighting gives the stem a certain gleam that an iron rod might share. The leaves of the fern curl in with the stem. Toward the center of the unrolling fern, there is a blur in detail, reminding the viewer that he or she is examining a photograph. The photographic blur suggests that the fern is uncoiling in front of our own eyes. The natural lines and curvature of the fern are easily identified with the monochrome coloring. The clear interest in the structure of the ostrich fern translated well into Blossfeldt’s drawing and craft classes. The photographs demonstrated how the structure of plants and nature might serve as inspiration for ornamental designs.

By wanting to create teaching tools for art students, his photographs were more related to art than science, so although there is a clear botanical interest, there is an even greater interest in the plants’ individual structural appearance. Blossfeldt was not shy

[77] Taussig, "The Language of Flowers," in an Editorial Note to Walter Benjamin, “News about Flowers,” trans. Michael Jennings *Walter Benjamin, Selected Writings*, trans. Rodney Livingstone et al., ed. Jennings, Howard Eiland, and Gary Smith, 4 vols. to date (Cambridge, Mass., 2003-), 108.
[78] Adam and Blossfeldt, *Karl Blossfeldt: 1865*-1932, 331.

about readjusting the photographs to create the outcome of the image that he preferred.[79] He did this without any hesitation, in order to create a clear view of the form that he wanted the student to examine. With plants like the ostrich fern, he even perfected their outward appearance by clipping off some leaves emphasize certain forms of the plant.[80] The adjustments further allowed the photographs to showcase the dramatic detail of the minute botanical forms. Some plant outlines were even retouched with fine brushstrokes to emphasis their veins, stems, or leaves. *Saxifraga wilkommiana* exhibits additive retouching with watercolor or ink on the edges of the plant's leaves (Fig. 8). He did these retouches and reductions on the negatives and the prints with such precision that they are practically invisible to the naked eye. At the same time, without even meaning to produce these photographs as works of art, Blossfeldt's examinations of the intricacies of nature appearance and his painstaking effort to craft and frame each work made them perfectly worthy of aesthetic attention. But it was not until the mid-1920s that someone took notice of them as artworks.

Blossfeldt had compiled a large collection of his own photography by the time he met Karl Nierendorf in 1926. Nierendorf most likely stumbled upon Blossfeldt's photographs at the Berlin College of Art and realized their potential.[81] Karl Nierendorf was a German art dealer and collector who had an extensive collection of German Expressionist art, including the well-known artists like Klee and Kandinsky. That year Blossfeldt was persuaded by Nierendorf to show his photographs in a gallery. The

[79] Hanako Murata, "Material Forms in Nature: The photographs of Karl Blossfeldt," in *Object: Photo Modern Photographs; The Thomas Walther Collection 1909-1949*, ed. Mitra Abbaspour, Lee Ann Daffner, and Maria Morris Hmabourg (New York: The Modern Museum of Art, 2014), 2, http://www.moma.org/interactives/objectphoto/assets/essays/Murata.pdf.
[80] Adam and Blossfeldt, *Karl Blossfeldt: 1865*-1932, 31.
[81] Ibid, 22.

popularity of the gallery exhibition sped up the process of publishing Blossfeldt's first book in 1928. The title *Urformen der Kunst* (*Art Forms in Nature*) clearly paid homage to Haeckel's famous *Art Forms in Nature* from 1904. Blossfeldt's monograph was primarily used to reproduce finely detailed photographs printed in photogravure. The process is closely related to engraving; photogravures utilize a copper plate that is dipped into light-sensitive gelatin, exposed to a negative, and later etched. The resulting image has a velvety appearance. Photogravure was used for the first edition of *Urfromen der Kunst* prints of the everyday plant, magnified and tightly cropped their transformative qualities stimulated the interests of artists like the Surrealists.

Although Blossfeldt's photographs in *Art Forms in Nature* suggested Art Nouveau deigns, with their emphasis on extravagant forms in nature, many people within Surrealism movement were intrigued by the images in Blossfeldt's book, due also to how these images represented a modern magnified approach of photography. Surrealists were fascinated by the way Blossfeldt's photographs revealed a world that is hidden to our senses, making everyday and familiar objects strange. Blossfeldt's photographs were of a new sublime world. In his introduction to the book, Nierendorf wrote: "As Nature, in its endless monotony of origin and decay, is the embodiment of a profoundly sublime secret, so Art is an equally incomprehensible second creation, emanating organically from the human heart and the human brain…"[82] The photograph reveals another level of reality, the reality of magnified nature. According to Nierendorf, art and nature go hand in hand and are therefore constantly being recreated. Blossfeldt's photographs of archetypal forms involve both art and nature and therefore divulge this sublime secret of endless recreation.

82 Karl Blossfeldt, *Art Forms in Nature* (n.p. : Charing Corss Road, 1929), IV.

In 1929, George Bataille published his article, *Le Langage des Fleurs*, containing five of Blossfeldt's photographs within the periodical *Documents*.[83] Bataille edited and ran the magazine, *Documents*, which contained a variety of photographs and writings. The magazine attracted surrealists artists like Joan Mîro and André Masson. Although Blossfeldt's photographs attracted plenty of attention from those who associated themselves with Surrealism and Art Nouveau, his photographs were also categorized as a part of the New Objectivity movement. New Objectivity photography included precise, detailed, and formalist representations of real objects that were seen as a counter movement to Expressionism. Although Blossfeldt's photographs contained a design interest that sprang from Art Nouveau, his photographs objectively portrayed the visible world. The plants he photographed appeared honest and not exaggerated, unlike some of Art Nouveau's style. In a monograph from 2007, Gert Mattenklott, a literary historian, goes so far to relate this back to Haeckel, writing that the public no longer wanted to read or hear about Haeckel because he was partially responsible for the Art Nouveau and "molluscan style" it produced: "When Blossfeldt's photographs appeared toward the end of the twenties and early thirties, they enjoyed a popularity that left even the most successful photographers of the day far behind. They were also popular among an audience who knew nothing of Semper and no longer wanted to hear of Haeckel because he had been made co-responsible for Art Nouveau, the "molluscan style' that was now a source of red-faced embarrassment much like an incident of anal excess."[84] This comes across as a bit extreme; although Haeckel's work was very stylized, it still resonates

[83] "Karl Blossfeldt – Art Forms in Nature," Southbank Centre, accessed May 2, 2016, http://www.southbankcentre.co.uk/find/hayward-gallery-and-visual-arts/hayward-touring/future/karl-blossfeldt-%E2%80%93-art-forms-in-nature-0.
[84] Blossfeldt, Bataille, and Mattenklott, *Art Forms in Nature*, 18.

today as beautiful and aesthetically pleasing. Whether or not it is true that people wanted to forget Haeckel, it is certainly true that Haeckel was very well known by the time Blossfeldt was organizing his own book and that Blossfeldt would have known Haeckel's work.

There is also a clear connection between the work of Haeckel and Blossfeldt, given their similar titles and their explicit interest of the forms of nature and how they related to art. Blossfeldt's photographs were taken with the purpose of showing the unknown patterns and designs of a plant to his students. His photographs successfully revealed the intricacies that were typically unnoticed in our "everyday" nature. This is where he differed dramatically from Haeckel. Haeckel expressed an interest in teaching not only his students about the forms of nature, but the public. He did this in a more deliberately "scientific" way. Haeckel's illustrations of the developmental stages of the aesteridea (starfish) and some of its cross-sectional views are all placed on one plate about the same size of one of Blossfeldt's photographs (Fig. 9). The top of the plate shows the larval development of the starfish and as the eye continues down the plate, the overall structure of the starfish is depicted. Haeckel used the bright red to emphasize the dimensions of the starfish, and produce an understanding of its appearance; even the embryological structures have the same red outlining as the starfish's outer surface. The brilliant colors helped to capture the imagination. His interest in form goes beyond the starfish's mere outer appearance, allowing him to evaluate the biological stages of the starfish's development. Haeckel's goal for the book was to teach the public of the forms within nature and do so from a biological viewpoint. The red outline and coloring is in fact an actual physiological detail in some starfish, this coloring further establishes the morphology of the starfish. This differs from Blossfeldt, who only wanted to teach and show the design suggested by nature's forms.

All of Blossfeldt's photographs are magnified images of the plant; none of them give an overall picture of what the plant looks like. For Haeckel, the depiction of the whole image is important in order to understand the breakdown of the functions and formal aspects of the starfish before evaluating each individual form. Blossfeldt, however, immediately dives into the specifics and microelements that to him show the structural importance of the plant, which can then be translated into one's own drawings or architectural interests. The photograph of *Thujopsis dolabrata* depicts three different tips of fronds enlarged ten times (Fig. 10). The fronds appear similar to a beetle opening its wings for flight, but in multiples that are stacked on top of one another to create fronds. The frond tips have a notably glossy appearance, making them appear as if they have a metallic quality. The metallic quality is amplified by the black and white medium of the photograph, ultimately allowing the plant to look like a sculpture itself. The photograph gives a three-dimensional quality to the fronds.

This photograph differs significantly from Haeckel's illustration first in that it is a photograph. Given that they are photographs, Blossfeldt's images are more realistic than Haeckel's illustrations. The use of different mediums confirms and shows Haeckel and Blossfeldt's interests of how they wanted their images to function. For Blossfeldt, photography was the most straightforward medium to choose in order to show depictions of the plant forms to his students. It was objective and portrayed the objects realistically and honestly. The black and white medium of photography also assisted Blossfeldt map out the simple structures of plants, allowing the viewer to focus on the shape and structure of each plant and how that may be translated into their own work. Whereas the color of Haeckel's works lures the viewer's eyes, the realistic appearance of Blossfeldt's photographs seduces the viewer. Haeckel's use of illustration was better suited for his needs and interests since he wanted to engage viewers outside of the professional field of science.

Haeckel included some illustrations of plants within his *Art Forms in Nature*; however, they did not appear nearly as detailed as Blossfeldt's magnified images. The illustration of the *hepaticae* displayed a range of green colors to depict a plant that has the similar appearance to moss, but with a waxier outer surface (Fig. 11). In this illustration, it is hard to recognize that Haeckel is depicting a plant form that has a similar appearance to mossy plants. He romanticizes the plant, by idealizing and simplifying its appearance, and loses some of its waxy and oily texture that it is known to have. Again, Haeckel focuses upon evaluating the developmental phases of a species. Blossfeldt's focus remains more upon showing each unique aspect of the plant. Blossfeldt's structures of the *thujopsis* are not as perfectly symmetrical as many of Haeckel's plant illustrations. Blossfeldt's photographs of the *thujopsis* are abstracted both due to the lack of color, and the up-close vantage point. The black and white aids in producing an image whose sole interest is in the form and curvature that each leaf makes as you approach the tip of the branch of the *thujopsis*. In the photographs, the natural wrinkles and unperfected curve of each leaf is directly translated into black and white, further emphasizing these characteristics. Haeckel, on the other hand, tries to recreate the lines and wrinkles of the *hepaticae* on the bottom left corner of the plate. In comparison to the photographs, the illustration appears rather flat. However, in the end both illustrations and photography lose the essence of the plant, because they are only representations.

Haeckel and Blossfeldt share many similar interests and ideas concerning the forms and designs of nature. Moreover, their respective titles make an interesting comparison. While they both are translated as *Art Forms in Nature* in English, they differ by one crucial word in German. Haeckel's book was published as *Kunstformen der Natur*, while Blossfeldt's was titled *Urformen der Kunst*. Blossfeldt would naturally have understood the differentiation that he was making from Haeckel's own title. The slightly different arrangement of words and elimination of the word *Natur* in Blossfeldt's title changes its meaning.

In English the best translation for Blossfeldlt's *Urformen der Kunst* is "Primeval Forms of Art."[85] The arrangement of the words and meaning playfully engages Haeckel's own title, showing Blossfeldt's explicit interest in the primeval forms, which are forms that relate to the earliest history of the world. There is a new element of interest in time and history; by photographing everyday plants, he depicted an already familiar world, yet, his magnifications shed a new light on these existing plants. Many of the plants he selected had been around for millennia and were already part of the world's history. Plants are viewed as the foundation of design; they were studied and stylized by ancient civilizations like that of Ancient Greece and Egypt. Plants are one of the oldest motifs in art, from their presence ancient Egyptian capitals in the form of a lotus flower to the decorative vegetations of Art Nouveau.

Nierendorf mentioned the idea of primeval nature within the introduction of *Urformen der Kunst*: "Art has its immediate origin in the latest powerful incentive

[85] My thanks to Katherine Boivin for this translation.

existing at the time, the most visible expression of which it is. In the same way that time has no part in the existence of a blade of grass which, being a symbol of everlasting primeval laws governing all life, appears monumental and worthy of veneration, so a work of Art has an overwhelming moving effect through its very uniqueness as the most concentrated manifestation, as an arc of light joining the two poles of the Past and the Future."[86] Nierendorf's introduction gets to the core of what Blossfeldt meant to do when publishing his photographs. Art, as Nierendorf explained, has the ability to unite the primeval forms of nature and bring them into the present; Blossfeldt is doing just this with his photography. He makes his viewers aware of the primeval by shedding a new light on their existences and forms through his magnified photographs. Blossfeldt brings forth the old governing ideas of nature within ancient civilizations into the 20th century; he reintroduces these old ideas in a new light to clearly show where many of our own design prospects have originated.

Haeckel's book, on the other hand, might be said to have a more contemporary time frame. The forms he depicted were newly discovered and never seen before. His illustrations focused upon creatures like the medusa or radiolarian that were not well known before he published his book. By creating illustrations based upon these newly discovered or not very well known creatures, he evaluates the forms of nature in a new light; he stimulates an explicit interest in their biological forms. Blossfeldt created a different hyper-attention to the art forms in nature through both his use of photography and his book title. The slight differentiation of the German titles and the connections that Haeckel and Blossfeldt share allow us to conclude that at the very least Blossfeldt was

[86] Blossfeldt, *Art Forms in Nature*, III.

toying with the connection that the two of them shared through their obvious interest in forms of nature.

Still, these photographs establish a clear connection between both art and scientific illustration. Blossfeldt's botanical interests led to photographs that share many similarities to scientific illustrations like those of Haeckel. The magnified view of specific sections of nature were seen in both Blossfeldt's and Haeckel's works. The scientific interest in photography was partially due to the interest in technology. Scientific illustration had a clear influence on the art of Blossfeldt's photography. His work coincided with the industrial and technological advancements of the modern world of the 20th century. Nierendorf believed that, "Modern technics bring us into closer touch with Nature than was ever possible before, and with the aid of scientific appliances we obtain glimpses into worlds which hitherto had been hidden from our sense. And it is technics also that provide us with tools for artistic moulding."[87] There was a unity of the spheres of art, technology, and science combining with one another, which was ever present in Blossfeldt's work.

Finally, even though photography might seem to have made illustration obsolete, Haeckel's illustrations still had the ability to show things that photography cannot. Haeckel's illustrations show a simplified version of what he observed, and a simplification that allows the viewer to easily understand and differentiate between certain forms. For this reason, scientific illustration still exists today, and is often still exhibited alongside a photograph. The act and tradition of drawing organisms is still relevant because of its ability to hone the observational skills of a scientist or student.

[87] Ibid, V.

Figure 1. William Henry Fox Talbot, Buckler Fern, 1839, photogenic drawing negative, 22.1 x 17.7 cm.

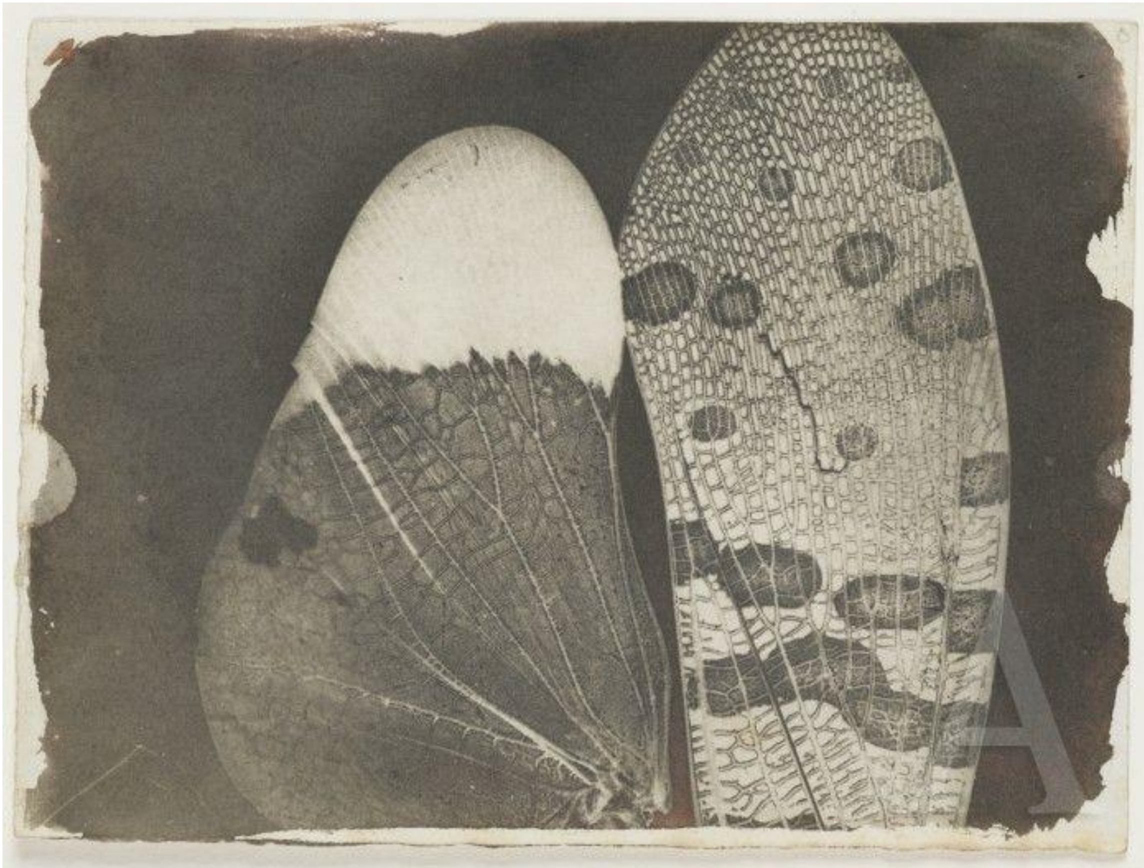

Figure 2. William Henry Fox Talbot, Moth Wings,1840, calotype.

Figure 3. Victor Regnault, *The Acoustic Experiment*, 1850, calotype.

Figure 4. Karl Blossfeldt, “Equisetum Hiemale,” *Urformen der Kunst*, 1928, photogravure, 25x magnification.

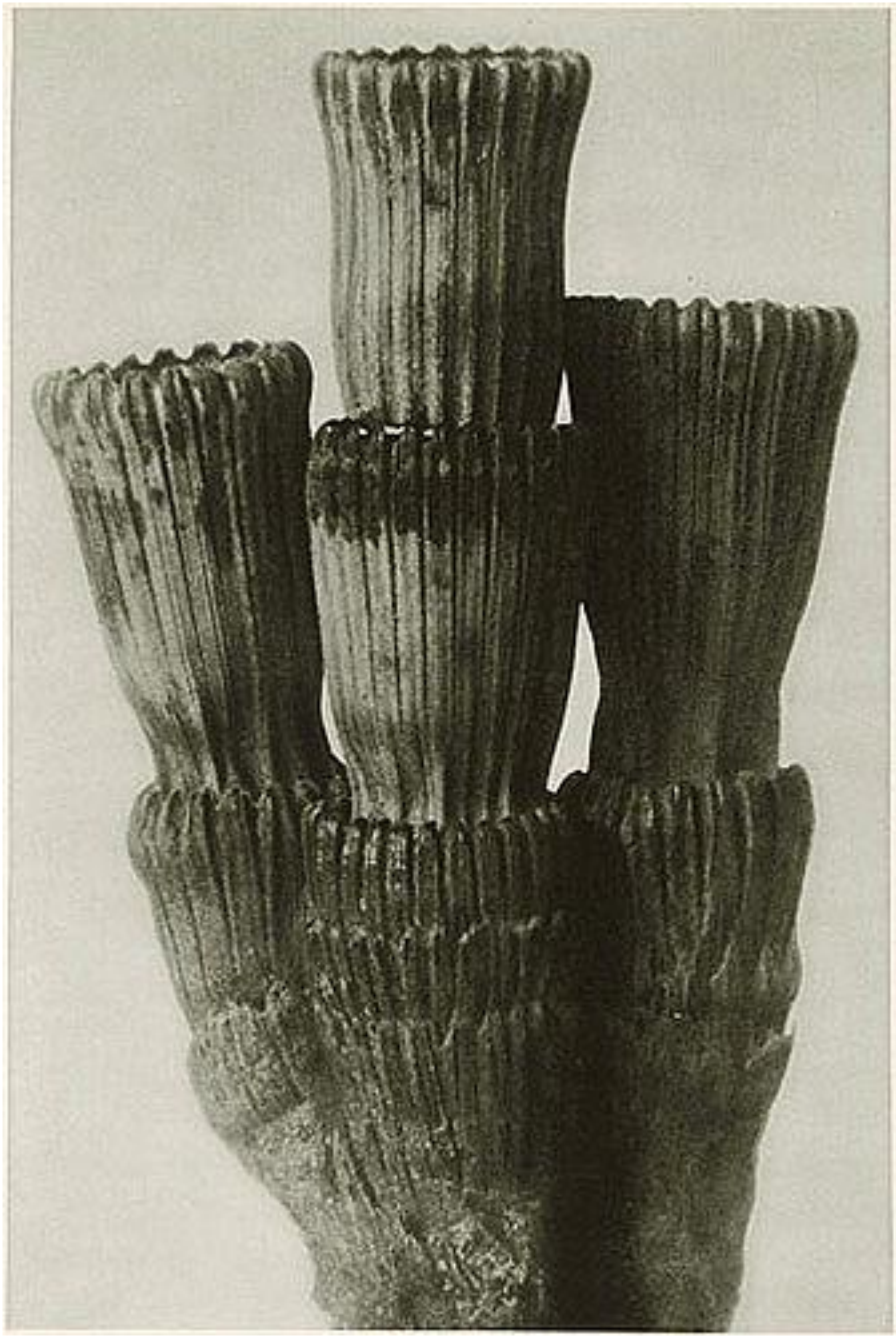

Figure 5. Karl Blossfeldt, “Equisetum hyemale” (Dutch rush; stem bases), *Urformen der Kusnt*, 1928, photogravure, 8x magnification.

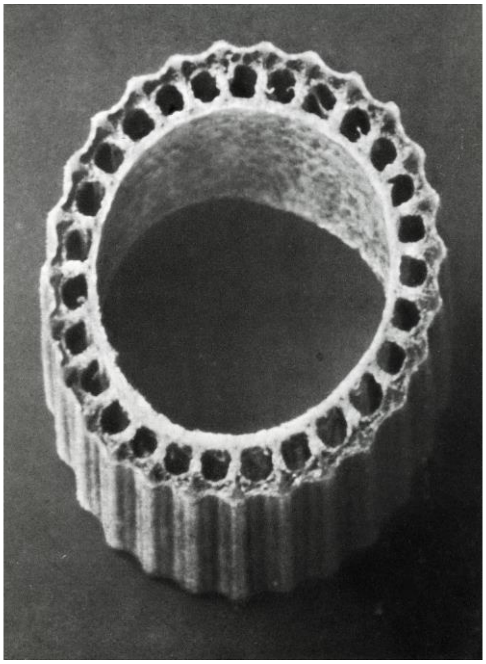

Figure 6. Karl Blossfeldt, “Equisetum hiemale” (Winter Horsetail; part of a root), *Urformen der Kunst*, 1928, photogravure, 30x magnification.

Figure 7. Karl Blossfeldt, “Matteucia struthiopteris,” *Urformen der Kunst*, 1928, photogravure.

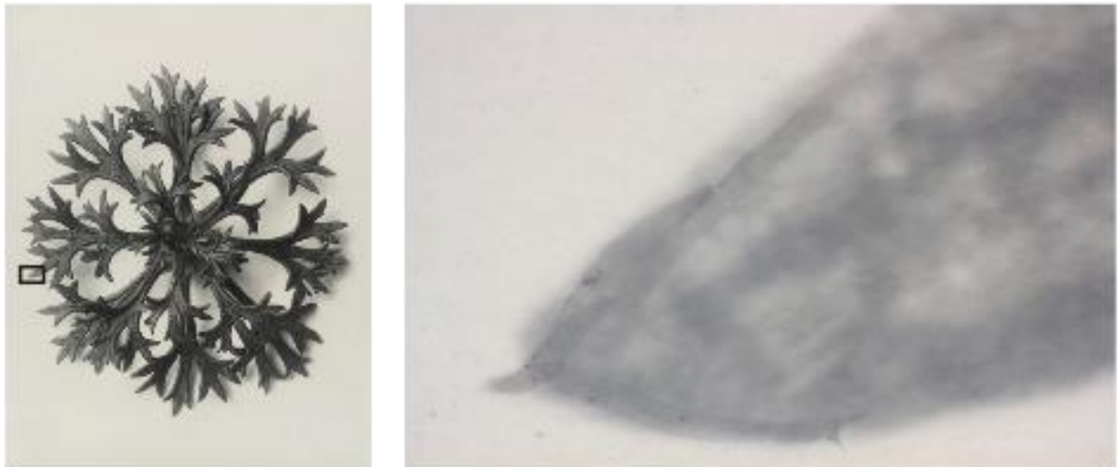

Figure 8. An example of additive retouching in Blossfeldt's prints from the Walther Collection: *Saxifraga wilkommiana* (MoMA 1629.2001). The retouching here occurs on the plant's the edges of the plant's leaves. Hanako Murata, *Material Forms in Nature: The Photographs of Karl Blossfeldt*. In Mitra Abbaspour, Lee Ann Daffner, and Maria Morris Hambourg, eds. *Object: Photo. Modern Photographs: The Thomas Wlather Collection 1909-1949. An Online Project at the Museum of Modern Art*. 2014.

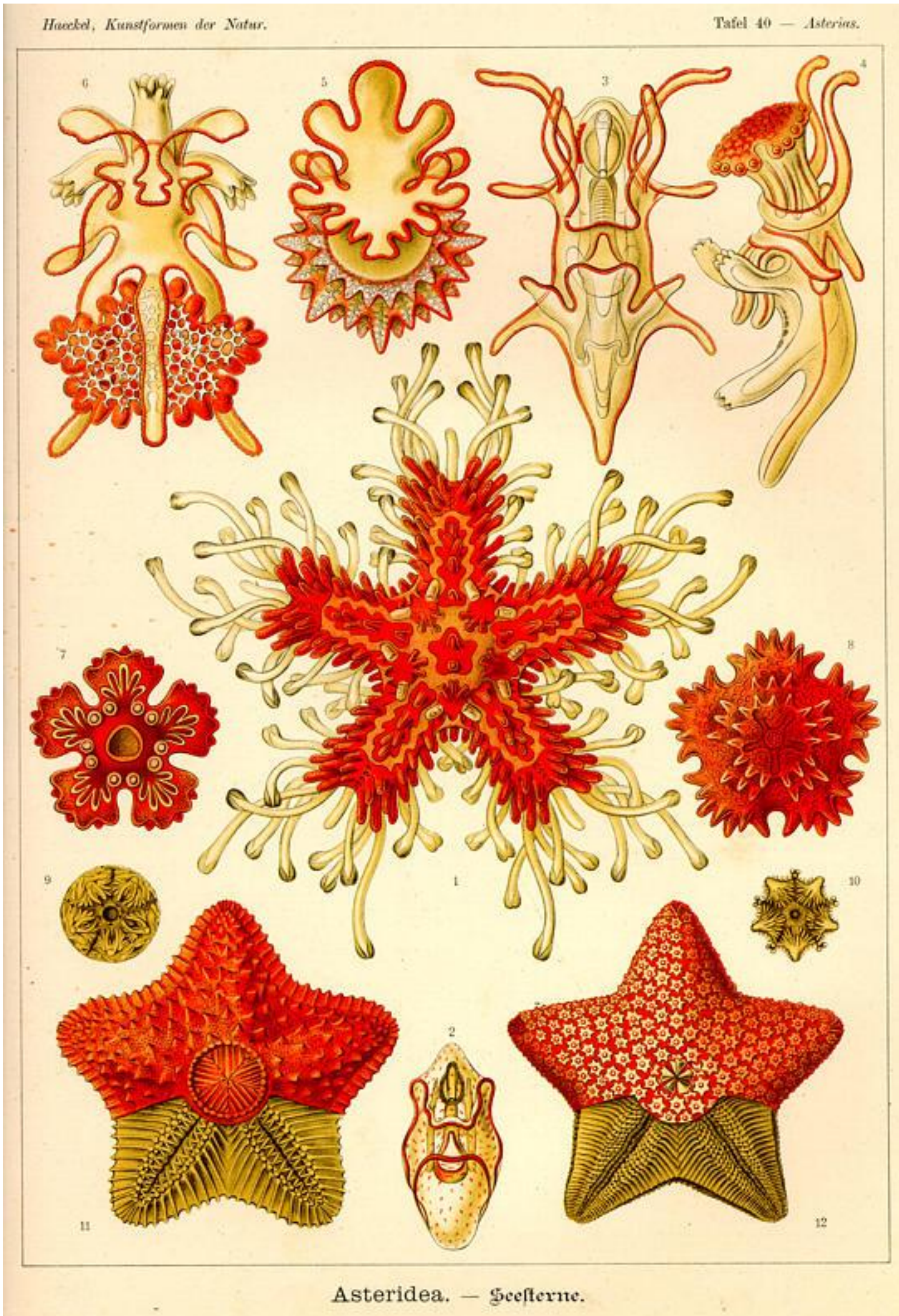

Figure 9. Ernst Haekcel, "Asteridea," Seesterne, *Kunstformen der Natur*, c. 1900, lithograph.

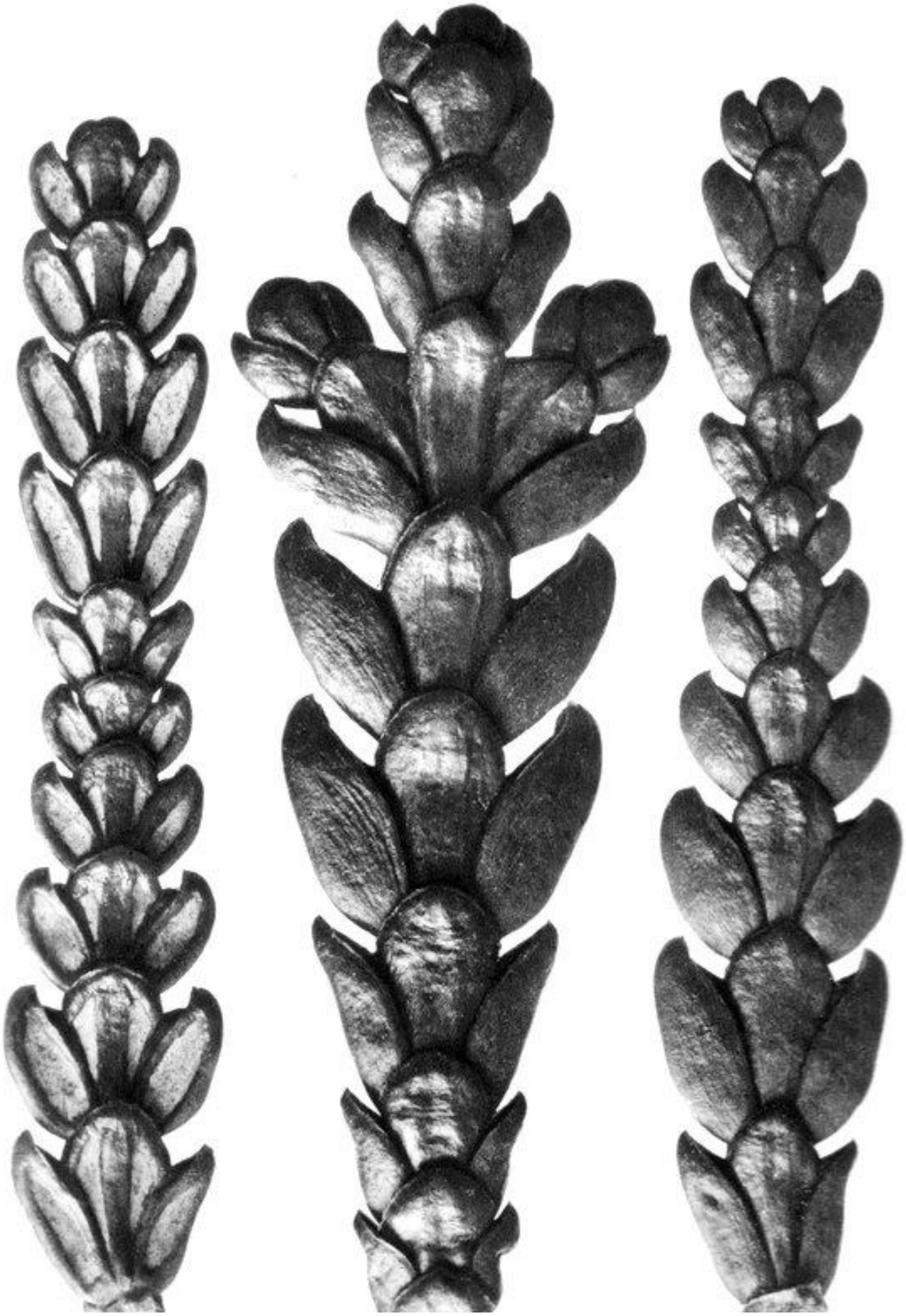

Figure 10. Karl Blossfeldt, “Thujopsis dolabrata,” *Urformen der Kunst*, 1928, Photogravure.

Figure 11. Ernst Haeckel, "hepaticae," *Kunstformen der Natur*, c. 1900, lithograph.

CONCLUSION

Throughout these three chapters, I have attempted to trace scientific illustration and its influence on art. Chapter one situated us in the world of scientific illustration. It produced an understanding of what scientific illustration and how it started to become interested in artful visual depictions. Chapter two was about how artistic and aesthetically aware scientific illustration was becoming through Haeckel's idealization of the marine and natural world. The tension between art and science was evaluated in Haeckel's work and reconciled through how he depicted nature in his scientific illustrations. Chapter three then led to photography's involvement in what we previously defined as scientific illustration. Blossfeldt's photographs were heavily influenced by scientific illustration, especially that of botany. Blossfeldt, like Haeckel, connected his interest in art and science through examination of nature, however, this time through photography.

Even from a brief examination of the history of scientific illustration, and especially the work of Blossfeldt and Haeckel, it can conclusively be said that nature is what combines art and science with one another. Especially, when taking into account their interests in the microscopic details of nature's biological forms and structures. However, that then leads us to question the future of scientific illustration with the development of new technologies, more specifically photographically based imaging technologies. For example, there are close up images of the neurons in the brain of mice in which each individual neuron is indentified through using fluorescent proteins (Fig. 1). These so-called 'brainbow' images appeared on the cover of *Nature* in 2007. The photograph was created with the use of the confocal microscope, which filters out the out-of-focus light and focuses it to the object being magnified with the help of a pinhole inside the microscope's structure.[88] The final photograph contains an obvious visual appeal due the use of florescent color to identify the various aspects of different neurons. If someone were to examine the photograph without any context, they might assume that it is an abstract painting. This image in no way appears to be scientific, unless the viewer is already familiar with the neural structure within a mouse's brain. The artistic elements are clear in the photograph the moment one examines it.

Since photography is able to depict this level of detail, the question then becomes: is manual scientific illustration becoming obsolete due to the evolving technology that surrounds us today? While these brainbows hold artistic interest, like Haeckel's illustrations, in their form and color, like the Haeckel's illustrations, they are can be overwhelming to one's sense. The act of creating a scientific illustration allows one to observe details and aspects of the specimen that one might not have noticed before. Scientific illustration is a form of learning that photography cannot replicate. Photographs are an excellent way to capture a moment; however, both illustrations and photography have their strengths as a visual analysis, scientific illustration continues to be relevant to this day.

[88] "The Confocal Microscope," accessed May 2, 2016, http://www.gonda.ucla.edu/bri_core/confocal.htm.

Conclusion Figure

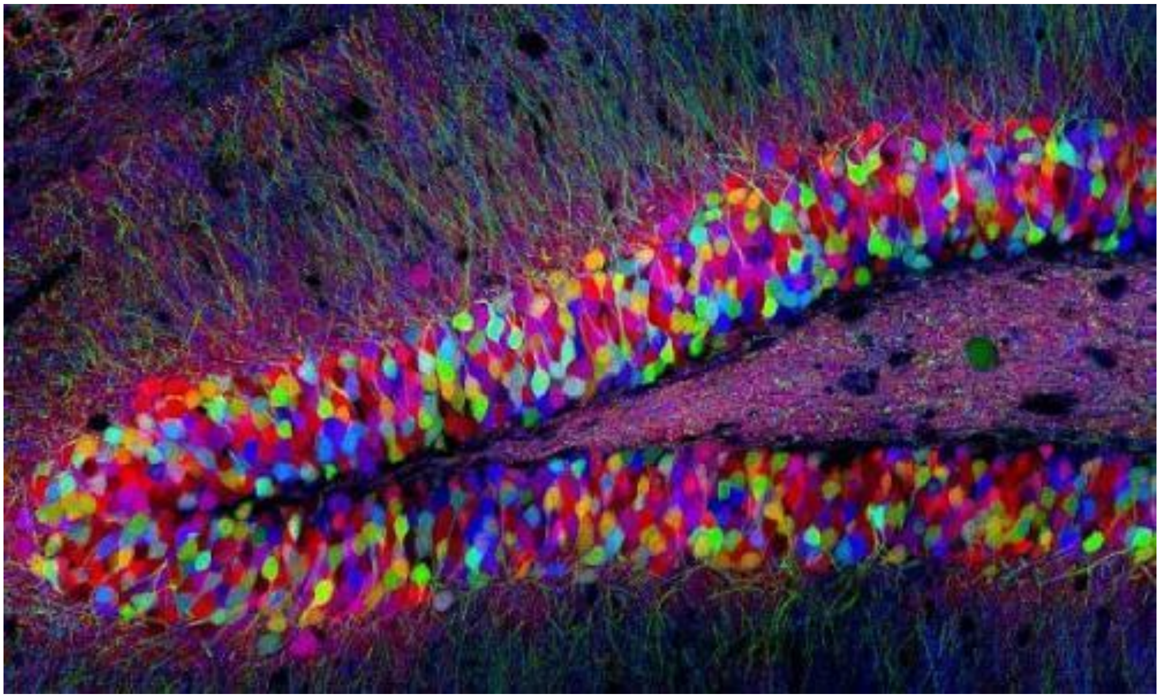

Fig. 1: Brainbow, Dentate Gyrus - Hilus, *Nature*, 2007, confocal microscope photograph.

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