Spring 4-19-2019

Taxonomy and the History of Science: A Critical Analysis of Four Historic Publications

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Kennesaw State University Honors Capstone Thesis

April 19, 2019

Introduction

Taxonomy, or more simply the way that we classify organisms, is arguably one of the foundational concepts of modern biology. How we characterize and classify organisms inherently informs our understanding of the world and the organisms that inhabit it. Modern biology textbooks, such as *Campbell Biology* (2014), introduce students to Carl Linnaeus's binomial nomenclature and classification system as the basis of our understanding of taxonomic thought. Binomial nomenclature refers to the system in which organisms are given two names in Latin based on their genus and species, respectively to uniquely identify them. This is the system that is used today, in part because of its ability to be universally used and understood. For example, *Xenopus laevis* is the name given to what those in English-speaking countries know as the African clawed frog. Though "African clawed frog" will not be understood across different languages, *Xenopus laevis* will be understood and can therefore be used by scientists from different cultures.

Despite the importance of taxonomy as a tool and practice, the history and development of this concept in scientific writings before Linnaeus is not thoroughly discussed in textbooks used by biology majors at Kennesaw State University. In the fifth edition of *Campbell Biology* (2014), the authors briefly describe Carl Linnaeus' binomial nomenclature and classification system, then move on to present Darwin's research on the idea of evolution and the rise and fall of Jean-Baptiste Lamarck's mistaken hypothesis of inherited characteristics. The textbook used for a course on vertebrate zoology emphasizing evolutionary taxonomy briefly describes the binomial nomenclature system and the systematics of the phylogenetic tree system that modern biological scientists use to group and organize organisms by evolutionary lineages but does not discuss pre-Linnaean classification. Scientists have long recognized how Carl Linnaeus' taxonomic system merged with Charles Darwin's 19th-century evolutionary ideas to form a single taxonomic system. But what did scientists before Darwin and even before Linnaeus think about classifying plants and animals? How did they classify plants and animals and to what purpose?

To address this question and to better understand the historical grounding of my own discipline of biology, I decided to focus my capstone project on the works of great scientists, botanists and natural philosophers of the past, specifically Pliny the Elder (24-79 CE), Rembert Dodoens (1517-1585), Nehemiah Grew (1641-1712), and Carl Linnaeus (1707-1778). In this paper, I explore the lives and works of these individuals, and consider the significance of their contributions. I am particularly interested in the differences in the modes of thinking that were present in the past as well as those factors that have stood the test of time in the dissemination of scholarly information. Looking at the intersection between the history of science and the history of book production allows modern scholars to better understand the historical and material contexts that shape the development of scientific principles, such as evolutionary taxonomy, that are prevalent today.

The research for this paper was completed by examining four volumes from Kennesaw State University's Bentley Rare Book collection as well as two modern-day textbooks and multiple secondary sources on the printing process, the dissemination of the information, and the authors of the four volumes themselves. I chose the four texts based on their availability for study, their accessibility in terms of language, and the historical eras they represent, specifically the 16th to the 18th centuries. I began with Linnaeus's work as a familiar starting point, then moved back in time to consider Grew, Dodoens, and Pliny. In this way, I was able to immerse myself in the mindset of the time periods associated with each work in order to better understand it. After examining the texts, I used a variety of secondary sources to clarify not only historical events that occurred before and after each work was published, but to better understand the lives of each of the authors as well. Upon completing the research for each of these works and their respective time periods, I wrote short essays that helped to further clarify the history of these works and their authors.

Taxonomy in Modern Textbooks

As a widely adopted textbook for use in colleges and universities, *Campbell Biology* (2014) is broad in scope and presents a great number of aspects of biological study. In Chapter 22, the authors briefly discuss Linnaean binomial nomenclature as well as Charles Darwin's contributions to evolutionary taxonomy and its application today. According to the textbook, Darwin was notable for challenging traditional views of the history of the earth and its organisms. His idea of descent with modification through the process of natural selection is supported with an overwhelming amount of scientific evidence. To their credit, the authors of the textbook discuss how the work of earlier scientists influenced his thought: Darwin was greatly influenced by French scientist Georges Couvier's (1769-1832) work on fossils as well as Scottish geologist James Hutton's (1726-1797) proposition that land forms can be explained by gradual mechanisms such as rivers, popularized later by scientist Charles Lyell (1797-1875). The authors even consider the mistaken hypothesis of Jean-Baptiste Lamarck (1744-1829) who was among the first to propose a theory of evolution. The basis of Lamarck's hypothesis of use and disuse was that organisms pass on the physical traits that it developed during its lifetime to its offspring.[1] Darwin's theory is similar but more refined. According to Darwin, if an organism doesn't use an anatomical structure it was born with, the structure will be reduced and eventually disappear in future generations. Conversely, if an organism successfully uses an anatomical

[1] According to Lamarck, a giraffe that developed a longer neck in the course of a lifetime stretching its neck farther and farther for food was thought to pass on this acquired physical trait to its offspring.

structure more and the structure aids the organism's ability to survive or reproduce, then the same structure will be more exaggerated in future generations. As absurd as Lamarck's idea sounds today, it was largely held as true until the popularization of Darwin's work some fifty years later. It is for this reason, presumably, that the textbook authors chose to recognize Lamarck's work, as it is essentially the closest precursor to Darwin's theory. It is interesting that the authors chose to highlight Lamarck in discussions of evolutionary taxonomy but provide no comparable consideration for the development of taxonomy as a foundational principle. It is hoped that this paper may contribute to this gap in our understanding of taxonomy.

Carl Linnaeus and *Species Plantarum* (1753)

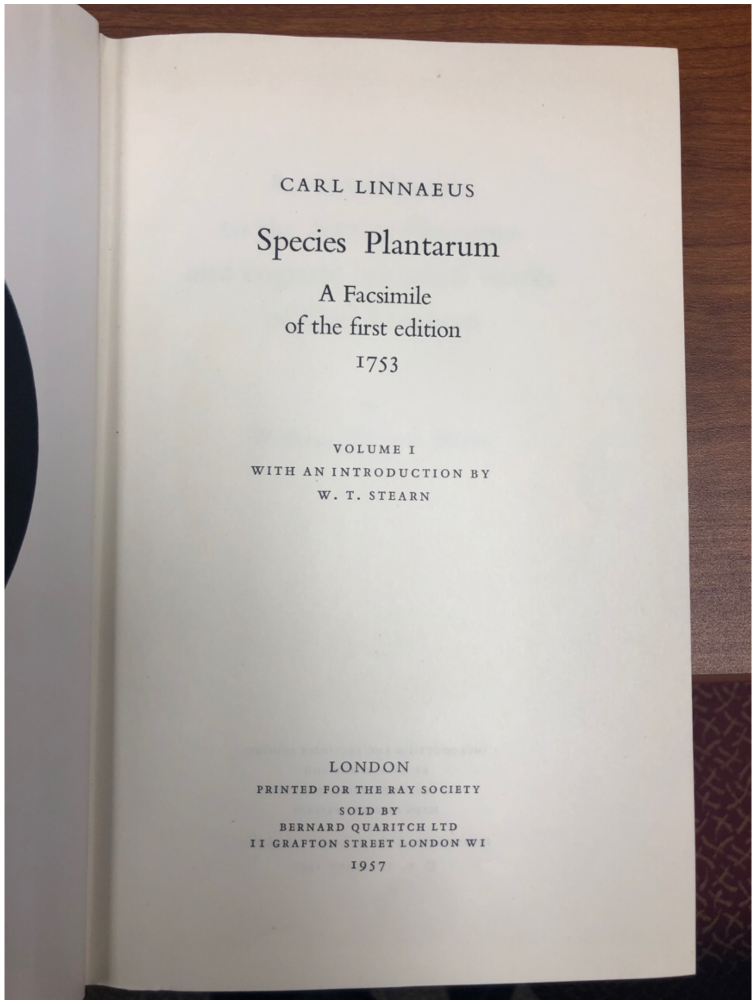

Figure 1: The title page of the copy of the *Species Plantarum* facsimile (Bentley Rare Book Museum).

Having looked at the historical development of scientific ideas of taxonomy in modern textbooks, I will now examine and critically analyze four works by botanists and natural philosophers before the 19th century. I will consider Carl Linnaeus' Species Plantarum of 1753,[2]

[2] As Linnaeus' work is in Latin, I was unable to read it for myself. Therefore, I have relied heavily on the commentary of Ray Society's translators and editors who are most interested in the relationship between this work and the namesake of the society, John Ray. This may have affected the analysis and biography given at the beginning of the work, but there is little way to tell as this was the only version available to me.

Nehemiah Grew's The Anatomy of Plants of 1682, Rembert Dodoens' Great Herbal of 1583, and Pliny's Natural History completed in 77 CE and published in English translation in 1635. All of these works discuss and classify plants according to various schema, and each is a reflection of the concerns and historical contexts in which it was produced. Together, they provide a fascinating glimpse into the development of taxonomy which highlights the enormous contributions of Linnaeus in developing a precise, robust yet standardized system.

Carl Linnaeus (1707-1778), also known by the Latin variant of his name, Carolus Linnaeus, stands today as one of the most important figures of scientific history. His famous work, *Species Plantarum* (1753), is said to herald the transition towards a standardized system of plant nomenclature throughout Europe and eventually the world through the use of binomial nomenclature used to identify species of plants included in the book. The work is also notable for its concise and comprehensive content, logical arrangement and clear references to previous literature on the subject of botany. *Species Plantarum* was used as field guide for other 18th century botanists, yet it required less expert and detailed knowledge of plants to be used than other field guides of the day. Previous works referenced by *Species Plantarum* included multiple works that Linnaeus had written himself, including *Flora Lapponica* (1737), *Hortus Cliffortianus* (1738), *Flora Suecica* (1746), and *Flora Zeylanica* (1747), as well as works written by other famous botanists, most notably Johann Freidrich Gronovius' *Flora Virginica* (1739) (Stearn, 1957). Linnaeus' previous works were largely based on his personal herbarium. This collection of dried plants was adapted by Linnaeus to fit his individual needs, which involved the changing of order of the pages. Linnaeus kept each plant on a separate page so that as his herbarium grew, he could rearrange them (Stearn, 1957) and create categories to organize the collection. Because he kept his collection on unbound pages, he was able to increase the complexity of his categorizations while maintaining the flexibility he needed for his work (Dover, 2019).

Linnaeus based his system of classification on sexual organs in plants, similar to the form we use today. He borrowed this concept from French botanist Joseph Pitton de Tournefort (1656-1708), who developed the concept of genus by grouping plants according to an inherent natural characteristic. Today, a genus is considered a subclass of the biological classification system having been refined as a concept since the time of Linnaeus. Interestingly, the consideration of plant sex organs as the basis of classification was decried by many when it was initially published as being too vulgar a concept for the young minds of students; despite this minor setback, the system was used extensively by botanists between 1760 and 1810 (Stearn, 1957). Later, this system was modified, and plants were classified according to the similarity of structures giving rise to the system of classification based on evolutionary relationships we use today.

Contrary to what many scientists believe today, the binomial nomenclature system was only popularized by *Species Plantarum* and not introduced by it. The system was initially presented in Linnaeus' 1745 work, *Öländska och Gothländska Resa*. It was first applied in 1749 with two of Linnaeus' dissertations and first elaborated as a method of nomenclature in his work *Philosophia Botanica* (1751). The system was initially favored by publishers interested in lowering printing costs; since the classifications were shorter, they required fewer printed pages (Stearn, 1957). Before too long, scientists recognized its efficiency and utility and began to adopt it on their own. The nomenclature system used in Linnaeus' early works exhibit two to three separate elements but in 1749, he settled on the nomenclature system of just two elements. The system's effectiveness is exemplified in two of Linnaeus' previous works, *Pan Suecicus* and

Gemmae Arborum, both of which were printed in 1749. *Pan Suecicus* identifies and describes 856 species printed on only 27 pages whereas the 100 species in *Gemmae Arborum* required 18 pages. *Gemmae Arborum* did not use the binomial nomenclature system whereas *Pan Suecicus* did (Stearn, 1957).

Reception in Britain

Linnaeus' system, while generally well-received in much of Europe, initially encountered a degree of resistance in Britain, where the works of Englishman John Ray were still favored, despite having been produced in the last half of the 17th century. John Ray's *Synopsis Methodica Stirpium Britannicarum* (1689) was the dominating handbook for British naturalists up until 1762 including his system of classification. Ray is generally credited with introducing the concept of species as the fundamental unit of taxonomy. Ray's system was based on all of the characteristics of an organism, including anatomy. It thus differed from Linnaeus' system as it was more informative but much less concise than Linnaeus' system. Linnaeus' system finally gained a foothold when it was accepted by Britain's Royal Society, a powerful group of scholars and scientists. The Royal Society was granted a charter by King Charles II of England in 1660 and served as the first and oldest national scientific professional organization in the world. In 1754, one of Linnaeus' students took upon himself the task of assigning all the plants in Ray's *Synopsis* a classification based on Linnaeus' binomial system and successfully presented it to the Royal Society. From this point on, Linnaeus' system gained attention from scholars across Britain and began to be used more widely. It was first used in 1759 by Patrick Browne in *Civil and Natural History of Jamaica*. In 1762, botanist Johann Jacob Dillenius published a revised edition of Ray's *Synopsis*, which fully incorporated Linnaeus' system, effectively replacing Ray's system with Linnaeus' system as the standard for British botanists (Stearn, 1957).

Linnaeus' success can be attributed in part to his proud and stubborn nature. With the exception of the works of Joseph Pitton de Tournefort (1656-1708), he almost exclusively cited his own work in his publications. Linnaeus was conscious of the worth of his achievements and he made sure that none of them would go unnoticed or unrecorded by writing several autobiographies; as a result, he is now one of the most documented 18th century botanists (Stearn, 1957).[3] Another indication of Linnaeus' view of himself came through the development of his work *Hortus Cliffortianus*, which was written over the course of nine months and based on George Clifford's garden and herbarium. With this work he began to translate the previous works of naturalists including Tournefort and Ray into his own binomial system. He suspended the publishing process of this work for an entire year to give time for an elaborate allegorical portrait frontispiece to be made for it. The frontispiece featured a depiction of Mother Nature next to a Celsius thermometer that Linnaeus himself had modified for use in greenhouses. Linnaeus is depicted as the god Apollo, who is casting aside the shroud of darkness around the goddess of Nature and stomping the dragon of falsehood beneath him (Stearn, 1957).

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[3] From early on, Linnaeus also made sure that his critics were also remembered. He had a habit of naming weeds after his critics, and many of those critics are now ironically only known today for being having the name of such plants.

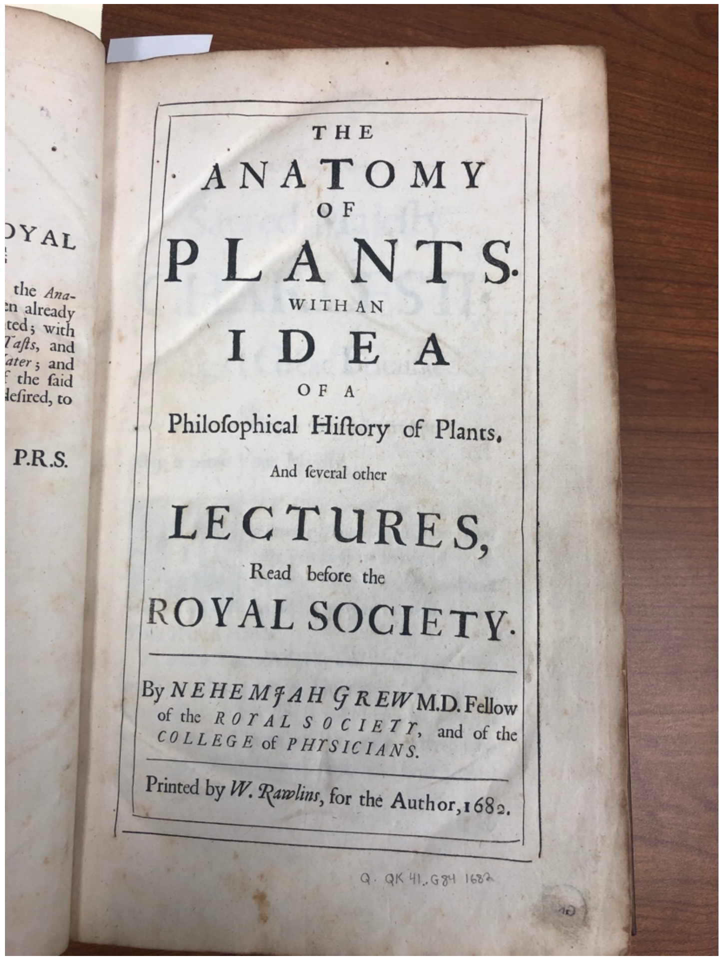
Figure 2: The Frontispiece of *Hortus Cliffortianus* (Wikimedia.org, 2015)

By 1905, the *Species Plantarum* was generally considered to be a foundational work for modern taxonomic organization (Stearn, 1957). After a publishing hiatus of over 100 years, a number of facsimiles of his seminal work began to be published in the twentieth century. The first facsimile edition was published in 1907 in Berlin, followed by three subsequent facsimile editions, translated into a number of different languages. The final facsimile published by the

Ray Society in 1957, is regarded as the most accurate of the facsimiles, as it contains the work in its unedited eighteenth-century Latin.

Having looked into Linnaeus' work and life, I was struck by Linnaeus' concern for self-promotion and for making sure his scientific contributions would forever be connected to his name. Certainly, there is no denying that his system of classification has stood the test of time as it is considered an unshakeable foundation for further work, including Darwin's, into understanding the relationships between different groups of plants and animals. Yet, his approach to scientific discovery and discourse is distinctly different from that of Englishman Nehemiah Grew from the previous century, whom I consider in the next section.

Nehemiah Grew's *Anatomy of Plants* (1682)


THE
ANATOMY
OF
PLANTS.
WITH AN
IDEA
OF A
Philosophical History of Plants,
And several other
LECTURES,
Read before the
ROYAL SOCIETY.

By NEHEMJAH GREW M.D. Fellow of the ROYAL SOCIETY, and of the COLLEGE of PHYSICIANS.

Printed by W. Rawlins, for the Author, 1682.

Figure 3: The title page of the copy of Grew's *Anatomy of Plants* (Bentley Rare Book Museum).

Nehemiah Grew's *Anatomy of Plants* is a remarkable work in many ways. Undeniably, the numerous, incredibly detailed copperplate engravings presented in the back of the work are spectacular. I have never seen handmade images in such a detailed fashion before and have only seen similar images from looking through microscopes myself, as most images in modern textbooks have been drawn in a cartoon fashion in order to enhance the understanding of structures. The author of the work, Nehemiah Grew (1641-1712), was an English botanist and physician who is considered by many to be among the founders of the science of plant anatomy.

His book *The Anatomy of Vegetables Begun* (1672) was among the first to include a detailed consideration of the structure of plant seeds. In addition, he notes the existence of plant structures we now call cells and introduces many terms we use today to describe the anatomy of a seed. Around the same time, Marcello Malpighi (1628-1694), an Italian naturalist and another founder of the science of plant anatomy, presented similar findings about plant structures to Britain's Royal Society. The debate that ensued as to who should be credited with first describing seed anatomy shows how competitive the field of science was in the past which was arguably just as, if not more, competitive than modern times (Britannica, 2018). Grew's interests were not confined to botany; he is also recognized as a pioneer of dactyloscopy, the study and analysis of fingerprints, due to his 1684 drawings of finger ridge patterns that were the most accurate for the time period (Revolvy, accessed 2019).

Grew's induction into Britain's Royal Society allowed him to make much progress in the field of botany as the Society financially supported much of his work. Interestingly, his membership came about from a chance meeting with John Wilkins (1614 -1703), who was a founding member of the Royal Society and supported Grew's petition to join. Under the guidance of the Royal Society, Grew was one of the first naturalists to utilize the microscope in the study of plant morphology and established the observational basis for botany into the early 1800s (Garrett, 2011). He is also credited as the first to use the phrase "comparative anatomy," a field he pioneered by noting similarities in function and structures across the animal and plant families. Based on his William Harvey's discovery of blood circulation in 1628, he hypothesized that sap circulated in plants in a similar fashion. He worked with several prominent members of the Society including famed philosopher and inventor Robert Hooke (1635-1703). He collaborated with Hooke to research the little "bladders" that Grew had discovered in plants, later coining them as "cells." In addition to these achievements, Grew also expanded on the idea of plant sexuality by noting that the stamen was the male sex organ of a plant and pollen is its seed (Garrett, 2011). In addition to serving the Society as a contributing scientist, he also served as secretary of the organization from 1677 until his death in 1712.

Grew's writings and scientific experiments suggest that he looked at nature as part of a mechanical clockwork universe, in which observations of cause and effect could be discovered and explained without recourse to earlier ideas of mysterious and inexplicable forces. His ideas were influenced by his father, a nonconformist cleric, who believed that God had no need to interfere with the world after creating it in accordance to his laws. Because of this belief, Grew strictly denied miracles, which was potentially significant in his findings (Garrett, 2018). Grew saw naturalists as "Carpenter[s] in the secrets of devine [sic] art" and that God has seen such scholars fit to reveal his work (Grew, 1682). He also said that no man who denies God can truly philosophize because to philosophize is to have an idea of the causes and ends to things, a task he believed impossible for a non-believer. Grew also noted that he saw his work as a way to venerate God. These religious beliefs may have motivated him to spend an extraordinary amount of time and effort on his work, resulting in numerous discoveries and advances in botany.

The Anatomy of Plants, Grew's magnum opus, is a collection of several lectures presented to and published for the Royal Society. The book as a whole was dedicated to King Charles II and each lecture within was dedicated to a different aristocrat, hinting at the amount of patronage required at the time to bring one's work to fruition. In *The Anatomy of Plants* Grew expounds on his ideas of scientific contributions. He states that the "journey for the knowledge of nature" is longer than the time a man has to live and so therefore scientists depend on each other and must base their work on that of previous scholars (Grew, 1682). He goes on to mention that scholars must do their part before the next generation takes over and that they must be satisfied with the previous works of others rather than decide which scholar has the fairest representation, since no one person is capable of fully understanding nature to its fullest. Grew's work is full of philosophical observations guiding his research as to how plants live and function. Grew hypothesized that plants must have homologous structures, for plants grow "in the same manner, with one sun, one rain, indifferently well upon one soil, and… have the same common parts" (Grew, 1682). Because plants share similarities in the ways they survive and reproduce, they must also be able to come together in specific ways to produce medical benefits.

Grew classified plants by a number of observable characteristics including color, taste[4], odor, "arefaction" (observed in drying the plant specimen) "ustion" (observed in burning samples), and calcination (what happens to the plant specimen when it is heated without oxygen). He gives great significance to observable characteristics of taste and claimed that taste can reveal more about a plant than simply observing colors and odors. Grew includes "composition" as a category; by this he means the effects of infusing the plant with various liquids. As described in *The Anatomy of Plants*, these liquids include water, liquor, vinegar, urine, blood, and milk. Lastly, Grew describes the category of "compounding," referring to the combining of two of the factor tests concurrently and observing the outcomes.

Through his philosophies as well as observations of plants with the naked eye and his microscope, Grew identifies and discusses the importance of the six parts of plants: the seed, the roots, the trunk, the flower, the fruit, and the seed in its state of generation. He also describes how nutrients are recycled in the soil after they die in order to provide essential minerals for other plants. He differentiates hardwoods and softwoods as well in *The Anatomy of Plants* and

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[4] Grew was so dedicated to his work and his classification system that he made sure to taste each plant that he classified himself.

introduces the porous "pith" of plants that allows for the uptake of water and prevention of water loss due to the environment around it. He also postulates that flower color is due to the air and minerals present in the production of the flower.

Despite his tireless efforts, Grew's works seem to have become forgotten after his death. He is rarely, if ever, talked about in modern science classes, even though he is credited with significant breakthroughs in comparative and plant anatomies. Even with his expansions on plant sexual reproduction and cell identification, he is eclipsed by naturalists such as Linnaeus and even Robert Hooke. Many of his achievements however, such as the general anatomy of a seed, are now incorporated into the scientific canon even though his name may be largely lost to history. Of course, it is not possible to mention all of the scientists who contributed to our scientific canon by name nor include them in textbooks. But the question as to why certain individuals are remembered and others are not, remains. Overall, I believe Grew's work and collaborative ethos foreshadows the modern scientific endeavor in which scientists work together for the purpose of contributing to mankind's understanding of our world. This for me was the most fascinating aspect of studying Grew, as he clearly expressed and represented a focus on the scientific community rather than on himself, an attitude which was vastly different from the other scientists I studied during the course of this project.

Rembert Dodoens' Great Herbal (1583)

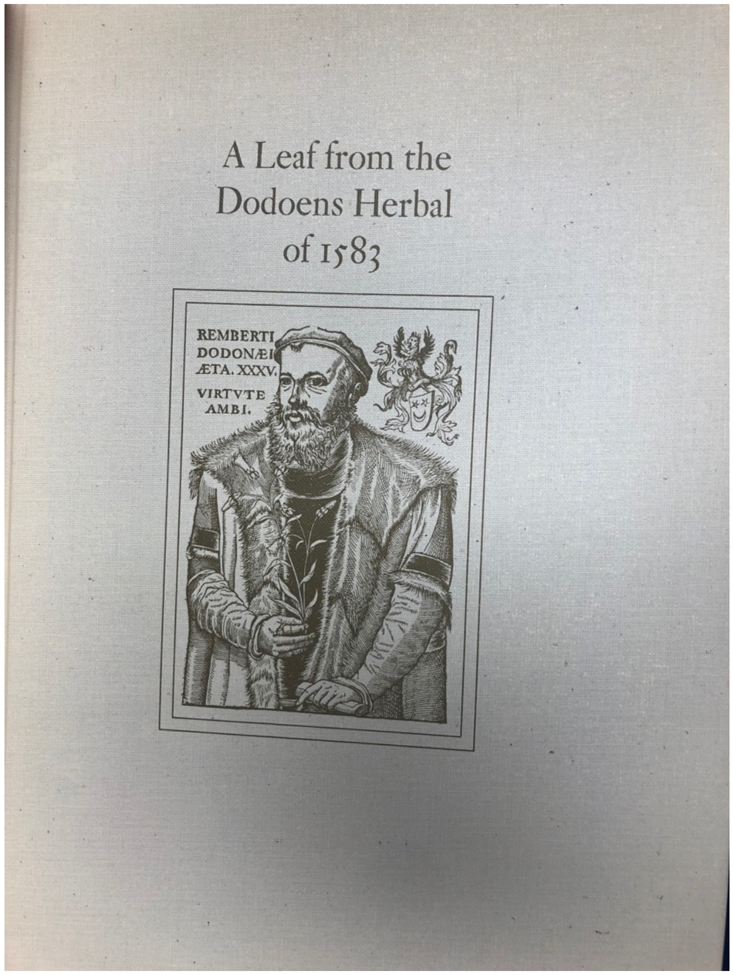


Figure 4: The title page of *A Leaf from the Dodens Herbal of 1583* (Bentley Rare Book Museum).

One of the most influential natural philosophers of the century before Nehemiah Grew's era was 16th century Flemish botanist Rembert Dodoens (1517-1585). Like many other scientists before Linnaeus, Dodoens was educated in a wide array of sciences and philosophies including Greek literature, cosmology, geography, botany, medicine, and other sciences. Dodoens spent most of his life practicing medicine, at first in his home town of Malines, Netherlands (now Mechelen, Belgium) and later as physician to the Holy Roman Emperors Maximilian II and Rudolph II (Bliss, 1977).

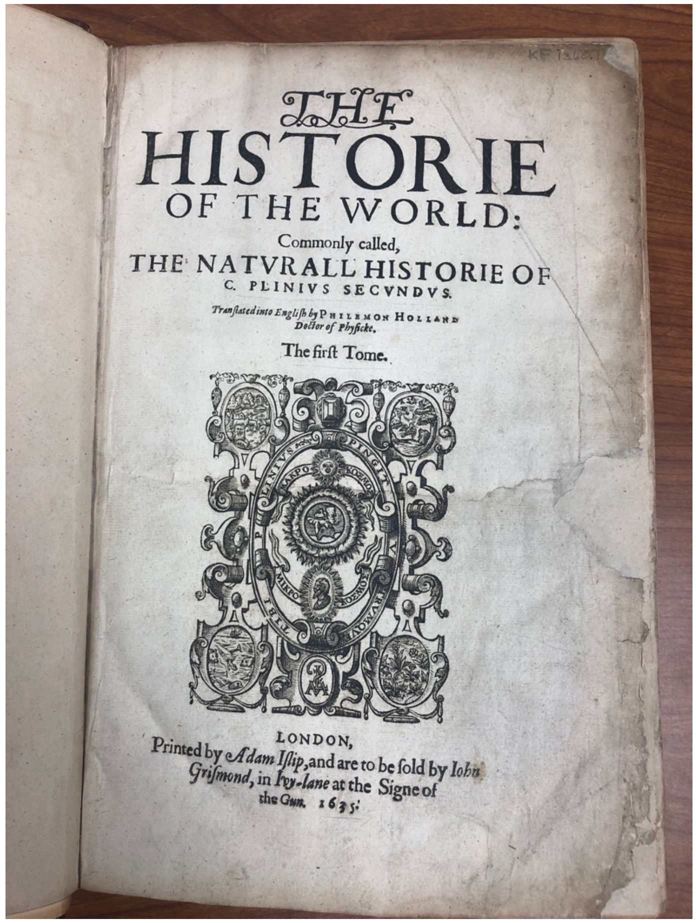
Dodoens' works vary in subject as much as his interests did, starting with *Cosmographica in Astronomiam et Geographiam Isagoge* (1548). In this compact book measuring under six inches in height and containing 122 pages with woodcut maps, Dodoen discusses and elaborates his ideas of the geography of the world and the heavens. His first botanical work, *De Frugum Historia* (1552) consists of 94 leaves describing cereals, vegetables, and animal fodders. He published *Cruydeboeck* (1554) soon afterwards; this book was an herbal, identifying and describing plants indigenous to the Flemish region. Dodoens' masterpiece was his *Stirpium Historiae Pemptades Sex Sive Libri XXX* (1583), which roughly translates as "a history of plants in six sections of five parts of thirty books." It is a large impressive folio volume, containing 860 pages illustrated with 1,305 woodcuts. The primary text is preceded by three poems praising Dodoens' work, a listing of classical and contemporary writers consulted during the creation of the herbal, and a half page listing of residents whose gardens were studied.

The work itself is divided into six sections: vegetables, plants known for flowering, medical plants, food plants growing in water, plants used as condiments (both edible and not), and trees and shrubs. From this we can surmise that Dodoens classified plants by their uses instead of physical features. Like Linnaeus, Dodoens appears to largely depend on his own work rather than relying on others, although it is clear that he incorporated the earlier works of the German botanist Leonhart Fuchs and others. It is around this time we see a shift among scholars towards a focus on observation and data gathering, captured in written documents. In addition, the increasing availability of books at the time allowed for the dissemination of printed observations and data amongst scholars (Dover, 2019). One could argue that this set the stage for the race to claim one's observations and ideas as his own, as seen in the case of Linnaeus and others. Dodoens' *Stirpium Historiae* is distinguished by its beautiful woodcuts and the use of nomenclature given in ten different languages, linking new names for plants to older names whenever possible. In this sense, we have a record of the history of classification before Dodoens. The work was praised by many during his time, including William Ram (a botanist who translated the work to English), Thomas Newton (a cleric and author), and William Clowes, a surgeon and botanist (Bliss, 1977).

This work was one of the first illustrated herbals to be produced on a printing press, therefore reaching a larger audience in less time than most works published before it. Original copies of *Stirpium Historie* are difficult to find in good condition today. Many of these surviving works were broken up by book dealers who could make a greater profit selling individual leaves; the copy I examined falls into this category. The 1977 leaf book published by the Book Club of California bears a single leaf from a copy of the original text supplemented with modern text about the original work, the author, and the printer. Prior to this version of his work, Dodoens' works have been published about five times in the twentieth century alone (Bliss, 1977).

Dodoens' work is similar to Grew's in the respect that they are both herbals. According to The Oxford English Dictionary (2019), an herbal is "a book containing the names and descriptions of herbs or of plants in general, with their properties and virtues." They were culturally important works that were used by common folk for everyday uses. They were especially used by physicians, alchemists, and others in similar professions. The first printed herbal dates back to 1470 during the early days of the printing press. Herbals were certainly considered a lucrative genre by publishers as they were used by laymen as well as scientists and physicians as part of their work (Bliss, 1977). As printing became cheaper and books became more commonplace, the general public began to buy herbals for the use in home remedies and for the images within the herbals, which were often quite detailed. In order to meet the demand of consumers, printers would print herbals often and cheap enough for the common person to obtain. In the early 16th century many printers began to print images alongside of mostly unrelated texts in order to decorate the text and make them more visually appealing. An example of this practice is Otto Brunfels' 1530 herbal *Live Images of Plants*, which features woodcut images of plants barely mentioned in the work, while plants described in detail were not illustrated. It is known that the artisans making the wood cuts for the image and the author of the text worked separately and were only brought together by the printer. In some cases, printers reused older wood cuts of images instead of commissioning new ones. This saved printing costs for the printer and increased his profit, as illustrations for a publication took up three fourths of the capital investment required in producing a book. Several illustrated and printed texts from the early modern period seem to coexist alongside each other without any care as to whether the two were linked or even consistent (Kusukawa, 2000). From this we can see that aspects of book production we take for granted today were not necessarily the norm in various historical periods. This fact makes works such as Dodoens' *Great Herbal* and Grew's *Anatomy of Plants* all the more impressive, as they use elaborate woodcut and copperplate engravings as an integral part of the text and the work itself.

Pliny's *History of the World* (1635)



THE
HISTORIE
OF THE WORLD:
Commonly called,
THE NATVRALL HISTORIE OF
C. PLINIVS SECVNDVS.
Translated into English by PHILEMON HOLLAND
Doctor of Physicke.
The first Tome.

LONDON,
Printed by Adam Islip, and are to be sold by Iohn
Grismond, in Ivy-lane at the Signe of
the Gun. 1635.

Figure 5: The title page of the copy of Pliny's *Natural History* (Bentley Rare Book Museum)

The final historic book I examined was a 1635 English translation of Pliny the Elder's *History of the World*. This work represents one of the few remaining texts that have survived through the ages from the ancient world of Rome to the present day. This work was considered a staple for the library of all educated people, and was certainly known and used in medieval universities. Despite having been originally written more than a millennium and a half earlier, this work was still considered relevant enough in 17th century England to be translated into English and published.

The author of the work, Pliny the Elder (23-79 CE), was a Roman naturalist, philosopher, and military commander. He was born to a privileged family within the second rank of the Roman Empire's aristocracy, giving him the opportunity to not only be a naturalist and philosopher, but to present his findings to the Emperor. Pliny the Elder was educated in Rome during the reign of Caligula, at a time when one had to be careful what he said and did so as not to be accused of being a dissenter and executed. When he was about the age of 23, Pliny began military service in Germany where he completed three tours of duty during his ten years as a cavalry commander. He was well known for his excellence as a military officer and befriended future Roman Emperor Vespasian during this time. He began writing during his time in Germany, releasing an instruction manual on the utilization of javelins by cavalry troops. When he was 36 years old, he returned to Rome, where the infamous Nero, whom Pliny described as "an enemy of the human race" (Stewart, 2017) was in power. Most of his time was spent on his studies and his writing. Towards the end of Nero's rule, Pliny became the procurator in Spain but returned to Rome in 69 CE after Nero's death and Vespasian's subsequent accession (Stannard, 2019). Pliny soon became one of Vespasian's most trusted advisors and would serve as governor of a succession of Rome's imperial provinces, likely including Spain, southern France, northern Africa, and Belgium. In addition to his governances, Pliny spent time in Rome advising both Vespasian and Vespasian's son, the future Roman Emperor Titus (Stewart, 2017).

In 77 CE Pliny published his famous 37-volume work, *Naturalis Historiae*, also known as *The History of the World* or simply *Natural History*. Dedicated to Emperor Titus, his work was the world's first encyclopedia. The work is one of the most substantial ancient works available in the modern age for modern readers (Stewart, 2017). The work of just over a million words was worked on for many years, with two assistants at Pliny's employ during its writing.

One assistant was responsible for reading aloud works by greats such as Aristotle, Hipparchus (a Greek astronomer, geographer, and mathematician), and Eratosthenes (a Greek mathematician, geographer, poet, astronomer, and musician) while Pliny noted the relevant facts from what he heard and dictated them to his other assistant to be included in his book. *Natural History* was especially important for the time period, as Pliny not only cited his references, a practice unheard of at the time, but also because he cited twice as many Greek authors as he did Roman authors. Though honest, this likely vexed him because Romans liked to believe that their civilization was in every way superior to that of the earlier Greeks. Romans had a tendency to portray the Greeks as untruthful, unscrupulous, and gullible (Stewart, 2017). Pliny cited over 100 sources in *Natural History*, using the first book of the work to summarize the remaining 36 books, and to list authors and sometimes the titles of the books he consulted, some of which are now lost (Stannard, 2019).

According to Pliny himself, his work was intended "for the masses, for the farmers and workers, and to interest people in their leisure time" (Pliny, 1635). He justified the title and explained his purpose on utilitarian grounds, stating that the book was a study of life itself. He continues to say that no one had previously attempted to bring together older, scattered material that belonged to the study of nature. In order to reinforce that the work was created for the common man, Pliny uses a plain style of writing. With such an ability to reach a broad audience, *Natural History* quickly moved through the population, largely due to a lack of copyright laws. With the decline of the ancient world and the loss of the texts upon which Pliny had so heavily depended, *Natural History* became a substitute for a general education for decades. The work was an unchallenged authority until 1492, when Niccolò Leoniceno (an Italian physician) published a work exposing Pliny's errors. At this point, *Natural History* and Pliny's teachings began to tumble and before the end of the 17th century they had been rejected by world's leading scientists. Though no longer a scientific authority, *Natural History* has been used to build an idea of first-century Rome and its culture (Stannard, 2019).

The work's thirty-seven volumes are divided by subject, and chapters of each volume are further separated into ideas. Various subjects, including astronomy, anthropology, geography, botany, horticulture, farming, zoology, medicine, chemistry, and art are all discussed in the massive work. To the modern reader the work seems a curious blend of scientific observations and strange myths. In the second volume, Pliny discusses cosmology and astronomy, though he was sometimes careless in translating details, resulting in distortion in the technical and mathematical passages. In Books 3-6, on the physical and geography of the ancient world, he emphasizes major cities of his time, many of which no longer exist. Books 7-11 discuss zoology, beginning with humans, then land creatures (mostly mammals and reptiles), creatures found in water, birds, and finally insects. Most of his biological data was derived from Aristotle, while his own contributions were concerned with the habits of mythical beasts such as the manticore, lycanthropes, and basilisks. In Books 12-19, Pliny discusses botany, the section in which he comes closest to "making a genuine contribution to science" according to Stannard (2019). Though he derived most of the information in these books from Theophrastus (a Greek philosopher and pupil of Aristotle), he reported many of his own observations from his travels in Germany. His observations are the main reason we know about Roman gardens, early botanical writings, and the introductions of new horticultural and agricultural species to Italy. Book 17 is especially important, as it details agricultural techniques such as crop rotation. In this book he also records the Latin synonyms of Greek plant names, making most plants mentioned in earlier Greek writings identifiable today. In Books 20-32, Pliny focuses on medicine and drugs that were not only useful for later physicians, but the average person as well in the form of home remedies. The final volumes of the work, Books 33-37 discuss minerals, precious stones, and metals as well as describing their uses in famous Roman artist's creations and their uses in Roman architecture and technology (Stannard, 2019).

The organization of the chapters reflect Pliny's classification of organisms. He fits all animals into five distinct groups: humans, land creatures, creatures found in water, birds, and finally insects. Though not explicitly stated, it appears that his grouping is based on Aristotle's hierarchy of living things as well as their uses for humans. This idea is derived from the order he placed the groups in as well as his descriptions. Land beasts are categorized by their ability to be harnessed or utilized for warfare, how they can be killed, and how effective they are at killing. He divides plants up into loose groups of exotic plants, aquatic plants, vines, fruit and nut trees, and evergreens. He does not provide reasoning for doing so and the groups are not as clear cut as defined as those for animals.

Pliny the Elder's ability to amass such a work in his later life is attributed by his nephew Pliny the Younger to be his nearly inhuman work ethic and his belief that "there is no book so bad that some good cannot be got out of it." In this spirit, Pliny the Elder read everything he could get his hands on. Indeed, he seems to have spent the entirety of his waking hours working and "the only time he took from his work was for his bath, and by bath, I mean his actual immersion, for while he was being rubbed down and dried he had a book read to him or dictated notes" (Lendering, 2000). Pliny was said to always have kept a secretary at his side with a book and a notebook and that he would be carried around Rome in a chair, so as to be able to continue working without wasting time walking (Lendering, 2000). Pliny the Elder was also credited with stating that "you must be awake to be alive." From accounts of Pliny the Younger, he held that philosophy close to him, as he only slept a few hours a night so as to have more time to work on his encyclopedia.

Natural History, though it does not directly contribute to modern classification or taxonomy, provides a fascinating glimpse into how the ancient world viewed the world and its living creatures. It is the only one of the seven works Pliny the Elder wrote that survives to this day. It is notable that Pliny's encyclopedia was compiled in the spirit of independent research with a desire to contribute to the world's knowledge, which was a foreign concept to the Roman mind. Scientific innovation had ground to a halt in the Roman Era prior to *Natural History* and was nearly as stagnant after its release (Williams, 2018). The work is not only one of the most important works in history, but potentially one of the most important works to pass on both the Roman worldview and scientific advancements from the era. It is quite likely that all the scientists discussed in this paper were aware of Pliny's work, whether or not they directly influenced them, and Pliny certainly shared their desire to contribute to the state of mankind's understanding about the world around him.

Early Printing and the History of Science

As part of my project, I researched the history of book production and publishing to better understand its impact on the dissemination of scientific works, including those works examined in this paper. Publishing is a particular concern with all books, as it has been an ever-changing process since its beginning. Before paper was introduced to Europe in the tenth and eleventh centuries, animal skin was used as the material for the pages of books. The skins went through a highly skilled process where they were treated, washed, and scraped in order to become parchment. This likely had its own market, similar to the production and trade of paper (McKitteric, 2000). There is evidence to suggest that animal skins were sometimes reused after a process of washing or otherwise erasing the text it held. Scribes often replaced texts for various reasons or made corrections rather than discarding the skin and starting over. Inks were made from a variety of substances, but iron gall ink and lamp black carbon-based inks were common. Quill pens were made from goose feathers or common reeds that are found on river banks across Europe. During the time that animal skin was used as parchment, scribes carried out an important function and were considered to be skilled workers (McKitteric, 2000).

As printing technology advanced, paper and illustrations made from woodcuts or later on, copper plates became commonplace. Due to the price differences between the two, copper plates were used almost exclusively for stand-alone images, maps, or title pages. Woodcuts were then used to fill in the space left by gaps in the text in the rest of the work. Woodcuts often had less detail because of the process of making them but were easier to make and therefore cheaper than copper plates. Woodcuts were made usually through a three-step process where an illustrator would draw the image intended to be used in the work, a second individual would transfer the drawing to a wood block, and then a sculptor or carpenter would cut the wood block. The sculptor or carpenter would be paid at a rate of three to five times that of a draughtsman per picture due to the skills required for the job. As stated earlier, this process was the most expensive aspect of printing a book, and due to this, printers often took out privileges to guard against the copying of the images that appeared in the books. These privileges usually ran between five and ten years and covered pictures and text found within the books. These early forms of copyright laws, however, were rarely enforceable and did little to stop others from doing what they were designed to protect from (Kusukawa, 2000).

As the printing process became more and more advanced, the ability for books to reach the common person increased at a nearly proportional rate. The first books were incredibly expensive and were often used almost exclusively to serve the needs of the church such as the printing of bibles and liturgical materials. When the printing process no longer required the copying of texts by hand, and a market appeared and a larger number of people could afford to not only to have books printed for them, but to also purchase already-printed books. This took time, as initially artificial prices were set by the publishing elite until 1774, when books had become cheaper and more readily available to the general public (Murphy, 2010). This, like all new markets, started exclusively serving the rich and eventually moved its way down to the average person. Between 1600 and 1800, the production of books began with the author, who contacted a publisher. The publisher contracted a printer to print the work, afterwards selling it to a distributor. The distributor sold the book to individual booksellers, who would then pass works on to readers. This process was a sharp contrast from how books were produced in the early years of printing. Previously, the author contacted the publisher, who then may have contracted a printer or printed the book themselves. The publisher would then sell books to the bookseller, who would pass the books on to the readers. This slight change in the circulation process had a large effect on the authors, who began to increasingly write for the bookseller instead of writing for themselves (Feather, 2009).

As books became more commonplace, they began to be sold internationally. Initially this new international market was dominated by the Dutch, who were able to increase their book markets due to Antwerp's fall to the Spanish in 1572 and the persecution of Jewish peoples at the time. The Spanish sack of Antwerp allowed Amsterdam to assume a position as the center of the international trade. Many Jews persecuted by the Spanish moved to Amsterdam, increasing the Hebrew book trade and subsequently dominating the Eastern European book market. Amsterdam's international reach was further increased due to refugee migrants coming to the city in 1685. France later took the place of the Netherlands just after 1750, when Guillaume-Chrétien de Lamoignon de Malesherbes (1721-1794) became the director of Louis XV's office of pre-publication censorship. He heavily opposed the censorship privilege claims of France's parliaments and episcopacy. With only a few years of holding his position as director, Malesherbes increased the French book trade to a level that could compete with, and eventually surpass the Dutch (Van Vliet, 2009). With the international book trade largely being centered around Eastern Europe, it is important to note that information was spread largely between major European cities. The farther away from the city you moved, the more difficult it was to get information. Large distances meant that information was likely passed more slowly between European and Arab cities, with information being passed to and from Asian civilizations at an even slower rate.

The increase in book production also encouraged scientists to write about and claim their position in history, whereas in the past they would tend to keep their findings mostly to themselves, being afraid of others falsely claiming ownership of them. With the publishing process becoming cheaper, scientists, though in their eyes still competing with each other, were more willing to release their works because they could more easily prove that their ideas were indeed their own.

Factors Inhibiting Publication and Scientific Dissemination in Britain

In Britain, government legislation restricted the conditions under which foreigners could conduct business. This especially applied to printing and other publishing techniques. As time progressed, printing companies became more complex organizations, employing scribes, illuminators, and book binders. Control of published works in the country was further increased in 1557, when the Stationers Printing Company used individuals under its employ to create a partial hold on the government, in turn forming a virtual monopoly on printing in England. The government allowed Company officers to search and seize "seditious or heretical material" from all printers and associated trades in London (Murphy, 2010). In addition, they were given almost complete control in regulating the publishing process and enforcing a system of copyright. The company ran aspects of the printing, publishing, and sale of books in Britain. Being based in London, the Stationers Printing Company reduced publishing in other parts of the country as well, making London the main hub of printed information. In 1662, a governmental position for official surveyor and licenser of the press was created. This signaled the demise of the Stationers Printing Company as the office associated with this position took over the vast majority of the duties given to the company. In 1693, the government control of printing (even with the loss of licensing provisions) was established; the seriousness of this is exemplified by the case of printer William Anderton who was tried and executed by the government for treason because he printed an anti-parliament work at his press (Murphy, 2010).

In the 18th century, printers began to offset their costs by using a subscription service as their business model. Large or costly projects could be undertaken by first securing a subscription from an individual who reserved his or her copy of the printed work. Another strategy used at this time was to print separate parts of a work through different publishing companies, effectively alleviating the financial burden of a single publisher taking on the work. According to law, publishers were given power to the extent that they were allowed to buy and sell rights to a book and could will it to another person upon their death (Murphy, 2010). It would be fair to assume that similar controls and restrictions, ranging from outright censorship to constrains of the marketplace were common throughout Europe.

Scholarly societies also served to support publication of some work and suppress the publication of other works, much like professional societies today. Such groups, like the Royal Society of London for Improving Natural Knowledge (or Royal Society for short) were made up of scholars from many of the top universities of the time and often had the last say as to whether a scholarly work was acceptable for publication and dissemination. Though many of these groups started as independent organizations, they were often associated with the government during this period. The Royal Society, being one of the most influential and important scholarly societies in the world, had a significant influence on scientists such as Nehemiah Grew and others. The Society began in 1660 when twelve men at Gresham College in London met and resolved to set up a group to promote science and mathematical experimental learning. This meeting marks the beginning of like-minded scientists working collaboratively for the sake of scientific progress. The idea of the group was to combine the role of research institute with that of a clearing house for knowledge and an establishment for settling scholarly disputes, of which there were many. (Hunter, 2017). Initially, disputes were settled by referring back to statements of an older authority, such as Aristotle and Galen, who were the source of much of the scientific and medical knowledge that was known at the time. As the Society progressed into the seventeenth century, its members collectively decided that while older authorities' experiences were important to set the stage for a topic, they should not necessarily take the place of experiences of Society members. This marks a turning point in the history of science, in which the works of ancient Greece and Rome were regarded as important representations of their time, but no longer relevant to the modern era. (Skouen, 2015).

In addition to censorship and factors inhibiting the flow of published material including scientific works, the scientific community also influences scientific discourse. Although scientists may work together to contribute to scientific understanding, they may still be competing with each other for reasons that don't appear to have changed much through the ages. A place in history is the end goal for many and the greater the impact of their findings, likely the greater their place in history will be. There are numerous occasions in history when the scientific community itself refuses to accept new findings, especially if they appear to disrupt or question the scientific canon. A recent example serves to illustrate exactly this. Not long ago, a scientist discovered an interesting DNA sequence in fruit flies (Nowak, 2019). This gene, called *Dscam*, is able to code for over a thousand combinations of genes, each of which are expressed under different circumstances. The scientist who discovered the gene drove himself to insanity attempting to replicate his initial finding, only for the gene to be sequenced years later and discovered to do exactly as he had described. Prior to the gene's sequencing, a majority of scientists believed that his findings were false because they could not be verified by replication. This case was used to discover a process whereby genes sometimes combine to express differently, called alternative gene splicing. All of the factors inhibiting scientific discourse discussed in this section are still with us today and sometimes they occur in surprising contexts.

Conclusion

The history of the sciences is often distorted by the sheer amount of discoveries, the loss of scientific works to time, and the indifference of historians to lesser discoveries. This is especially true with scientists whose ideas, such as taxonomy, have been eclipsed by another's. From this project I have learned of three great scientists that I had otherwise never heard of and I had the opportunity to explore not only their greatest works, but their ideas and points of view. I have had the pleasure of gaining an understanding of biological sciences and taxonomy from a historical perspective, which I would have been unable to obtain otherwise. I have learned that the history and even modern views of science have been dictated and influenced by not only other scientists, but organizations and governments that have acted upon their own interests.

As this was a relatively short project restricted to two semesters of time, there was no way to write a comprehensive history of the development of the current taxonomic tool we have today. Given more time to work on this project, I would have explored other perspectives of the classification of organisms and the scientists that proposed them. A few questions that have been raised and could not be fully explored by my research include how censorship and the stifling of scientific publication has influenced scientists and how their ideas were therefore influenced by third parties. I would also like to investigate how other prominent scientists (who were not explored) classified organisms, and how Darwin's theory of evolution has combined with Linnaeus' classification system to create the modern structure and beliefs in the study of biology. These are questions that I will definitely be looking into further in my career as a biologist and I hope will be looked into by others so as to create a more complete view of the science of biology as a whole and a better understanding of its history.

Annotated Bibliography of Historical Works From the Bentley Rare Book Museum Collection

Bliss, Carey S. (1977). *A leaf from the 1583 Rembert Dodoens herbal printed by Christopher Plantin*. San Francisco: Book Club of California.

This book features a single printed and illustrated leaf of an original printing of the 1583 Rembert Dodoens herbal entitled *Stirpium Historiae Pemptades Sex Sive Libri XXX,* also known as Dodoen's "Great Herbal." One of the last works to appear during Dodoen's lifetime, the work relies on Dodoens' own observations and knowledge, taking little from previous scholars. The original leaf is supplemented by essays on the history of herbals, a biography of Dodoens, a biography of Christopher Plantin, the printer of the book, and finally an analysis of the work itself. Plantin is notable for his prolific publishing and printing activities in the 16th centuries.

The leaf is printed on both sides and represents pages 139 and 140 of the original volume. The text is in Latin and the woodcut illustrations are labelled and correspond to descriptions in the text.

Grew, Nehemiah (1682). *The anatomy of plants: with an idea of a philosophical history of plants, and several other lectures, read before the Royal Society*. London: Printed by W. Rawlins.

This book consists of a number of lectures on plant anatomy and other aspects of plants such as color and the nature of salt solutions. The most notable aspect of the book, besides Grew's observations on the mechanics of plants is the 83 leaves of fine detailed copperplate engravings of plant specimens, many of which show the structures of various components of plants. This text is significant as it illustrates the advances made in botany at this time. Advances in botanical sciences were made more quickly and earlier than other life sciences, so this book stands at the beginning of our current modes of scientific understanding, at a time when other sciences such as anatomy and physiology and chemistry were just beginning to come into their own. It is especially useful for understanding the ideas and thought processes of scholars from the time period and for understanding the significance of the Royal Society in fostering scientific discourse in Britain.

Pliny, the Elder (1635). *The historie of the world: commonly called, the natural history of C. Plinius Segundus* (Vols. 1-2). Translated by Philemon Holland. London: Adam Islip.

This two-volume set of books was published in 1635 and is an English translation of Pliny the Elder's *Natural History*, completed and published 77-79 C.E. It covers a variety of topics, including astronomy, biology, physics, alchemy, and geology and is a fascinating view into the ancient Roman worldview. Pliny intended the work to be a comprehensive work representing all that was known; in this respect it can be considered the first encyclopedia ever published. The translator of the work, Philemon Holland, was notable for his work translating ancient authors into modern English and presenting them to Queen Elizabeth I. Pliny's work was already known in England, but Holland was the first to translate it into English. It is notable that the work of ancient authors such as Pliny were still of great interest in 17th century England.

Linnaeus, Carl (1957). *Species plantarum: a facsimile of the first edition 1753*. With an introduction by William T. Stearn. London: Bernard Quaritch.

This two-volume set of books is a 1957 facsimile of the 1753 edition of *Species Plantarum* printed for the Ray Society. The Ray Society honors the memory of the great English naturalist

John Ray (1628-1705) who, like Linnaeus, worked with the classification of plants. The book includes a preface and introduction by William Thomas Stern in the first volume, and an explanatory index of Linnaeus' abbreviations in volume 2, provided by J. L. Heller. The facsimile was made from a clean copy of the text in belonging to the Linnaen Society of London. Unlike Nehemiah Grew's *Anatomy of Plants*, Linnaeus' work does not include illustrations.

References

Banham, Rob, et al. (2009) The Industrialization of the Book 1800-1970. *A companion to the history of the book* (pp.273-290), Blackwell Publishing Ltd.

Britannica, T. E. (2019, March 21). Nehemiah Grew. Retrieved March, 2019, from http://www.britannica.com/biography/Nehemiah-Grew.

Dover, Paul. (2019). *The Book of Nature and the Books of Man*. Unpublished manuscript.

Eliot, Simon, and Rose, Jonathan (2009). From Few and Expensive to Many and Cheap: The British Book Market 1800-1890. *A companion to the history of the book* (pp. 291–302). Oxford: Wiley-Blackwell.

Feather, John (2009). The British book market 1600-1800. In Simon Eliot & Jonathan Rose (Eds.) *A companion to the history of the book*, (pp. 232–246). Oxford: Wiley-Blackwell.

Frasca-Spada, Marina, and Jardine, Nick (2000). Introduction. *Books and the sciences in history* (pp. 1–10). Cambridge University Press.

Garrett, Brian Johnathon (2011). The Life and Work of Nehemiah Grew. *The public domain review*. Retrieved from https://publicdomainreview.org/2011/03/01/the-life-and-work-of-nehemiah-grew/.

Hunter, M. (2017, January 12). Royal Society. Retrieved March/April, 2019, from http://www.britannica.com/topic/Royal-Society.

Kusukawa, Sachiko (2000). Illustrating nature. In Marina Frasca-Spada & Nick Jardine (Eds.) *Books and the sciences in history* (pp. 90–113). Cambridge: Cambridge University Press.

Landau, David, and Parshall, Peter (1994). The Cultivation of the Woodcut in the North. *The Renaissance in print: 1470-1550* (pp. 245-259), Yale University Press.

Lendering, J. (2000). Pliny the Elder, Natural History. Retrieved March, 2019, from http://www.livius.org/articles/person/pliny-the-elder/pliny-the-elder-natural-history/.

Linnaeus Hortus Cliffortianus frontispiece cropped.jpg. (2015, November 01). Retrieved April 08, 2019, from https://commons.wikimedia.org/wiki/File:Linnaeus_Hortus_Cliffortianus_frontispiece_cropped.jpg

McKitteric, Rosamund. (2000). Books and Sciences Before Print. In Marina Frasca-Spada & Nick Jardine (Eds.) *Books and the sciences in history* (pp.13-31). Cambridge: Cambridge University Press.

Murphy, Andrew D., et al. (2010). "History of the Book in Britain, C.1475-1800 " *History of the book in Britain, C.1475-1800* (pp. 172–179). Oxford University Press.

Nowak, Scott J. (2019, January 11-14). *Chapter 3: Developmental Genetics*, lecture notes, Developmental Biology BIOL4390, Kennesaw State University.

Pough, F. Harvey, and Christine M. Janis. (2018) *Vertebrate life*. 10th ed., Oxford University Press.

Reece, Jane B., et al. (2014) *Descent with modification: A Darwinian view of life*. 10th ed. (pp. 462–478). Pearson Education Inc.

Revolvy, LLC. (accessed spring 2019) "'Nehemiah Grew." *Revolvy*, www.revolvy.com/topic/Nehemiah Grew.

Rossi, Paolo L., and Maurice Slawinski (1991). *Science, culture and popular belief in Renaissance Europe* (Stephen Pumfrey Ed.). Manchester University Press.

Skouen, T., et al. (2015). *Rhetoric and the early Royal Society: A sourcebook*(Vol. 3) (T. Skouen, et al Ed.). Koninklijke Brill, NV.

Stannard, J. (2019, February 14). Pliny the Elder. Retrieved March/April, 2019, from http://www.britannica.com/biography/Pliny-the-Elder.

Stewart, D. (2017, May 23). Pliny the Elder. Retrieved March 25, 2019, from http://www.famousscientists.org/pliny-the-elder.

Van Vliet, Rietie, et al. (2009). Print and Public in Europe 1600-1800. *A companion to the history of the book* (pp. 247-258). Oxford: Wiley-Blackwell.

Williams, L. P. (2018, November 30). History of science. Retrieved March/April, 2019, from http://www.britannica.com/science/history-of-science#ref29324.