How Have Human Elements Influenced Affected Animal Taxonomy Since the 1850s in Comparison to Botanical Taxonomy?

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"I didn't fail 1,000 times. The light bulb was an invention with 1,000 steps" (Albert Einstein). This famous quote illustrates the view of most scientists. Even when they fail (possible numerous times) scientists who believe they are correct will continue to try to prove that they are right. Taxonomists, biologists that group organisms into categories, are no different. Their concept of how to arrange species is the best in their opinion, and it takes quite a bit to change their opinion. Along with arranging species, taxonomists also commonly name them--especially the early scientists.

Early taxonomists understood the value of a name and the way that it conveys knowledge. In fact, Sir William Kirby said that without naming, species may just as well have died unknown in the wild than to mold unnamed in our drawers (McQuat 2016). To him, it would be better for humans to never discover a species than to collect it and never name it.

Importantly, once specimens are named, they become a possession, and their values increases (McQuat 2016). One scientist, Gordon McQuat (1996) has a cynical view that species are only about power, possession, capital, and their influence on the status of naturalists. Considering the benefit that naming a new species is to a career, McQuat may be correct in that opinion.

But not all naming systems are the same or of equal value. An important concept to summarize is taxonomy which produces a formal system for naming and grouping species to communicate a specific order within nature. Taxonomy has a basic goal--it simply seeks to organize and classify species. However, as we will see, every part of that goal has conflict and hidden agendas and can never quite seem to escape evolutionary theory after it was proposed.

History

Taxonomy has its main origins in Aristotle when he created his *Scala Naturae*, or a ladder of nature (Tilton 2009). The ladder is referring to the concept that there is a natural hierarchy of importance to animals. For example, fish are lower than reptiles, which are lower than birds, ending with humans on the very top. He named some species and made some attempts to classify them but did not create an entire taxonomic system. Aristotle's concept of hierarchy among animal groups existed for about 2000 years.

In 1735 Linnaeus, a Swedish naturalist who focused mostly on botany, established a naming and classification system with ranks. Most scientists organized animals anyway they wanted without trying to synchronize with other taxonomists. The problem with that practice is the confusion that arises when multiple scientists name the same species different things. This habit is still in practice with common names, largely due to language barriers, but the problem was that species had multiple scientific names. This practice meant that any publication under one name might not be read by another scientist studying the same species under a different name. Synonyms (different names for the same species) are still an occasional problem now and create a gap in knowledge and application until discovered and corrected (Witteveen, 2016).

Before 1753, when this practice was common, this bad habit resulted in ineffective communication (Dixon & Brishammar, 2017). The solution was highly debated within certain groups of scientists (e.g., those studying birds, mammals) instead of trying to compromise or agree on one solution. Linnaeus created a system that gave the field a chance to start over, a binomial nomenclature system with rules to be followed, for all species (that he knew). Such an undertaking meant that Linnaeus named 4,400 animal species and an impressive 7,700 plant species (Dixon & Brishammar, 2017). As the numbers display, Linnaeus was much more of a botanist than zoologist--not as large a distinction in the 1700s, but it became an issue in the 1800s. Why? Linnaeus started botany and zoology on parallel tracks; however, he was not familiar with situations zoologists have to deal with. For example, plants do not mutate as quickly as animals, and zoologists have to investigate varieties much more than botanists (Zimmer, 2014). This lack of familiarity is one of the causes for the chaos in the field of zoological taxonomy. Linnaeus' spot in history is where most schools end teaching on taxonomy. But they are missing the best parts. They are missing the human component, scandals, and personality.

How does science get influenced?

Science is more than facts and conclusions. A large step of the scientific process is 'interpreting' the data using statistics. Scientists collect data and try to understand what the data is telling them. Just collecting data does not inform others of what conclusions can be made. The use of statistics helps scientists to determine objectively whether results are valid or invalid.

As necessary as statistics is, there are some conclusions that require a subjective evaluation as well. A researcher could measure the time an animal spends pacing, but that does not explain why the animal is pacing. That last part is where the human reasoning and beliefs come in. Although science is meant to be unbiased, humans are the ones performing science; therefore, it always has desires attached. We see the public influence on modern science with global warming. This topic should be scientifically decided and accepted or rejected based on unbiased data. Any scientist can create graphs or charts that show plainly the Earth is warming up faster and to a higher degree than we have ever seen. Based on accurate data, global warming is in fact occurring. However, we see politics and personal opinions affecting what scientists do and do not publish.

Beyond the political realm, the public concern also affects what is being researched. Citizens prefer that tax dollars are spent funding academic areas that will directly benefit them or that they support. This desire of the public, as well as private funding agencies, have a far-reaching effect on science. For example, more money is spent supporting cancer research and less on how well squirrels remember where they buried their nuts. Scientifically, both are important, but in culture, cancer has a greater personal impact. Beyond that, there is often public outcry that tax dollars (even a minute amount) are spent on anything as ‘frivolous’ in appearance as this squirrel research.

Taxonomy has not been unaffected by this interconnection between science and society. Since before Linnaeus, there have been arguments over the best way to classify animals, and even which system to use. These arguments led to alliances and personal attacks between taxonomists who sought to have their way accepted, which have shaped the path that this scientific field took.

Beyond the common debates and arguments are scientists who want to be remembered. There is a lot of pressure in the scientific field to be published and discover or invent something vital to the specific field of study. That drive can cause otherwise upstanding scientists to push boundaries or morals aside.

Although not the most popular field, systematics is an important part of the natural history of animals. Knowing which species are related to an organism about which little is known often helps zoological organizations predict and prepare for possible behaviors of the lesser-known species. One example is Sichuan takin. They are a goat-antelope species from China. This species lives very high up in the mountains, and because they live at dangerous altitudes, they are very difficult to study. China decided to send some takin to The Wilds in Cumberland, Ohio. Without much to go on, The Wilds had to set up habitats based on the behavior of goats and antelopes. Through this connection, they were able to provide the correct care while quickly improvising for species differences.

Taxonomy often plays into many different disciplines as well. For example, taxonomy can give a basis of research for a new species by knowing and defining characteristics of others in its genus. Beyond that, taxonomy today often partners with genetics. Genetics helps systematists correct their trees, and taxonomy helps geneticists compare and research genomes in a real-world context. In fact, a new orangutan species was recently discovered using genetic analyses (Goldman, 2017).

Because taxonomy impacts so many other fields of biology, it is important to know the history of taxonomy. Why do we follow the rules we do? Also, we should know what ideas were rejected and why. There may have been a fantastic system introduced that was rejected at the time but would have made taxonomy so much easier. Culture and science interact on a daily basis. This process needs to be more recognized in the sciences, and its effects need to be analyzed on a deeper level. This thesis endeavors to do just that.

Background

To accomplish this goal, I will be investigating what cultural influences have affected animal taxonomy since the 1840s and will interweave the effects of those same influences on changes in botanical taxonomy. There are, in place, different taxonomic societies for both botany and zoology. These societies have established rules to be followed if the taxonomists want to receive validation. There are rather extensive rule systems with very lengthy handbooks. Botany's International Code of Botanical Nomenclature (ICBN) was formally started on May 1st 1753 (International Code of Botanical Nomenclature, 2012) and the International Commission on Zoological Nomenclature was founded on the 18th of September 1895 (History of ICZN, 2016). The difference in established dates may seem extreme. However, the ICBN is very loyal to Linnaeus and states his publication as their beginning. In zoology, the rules of taxonomy were established through museums rather than a particular code.

The comparison between zoology and botany is to try to evaluate why botany went in some different taxonomic directions and why its independent rules of naming and classifying focus on different things than zoological taxonomy rules do, when the taxonomists often went through the same influences or were the same people. My current hypothesis is that, to botanical taxonomists, the ideas of evolution are not as threatening. There is little published evidence for this hypothesis, however, there is many circumstantial pieces. For most individuals the idea that plants come from bacteria is not a far stretch. In opposition, the concept that humans came from the same bacteria often seems unbelievable. I also propose that the subject matter influences the type of person who chooses it. The chaos we will see in animal taxonomy is often reflected by the personalities of its taxonomists.

From 1735 to the 1840s, there were minor disputes but nothing that changed the system in a drastic way. In fact, we saw very little communication between scientists within the taxonomy field. Then in the 1840s, with America growing, Europe fighting within itself, and Asia being sliced up by European powers, we see a similar theme of disunity and fighting within taxonomy. A recurring cycle of quiet and chaos plagues the taxonomic system from the 1840s on. We will investigate some reasons why, as well as how the key players in the disputes and how the cultural opinion of the topic influenced who won, and what system scientists use today.

To do this we will focus in on four different time frames. The first is the 1840s, when Edward Gray and Hugh Edwin Strickland (both taxonomists) competed for whose taxonomic system would be accepted. In the same time period a nephew of Napoleon sought to unify taxonomy and his country. Then after the 1940s, population geneticists joined the fray; Ernst Mayr founded the field of systematics. This new field changed the way that scientists thought of how species relate to one another. In the 1950s, Willi Hennig took this new field a step further and founded the field of phylogenetics, which established stricter rules on the way to think about species and taxonomic groups, placing a higher importance on evolution than some scientists felt comfortable with. Finally, we will look at the modern age and possible future routes. These are the four time periods (after Linnaeus) that most shaped the current taxonomic system, but they were times of bickering and chaos.

1840: Strickland Code

This thesis begins in the 1840s with Hugh Edwin Strickland developing and proposing the Strickland Code to the British Association for the Advancement of Science (BAAS). He was born in 1811 in Yorkshire (Jardine, 1858). From a young age, he desired to see the world and be ‘locomotive’ rather than be educated and sit on his estate doing very little (Jardine, 1858). Instead of hanging around his estate, he became a naturalist. In his time this was the equivalent of a general biologist. Strickland studied everything from taxonomy to ornithology to geology.

Strickland wanted to standardize naming because a common problem in this time period was synonyms for species named after Linnaeus. Synonyms occur when one species has been given different scientific names by different people. In fact, he stated that “species names are as variable as the London fashions” (Witteveen, 2016). He made the connection between the fickleness of his peers and their scientific habits. Just as his peers were inconsistent in their social lives, they changed their fancy in their scientific decisions. Darwin even commented that the wrong spirit influences natural history because some felt that they had earned some merit just by merely naming a species (Darwin, 1887). Taxonomists would gain some fame through ‘discovering’ a new species, and often did so for that simple reason. They would then not describe the animal fully, and it would end up being a synonym.

Strickland worked to clarify a species’ true scientific name through his revolutionary idea of priority. His rule said that, starting with Linnaean names, the name assigned by the first person to name it is the name that should be used. In the proposal, Strickland stated that the purpose was to “establish the rules of the nomenclature of zoology on a uniform and permanent basis” (Strickland, 1864). The main concern was what to do when a commonly used scientific name was not the first one. Strickland wanted a strict adherence to the rule, and for the most part that was achieved, but some ‘first names’ were in small publications that hardly anyone had read. Most taxonomists of Strickland’s time still used the common scientific name, acknowledging that this was not the best option, but they were too inconvenienced to care (Darwin, 1887).

Strickland himself was not well known in the BAAS. However, that was the society that almost any British naturalist would listen to, so he had to get them to support his idea if he wanted a universal application of this concept. He was a part of the society since 1837 and asked his father in law, William Jardine to support him (Rookmaaker, 2011). Jardine was a rather famous naturalist himself;

he was one of the first to publish pocket-sized field books of species. Despite the fact that the official minutes of the society meeting in 1841 did not include anything about the proposal, a committee was appointed (Rookmaaker, 2011). This is an interesting aspect; it shows that the society was behind it unofficially but at the time did not devote much official meeting time to the idea. In December 1841 Strickland was granted a BAAS supported committee--as long as Strickland found the people himself.

The committee had 12 members, and Strickland actually chose more of a recorder role than chair member. There were several ‘big names’ on the committee. Probably the most well-known one was Charles Darwin, the father of evolutionary theory (although his *On the Origin of Species* wouldn’t be published for another 17 years). Darwin was on Strickland’s committee because he believed priority would help to solve the problem of rampant naming, even if he struggled to follow it completely himself (Darwin, 1887). The proposal was presented in 1842. At first, the general idea was accepted--no one could argue about the current chaos in the taxonomic system.

However, several of the members present felt that Strickland was attacking them personally and started to object to his ideas. In the words of Jardine (his father in law), there was “an opposition that was scarcely expected, couched in a spirit of prejudice, and almost jealous animosity, which was discreditable to the contents” (Jardine, 1858). Because this further bickering took so much time, the report could not receive a final decision.

Although the BAAS gave a very small amount to help in the dispersal of pamphlets detailing the Code, the association never officially reported the code in their minutes. But when Strickland published and dispersed those pamphlets, the title included the BAAS. How then did Strickland have the right to attach their name to his proposal? Rather ingeniously actually.

Strickland had to be sure that he would be heard, and without a publication in the official report, he would not have the backing of the Society. Overall the distinction is not a large one, but being able to directly print the rules with the Society's name (and therefore the impression of a backing) would solidify the authority of the rule (Jardine, 1858); in other words, with this backing, other taxonomists would be more likely to follow the new rule. Even though largely ignored by history, Strickland showed his political maneuvering in the final title of his rules. The full title is "Series of propositions for rendering the nomenclature of zoology uniform and permanent, being the report of a committee for the consideration of the subject, **appointed by the British Association for the Advancement of Science**" [bold face added] (Rookmaker, 2011). He did not say anything out of turn, but the bolded part suggests a close connection to the Association that was not there.

This rule of priority suggested by Strickland is still used today, in fact, and most modern codes have been somewhat influenced by Strickland (McQuat, 2016), but few people have heard of Strickland. How did he get lost in history?

Around the same time that Strickland proposed his code, a colleague of Strickland (John Edward Gray) was developing his own system based on the idea of typological species established in the British Museum. Gray was born in 1800 in Staffordshire, eleven years before Strickland. Gray was a part of zoology specifically. Gray's idea of classification hinged on a physical typological species system. This system is where, for each genus, there is one species that defines what it means to be a part of that rank. For example, humans are the type species of the genus *Homo*. Gray would have the type species established at his museum. Once Gray recognized the threat to his system by the potential fame of Strickland's new code, if supported, he set out to disgrace Strickland's name--not specifically his code (McQuat, 2016). At the meeting in Manchester, where Strickland's proposal ran out of time to receive an official vote, Gray made several arguments against Strickland's new system. He proposed that the new code should be directly compared to Linnaeus's, and any changes should have a detailed explanation for their necessity (Witteveen, 2016).

Although the idea of type species is not mutually exclusive with a priority rule (as shown by both being in use today), Gray's new code would be overshadowed by the acceptance of a new system. Gray used the chaos of other systems to his advantage. By this time period, taxonomists were rather tired of the constant bickering. To make scientists feel secure, he strategically established his code with the British Museum--a well-respected and stable foundation (McQuat 2015).

He knew that fame would come to the scientist (and organization) whose system was used. Fame seeking is actually the exact way his system was designed--to make the museum curators (of whom he was an assistant in the

British Museum Zoological Department at the time) the protectors of the new species. Even a step further, he would make them "guardians of species limits" (Witteveen, 2016). This designation meant that even if classification radically changed, the species themselves could not. The species as defined in the early 1840s would be the same species today because we had a visual model to compare to. This continuity is what Gray strived for and on which his system was based. As history played out, he was correct in his belief of the personal benefit of a successful system attempt, as his efforts led to him being instated as the head curator of the British Museum (Witteveen, 2016).

To accomplish his system's acceptance, Gray used his popularity and connections to push his code. It was rather easy for him because Strickland was concerned with his own code but was not well versed in the subtle politics of the BAAS. Strickland did not lobby for his code very much, trusting in the inherent logic of his system rather than actively defending it. Strickland also was not able to fully express the need for his rules; in fact, after the Manchester meeting, a reporter described them as 'personal opinion,' even though Strickland strove for strict science and no bias (Rookmaaker, 2011). Strickland was someone who thought that if it made sense, it would be accepted, and to him, priority was common sense. Without the fight on Strickland's part and with the connections of Gray, Gray was able to discredit the code by getting the other scientists to ignore Strickland's suggestions (Rookmaaker, 2011).

Interestingly, in comparison to botany, when Strickland started to circulate his ideas, one of his peers, Professor Owen, encouraged his efforts. The reason for the encouragement? Owen stated that botany had been regulated by its botanists setting the taxonomic rules, and he posed the question “may not zoologists yield to similar guidance?” (Jardine, 1858). It seems that even in the 1850s, zoologists seemed to be the independent ones of science, while botanists, in general, were known as the orderly ones. This stereotypical distinction will continue to be a common theme throughout the history of taxonomy. One of the reasons for this distinction may be because plants are mostly stationary with little violence. Animals are rather the opposite and we see this difference reflected in the taxonomists.

1842: Biocode

In the same time period as Strickland’s drama, Italy was undergoing a period of reunification. There were four rulers of Italy: the king of Sardinia, the Austrian emperor, the pope, and the king of the Two Sicilies (History of Italy, 2017). In 1848 citizens in multiple regions begin to revolt, demanding a united Italy (History of Italy, 2017).

The nephew of Napoleon, Carlo Luciano Bonaparte, the Prince of Canino (a western province of Italy) saw a similar chaos in taxonomy and tried to solve it. During this era, politicians often had a closer tie to the scientific realm than they do today, as it was seen then as a position of intellect. A gentleman needed to be well rounded in many fields, and many individuals had their hands in multiple pies. Science and learning was a way to separate themselves from peasants, which meant the ones in power were also the ones conducting research--there was very little distinction (Carter, 2011).

So Bonaparte suggested a new taxonomic code: the BioCode. His idea combined both fields of animal and botanical taxonomy under one set of rules. This was the main point of his proposal, and he set up a committee to begin drafting rules (Minelli 2008). Bonaparte proposed it at one of many ‘congresses’. These meetings were places where different viewpoints could be discussed freely. It can be argued that the congresses Bonaparte created, such as this one, led to the reunification of the Italian state (Minelli 2008). He invited scientists and politicians from the eight realms of Italy that he was trying to reunite, which provided a setting for them to express both kinds of views (Minelli 2008). In fact, debating and expressing political views were encouraged, if not the main point of the meetings (Minelli 2008).

As we do not have a Biocode currently, the question has to be asked ‘why not’? There was strong opposition from several influential scientists, as well as some concern over the difference of terminology already present between botany and zoology (Minelli 2008). We see many similarities between the code he was proposing and the political goals he had. Both looked to reunite, end chaos, and bring Italy to the forefront of discussions.

1940s: Mayr and Simpson

In 1859, around twenty years after Strickland’s proposal, Darwin published his revolutionary book *On the Origin of Species*. He detailed how evolution could work through the process of natural selection. Before its publication, his work could not influence taxonomy, but almost eighty years later it would.

Jumping forward to around the 1940s, taxonomy had settled down a bit. Strickland's Code was largely forgotten, but his idea of priority was widely established. Gray's idea was often mistaken for a different concept and in the end was largely ignored. On the scene comes Ernst Mayr; he was born in 1904 in Germany (Meyer, 2005). Arguably his most influential work was *Systematics and the Origin of Species*; for which he earned the nickname 'Darwin of the 20th century' (Meyer, 2005). In this book, Mayr emphasizes that geographic variation occurs when new geographic boundaries divide populations, either quickly (a new highway being built) or over time (mountain ranges forming), and these populations often evolve into separate species. In Mayr's view, the acceptance of Darwin's theory of evolution, combined with geographic variation, could not help but produce a 'revolutionary change' within taxonomy (Mayr, 1942), with evolution tying everything together. Instead of grouping animals based on physical similarities alone, taxonomy now should reflect evolutionary relationships.

One of Mayr's most memorable contributions was his work with the Modern Synthesis. This new theory combined genetics, paleontology, systematics, and other fields into one that showed how evolution was possible. In other words, the Modern Synthesis combines Darwin (the father of evolutionary theory) and Gregor Mendel (the father of genetics) through statistical population genetics models (Ernst Mayr and the Evolutionary Synthesis, 2001). The Modern

Synthesis' actual end result was that evolution was applied to every aspect of science. One devoted founder even wrote a paper titled "Nothing in Biology Makes Sense Except in the Light of Evolution" (Thomas Dobzhansky).

In this time period, the question of a classification system had not ended, but it was on the backburner because there was another question that taxonomists had to attempt to answer first.

What is a species? This question was not innovative to Mayr. Thomas Huxley and other contemporaries of Darwin asked the same question when he proposed his theory on the origin of species. Huxley was nicknamed the bulldog of Darwin because he faithfully defended Darwin's theory of evolution against the critics. In one speech to the Royal Institution of Great Britain, Huxley detailed several important points (to his time period) for deciding what a species was. Among them were structural characteristics, how those characteristics functioned, the geographic range, if they interbred, and the presence of characteristic markings (*Proceedings of the Royal Institution of Great Britain*, 1860). This set of criteria was enough for the general taxonomist in the 1800s, but by Mayr's time, scientists needed more firm guidelines.

Mayr suggested that the origination and classification of species cannot be discussed until we know what species are (Mayr, 1942). This statement is rather accurate, because if taxonomists are not sure of the definition of the units they are grouping, they may or may not group them correctly. He did not have an answer to end the debate forever, but Mayr did suggest a new species concept that was accepted for many years and is still the most widely used definition today. His concept is usually referred to as the biological species concept and simply states that a species is composed of all potentially interbreeding individuals that share a niche and excludes any individuals with which they cannot produce viable, fertile offspring (Mayr, 1942). A niche is the specific range of conditions within which an organism can live and reproduce and the role it plays (e.g., producer, herbivore, carnivore).

George Gaylord Simpson (a colleague of Mayr) added to Mayr's species concept. To nonscientists Mayr's concept seems to cover all bases--if it breeds together and has the same niche and looks the same it must be the same thing. After all, there is the old adage that if it walks like a duck and talks like a duck--it is a duck. But Simpson thought about the organisms that do not sexually reproduce and also about how to classify fossil species, because it is impossible to know with whom extinct individuals could breed. Simpson's additional concept was much more technical but stated that species should have "a phyletic lineage evolving independently of others, with its own separate and unitary evolutionary roles and tendencies" (Simpson 1951). A phyletic lineage means one where there are ancestors and offspring. This point allows for asexually reproducing animals, as they do have generations. Also, separate evolutionary tendencies can be traced through the fossil record most of the time. Simpson felt that this was the best way to decide a species.

Beyond recognizing the problem facing taxonomy, and offering a solution, Mayr recognized how evolution and taxonomy would begin to be intertwined. He was one of the first to say that Linnaeus' phenetic system (one based on similarity) should instead be one based on relationships--or a phylogenetic system (Mayr, 1942). This switch did not require a complete redo to Mayr--that should be clearly stated. However, he did think that the connection of a common ancestor should be recognized. His argument was that the reason taxonomists were having such a difficult time separating species based on similarity was that everything was similar because they shared a common ancestor (Mayr, 1942). This theoretical point was where he began his affirmation of monophyletic taxa, or taxonomic group or rank (such as genus, or phylum). To restate the definition: these groups are those in which the common ancestor and all of its descendants are included because they are all more similar to each other than any of them are to anything else. For example, all living birds are included in Class Aves--this means the presumed common ancestor and all of its descendants are in that class, making it monophyletic. How do we know that is true? Among other traits, all birds have feathers, and nothing outside of birds have feathers.

Mayr put taxonomists into two groups based on their way of making taxa monophyletic: the ones who believed in making new taxonomic groups for every little difference in morphology or behavior or location (idealists or splitters), or the ones who see that there is no possible way to express the entire complicated picture accurately and so choose not to create an innumerable amount of higher groups (realists or lumpers) (Mayr, 1942). In other words, splitters believed in marking every difference with a new species or higher taxon (i.e., splitting up the current taxonomy into smaller and smaller units). Lumpers solved the same problem by grouping as many taxa as possible together.

One topic that Mayr discussed in depth was the separation between zoologists and botanists. He offered several suggestions as to why the separation exists: different characteristics are used by each group, geographic speciation is not as emphasized by botanists but it is a large point for zoologists, plants tend to have simpler morphology leading to ‘practical’ classification that taxonomists cannot have, and (especially by now) they speak a very different language (Mayr, 1942). One example is the term “valid.” Botanists apply this to new names, while zoologists call new names “available” (McNeill, 2017). In contrast, “available” in botany means “potentially valid” (McNeill, 2017). To nonscientists, these definitions seem arbitrary, but, the situation is like the word “sensible”. In English it means “reasonable,” but in Spanish, it means “sensitive.” This different use of the same term can result in miscommunication because scientists will talk past each other, not realizing that they mean different things when they say the same word.

Recently some controversy has come to light over Mayr and his teachings. Mayr claimed that before and during Darwin’s time, zoologists were stuck in this idea that species had a type and that this type was set (or essential) (Richards, 2010). Essentialism is the concept that each genus or species has one example or true form. In other words, a lion has a pure essence, and all of the lions we see today are variations of that same essence. This belief dates back to Plato. Some biologists and historians are now arguing that the problem Mayr suggested was there before Darwin (and that Darwin solved) was actually never there (Richards, 2010).

Why is this a problem? If species have an essential essence, then they could never change or become another species. This point makes evolution impossible. Every species we know today would be the same one we see in the fossil record. As this is not the case, scientists are forced to find an alternative explanation. Darwin was dealing with the same question ("what is a species?") that Mayr confronted.

Historian Mary Winsor suggests evidence that the reason Mayr popularized the essentialism problem was actually an effort to bolster Mayr's own views and teachings. In 1959 Mayr wrote that Darwin replaced typological thinking with Darwin's population thinking (Winsor, 2003). Such thinking focuses on the variation among individuals within a population (Hey, 2011). Population thinking (or the idea of varieties) is the only way that evolution (and the Modern Synthesis that made Mayr famous) was able to be respected as a scientific theory.

This use of the word varieties is a different concept than the one Plato suggested and to which essentialism clung. Plato's idea was that a domestic dog had this certain essence that made it a dog. We may see different kinds (e.g., pomeranian, dalmatian,) flicker on either side of what being a dog means, but there is a core that only dogs have. A variation of dog will not become a wolf in time--that is the point Plato made and why he thought that species do not change. When Mayr discusses varieties, he means individual differences such as blonde and brunette humans or different shading of songbirds. They are the same species, just colored slightly differently because of where they live, the food they eat, and other influences. Mayr’s varieties occur through mutations that appear in a certain population that cannot be shared with other populations because of the lack of gene flow. They do not have a set core of characteristics like Plato’s. If the populations come to differ in enough traits, they may eventually become different species. So the varieties themselves do not become their own species, but varieties can compound into enough consistent differences to form a new species.

The reason the Modern Synthesis needs varieties is that it makes geographic speciation (what Mayr proposed) easier to accept. If each population is slightly unique with characteristics that the other populations do not have but theoretically could, they are the same species. Then when a new geographic boundary emerges (such as flooding that washes an insect population downstream), natural selection would work on this separated population and send it down a different path than that of the original population. They start as different populations of the same species and because of different pressures result in two or more distinct species.

One of the things that led to this confusion, between what Plato meant and what the scientists during the 1850s mean, is the fact that sometimes scientists accept what others publish without looking at the history or underlying terminology. It is one of the reasons that science needs theses like this one. In 1968 Mayr accepted the word essentialism as the same as typological thinking, and from then on they were linked and popularized by Mayr (Winsor, 2003) and continue to be perceived as synonymous (e.g. Hickman et al, 2015). Typological thinking in its original meaning within systematics was a form of classification by John Edward Gray in which a species had a type in a museum to which other specimens could be compared. This classification and essentialism are similar in concept, but the former is a physical system whereas the latter was a philosophical theory. They did not refer to the same exact idea, but when combined, it appeared to be a much more common problem at the time than it actually was. When scientists were discussing typological classification, they were likely referring to Gray's system rather than Plato's teachings.

To put it clearly, there are three different meanings of the word "type" in taxonomy that have become synonymous. The first is the morphological type, which is similar to a blueprint that each group of organisms fits into to be part of the group, and they can never move into another group (or come from another group) (Witteveen 2016). This definition has become the feared essentialism problem that Mayr discussed and popularized. The second is the classification type--using a member of the current group as a model of comparison (Witteveen 2016). Using the member would start to limit the boundaries of the group--this limitation would not stop evolution but may create more groups as species are discovered. This type is a list of characteristics or a set idea to which a species can be compared. The last is the collection type, in which there is a physical organism to which other organisms are compared, rather than a set of characteristics (Witteveen 2016). This one is Gray's concept. These are three separate types, but they have been combined into the same meaning by Mayr, making the essentialism problem seem very prevalent.

Mayr proposed that a strong opponent to Darwin was Louis Agassiz (an American naturalist). He argued that Agassiz was unable to accept evolution because of his indoctrination with Plato (Winsor, 1979). In fact, he thought that only individuals could be the true basis of classification--therefore he would not have been a follower of essentialism because it inherently requires species (Winsor, 1979). Agassiz thought that the species question was a false problem because only individuals could be studied, and species were man-made concepts (Winsor, 1979). Essentialism says that there are certain characteristics that make up a species--species are not individuals but groups, and these groups do not ever change.

Although Mayr's assertions are now coming under review and being questioned, one concrete example of his personal bias was Agassiz's fishes. Agassiz investigated some fish in the Tennessee River and named several species. Mayr was quoted as stating that Agassiz's disbelief in variation between individuals (i.e. sticking to essentialism) led him to make seven species out of one true species (Winsor, 1979). To clarify Mayr's statement, he thought that each species distinction Agassiz made was because he found a fish that was a little differently colored than the others (similarly to grouping humans as separate species based on differences in hair color). This decision sounds incredulous to anyone--we all know that humans are the same species despite different hair colors. That feeling of incredulousness is what Mayr was trying to get his readers to feel about Agassiz's choices. If Mayr could get scientists to be shocked by the ludicrousness of the followers of the idea (essentialism), then they would naturally be suspicious of the original concept.

The individuals did vary and have been accepted as synonyms, except for two cases (referred to as *taurus* and *urus*) (Winsor, 1979). This habit was not due to a devotion to essentialism but was rather a form of extreme splitting common to his time period. The variation he found in the specimens was not very small, and therefore it was not ridiculous that he claimed them as new species. Those two cases (*taurus* and *urus*) that Mayr included were not described by Agassiz in the Tennessee River but in another location entirely: one was from the Ohio River and the other from the Osage River (Winsor, 1979). In other words, in these seven species selected by Mayr, Agassiz was discussing three populations (separate from each other). With the information taxonomists have now, the other two populations are the same species (argued at a subspecies level). In summary, Mayr collected several different pieces of Agassiz's work and claimed it was the same piece. This incorrect comparison made Agassiz's extreme splitting appear to be the work of Essentialism instead of the habit of his day. In this case, at least, it has been demonstrated that Mayr used false data to ruin another scientist (whether or not he did it on purpose). But what did this action do?

Making a contemporary (and somewhat enemy) of Darwin look foolish automatically makes Darwin look better. It also reflects an incorrect image of anyone that did not agree with Darwin because it makes them seem to be stuck in a certain mindset.

Another taxonomist (Gareth Nelson) provides evidence that Mayr is not as closely tied to Darwin as he tries to appear. In fact, he suggests that Mayr's 'synthetic or evolutionary method of classification' is not of Darwinian but rather of Mayrian manufacture (Nelson, 1974). Darwin has published work stating that humans (*Homo*), gorillas (*Gorilla*), and other apes (*Pan*) should stay in the same group (Nelson, 1974). Mayr, in fact, believes that humans are unique enough that they deserve their own family. He even goes as far as to say that *Pan* and *Gorilla* should be grouped with *Pongo* instead; while doing this different classification Mayr says he sticks to Darwinian doctrine without fault (Nelson, 1974)

Despite the many achievements and respectability of Mayr, some of his points seem to be exaggerated in taxonomy in the effort to gain popularity.

Comparison to Botany

Mayr's geographic speciation had a large impact on animal taxonomy (as discussed) because it gives at least one pathway for evolution. Mayr, himself, says that this form of speciation is not very important in plants (Mayr, 1942).

A paper in 1994 was one of the first to detail geographic speciation in plants. There are two main types: allopatric, and sympatric. Allopatric speciation is caused by geographic isolation. In an example, a species (through an accident) ends up on an island and cannot find its way back to its original territory. This isolation prevents gene flow and often sends species on a new independent evolutionary path. Sympatric speciation is when two species that are not geographically isolated begin to evolve differently and over time lose the ability to interbreed. Most botanists have been able to accept allopatric speciation, but most question the existence of sympatric speciation (like most other biologists) (Rieseberg 1994). Unlike animal taxonomists, when plant taxonomists come across something with which they disagree, they ignore it (Rieseberg 1994). However, just because the scientists do not agree with a particular hypothesized process, overall, botanists agree with evolution. Any that do not just seem to ignore the conflict and focus on other problems.

Mayr also made the suggestion that "the morphology of plants is vastly simpler and less varied than that of all but the simplest animals" (Mayr, 1942). Considering Mayr was a zoologist, this claim may be rather biased. This statement does reflect the perspective of most animal scientists. They feel that their subject is much more complicated than that of the average botanist. In conjunction with this statement, Mayr says that botanists, in general, are more practical (Mayr, 1942). This statement is evidence that the subject matter seems to attract certain types of individuals.

1950s: Willi Hennig versus Simpson

We have seen several changes to taxonomy in the last roughly 100 years. The addition of a strong evolutionary theory added another layer to the already confusing questions of classification. Mayr and Simpson took the first step in trying to solve the basic question of taxonomy with the newest knowledge of their time. However, about twenty years later, we see a deep divide between Mayr and Simpson and Willi Hennig.

Willi Hennig was a German zoologist who created a revolutionary way to order taxonomy. He proposed that instead of grouping organisms based on evolution with a priority on the unique (as proposed by Mayr and Simpson), species should be organized by their genealogical relationships, focusing on showing which are more similar.

This concept became the basis of a new field called cladistics. Hennig based these relationships on the number of common measurable derived characteristics, which is based on the assumption that the more similar two species are, the more recent their divergence from the common ancestor was. The basis of the argument is the inclusion of ancestral versus derived traits. Ancestral traits are ones that species share because the common ancestor had them. For example, humans have four limbs because the tetrapod ancestor had (by definition) four limbs. Derived traits are the differences between species on which we base groups. For example, birds have a derived trait of feathers that taxonomist have used to put them into their own class, without addressing what happens to the rest of the reptiles.

The difference in value of ancestral versus derived traits is one place where we see the divide between Mayr and Simpson on one side and Hennig on the other. It is not a question of evolution but a difference in the philosophical value given to the two types of traits. For example, if taxonomists grouped by ancestral traits (as they tended to do) and made all taxa monophyletic (which is the true source of the conflict), then the Superclass Osteichthyes would require humans down to fish to be in the same group. A monophyletic group would require that the ancestor and all of its descendants be included in the same group. For fish (Superclass Osteichthyes) to be monophyletic, all descendants of fish (every tetrapod [four-limbed organism] must be included). However, grouping on derived traits means that every time a species has a new trait that is different than the last common ancestor, they are separated. Hennig says that grouping decisions can only be based on shared derived traits; ancestral traits (i.e. lack of derived traits) are irrelevant to grouping decisions. Reptiles (including birds) share a number of derived traits that other vertebrates lack, so they form a group within vertebrates. Birds share a number of derived traits that other reptiles lack, so they form a group *within* reptiles. But the lack of those traits does not justify making the rest of reptiles their own group.

This difference in philosophical opinion is one of the reasons Mayr and Simpson disagreed with Hennig. Mayr and Simpson thought that groups should be monophyletic when possible but that there are situations where certain groups should be given priority, such as humans. Humans have several derived traits unique to themselves. They are special enough that Mayr and Simpson believed we should be in our own family. Hennig said that chimps and other great apes share enough of those derived traits that they should be included in our family. At the very least, they should not be put in a family together that excludes humans, as Mayr and Simpson did. Hennig and Mayr/Simpson agree that humans should be in their own genus (we are after all different than chimps in several important ways). But Mayr wanted to put humans in their own family, with all other great apes in another one together.

Humans have been classified as great apes, and that means that the great ape family (that excludes humans) is not monophyletic. This practice disregards the common suggestion of monophyly because the species in question (humans) is unique enough. Beyond the genus level, any great ape taxon that does not include humans would not be monophyletic, Hennig would not accept such a taxon, but Simpson/Mayr would say that humans are unique or special enough to allow the exception to the monophyletic guideline. Hennig says monophyletic groups are necessary, but Mayr says they are good but not necessary.

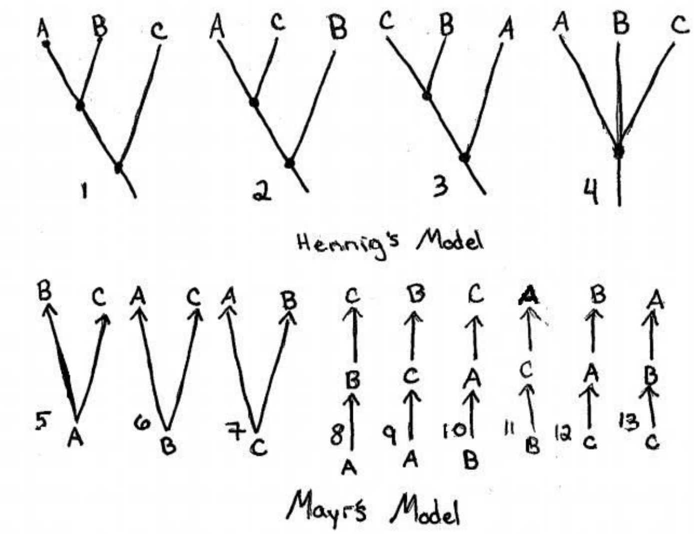

Figure 1: Depicted are the 13 different ways three species could be classified in relation to each other (after Cracraft, 1974). Hennig would only accept the first four, though he would only accept number four as a result of incomplete knowledge. Mayr/Simpson would argue that species could be classified using all 13.

These two paths bring the subjectivity to taxonomy. Taxonomists are left to decide which one, or both, are appropriate to use. Just because birds have feathers (and other derived traits), should they be their own class, or because they have so many more shared derived traits, should non-avian reptiles be grouped with birds? Birds are currently in their own class, just like reptiles. But are the non-avian reptiles a complete group without the birds? Reptiles are grouped because of shared derived traits (e.g. epidermal scales with beta-keratin). The problem? All of these traits are shared with birds, and some reptiles share traits with birds that they do not share with other reptiles. For example, within reptiles, only crocodiles and birds demonstrate parental care; they also have the same unique ankle structure. According to the monophyletic rule, groups should have species that are more similar to other members than they are to anything else. Crocodiles are more similar to birds than they are to other reptiles. That decision in grouping is a large debate without a popular solution yet. According to monophyly, reptiles should be grouped with birds, but it is a difficult concept for the general public to accept.

Most current taxonomists would agree philosophically with Hennig. All animals that are more like each other than they are to anything else should be in the same group. It seems rather simple and intuitive. Actually accomplishing this means we hit a familiar roadblock--lumpers versus splitters. Lumpers create a large group every new common ancestor which makes a few, very large groups. This lumping would solve the issue, but critics argue that it makes the groups themselves almost pointless. They would be so broad and vague that they would give no information about the species.

Another reaction is to create a new group every new common ancestor or derived trait. This system would create numerous taxon groups. Taxonomists would also need to rearrange current classification (which happens currently). It is possible but very messy. Many taxonomists would have to relearn names for groups they have worked on for twenty years. Beyond that new information, many papers written would be harder to obtain due to the problem of synonymy (Guala 2016).

Neither reaction gives a perfect or simple solution. For the fish example we used earlier, Osteichthyes is monophyletic only if it includes all tetrapods (one big lump). But most classes underneath it would also need to be split to be monophyletic, creating at least six new classes from the original ones.

The application and comparison of Mayr/Simpson and Hennig's ideas can be seen in a couple statements (Cracraft, 1974). One main question is whether or not the ancestral species can be known. Hennig's model would say it cannot, while Simpson/Mayr believe that it could be known and even recognized (the current general consensus is on Hennig's side). Hennig did not allow for phyletic gradualism (a model of evolution which theorizes that most speciation is an entire species going into another one). Hennig says for a new species to form, one species must split into two. Neither new species would be exactly like the first one. Mayr says that one species could become a new one. To explain Hennig's concept, one population of a bird species begins to drift towards one end of its color range. Over a long time this progression, would result in a bird population that does not reflect the original species (as demonstrated by a population existing of the original species). As discussed, actually compiling their classification system is based on either shared derived traits (Hennig) or ancestral traits (Mayr/Simpson).

As Mayr and Hennig lived in the same time period, they did critique each other's theories and ideas. In response to a critique by Mayr, Hennig stated: "[Mayr] is flawed by misunderstanding, conceptual imprecision, and inconsistency" (Hennig 1975). These are not the worst insults given to a scientist, but they are rather personal ones. Hennig did not attack Mayr's ideas but his process and abilities. Hennig takes this critique further stating his "doubt, therefore, if Mayr's 'evolutionary systematics' is really based on scientific theory" (Hennig 1975). This personal touch to the critiques and arguments shows the personal connection that scientists often have in regard to their ideas and concepts. Hennig wrapped up his twelve-page critique with a final jab stating "[Mayr's] indisputably great achievements lie in another field" (Hennig 1975). Although at first glance, this statement could be confused with a compliment, when it is given further thought, the insult becomes clear. Mayr has no place in systematics, according to Hennig.

1970s: Endangered Species Act

In 1966 Congress decided that it needed to act to protect species that were going extinct and passed the Endangered Species Preservation Act (A History of the Endangered Species Act of 1973, 2016). The wording proved slightly ambiguous, and they repassed the Endangered Species Act in 1973 (A History of the Endangered Species Act of 1973, 2016). This act was a triumph for scientists, as they would finally get the support they needed to save species from extinction.

A species is listed because it is endangered or threatened through (1) habitat destruction, (2) overutilization, (3) disease, (4) inadequate regulatory mechanisms, or (5) other natural manmade factors (Listing a Species as a Threatened or Endangered Species, 2017). Once the species are protected by the Act, there is a lot of leeway on how they are protected. Some species are given safe space, which seems like enough--animals can live if they have somewhere to live. However, many of these spaces are surrounded by non-protected land with little or no fencing.

This Act is one of the first times we see an indirect influence of the government over taxonomy. The government pays more if there are more species--which is not something the government wants to do. There was just one problem--taxonomists still did not agree on the definition of species. How could the government protect something (a species) without really being sure of what it was?

The answer was left up to taxonomists with slight pressure from the government. This conundrum is where Mayr’s splitters and lumpers come back in full force at the species level. Splitters (who create new species based on minute differences) often, through their work, also begin to describe smaller and more specific populations as their species. When this narrowing occurs, the number of members of that species drops because the definition is so specific. Such occurrences would also increase the number of threatened or endangered species. This habit would put more pressure on the Endangered Species Act, requiring more funding. In the last fiscal year report (2014), the act cost the government over $1.3 billion (Federal and State Endangered and Threatened Species Expenditure, 2017). This budget is spread over about 2,340 species including plants and animals (Jacobson, 2013). In contrast, the IUCN Red List is an international directory of endangered species that covers 22,326 species of plants alone and 63,939 species of animals (Red List Tables, 2017).

The Endangered Species Act is the first direct application of taxonomy in the public sphere. How we classify species has a large impact on where tax money goes. Depending on whether the trend is to save any population that has any genetic difference or not, the budget will change (either spread thinner or increased). Less money will be spent on each species individually because there are so many to protect.

One famous splitter is Joel Cracraft. He states that which phylogenetic model scientists use influences their perception of the real world (Cracraft, 1974). Cracraft is a follower of Hennig and has written comparing Mayr's and Hennig's models. He acknowledges a lack of objectivity (on both parts) but even goes so far as to say that Mayr "has not justified (his proposition) on any grounds of reasoning" (Cracraft, 1974). There is a certain edge to his criticism that goes beyond a disagreement with Mayr's system. He even goes as far as to suggest that Mayr bases his classification on illogical concepts--which for a scientist is one of the worst insults.

Cracraft takes Hennig's system and tries to be strictly loyal to it. In fact, in one study, he proposed that the estimated species of birds is not 9,000 but is closer to 18,000 (Nelson, 1974). Doubling the number of species we know halves their average population sizes, which could have a large impact on the Endangered Species Act.

Even though the listing process is extensive, sometimes the public influences the choice. The African lion was included as a protected exotic species because of Cecil the lion's death. Cecil was a lion who lived in a national park in Zimbabwe and was recognizable to tourists. Since it is illegal to hunt lions in the park, hunters put a dead animal on a car to bait Cecil. This technique effectively lured him off protected land, where a Minnesota dentist (with a permit) shot him with a crossbow (Rogers, 2015). It is reported that it took two days for Cecil to be found--and when he was, the hunters beheaded him and left his body to rot (Rogers, 2015). Killing lions on unprotected land is not illegal in Zimbabwe, but Cecil was a special lion--a tourist favorite, collared for a study. When the American public heard about the story, because of their love for this lion (and their disgust at the way he died), they cried out for justice.

When the original author of the law (John Dingell, MI Rep) wrote it, he wanted it to be run by scientists, not the economy. Dingell even made sure to write in the Act that listing decisions have to be based purely on biology and not economics (but how to implement protection can be based on economic considerations). He was quoted as saying that “today we have a bunch of anti-science ignoramuses and vicious lying people in Congress” (National Geographic 2017).

The Act is currently under strong opposition from several factions, claiming that it is stalling their prosperity. Rob Bishop, a Representative of Utah (and a strong enemy of the Endangered Species Act) stated that the Act “has never been used for the rehabilitation of species…(the Act) has been hijacked” (Fears 2017). He makes these claims despite evidence that 200 species have not gone extinct due to this Act being in effect (Jacobson, 2013). A supporter of the Act (Peter Alagona, conservationist) counter-argues, stating, “If the complaint is (that) the recovery of a species takes too long, the question is for whom” (Fear, 2017).

Those lobbying to remove the bill are also trying to play into the current American culture by claiming the federal government is overreaching its power. They call for the act to be handled at the state level (National Geographic 2017). This choice, in fact, had been tried before, but with disappointing results, as the species (the lesser prairie chicken) in question actually declined (National Geographic 2017). They were put into the hand of the governors’ of the five states where the chicken lived. The states allowed drilling for oil and gas to continue in the hopes of decreasing the economic effect, and within two years the chickens were even worse off.

If the act moves toward more state control, we will see a startling new approach to their protection. Most states do not require scientific evidence to list or delist their species (Fears, 2017). This freedom of choice allows for the public, the economy and personal feelings to impinge on what should be a purely scientific process. Importantly there are 17 states that do not protect plants at all (Fears, 2017). This fact is a great concern for botanists, who would see several species of plants go extinct due to their lack of protection.

2000s: Phylocode

The taxonomic field is not yet done with evolutionary theory. In 1998 a workshop at Harvard created the next revolutionary idea--the PhyloCode

(Keesey and Cantino 2014). This code takes systematics a couple of steps further. Not only does it make evolution the entire basis of classification, it uses very little from Linnaeus' founding. One of the most surprising changes regards the standard Linnaean binomial nomenclature. This naming system gives each species a Latinized genus and species name. Such a system distinguishes species from each other easily in literature while ensuring that no matter their native language, scientists know the exact species being discussed. The PhyloCode planned to change this naming by removing the genus name and changing the species name in one of three ways (Pennisi 2001): either losing the genus and shortening the species name, changing the species name and hyphenating it with the genus name (making it one unit), or simply giving it a numeric designation. Under opposition, the PhyloCode backed down on this point.

The largest change will be how species are grouped. Currently, they are grouped within ranks, which shows a certain order or nested hierarchy of species. Within the new PhyloCode, species are put into clades that reflect the shared ancestry only (Pennisi 2001). Since the species would no longer be named in connection to their rank, they could be moved around the classification much easier. Based on Linnaean rules, when a species changes genus the species name would change and often the genus' name as well. In the PhyloCode code there would not be a change in the different names. This ability allows for a flexibility in classification that scientists have not had since Linnaeus.

Some of the ‘old’ thinking of scientists do not appreciate that the PhyloCode followers are seceding from the code’s established rules; in one scientist's opinion, it is arrogant (Pennisi 2001). The PhyloCode was published online and offered up for comments but has not been proposed to the international communities. The decision to secede struck a chord, with most taxonomists and systematists feeling it was an insult. Taxonomists care deeply about their rules as they attempt to minimize chaos. As this thesis has discussed, more chaos is hardly something the taxonomic field needs.

Some systematists are not against the reform of the system (as the current classification does make it difficult to reflect evolutionary history). However, they are concerned about the complete undermining of the Linnaean system. Many are convinced that the benefits of the PhyloCode do not outweigh the costs and upheaval it will cause (Withgott 2000).

Interestingly, since the ranks would be removed with the new system, then the rank of species should also be removed, according to some, but not all, PhyloCoders (Withgott 2000). Either move would create several problems and confusion. Either PhyloCoders would have to say that all ranks are arbitrary other than the species rank, or they would have to say that all ranks are arbitrary. But what would the smallest unit they classify be? This question is the only major debate among the followers of the code.

At this time it is a theory without application. Scientists are still trying to clarify the boundaries and rules of the PhyloCode and how it will affect the taxonomic world. The debate is not yet over.

Conclusion

We have discussed several points of chaos and change in animal taxonomy. First, we saw the rivalry between Strickland and Gray over whose code or system would be accepted (and in theory make them famous). Around the same time, Bonaparte was attempting to create unity in Italy and taxonomy through a draft Biocode. Darwin published his *On the Origin of Species* and revolutionized the field of biology. When Mayr and Simpson came on the scene decades later, we saw a lot of new things happen, including the push towards evolutionary taxonomy. Hennig argued against their system and founded the field of cladistics (phylogenetic systematics). Some loyal Hennig followers are pursuing that field and turning it into the new taxonomic system of the Phylocode.

Another aspect of this thesis tried to understand why we barely saw any such conflicts within botany. Botany and zoology started on parallel tracks from the same man. However, they quickly developed their own languages and perspectives. Animal taxonomists have to follow evolution to the natural conclusion that humans have also evolved from some unknown common ancestor. Religious beliefs are not as threatened when science says plants came from bacteria. But say that humans developed from an ape common ancestor, and the most common counterargument you will receive will be biblical.

This thesis adds some historical background to the many debates facing taxonomy. Like any issue, it can only be understood through the entire context. There have been several misunderstandings because papers are read or written without a firm grasp on the big picture. Science, in general, often views itself as being objective and above the petty bias that gets other fields in trouble. As we have seen even in this small subset of biology--human bias is alive and influential.

Currently, taxonomy is relevant to the world and the United States in particular. If trends favor splitting species, the number of endangered species will go up, which requires more funding or spreads limited funding even thinner. How the public feels and the pressures it applies also influence tax money.

In the coming years, the pathway of taxonomy may take a sharp turn. It will be interesting to see what outside of science influences any new paths or concepts taken.

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