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# From Aristotle to Wunderkammer: The Development of Entomology and Insect Collections

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## Cover Page Footnote

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# From Aristotle to *Wunderkammer:* The Development of Entomology and Insect Collections

The development of insect collections and displays, this paper argues, shaped the development of the modern natural history museum of the Western world, though the greater interest in museology has been on mammals and other 'big' creatures. Entomology also influenced the development of the biological sciences in a broader sense through investigations into taxonomic classification, and the use of new tools such as the microscope, among other areas of study. Much of the work on the history of entomology until now has concentrated on a single time period, putting it in the context only of the development of the biological sciences. Individual or small groups of systematists throughout the ages have been addressed in previous publications. Much of the work done by other historians has thus focused on bits of the larger picture of the development of entomology and of biology as a more general field on the European continent. In this paper, the development of entomology is investigated as a specific branch of biology from the ancient world through twentieth century in an effort to show how the field influenced development in the areas of taxonomy and interest in understanding the natural world.

Entomology saw its start in antiquity with a utilitarian emphasis in understanding insects. There was not a true interest in the concept of 'insect' for its own sake until the time of the ancient Greeks.[1] Though Plato (429-347 BCE) was the first to define terms related to the classification of insects, Aristotle (384-322 BCE) was the first to attempt a systematization of insects. This classification scheme centered on the anatomical differences and similarities between the insects he encountered. Aristotle's work was based around characteristics of insects, starting with the wings and mouthparts, and resulted in a rudimentary dichotomous key.[2] With the rise of the Roman Empire came a decline in interest in categorization; the focus of the entomology of Rome was instead the study of pests and pollinators to support agricultural progress and other utilitarian purposes. In 77 A.D., however, Pliny (23-79 AD) published his encyclopedia, *Historia Naturalis*, the eleventh volume of which addresses insect life. Pliny's encyclopedia used a classification scheme very similar to that of Aristotle and influenced many works that came after it.[3] For example, discussions of insects from *Historia Naturalis* were included in Conrad Gesner's *Historia Animalum,* published between 1551 and 1587.[4]

[1] Günter Morge. "Entomology in the Western World in Antiquity and Medieval Times." In *History of Entomology*, edited by Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith (Palo Alto: Annual Reviews, Inc, 1973), 38.
[2] Morge, "Entomology in the Western World", 40.
[3] Morge, "Entomology in the Western World", 49.
[4] Harry B. Weiss. "Four Encyclopedic Entomologists of the Renaissance." *Journal of the New York Entomological Society* 35, no. 2 (1927): 196.

Morge and others have argued that by the Medieval period, much of the knowledge of insects gathered in antiquity had been lost to Western Europe; despite this, some works on natural history created in this time included information about insects, though they were limited to lists of names with sparse information on the insects themselves.[5] Isidorus, Bishop of Sevilla (c. 560-636), addressed insects in the twelfth book of *Origines sive Etymologiae*, in chapters entitled 'de vermibus' ('Vermin'[6]) and 'de minutis volatilibus' ('Tiny Flying Animals'[7]). Though these chapters addressed only a very small number of insects, this was the entirety of biological understanding of insects until the end of the period[8]; Isidorus of Seville's work discussed only what was known at the time regarding the natural histories and lives of animals such as the 'Spanish fly' and other insects such as bees, scarab beetles, moths, and flies.[9] This work represents a return to the investigation of insects purely for the sake of knowledge about the natural world, instead of for economic purposes, as it contained no information as to the effects insects may have on crops or other areas of economic pursuit. Though a number of books on natural history were printed in the eighth and ninth centuries, they were largely collections of the information of insects already available in other works[10];

[5] Morge, "Entomology in the Western World", 58-63.
[6] Stephen A. Barney, W. J. Lewis, and J. A. Beach. *The Etymologies of Isidore of Seville*. Cambridge, GB: Cambridge University Press (2006), 258.
[7] Barney, Lewis, and Beach; *The Etymologies of Isidore of Seville*, 269.
[8] Morge, "Entomology in the Western World", 59.
[9] Barney, Lewis, and Beach; *The Etymologies of Isidore of Seville*, 258-269.
[10] Morge, "Entomology in the Western World", 63.

nonetheless this reproduction of entomological material assisted with preservation of knowledge.

With Early Modern exploration came further opportunities in the study of insects from a standpoint of interest for the sake of understanding the world. Thus, naturalists continued the trend of focusing on basic, rather than applied, concerns regarding the study of living things. People of diverse interests placed importance on the exotic locations where insect specimens were found when engaging in such study.[11] This idea of exoticism and subjugating the natural world, even in far-away places, also manifested itself as an emphasis on natural singularities and the oddities of the natural world.[12] These curiosities, including insects, were placed in collections of objects that were reserved for private viewing and demonstrated the collector's power and social status. Only the collector and a select few would be allowed to see the items the collection contained. Collections took much in the way of wealth to generate; specimens, free time, and space were necessary for this hobby, making participation only available to a few.[13]

Also in the Early Modern era, the publication of true encyclopedias became relevant to the study of natural history. Among the most well-known encyclopedia authors was Conrad Gesner (1516-1565), who published *Historia Animalum*

[11] Janice Neri. *The Insect and the Image: Visualizing Nature in Early Modern Europe, 1500-1700* (Minneapolis: University of Minnesota Press, 2011), 3.
[12] Deborah E. Harkness. *The Jewel House: Elizabethan London and the Scientific Revolution* (New Haven: Yale University Press, 2008), 53.
[13] Harkness, *The Jewel House*, 22.

between 1551 and 1587. Gesner's work was written in Latin and compiled partially through his communication with other naturalists around the world.[14] Gesner's work also included information assembled from earlier famous naturalists, such as Aristotle and Pliny, mixed with his own observations of the insects he collected. It would come to be a text well-regarded throughout the naturalist community and a standard in encyclopedia quality for many.[15] The knowledge surrounding insects was related to a continuing conversation on things such as morphological features and value, and collections of natural objects in special cabinets came to represent not only wealth but intellectual status as well.[16]

In the next century, the rise in popularity of the *Wunderkammer*, or cabinet of curiosities, meant that collectors designed new organizational schemes, though these were largely unique to the collection.[17] Insects worked well in cabinets of curiosity due to their small size and visual interest; they were largely preserved in boxes and the wings of butterflies and moths were spread, as is still considered standard. Unfortunately, there are no known collections from this period in natural history collecting that have survived.[18] It is known, however, from inventory lists and images that biological specimens, including insects, commonly made up a

[14] Weiss. "Four Encyclopedic Entomologists of the Renaissance", 196.
[15] Brian Cummings. "Pliny's Literate Elephant and the Idea of Animal Language in Renaissance Thought." In *Renaissance Beasts: Of Animals, Humans, and Other Wonderful Creatures*, edited by Erica Fudge (Champaign, IL: University of Illinois Press, 2004), 166.
[16] Harkness, *The Jewel House*, 31.
[17] Christine Davenne and Christine Fleurent. *Cabinets of Wonder*. New York: Harry N. Abrams, 2001.
[18] Neri, *The Insect and the Image*, 76.

significant portion of these menageries. Such collections were very costly to build up and maintain; only the wealthy could acquire and interact with specimens, especially those collected in overseas explorations, and the space needed to house them.[19] The process of building a collection was largely a social endeavor; naturalists communicated among themselves in order to gather specimens from different places.[20] Early modern collectors can be seen as amassing a kind of encyclopedia, consisting of large numbers of specimens, images, and objects.[21] The larger and more complete the collection, the more complete the encyclopedia of physical objects was.

While naturalists found that an image was a better source of information about an organism than descriptive words or summaries, actual specimens were the best possible source from which to gain knowledge of an insect's morphological features. Items such as drawings and preserved specimens were considered immutable and the best way to keep information for future study by interested parties.[22] Intellectual status required the others to be able to replicate and verify or challenge evidence. With the intention of verifying the reports of others, the Scottish physician and naturalist Thomas Moffett (1553-1604) investigated the claim that only male wasps had stingers by observing the creatures first-hand. After

[19] Harkness, *The Jewel House*, 22.
[20] Harkness, *The Jewel House*, 22.
[21] Neri, *The Insect and the Image*, 89.
[22] Harkness, *The Jewel House*, 37.

killing an entire nest of wasps, Moffett looked at all of the wasps present and found that each had a stinger; the trait was not limited to male wasps.[23] Like many of the naturalists studying insects at this time, Moffett's observations of the insect world were published as a book; Moffett's effort was divided into two volumes. Though it was published posthumously, "Insectorum sive Minimorum Animalium Theatrum…ad vivum expressis Iconibus super quingentis illustratum," which was published in English as "The Theater of Insect, or lesser living Creatures," was a natural history of insects with additions from the efforts of other men, including Gesner.[24]

With the invention of the microscope in 1599 came fundamental changes in the way biology in general and, by extension, entomology was approached.[25] Arguably the most famous of works assembled by early microscopists, Robert Hooke's (1637-1703) *Micrographia* included numerous written observations and illustrations of insects as they appeared under the microscope. Hooke, in following with the contemporary trends of natural history illustrations and collections, concerned himself with the oddities of the natural world and focused his attentions on a single object for each of his illustrations.[26] Unfortunately, Hooke's specimens

[23] Harkness, *The Jewel House*, 38.
[24] Harry B. Weiss. "Thomas Moffett, Elizabethan Physician and Entomologist." *The Scientific Monthly* 24, no. 6 (1927): 563-564.
[25] Max Beier. "The Early Naturalists and Anatomists During the Renaissance and Seventeenth Century." In *History of Entomology*, edited by Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith (Palo Alto: Annual Reviews, Inc, 1973), 89.
[26] Janice Neri. "Between Observation and Image: Representations of Insects in Robert Hooke's "Micrographia"" *Studies in the History of Art* 69 (2008): 90.

of choice were easily broken and most had to be killed before their anatomy could be illustrated.[27] The killing of insect specimens, however, made them harder for Hooke to pose as he wished.[28] The images included in *Micrographia* allowed Hooke to organize his thoughts and the observations he made through the scope for publication.[29] In this way, Robert Hooke made the microscope a useful scientific tool for the gathering of data and observations about the natural world.[30] In publishing his *Micrographia*, Hooke set himself up as a distant observer of nature, whose knowledge about the natural world was unbiased truth.[31] Hooke thus made himself appear to be an ideal member of the Royal Society, which placed high value on the opinion and observation of gentlemen-scholars.[32]

However, Hooke was not the only one engaging in close, systematic study of insects with the intention of understanding the natural world. Though efforts in other fields of study were aimed at determining universal laws, in the biological sciences—in particular entomology—such close explorations resulted in the foundations of classification. One naturalist working in such areas, Ulysses Aldrovandi (1522-1605)—who was in contact with Gesner—was an entomologist, physician, and botanist working from Bologna. His work, "De Animalibus

[27] Neri, "Between Observation and Image", 92.
[28] Neri, "Between Observation and Image", 90.
[29] Neri, "Between Observation and Image", 91.
[30] Neri, "Between Observation and Image", 102.
[31] Neri, "Between Observation and Image", 83.
[32] Neri, "Between Observation and Image", 85.

Insectis," was published in 1638 and contained entries on insects that ranged in length from very short blurbs to incredibly long descriptions—up to seventeen pages. These articles contained a wide variety of information, including a range of name information, information from ancient naturalists, histories, and medicinal value, among other things.[33] Aldrovandi's "De Animalibus Insectis" was an early piece of scientific literature addressing insects specifically, thus establishing entomology—especially insect systematics—as a specific field of study. This work even included an early dichotomous key for the identification of the upper levels of the contemporary classification hierarchy.[34]

The organized field of insect systematics was not formally founded until the second half of the sixteenth century, as such things were not a focus of earlier scientific thinkers and collectors, and systems other than that of the ancients were few.[35] [36] With equipment such as the microscope came the ability of naturalists to study the minute aspects of insects that were linked to their physiologies. Amongst such early insect anatomists was Jan Swammerdam (1637-1680), who contributed to the study of insect respiration in the seventeenth century.[37] He was among those working on new systems of classification for the insects and classified the

[33] Weiss, "Four Encyclopedic Entomologists", 196-198.
[34] Beier, "The Early Naturalists and Anatomists", 85.
[35] John F. Clark. *Bugs and the Victorians*. (New Haven: Yale University Press, 2009), 3.
[36] Neri, *The Insect and the Image*, xxi.
[37] Gerhard H. Müller. "The Development of Thought on the Respiration of Insects." *History and Philosophy of the Life Sciences* 7, no. 2 (1985): 305-307.

organisms based on the nature of their life cycle. Though the terms for forms of insect metamorphosis came after Swammerdam's time, his differentiation of insects as holometabolic, hemimetabolic, or ametabolic is still used in the modern classification and description of insects.[38] Elaborations made on this system consist of additional information on the morphological and biological characteristics of the insects studied, but in many ways remain based on Swammerdam's scheme based in metamorphosis.

The eighteenth and nineteenth centuries saw the continued rise of morphological focus in entomology with the intention of making naturalists' collective knowledge of insects more complete. Entomology thus stayed within the realm of study for curiosity's sake, though the field would become progressively more closed off from the amateur. Among the authors publishing at this time was René Antoine Ferchault de Réaumur (1683-1756) whose work, *Mémoires pour server à l'historie des insects*, was based in the description of the anatomies of insects and their life histories for the sake of knowledge, not application.[39] Like many entomologists of the time, Réaumur saw the ideal for the study of natural history to be compiling all possible knowledge about the lives and "industries" of as many insects as possible.[40] Réaumur stated that "[a] class and a genus of animals

[38] Beier, "The Early Naturalists and Anatomists", 90.
[39] S. L. Tuxen. "Entomology Systematizes and Describes: 1700-1815." In *History of Entomology*, edited by Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith (Palo Alto: Annual Reviews, Inc, 1973), 98.
[40] Tuxen, "Entomology Systematizes and Describes", 98.

of which the characters have been well fixed, are for us what general formulas are for geometers."[41] In doing so, he linked a biological to the study of mathematical concepts and solidified the study of insects as a legitimate scientific pursuit. In his study of systematics, Réaumur considered individual species to be representatives of a higher level of classification.[42] Such 'levels' of classification refer to how inclusive or exclusive the group named is; the higher the classification level, the more organisms it includes. He even made note that the characteristics most obvious to the human eye are not necessarily the most important ones, stating that "[t]he signs which are most convenient to us to distinguish insects from one another, those which are most within our reach, and which rarely deceive us, sometimes can deceive us: they are not always taken from that which constitutes the essential character." [43] In this way, a taxonomic system was not complete until the defining characteristics for a unique insect species were known. This necessitated the inclusion of characteristics both obvious and obscure, which required thorough observation of a specimen's morphological traits. Obvious traits, he noted, might be useful for quickly differentiating between groups, but Réaumur did not consider such traits adequate to identifying the true 'essence' of an insect.[44]

[41] Mary P. Winsor. "The Development of Linnaean Insect Classification." *Taxon* 25, no. 1 (1976): 58.
[42] Winsor, "The Development of Linnaean Insect Classification", 58.
[43] Quoted in Winsor, "The Development of Linnaean Insect Collection", 59.
[44] Winsor, "The Development of Linnaean Insect Classification", 59.

Other naturalists also focused on exacting observation and description of insect specimens in a manner similar to that of Swammerdam; such naturalists were concerned with the intense observation of minute details related to the anatomy of their study insects. Though some of the naturalists working with insects at this time were associated with universities, many more participated in newly-formed natural history societies, both nationally and internationally. With these societies came the publication of the entomological findings of their members, allowing for more broad communication of classification efforts and techniques.[45] The Swedish entomologist Charles De Geer (1720-1778) worked on illustrations of anatomical structures in insects that had never been described before and made observations thereof. Pieter Lyonnet (1707-1789), a Dutch naturalist, also made precise illustrations and conducted anatomical investigations of insects, but he focused on all of the life stages of a single species.[46] Another influential entomologist of the time, Jules-César Savigny (1777-1851) of France, designed a way to describe and compare mouthparts based on their shape and the insect's feeding habits based on serial morphologies that are still used to describe insects today.[47] [48] Though collections underwent minor changes in their organizational structure, from simply

[45] Tuxen, "Entomology Systematizes and Describes", 95-96.
[46] Tuxen, "Entomology Systematizes and Describes", 99-103.
[47] Herbert H. Richards. "Anatomy and Morphology." In *History of Entomology*, edited by Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith (Palo Alto: Annual Reviews, Inc, 1973) 187.
[48] Tuxen, "Entomology Systematizes and Describes", 103.

the whims of the collector to organization by subject[49], systematization and classification continued to be the most important work of entomologists and others in the eighteenth century.[50]

For much of the history of the study of insects, organisms were named according to the whims of individual collectors and naturalists; there was no universal system for the naming of insects until the time of Linnaeus in the eighteenth century. With the introduction of Linnaeus' system of binomial nomenclature came descriptions of insects with systematized names of genus and species.[51] Carolus Linnaeus (1707-1778) focused on the wing and leg anatomies of terrestrial and aquatic insects. Because it was based on only those characteristics related to the movement of an organism, this system of classification was an artificial system. This resulted in an arrangement of a number of insect species that would later be changed in many dramatic ways, though his efforts to classify insects through comparison of easily-observable morphologies in adult insects was a change in focus that affected classification efforts well into the twentieth century. In this vein, Linnaeus published of his *Systema Naturae,* containing classifications of many plants and few insects, in 1735.[52] [53] He would later expand his efforts with insects, though the universal system of binomial nomenclature that Linnaeus

[49] Davenne and Fleurent, *Cabinets of Wonder.*
[50] Tuxen, "Entomology Systematizes and Describes", 105.
[51] Osborn, *A Brief History*, 47.
[52] Tuxen, "Entomology Systematizes and Describes", 107-108.
[53] Winsor, "The Development of Linnaean Insect Classification", 61.

introduced for the naming of living things was modeled on human census records, which is not how the natural world works.[54] In addition to the naming of individual species, Linnaeus also worked with higher-level classification based on wing morphologies. By naming four groups—the Coleoptera (for their hard, protective forewing), "Angioptera" (characterized as having wings but no hardening of the forewings), Hemiptera (for their existence as being winged but in a way different from the Coleoptera and "Angioptera"), and "Aptera" (for their lack of wings)—instead of simply describing them, Linnaeus set the stage for the overall classification of insects in use today.[55] Linnaeus' later versions of this classification system listed seven orders—Coleoptera, Hemiptera, Lepidoptera, Neuroptera, Hymenoptera, Diptera, and "Aptera." Six of these seven orders are still used today in the systematics of insects. This system also included descriptions of the characteristics of each given order.[56]

Johan Christian Fabricius (1745-1808) of Denmark, another influential entomologist of the late 18th and early 19th centuries, differentiated between more insect groups and renamed those originally described by Linnaeus using the morphology of mouthparts to distinguish between groups. His *Philosophia Entomologica* was published in 1778. It was the first true textbook on entomology to be published, though university instruction in the field did not begin until the

[54] Clark, *Bugs and the Victorians*, 45.
[55] Winsor, "The Development of Linnaean Insect Classification", 62.
[56] Winsor, "The Development of Linnaean Insect Classification", 63.

nineteenth century. Though his work expands on the artificial classification of Linnaeus by examining many characters, it is still not a natural system of classification as is thought of today.[57] Both Fabricius and Linnaeus followed the Aristotelian method of simplifying living things to a single character that is seen as sufficient to identify and describe. Fabricius suggested the existence of eight orders of insects based on the mouthparts, or '*Instrumenta cibaria*'.[58] He did realize that his system of classification was an artificial system of classification, writing that for *Philosophia Entomologica* "we have chosen an artificial system of insects based solely on the mouthparts" and went so far as to differentiate between such artificial systems and proper natural classification systems.[59]

Though these entomologists of earlier centuries were aware of with each other's work, they were largely working and publishing as individuals rather than as a community working with shared goals. With the nineteenth century came the development of professional societies dedicated to the natural history of insects in Europe, largely due to a growing need for entomologists to have a forum of communication outside of existing universities.[60] The Société Entomologique de France was founded in 1832 and supported the publication of papers written by entomologists. The Royal Entomological Society of London was started in 1833,

[57] Tuxen, "Entomology Systematizes and Describes", 109-111.
[58] Clark, *Bugs and the Victorians*, 28.
[59] Tuxen, "Entomology Systematizes and Describes", 98. (Trans.)
[60] Tuxen, "Entomology Systematizes and Describes", 95.

along with multiple associated publications. Similar societies were also started in other countries. The journal *Entomologist* was published in London as well. In addition to professional society-supported journals, some publications were printed without the support of such a society. Some professional societies and publications focused on how entomological knowledge could be applied to agricultural situations.[61] Though the amateur naturalists conducted much of the work done in entomology, from collection to description, the professional societies gradually came to reject the idea of natural history and the label "naturalist".[62]

The 19th century also saw the advent of early efforts toward specialization in researching specific groups of insects, such as the Lepidoptera, which includes butterflies and moths. As butterflies are lovely to look at in a preserved collection, many entomologists started with this group and gradually branched out to others. The first works in the vein of specialization were illustrations and art.[63] However, though some specialized in specific groups, much of the work done in the nineteenth century was mostly focused on taxonomy in the large sense.

The work of classifying insects broadly was pursued by entomologists in natural history in the late eighteenth and early nineteenth centuries as a way to better understand the variety and number of creatures inherent to the natural world

[61] Osborn, *A Brief History*, 24-29.
[62] Clark, *Bugs and the Victorians*, 105.
[63] Osborn, *A Brief History*, 56.

and order them according to their similarities and differences.[64] The development and systematization of entomology in this century was part of a larger trend toward the systematization of groups of living things found in nature.[65] The system of classification for insects that developed in the early nineteenth century emphasized the links between the insect, the complexity of its mind, and its physiology. In this way, systematists worked for a more natural system of classification, which grew with the importance of the classification of insects.[66] One of the major developers of this system was the Frenchman P. A. Latrielle (1762-1833), who wrote that "[n]atural classes and genera are based not on only the mouth-parts, the wings or the antennae, but on careful observation of the entire structure, even of the smallest differences." [67] In Latrielle's system, he became the first to limit the term "Insecta" to just hexapod arthropods. He also added more steps in the classification hierarchy between the order and the genus.[68] In spite of these developments, it was not possible to order the insects according to a universal, natural system until taxonomists had adopted the concept of evolution by natural selection.[69] With the acceptance of evolution as contributing to the natural history and identity of an insect came the idea that the classification of these creatures ought to follow the

[64] Clark, *Bugs and the Victorians*, 7-9.
[65] Clark, *Bugs and the Victorians*, 12.
[66] Clark, *Bugs and the Victorians*, 35.
[67] Carl H. Lindroth. "Systematics Specializes Between Fabricus and Darwin: 1800-1859." In *History of Entomology*, edited by Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith. (Palo Alto: Annual Reviews, Inc, 1973), 122. (Trans.)
[68] Lindroth, "Systematics Specializes", 122.
[69] Lindroth, "Systematics Specializes", 123.

evolution of species as one moves from the more general levels of the hierarchy to the more specific.[70]

The development of the theory of evolution by natural selection in 1858 was influenced by the study of insects; both Charles Darwin (1809-1882) and Alfred Russel Wallace (1823-1913) took examples from world of insects to elucidate the mechanism of evolution.[71] Many of the invertebrate specimens that Darwin collected during his voyage on the *Beagle* were insects, and these specimens helped give Darwin a sense of and information about the ideas of sexual polymorphism, geographical distribution, and mimicry. From his insect collections, Darwin gained empirical evidence from insects that would assist him in the development of his theory of evolution, though an account only of his insect collecting was never published.[72] The rejection of evolution based on a belief in the immutability and permanence of species would hold back the study of biological systems; Darwin once commented that the "entomologists are enough to keep the subject back for half a century."[73]

One of the aspects of Darwin's theory that is reflected strongly in insects is the concept of mimicry. Mimicry in insects is tied to both the development of new

[70] Osborn, *A Brief History*, 48.
[71] Herbert H. Ross. "Evolution and Phylogeny." In *History of Entomology*, edited by Ray F. Smith, Thomas E. Mittler, and Carroll N. Smith (Palo Alto: Annual Reviews, Inc, 1973) 172.
[72] Clark, *Bugs and the Victorians*, 108-110.
[73] Clark, *Bugs and the Victorians*, 111.

species and the geographic distribution of these species.[74] An example of mimicry in the insect world is the resemblance between species of butterflies belonging to the family Pieridae—consisting of the whites, yellows, and sulfurs—and butterflies of the genus *Heliconius*—the heliconian or longwing brush-footed butterflies—in tropical climates. Due to the actions of insectivores and the foul taste of some heliconids, certain colorations in tropical Pierids have evolved to resemble their distasteful neighbors. A brewer's clerk with an interest in natural history, Henry Walter Bates (1825-1892), studied mimicry in tropical species of butterfly in the Amazon Valley, saying that "on these expanded membranes Nature writes, as on a tablet, the story of the modification of species, so truly do all changes in the organization register themselves thereon." [75] By using butterfly species to establish his thoughts regarding mimicry in insect groups, Bates turned the group most sought after by insect collectors into a perfect example of mimicry and natural selection.[76] However, aspects of taxonomic research that were greatly affected by the theory of evolution did not apply to those who were more interested in simply collecting insect specimens and naming them.[77] Darwin's theory was not widely influential amongst such entomologists. In spite of this, insects were part of the

[74] Clark, *Bugs and the Victorians*, 116.
[75] Clark, *Bugs and the Victorians*, 115-117.
[76] Clark, *Bugs and the Victorians*, 118.
[77] Clark, *Bugs and the Victorians*, 127-128.

redefining of biological research as a true scientific endeavor thanks to the agency of those who accepted Darwin's theory. [78]

Until the 1870s, the sciences—including entomology—continued to be considered inferior to classics in the hierarchy of formal education, in particular at schools such as Oxford and Cambridge.[79] However, the end of the nineteenth century saw the beginnings of university instruction in entomology, along with the professionalization of entomology and foundation of entomological societies. University instruction in entomology was in many ways linked to the formal education of individuals in sciences related to agriculture.[80] [81] Textbooks in what is now called biology, however, were being published well before this time. Among the most influential textbooks in the study of the biological world was the *Introduction to Entomology,* originally published in 1815 by William Kirby and William Spence. The work helped pave the way for entomology to move from the focus of the early nineteenth century—natural history—to a more serious and professional study of the biological world. The textbook contained not only information on the classifications of insects, but also their physiological traits.[82] The shift from entomology as the realm of the amateur naturalist to the rigorous

[78] Clark, *Bugs and the Victorians*, 130.
[79] Clark, *Bugs and the Victorians*, 131.
[80] Clark, *Bugs and the Victorians*, 164.
[81] National Research Council, *Colleges of Agriculture at the Land Grant Universities: A Profile.* (Washington, DC: The National Academies Press, 1995), 84.
[82] Clark, *Bugs and the Victorians*, 15.

study of insects expected for a professional science left some in a grey area between the two forms of biological study. One entomologist who was stuck between amateur and professional was John Lubbock (1834-1913), who studied members of the Hymenoptera in England. For many, his publication of a popular science work on the behavior of ants, wasps, and bees was an example of experimental science that was not conducted in a way that agreed with the direction of professionalization the field was taking.[83] Lubbock was the first to track the individuals in a colony of social insects, however, and his artificial ant colonies work as an example of the transition from the semi-domesticated display to a true experimental set-up of domesticated study organisms. [84] On the subject of collections, Lubbock warned of complacency and underuse. Specimens had to be rigorously examined and described in order to be of value to the collector; Lubbock warned that "collecting for the sake of collecting" would come to "narrow the mind" of the entomologist. [85] In this way, Lubbock symbolized the awkward middle-ground between professional and popular scientific study. He also demonstrated the ideal of a pure science, one not driven by economic gains. His dedication to the objectivity necessary for science shows the changes that would be made in naturalists' work toward the end of the nineteenth century.[86]

[83] Clark, *Bugs and the Victorians*, 86.
[84] Clark, *Bugs and the Victorians*, 93.
[85] Clark, *Bugs and the Victorians*, 95.
[86] Clark, *Bugs and the Victorians*, 102.

Thus, in keeping with Lubbock's later specialized work with bees and ants, from the late eighteenth century on, entomologists became more and more focused on the specifics of groups and locales within the study of insects. No longer was the focus on the overarching concept of the 'insect'; instead, entomologists came to focus on specific orders and families. Many of the entomologists who specialized in the nineteenth century focused on the order Coleoptera, the beetles, possibly due to the relative ease with which these insects are preserved. One Frenchman, P. F. M. A. Dejean (1780-1845), focused on beetles after collecting insects of all kinds for a number of years. In *Spécies Général des Coléoptères*, Dejean worked to describe all of the beetles in his extensive collection, giving the name most commonly used to describe each insect instead of the first name given. He stated that he had "made it a rule to always preserve the name most generally used, and not the oldest one; because it seems to me that general usage should always be followed and that it is harmful to change what has already been established." [87] In doing so, Dejean ignored the priority principle of biological taxonomy, which defines the name of a species as the one given first, not the most common. This did not catch on as a popular method for naming beetles; the priority principle would remain the defining characteristic for determining a species name.

[87] Lindroth, "Systematics Specializes", 125-127.

Though beetles were an early specialized focus of many nineteenth century entomologists, they were not the only group to have been examined in such detail. Groups such as flies, butterflies and moths, and bees and their relatives were also studied in specific detail by entomologists of the first half of the nineteenth century. Some, such as J. W. Meigen (1763-1845) of Germany, studied the Diptera, the flies. Meigen's classification work in dipterology is known for taking into account more than one group of characteristics.[88] Others expanded on the earlier specialization of lepidopterists in their study of butterflies and moths and specialized in increasingly specific groups within the Lepidoptera. H. T. Strainton (1822-1892), an English entomologist, worked with the microlepidoptera. His work in classification was described as the gold standard to aim for; one man said of his work: "[h]e goes so far as to recommend that no species should be described upon less than twenty to thirty specimens," which is quite the leap in the number of individuals used to describe a species.[89] Yet others went on and studied the Hymenoptera—which consists of the ants, bees, wasps, and sawflies. This order is quite large and a challenge to define taxonomically.[90] As such, many entomologists who studied the Hymenoptera specialized further, choosing to focus on one of three suborders within the order. J. C. F. Klug (1775-1856), a director of the Berlin Museum, worked more broadly in the field of entomology but studied

[88] Lindroth, "Systematics Specializes", 131.
[89] Lindroth, "Systematics Specializes", 136.
[90] Lindroth, "Systematics Specializes", 137.

hymenopterans most specifically. In his obituary, it was written that "Klug provides the best proof of the truth, only too little admitted by many contemporary scientists, that the activities within a *special* branch only then may be of real importance if supported by broad *general* knowledge." [91] As a museum director, Klug was in a position for which a broad knowledge of insects was most likely useful, regardless of what he chose to study in a more detailed manner.

Classification of insect species and how a species was to be defined did not change drastically from the time of Latreille in the early nineteenth century. Relationships between species and the definition of species continued to be based around the most natural system of classification developed.[92] However, it took time for these changes to be reflected in collections; many institutions had their collections arranged according to the Linnaean classification system of the 1890s. Though these institutions, such as professional museums, worked to accommodate the needs of an increasingly 'professional' population of scientists, their collections were arranged in a way more suited to amateur naturalists, with arrangement based on few characteristics.[93] Efforts were made, however, to make collections of

[91] Lindroth, "Systematics Specializes", 137.
[92] Lindroth, "Systematics Specializes", 148.
[93] Rader and Cain, *Life on Display*, 35.

natural history museums suitable for relative ease of comparison of large numbers of insect specimens for the benefit of taxonomy.[94]

With the beginning of the twentieth century came a more complete shift from the amateur naturalist to the professional entomologist. This shift is reflected most succinctly in the types of research undertaken by the two forms of entomologist: while naturalists focused on description and field work, professional scientists were expected more and more to engage in laboratory-based research. [95] In the mid-1900s came a movement for cladistics, the concept of arranging groups of organisms according to how recently they shared a common ancestor, in taxonomic development; it was founded in the German insect taxonomist Willi Hennig's (1913-1976) effort to rework the traditional taxonomy of previous centuries was based in common ancestry.[96] Both cladistics and the phylogenetic system contributed to the growth in importance of evolutionary relationships to the determination of placement for insects in the taxonomic system.

Much in keeping with the trend of excluding the amateur from biological study, museums of the early twentieth century were institutions containing specimen collections that reflected the institutions' larger aim of making research

[94] Karen A. Rader, and Victoria E. M. Cain. *Life on Display: Revolutionizing U.S. Museums of Science and Natural History in the Twentieth Century*. (Chicago: University of Chicago Press, 2014), 14.
[95] Clark, *Bugs and the Victorians*, 238.
[96] C. Dupuis. "Willi Hennig's Impact on Taxonomic Thought." *Annual Review of Ecology and Systematics* 15 (1984): 3.

possible for experts in various fields of biological study.[97] In this way, early museums were not accessible to the general public. Much of the collections of these museums were divided into groups based on similarities in physical features and functions[98], which suited the needs of the professional biologist. With the advent of what we now think of as a natural history museum came efforts to organize collections based on the most up-to-date version of biological classification; this was reflected in museum displays to the public, later along with ecological context and other biological information, to varying degrees of success.[99] [100]

Museums retained their relevance to professional entomologists by continuing to conduct research in biological classification. Taxonomic research conducted in museums in the 1930s is reflective of an overall shift toward 'new systematics' based on evolutionary histories and adaptation to changing environments in the study of biology.[101] However, by the arrival of the 1940s and 1950s, collections-based research was again at odds with other forms of biological study. Much of the work done in these institutions continued to be focused on systematics, though this work was coming to be seen as the realm of amateur naturalists and not professional

[97] Rader and Cain, *Life on Display*, 2.
[98] Rader and Cain, *Life on Display*, 10.
[99] Rader and Cain, *Life on Display*, 36, 47.
[100] Donna Haraway. "Teddy Bear Patriarchy: Taxidermy in the Garden of Eden, New York City, 1908-1936." *Social Text*, no. 11 (1984): 24.
[101] Rader and Cain, *Life on Display*, 95.

biologists once again. Taxonomy was seen as removed from the actual needs of humankind as far as understanding the natural world in a broader sense.[102] [103]

In spite of a continuing trend in the field of biology—including the subtopic of entomological study—toward a system of taxonomy based on evolutionary relationships and molecular data, some professional biologists have continued to argue for the value of research based in the roots of the field. In 1998, Andrew Brower and Darlene Judd responded to an article in *Science* that suggested museum collections were no longer relevant to modern biological science; "[a]s insect-net-wielding curators of a natural history collection, we resent the implication that museum-based research is a dust-laden activity irrelevant to the study of evolution today."[104] The focus in entomology has shifted from the work of amateur naturalists to the endeavor of professional scientists, and from collections-based research to molecular data; as the field of entomology evolved, it shaped the development of our understanding of the natural world and the relationships between the organisms that inhabit it.

[102] Rader and Cain, *Life on Display*, 164.
[103] Rader and Cain, *Life on Display*, 166.
[104] Rader and Cain, *Life on Display*, 276.

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