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FISH FACTS:

DISCIPLINARY DEVELOPMENT OF ICHTHYOLOGY IN NINETEENTH-CENTURY EUROPE

A DISSERTATION APPROVED FOR THE
HISTORY OF SCIENCE

BY THE COMMITTEE CONSISTING OF

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Abstract

This dissertation chronicles the disciplinary development of ichthyology through the work of three prominent nineteenth-century naturalists: Georges Cuvier (1769-1832), Louis Agassiz (1807-1873), and Albert Günther (1830-1914). Cuvier argued that historical knowledge was necessary in order to understand the development of the natural sciences, and he devoted a significant portion of his career writing and lecturing on the development of these sciences. Cuvier's zoological studies focused on vertebrates, and he wrote foundational works in comparative anatomy and paleontology. He applied techniques from comparative anatomy and paleontology to the study of fish. Toward the end of his career Cuvier began working on a catalog of fish with the assistance of Achille Valenciennes (1794-1865). Cuvier died before this work was finished and Valenciennes continued the 22-volume series. Günther's work followed the methodologies promoted by Cuvier. Over the course of his career he produced a catalog of fish that described over 8000 species of fish. He also wrote the first English language textbook on ichthyology. Agassiz studied under Cuvier during the final six months of Cuvier's life. Between the early-1830s and mid-1840s Agassiz studied fish fossils in the museums of Europe, describing over 1600 species of extinct fish. Agassiz's study of fish paleontology influenced his interpretation of the fossil record and reinforced his belief that the geological evidence did not support evolutionary theory.

Acknowledgements

Over the course of my academic training I have had the good fortune to have been mentored by many exceptional teachers, but two people stand out as pivotal in shaping the path of my intellectual formation. While a graduate student at Scripps Institution of Oceanography, Paul Dayton helped to foster my love of natural history. Here at the University of Oklahoma my committee chair, Katherine Pandora, helped me craft that interest into a means of shaping analytical and historical ideas into a narrative describing the way people learned about the natural world. I have reason to be grateful to so many of the faculty, staff and students within the department of the History of Science, Technology, and Medicine at OU for providing the supportive environment I needed to finish a dissertation even while suffering from significant health issues. Two fellow graduate students, Margaret Gaida and Emily Margolis, have offered friendship and encouragement throughout my graduate studies at OU. I would like to extend special thanks to the members of my dissertation committee: Piers Hale, Kerry Magruder, Stephen Weldon and Bruce Hoagland. Each of the members of my committee provided thoughtful feedback at some point in the process of composing my dissertation. When it seemed like my dissertation might falter, Kerry Magruder and the staff at the Special Collections have provided me the haven I needed to finish my dissertation. I am grateful to my parents, who helped support me when I had to take time off work to finish my dissertation. And finally, I would like to thank my partner Robert and my friends Barbara and George who provided moral support when I needed it the most.

INTRODUCTION

Ichthyology: Organizing a Zoological Discipline

For many years before I became a graduate student in the history of science, I had been contemplating the question of information overload. How do people transform a large, disorderly assortment of information into a coherent narrative? It has always been a serious question for me, since I suffer from learning disabilities that seriously impair my language processing speed and that lead me to be easily overwhelmed in physical locations that are either noisy, crowded, bright, or hyperkinetic. Once I started my studies in the history of science, I quickly discovered that the problem of information overload was not new to either our own time or our culture. I was impressed by Ann Blair's book *Too Much to Know: Managing Scholarly Information before the Modern Age*, which explored how scholars during the early modern period coped with the rapid expansion of knowledge after the invention of the printing press.[1] Armed with this insight, I realized that considering how people attempted to solve this issue in the past might make it easier to understand how people might continue to address these issues in the future.

As a former biology major, and as someone who had also worked for five years editing a scholarly database for the aquatic sciences, I wanted to address my research to an issue relevant to my previous studies. Furthermore, as a master's degree student in Oceanography, I had developed an interest in marine conservation. I knew that in marine habitats the pressures of overfishing resulted in the decline of many species of fish, and that some were currently

[1] Ann Blair, *Too Much to Know: Managing Scholarly Information before the Modern Age* (New Haven: Yale University Press, 2010).

being threatened with extinction. Freshwater fish also face serious threats, although these are more frequently due to problems of pollution or habitat degradation. Conservation is a subject with historical ramifications, both in terms of the construction of knowledge, and in tracking populations of organisms over time. I decided that there might be practical benefits to understanding the development of knowledge about fish, in order to aid conservationists interested in using historical records to understand more about what fish populations may have looked like in the past.[2] These are the chief reasons I chose to write a history of the disciplinary development of ichthyology as my dissertation topic.

A limited amount of material relating to the history of ichthyology does appear within the literature for the history of science, but very little of this material is specifically related to the development of ichthyology as a discipline. As a result, it is easier to find the relevant material for developing an initial narrative of ichthyology among the work of past and now living ichthyologists. For anyone wishing to cultivate an understanding of the history of ichthyology, the best place to begin is a history of ichthyology written by the early nineteenth century naturalist, Georges Cuvier. Although Cuvier originally wrote in French, his ichthyology history is available in English translation, thanks to the scholarly efforts of ichthyologist Theodore Pietsch.[3] Cuvier's own career, including his ichthyology history, serves as a useful foundation on which to build the story of the disciplinary development of ichthyology. When I started working on my dissertation in 2013, besides myself and Pietsch, few people were

[2] When I was attending Scripps Institution of Oceanography and working on my master's degree in Oceanography, there were two other graduate students at Scripps working on projects that involved examining historical records in order to gain a better understanding of changes in fish populations over the past couple of centuries.

[3] Georges Cuvier, *Historical Portrait of the Progress of Ichthyology form Its Origins to Our Own Time*, Edited by Theodore W. Pietisch and translated by Abby J. Simpson (Baltimore: The Johns Hopkins University Press, 1995.)

currently working on extended projects in the history of ichthyology.[4] In 2015, Paul Smith, a professor of French Literature at the University of Leiden initiated a research project focused on ichthyological literature, although his primary research interests are largely confined to early modern texts.[5] Additionally, two Ph.D. students have been working under the auspices of Smith's project. Sophia Hendrikx's[6] work focuses on the sixteenth century naturalist Conrad Gesner. Didi van Trijp's[7] dissertation is focused on the work of four prominent ichthyologists who wrote foundational texts over the course of the century and a half leading up to where my dissertation begins. With the exception of the subjects of ornithology and entomology, historians of science have paid little attention to the development of the zoological disciplines. Zoological histories require specialized knowledge and a tolerance of a literature focused on the monotonous accumulation of detailed information. Since so few histories such as these have been written, it is unclear that they will yield a significant intellectual payout.

There is still some uncertainty regarding what constitutes a disciplinary history. The literature on disciplinary histories within the sciences is still quite modest, even though two

[4] There is a very useful book that came out in 2012 after I entered the History of Science Program at OU and was still working on my master's thesis. This book gave an account of the development of ichthyology in Australia and spans the nineteenth and early twentieth century. While this book is relevant to the development of ichthyology as a discipline, it is a work focused on colonial efforts. During the nineteenth century, European ichthyologists were still at the forefront of the disciplinary development of ichthyology. See Brian Saunders, *Discovery of Australia's Fishes: A History of Australian Ichthyology to 1930* (Collingwood: CSIRO Publishing, 2012).

[5] A brief description of the research project can be found online: Paul Smith, "New History of Fishes. A Long-Term Approach to Fishes in Science and Culture, 1550-1880," Leiden University, accessed 7/16/19, https://owl.purdue.edu/owl/research_and_citation/chicago_manual_17th_edition/cmos_formatting_and_style_guide/web_sources.html .

[6] Sophia Hendrikx's project is entitle, "Tradition and Innovation: Conrad Gessner and Sixteenth-Century Ichthyology (1551-1602)." Leiden University, accessed 7/16/19, https://www.universiteitleiden.nl/en/research/research-projects/humanities/tradition-and-innovation-conrad-gessner-and-sixteenth-century-ichthyology-1551-1602 .

[7] Didi van Trijp's project is entitled, "Enlightened Fish Books: A New History of Eighteenth-Century Ichthyology (1686-1828)." Leiden University, accessed 7/16/19, https://www.universiteitleiden.nl/en/research/research-projects/humanities/enlightened-fish-books-a-new-history-of-eighteenth-century-ichthyology-1686-1828 .

edited volumes on the subject were produced toward the end of the twentieth century. The first of these books *Functions and Uses of Disciplinary Histories* was published as the *Sociology of the Sciences Yearbook* in 1983 and includes ten chapters: five on the natural sciences, four on the social sciences, and one on the humanities and focuses on case studies of the history of disciplinary development ranging from the eighteenth to the twentieth century.[8] The second book is *History and the Disciplines: The Reclassification of Knowledge in Early Modern Europe* has an earlier chronological focus ranging from the sixteenth to nineteenth century and expands the discussion into one that attempts to consider the theoretical process by which knowledge is created.[9] Because the contributors of these works have only the space of a single chapter to make a statement about the process of disciplinary development for the field that they are analyzing, the discussion rarely involves the work of more than a handful of individuals, and sometimes only a single person is discussed in any depth.

Literature on disciplinary development in the sciences is still quite modest both in terms of the quantity of material that has been written on the subject and the depth to which case studies of individual disciplines have explored their subject material. Also, while there is general agreement that one of the primary functions of disciplinary development involved scientific practices becoming increasingly specialized over the course of time, it does not ensure consensus on the timing and means by which this specialization was achieved. An encyclopedia entry by Rudolf Stichweh has claimed that, "The scientific discipline as the primary unit of

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[8] Loren Graham, Wolf Lepenies and Peter Weingart (eds.) *Functions and Uses of Disciplinary Histories* (D. Reidel Publishing Company: Boston, 1983).
[9] Donald Kelly (ed.) *History and the Disciplines: The Reclassification of Knowledge in Early Modern Europe* (The University of Rochester Press: Rochester, 1997).

internal differentiation of science is an invention of nineteenth century society."[10] If this claim is considered valid it would mean that most of the discussion of disciplinary development in *History and the Disciplines* predates genuine disciplinary development. This difference of chronology can be explained by recognizing that Stichweh's article is largely focused on the point in history where increasingly specialized bodies of knowledge became formally structured with the academic setting. However, in terms of the formation of the basis of knowledge from which these academic disciplines were created, many were the product of centuries of previous efforts by scientific practitioners working in less formally didactic settings. Since Stichweh primarily is looking to the educational system as the locus of the institutionalization of disciplines, his article overlooks the significance of museums, which frequently served as more important sights for the institutionalization of the zoological disciplines. My dissertation is focused primarily on the intellectual foundations of the discipline of ichthyology, which were laid through the production of texts written on the subject over the course of the nineteenth century. These texts were written by naturalists working with specimens found in museums and can be seen as tied more closely with natural history collection practices than the establishment of academic disciplinary locations or community settings.

Zoological History

In order to understand the precedents for establishing ichthyology as a discipline, it is necessary to turn to the broader narrative as found in the development of the naturalists'

[10] Stichweh, Rudolf. "Scientific Disciplines, History of," *In International Encyclopedia of the Social & Behavioral Sciences*, edited by Neil Smelser and Paul Baltes (New York, Elsevier Science Ltd., 2001), 13727.

tradition and to zoological history. According to Paul Laurence Farber, author of *Finding Order in Nature*, the foundations of the zoological disciplines were laid down in the eighteenth century, and largely carried out during the nineteenth century. Farber has argued that the modern form of natural history emerged in the eighteenth century, with the work of the naturalists Carl Linnaeus and Georges Louise Leclerc, comte de Buffon provided the leading intellectual stimuli for this transformation.[11] He has identified the process of the development of taxonomic knowledge as a central project within natural history from this time period and has claimed, "What distinguishes natural history from the 'folk biology' of earlier studies is the attempt of naturalists to group animals, plants, and minerals according to shared underlying features and to use the rational, systematic methods to bring order to the otherwise overwhelming variation found in nature."[12]

An important transition that occurred during the nineteenth century was the specialization of science. Farber has indicated that this process was partially facilitated by changes in printing technology that allowed written work to be mass produced more cheaply and efficiently. As a result, it became more economically feasible to produce scientific literature that appealed to a relatively limited audience. He went on to state, "The rapid growth of research in natural history altered the character of the literature as well as the field itself in other ways. Monographs and articles grew noticeably more specialized, restricting questions of classification to limited subjects, such as a family of birds or genus of plants, and

[11] Paul Farber, *Finding Order in Nature: The Naturalists Tradition from Linnaeus to E.O. Wilson* (Baltimore: The Johns Hopkins University Press, 2000), 6.
[12] Farber, *Finding Order in Nature*, 1-2.

leading to more rigorous standards of analysis."[13] Natural history was initially divided into the fields of botany, zoology, and geology. By the middle of the nineteenth century, the process of dividing these categories of knowledge into disciplines and sub-disciplines was well under way. This further led to the production of specialized journals and the formation of more scientific societies. Within botany and zoology, the European cultural obsession with collection that had flourished so extensively in the eighteenth and nineteenth century, further augmented by naval and scientific expeditions, ensured that for those who had the time and financial resources to pursue their interest in natural history, there was a wealth of material to study.[14]

Comparative anatomy served as the basis for the formation of a natural system of classification. A central figure in the development of this narrative is Cuvier.[15] Since, as I have already indicated, Cuvier was also one of the leading ichthyologists of the early nineteenth century, he played a pivotal role in the development not only of comparative anatomy, but also directly to its application to the development of ichthyology. Additionally, Cuvier was a leading figure in the development of paleontology, so his presence in this narrative is also an important factor in the application of paleontology to ichthyology.

Setting out to tell the story of the development of ichthyology, I had identified a number of important texts such as Cuvier's *Le Règne Animal*[16] and *Histoire naturelle des poissons*[17] as

[13] Ibid, 33.
[14] Ibid, 33-36.
[15] Ibid, 37-46. In this section, Farber summarizes Cuvier's contributions to comparative anatomy on pages.
[16] Georges Cuvier, *Le règne animal distribué d'après son organisation: pour servir de base a l'histoire naturelle des animaux et d'introduction a l'anatomie compare*, 5 vols. (Paris: Deterville, 1817). Biodiversity Heritage Library, Date Scanned: 07/21/2010, https://www.biodiversitylibrary.org/bibliography/49223#/summary .
[17] Georges Cuvier and Achille Valenciennes, *Histoire naturelle des poisons*, 22 vols. (Paris: Chez F. G. Levrault, 1828-1849). Biodiversity Heritage Library, Date Scanned: 05/13/2008, https://www.biodiversitylibrary.org/bibliography/7339#/summary .

well as Albert Günther's fish catalogs and ichthyology textbook.[18] Initially, I was primarily interested in the organizational strategies employed by these texts. I thought I would tell the story of how ichthyology was organized into a scientific discipline through the analysis of the structural elements of these works. However, as I started engaging with this material, I soon learned that describing disciplinary formation within the branches of zoology, required acquaintance with a broad range of sometimes unexpected topics. Because the practice of natural history historically cut across boundaries of what are now distinct disciplinary fields, I found that to tell my story, I needed to have some basic understanding of the development of natural history from antiquity to the nineteenth century. This led me to recognize the entanglement of natural history practices with the now separate fields of geology, antiquarian studies, and medicine.[19] Understanding disciplinary formation also requires biographical knowledge of the leading figures who did the most to advance the state of zoological knowledge. This involves not only understanding personal history but identifying the educational and cultural elements in their stories that shaped how they viewed the natural sciences. But more than this, it is necessary to recognize how their personal interests shaped the development of the zoological disciplines they studied. In Cuvier's case, for example, in order to have an accurate understanding of the emergence of the discipline this entails analyzing his involvement in the development of comparative anatomy, paleontology and

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[18] Albert Günther was a Swabian born ichthyologist who was educated in the German speaking provinces but spent his career in London working as a curator and later as Keeper of Zoology at the British Museum. See Albert Günther, *An Introduction to the Study of Fishes* (Edinburgh: Adam and Charles Black, 1880) and Albert Günther, *Catalogue of the fishes in the British Museum*, Vols. 1-8. (London: Taylor and Francis, 1859-1870). Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/bibliography/8809#/summary .

[19] For an account of this relationship see, Gianna Pomata and Nancy Siraisi. "Introduction." In *Historia: Empiricism and Erudition in Early Modern Europe*, Edited by Gianna Pomata and Nancy Siraisi. (Cambridge, MA: The MIT Press, 2005), 1-38.

scientific historiography. Beyond the career of Cuvier, my dissertation considers the careers of two other prominent nineteenth century ichthyologists, the naturalists Louis Agassiz and Albert Günther. Aspects of their careers that must be considered include the way of Agassiz's interest in embryology shaped his views on paleontology, and how Günther's preoccupation with biogeography added a further layer of complexity to his narrative.

Zoological disciplinary histories cut across so many elements within the narrative of the development of the natural sciences that the only way they can be completed is by drawing limits on the scope of a given project and identifying which aspects of the narrative must be told and which can be left out. The scholarly work that provided me with the most useful model of how these kinds of histories could be written is Farber's book, *Discovering Birds*, which tells of the disciplinary formation of ornithology. Farber presented his work as a case study, but he indicated uncertainty regarding how representative his narrative would be compared to other zoological branches. In the introduction to his book Farber justified selecting ornithology as the subject of his case study because it had "emerged as one of the first zoological disciplines during the fragmentation of natural history."[20] He then ended the introduction to his book by stating that, "Only a full study of that chapter in the history of science will disclose to what extent this story is indeed representative. By attempting, however, to discuss in detail the many facets of the ornithological portion I hope to have provided a possible starting point of that wider issue."[21] My work on the disciplinary formation of ichthyology suggests that there are some standard elements across different branches of

[20] Paul Farber*, Discovering Birds: The Emergence of Ornithology as a Scientific Discipline, 1760-1850* (Baltimore: The John's Hopkins University Press, 1997), xxii.
[21] Farber, *Discovering Birds*, xxiii.

zoology: these include such issues as the importance of systematics, collection building, and the production of large descriptive works. Because the emergence of ornithology as a well-developed discipline proceeded ichthyology by several decades and because of differences in taxidermy practices, the disciplinary history of ornithology is less intimately tied to the development of comparative anatomy and paleontology. Additionally, although Farber discusses Darwin's relationship to ornithology toward the end of his text, Darwin's interest in birds was primarily as a beneficiary of the ornithological knowledge of discipline that was already well-established. As a result, this chapter in the history of evolution does not play a large part in understanding of the initial development of ornithology.[22] In contrast, factors in the timing and practice of ichthyology ensured that the study of fish played a significant role in evolutionary debate while ichthyology was emerging as a distinct zoological discipline, and my dissertation includes a discussion of the role of ichthyological knowledge in the development of evolutionary ideas in the final chapter.

A critical dimension of accounting for the development of zoology involves recognizing the scope of these histories which resulted from the activities of many participants spread over large geographical and temporal spaces. In a large and unwieldy subject like the disciplinary fragmentation of natural history so much happened, that the story simply cannot be contained by a single narrative. To really develop a full, rich understanding of this process, takes the accumulation of multiple narratives that help represent the variety of events, as well as the large number of participants, that helped make this happen. I cannot encompass all of these multiplicities in my dissertation, the chapters that follow provide a schematic description of

[22] Ibid, 140-146.

some of the most important events in the transition of ichthyology from a disorganized mass of facts into a discipline.

Dissertation Structure

When I began to organize this dissertation, I had no clear idea of a storyline. I had identified a number of primary sources from Cuvier and Günther that I believed were critical in describing the development of the foundational literature for ichthyology. At the time, I kept thinking, this is going to be the most boring dissertation ever written, because the goal I had in focus was simply the technical development of a zoological discipline. But as I began investigating the life and work of Cuvier, I was shaken by my growing awareness of the devastating impact that the French Revolution had on Cuvier and the scientific community in France. I spent almost two years of research trying to develop an understanding of how he experienced this powerfully traumatic event, and it is this exploration that is the focus of my opening chapter. Despite the passionate appeals to an evolving sense of social justice promoted by revolutionary radicals, when the Revolution transformed from peaceful demonstrations into bloody battles, nothing was safe, and no one was free. Fear became a corrupting contagion. There were members of the elite scientific community in France who survived the French Revolution and the political upheavals that followed, and were able to reestablish successful careers, but science in France was never the same.

Cuvier's career, which spanned the French Revolution, Napoleonic Empire, and restoration of the monarchy, represented an extremely politically unstable epoch in French history. Throughout this period, Cuvier held many roles within the community of science and public administration as naturalist, curator, public spokesman and educational advisor. His ability to successfully negotiate such a range of activities during an era of profound national uncertainty, speaks to his versatility to respond to change. This was an essential skill, at a time when the scientific community in France was grappling with redefining itself in the light of a rapidly changing civil landscape.[23]

In the first chapter of my dissertation, I explore the use Cuvier made of history as a means of reestablishing a sense of continuity with the past in the aftermath of the rupture that the French scientific community suffered as a result of the violence of the Revolution. History mattered to Cuvier on many levels; most significantly Cuvier used his historical narratives to make polemical arguments describing the best social and political conditions under which science could thrive, as well as the skills, methodological practices and philosophical commitments that represented true scientific rigor. Professionally he identified himself not only as a natural scientist but as nature's historian. In total, Cuvier's historical works account for approximately thirteen volumes of text, substantively outweighing his paleontological writings. Although the extent of his historical writings is modestly less substantive than his works in comparative anatomy, once one considers how much assistance Cuvier delegated in preparing his anatomical works, even here the original material of his historical contributions comes out as being roughly equivalent to his work in comparative anatomy.

Cuvier's insistence that facts within the natural sciences cannot be uncovered by *a priori* methods placed a significant burden on any naturalist hoping to forge a shortcut to discovery.

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[23] Dorinda Outram, *Georges Cuvier: Vocation, Science, and Authority in Post-Revolutionary France* (Manchester: Manchester University Press, 1984).

Cuvier indicated that hypothesizing was a waste of time, as the ideas about the natural world formed by these means are rapidly invalidated. Since the formation of knowledge came through the methodical accretion of many generations, to avoid the transgression of merely duplicating observations already made by others, the dedicated naturalist must take on the burden of collective memory. For, by Cuvier's logic, adequate knowledge of the history of the natural sciences was the only means of effectively navigating the tremendous body of knowledge to which the natural scientist attempted to add his contribution.

Over the course of his career Cuvier provided foundational literature that helped establish the disciplines of comparative anatomy and paleontology, and these interrelated disciplines are more fully explored in my second chapter. Cuvier devoted the final years of his life to further developing both his scientific historical narrative and attempting to describe the rich ichthyology collections that could be found at the *Muséum national d'histoire naturelle*, the natural history museum in France where Cuvier worked.

The history of the disciplinary development of ichthyology in the nineteenth century, is as much a story of collection building and curation, as it is about those specialists who analyzed the dried specimens, spirit-soaked organisms, or fossil remains of deceased fish. Two museums played central roles in the development of ichthyology in the nineteenth century, the *Muséum national d'histoire naturelle* in Paris and the British Museum in London. Chapters three and four of my dissertation follow the career of Günther and his work at the British Museum from 1857-1914. In London in the mid-1830s, management of the zoological collection at the British Museum became an object of Parliamentary inquiry, when a turbulent mix between discontent over inadequate career options for men seeking scientific careers intersected with debates over social reform. These Parliamentary inquiries helped establish the reputation of John Gray, who in 1840 was promoted to the position of Keeper of Zoology at the British Museum. Over the course of his career, Gray oversaw the publication of hundreds of zoological catalogs, including those by the ichthyologist Günther. Between 1859 to 1870 Günther produced an eight-volume catalog of fish, including descriptions of almost twice as many species as were included in the works Cuvier and Achille Valenciennes. These catalogs are examined in chapter three.

In the fourth chapter of my dissertation, I examine the ichthyology textbook published by Günther in 1880, showing how this text help bring together many of the elements on which the discipline of ichthyology was firmly established by the latter part of the nineteenth century. Günther's interest in biogeographical patterns of fish distribution led him to propose that there had one been marine passages connecting fish populations on either side of the Isthmus of Panama and that fish along the coast of Japan had once been able to more freely migrate to the region of the Mediterranean Sea. The closing of the Isthmus of Panama matches modern interpretations of continental movements within the Pliocene Epoch (5 - 2 million years ago). The final closure of the Tethys Sea is believed to have occurred during the Miocene Epoch (24 - 5 million years ago).[24] Günther made these observations five years before the Austrian paleontologist Melchior Neumayr and 13 years before the Austrian geologist Eduard Suess each wrote on the subject of the Tethys Sea.[25] The relationship of fish on either side of the Isthmus

[24] N. Hannon, P. Sepulchre, V. Lefebvre and G. Ramstein, "The Role of Eastern Tethys Seaway Closure in the Middle Miocene Climatic Transition (ca. 14 Ma)," *Clim. Past* 9 (2013): 2687-2702.
[25] Neumay wrote about the "Central Mediterranean" in 1885 and Suess proposed the Tethys Sea in 1893. See P. Sylevester-Bradley, "The Concept of Tethys," In *Aspects of Tethyan Biogeography* (London: The Systematics Association, 1967).

of Panama is now well recognized,[26] but I have not found any evidence regarding what ichthyologists currently think about biogeographic patterns associated with the closure of the Tethys Sea. I lack the expertise to evaluate the quality of Günther's evidence, but this raises an intriguing question regarding whether patterns of fish morphology might have been sufficient to reveal these kinds of changes to the geological landscape.

Cuvier died in May, 1832 with his fish cataloging project only one third of its final length, leaving it to his assistant Valenciennes to attempt to complete it. In the years leading up to Cuvier's death, a young ambitious student of medicine and natural history named Louis Agassiz was earning his doctoral degrees in medicine and natural history in the region that is now Germany. Anxious to court Cuvier's support of his budding career, Agassiz dedicated the first two book-length publications of his research on the ichthyology of Brazilian fish to Cuvier. During what turned out to be the final six months of Cuvier's life, Agassiz came to visit him in Paris. Cuvier not only lent Agassiz his support but granted him access to his private material so that Agassiz could investigate fish fossils. Over the course of the almost decade and a half that followed, Agassiz produced the most definitive book on fish fossils written in the nineteenth century, while also contributing significantly to the development of glacial theory.

In my fifth and final chapter I follow the course of Agassiz's early career and with it provide an account of the significance of fish paleontology during the nineteenth century. Agassiz's work took place against the backdrop of scientific controversy, both within the context of the geological community attempting to interpret the stratigraphical record, and in

[26] Gene Helfman, Bruce Collette, Douglas Facey, and Brian Bowen, *The Diversity of Fishes: Biology, Evolution, and Ecology* (Chichester: Wiley-Blackwell, 2009), 377.

the midst of intense debates regarding the implications of the meaning of animal morphology. Over the course of his career, Agassiz attempted to interweave his knowledge of animal morphology, embryology and paleontology into an integrated description of the history of life and in the process became one of Darwin's leading opponents regarding the processes of evolution. Cuvier had proposed that there were four basic body plans in the animal kingdom known as *embranchements*. Agassiz believed that the fossil record confirmed the distinct separation between these *embranchements* throughout the course of geological history. My final chapter closes with a discussion of Darwin's response to the Cuvierian *embranchements*.

Chapter 1

Nature's Historian: Making History of Science in the Wake of the French Revolution

Paris 1795

The acrid stench of fear must have still mingled with the malodorous scents of human refuse in the narrow Parisian streets when the young naturalist, Georges Cuvier, first emigrated to the city in the early months of 1795.[27] When the French Revolution first broke out in the summer of 1789, it seemed as if the fruition of the Enlightenment had finally come to France, ushering in a new age of equality and rational government. At first the euphoric, revolutionary optimism could not be contained in a single country, and supporters from neighboring European countries as well as the Americas looked eagerly to France to see where this new experiment in democracy might lead. As France's idealism took on a militaristic edge, in the coming years, and as the country began expanding its borders in an aggressive campaign to export revolution, such outside support rapidly dwindled among France's neighbors. Within France, support for the Revolution, although loud and contagious was far from unanimous. Royalists, devout Catholics, conservative factions suspicious of the Enlightenment,[28] and some rural inhabitants, never succumbed to revolutionary fervor and opposed the new republican regime. Such opposition was violently suppressed, turning revolution into civil war.

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[27] There is some ambiguity regarding when Cuvier first arrived in Paris. His autobiography claims that he first came to Paris in April 1795. Outram points out ambiguities in Cuvier's autobiography and indicates that he may have arrived as early as February 1795: Dorinda Outram, *Georges Cuvier: Vocation, Science and Authority in Post – Revolutionary France* (Manchester: Manchester University Press, 1984), 45.

[28] There were those in France suspicious of Enlightenment ideas, who made dire predictions that they felt were substantiated by the Revolution. For an account of anti-Enlightenment thinking both before and after the Revolution see, Darrin McMahon, *Enemies of the Enlightenment: The French Counter-Enlightenment and the Making of Modernity* (New York: Oxford University Press, 2001).

Spawn not just of the Enlightenment, but of the *ancien régime* it so violently repudiated, the Revolution inherited a poisonous legacy of suspicion. In the absolutist state, ideas not vetted by the government were viewed with wariness, and French intellectuals were subject to intense surveillance.[29] In some ways, the Revolution ushered in a new era of intellectual freedom as characterized by a lifting of restrictions within the press. Underneath this new freedom ran a rank undercurrent of fear and distrust. Conspiracies, real and imagined, haunted the imaginations of France's new leadership, eventually compelling authorities to seek enemies from within as well as without. Between the summers of 1793 and 1794, a fever seized the fledgling Republican government as moderate and radical political factions vied to control the revolutionary vision.[30] Violence and terror were naturalized as necessary means of ensuring the safety of the Republic.[31] In the Convention, rivalries turned into bloody purges. In the streets of Paris, an intoxicating mix of envy and suspicion led neighbors to inform on each other. Survival seemed dependent on acquiescence, as accusation and bloody vengeance fell on those few brave souls who sought to quell the tide of rising violence.

Eighty-two deputies of the National Convention had been executed, before the close of 1794, thinning their ranks by over ten percent.[32] The French Revolutionary historian Timothy

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[29] An example of the surveillance of French writers during the mid-eighteenth century is provided in the chapter "A Police Inspector Sorts His Files: The Anatomy of the Republic of Letters" in the book by Robert Darnton, *The Great Cat Massacre: And Other Episodes in French Cultural History* (New York: Basic Books, 1984), 145-189. For further discussion of issues of freedom of expression and of the press see Charles Walton*, Policing Public Opinion in the French Revolution: The Culture of Calumny and the Problem of Free Speech* (New York: Oxford University Press, 2009).

[30] Timothy Tackett, *The Coming of the Terror in the French Revolution* (Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 2015). This book provides an account of the early years of the revolution, including the events and suspicions that helped bring about the Terror.

[31] Mary Ashburn Miller, *A Natural History of Revolution: Violence and Nature in the French Revolutionary Imagination, 1789-1794* (Ithaca: Cornell University Press, 2011). Miller's book provides an account of the way metaphors depicting violent acts in nature were used to naturalize and justify violence during the Terror.

[32] Tackett., *Coming of the Terror*, 1-2.

Tackett describes the impact of the Terror, "Between March 1793 and August 1794, 16,594 persons were executed, and half a million imprisoned."[33] By June 10, 1794 (22 *prairial*)[34] accused persons lost legal recourse to defend themselves against charges.[35] Fueled by suspicion and paranoia, no one in the revolutionary government felt safe, so when Maximilien Robespierre[36] (1758-1794) announced a new set of purges, in late July members of his own party turned on him. Fearful of the next set of purges, on July 27 (9 *thermidor*), the Convention arrested Robespierre and several of his close compatriots. The next day, Robespierre himself was guillotined, and while this act did not end the Terror, it did set in motion the course of events that finally allowed for the conclusion of this traumatic episode within the history of the Revolution.

Cuvier's Revolution

In the immediate aftermath of the Terror, survivors scrambled to disavow any connection with the administration, policies, and behaviors that had allowed such violence to flourish. In the decades to follow, the Terror still represented such deep psychic wounds among the citizens of France, that towards the end of his life when he wrote his autobiography, Cuvier felt the need to obscure the role he played as a minor, provincial functionary from the years 1793 to 1795. Dorinda Outram, biographer of Cuvier's administrative career, called into

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[33] Dorinda Outram, "The Ordeal of Vocation: The Paris Academy of Sciences and the Terror, 1793-95." *Hist. Sci*, xxi (1983), 253.

[34] During the 12 years between 1793-1805, the French government implemented a new calendar so within texts describing the French Revolution, these alternate dates are frequently provided.

[35] Outram, "Ordeal of Vocation," 253.

[36] Robespierre was a French lawyer and politician, who became a prominent leader of the Jacobin party and used his influence during the Reign of Terror to suppress the rival Girondin party.

question not only the scant narrative of the turbulent years of Terror, but also the account Cuvier provided of his initial introduction into the community of savants in Paris during the early months of 1795. Cuvier's autobiography indicated he received his introduction through the recommendation of Henri-Alexandre Tessier, a member of the defunct Academy of Sciences, whom Cuvier met and helped to shelter during the Reign of Terror. However, Outram points out that such an introduction was not necessary, as a number of members of the community in Paris were already familiar with Cuvier's work and that he had already established contacts with notable members within the scientific community of Paris such as Bernard Germain de Lacépède, Jean-Baptiste Lamarck and René Just Haüy[37] prior to his alleged acquaintance with Tessier.[38] While some uncertainty regarding the precise nature of Cuvier's professional development linger, the broader outline of his early career seems more clearly defined.

Cuvier came of age in a time of Revolution. Born on August 23, 1769, he was still more than a month shy of his twentieth birthday at the time of the storming of the Bastille on July 14, 1789. He was born to a Swiss, Lutheran family residing in the town of Montbéliard, then part of the Duchy of Württemberg. His family was well connected, although far from wealthy, and Montbéliard was a town noted for the export of intellectual manpower.[39] Cuvier demonstrated strong academic aptitude from a young age, and this fact, coupled with that of his family's declining fortunes, meant that much was riding on his success. At the age of fourteen, under

[37] Outram, *Georges Cuvier*, 166.
[38] Ibid, 41-47.
[39] Ibid, 14. Outram makes the following observation regarding Montbéliard, "The combination of poverty and the high quality of Lutheran education, led the principality to explore intellectual manpower all over the German states and eastern Europe."

the patronage of the Duke of Württemberg, Cuvier was sent to attend the Académie Caroline at the University of Stuttgart. At the Académie Cuvier received an education in administration, with the expectation that after his training he would eventually acquire a government position at Württemberg. However, at the time of his graduation in 1788, no such position was immediately available, and his family's financial need drove him to seek alternative employment. That year, Cuvier took a position in Normandy as tutor to the son of a Protestant noble the Comte d'Héricy. Hence, it was with the d'Héricy family in Normandy that Cuvier was employed during the early years of the Revolution. The first three years of his employment were spent in Caen. In 1791 the d'Héricy retreated to Fiquainville, an even quieter portion of the Norman countryside, located close to the seashore. In this isolated location, Cuvier found himself for the first time in possession of a substantial amount of leisure time to which he could devote himself to natural history field study. This was no simple recreational activity. During this time, Cuvier produced his first natural history publications and began corresponding with savants in Paris.[40]

Under ordinary circumstances, it is highly unlikely that Cuvier would have risen to a position of prominence within the French scientific community, and even less so that he would take on important administrative positions through several regimes of the French government. But like so many of his peers, the convulsive events of the French Revolution, reshaped his world and in the process, rewrote the possible trajectories of his life. In October 1793, France annexed Montbéliard, converting Cuvier from a citizen of the Holy Roman Empire to one of the

[40] Ibid, 13-48. A biographical sketch of Cuvier's early life can be found in the two opening chapters of Outram's book.

fledgling French Republic.[41] In the late years of the *ancien régime*, fierce competition for the coveted positions within the Academy of Sciences and other Parisian institutions barred access to young savants hoping to advance careers within the sciences. But by 1795, many members of the old guard of the scientific community had either died, fled Paris, or forsaken scientific vocations, making new space for a select group of young savants to join the community. Furthermore, intense anti-religious sentiments of the early Revolution loosened Catholic influence for a time over public life in France.

1795 was a fateful year for Cuvier, as well as the scientific community of France. In the opening years of the Revolution, prominent savants such as Nicolas de Caritat, marquis de Condorcet (1743 – 1794) and Félix Vicq d'Azyr (1748 – 1794) actively participated in attempts to reform the sciences and bring them into conformity with the new ideals of the Republic.[42] However, the cresting tide of political animosities represented by the Terror negated such efforts, sweeping away almost all the scientific institutions in France. To understand the general effects of the Revolution on science in France, it is important to appreciate the unique ties that existed between science and the state during the *ancien régime*, particularly through the generations represented by the reigns of Louis XIV to Louis XVI (1643 – 1792).

Under the *ancien régime* the establishment of such institutions as the Académie des Sciences (founded in 1666) and the Académie Francaise (founded in 1635) fostered a unique relationship

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[41] Ibid, 31. According to Outram, Montbéliard has a complicated social history in the late eighteenth century, considering that linguistically the residents spoke French, but religiously, they were Lutheran. On page 13, Outram indicates that even before the Revolution, this region had been invaded by France and already held bitter memories of religious persecution.

[42] In Chapter 1 of his book, Charles Gillispie provides an extended discussion of reforms suggested by scientists in the first year of the Revolution. Unfortunately, neither Condorcet nor Vicq d'Azyr survived the Terror: Charles Gillispie, *Science and Polity in France: The Revolutionary and Napoleonic Years* (Princeton: Princeton University Press, 2004), 7-100.

between the French state and members of the Republic of Letters. A number of prominent scientific societies were established throughout Europe during the early modern period, but Louis XIV's Minister of Finances Jean-Baptist Colbert sought to "enlist the most talented people of France into the service of their monarch."[43] Although the concept of enlisting such talent to the service of the state was not unique to France, at this point in history the French monarchy was willing to provide resources to exercise this ambition on a larger scale than other European states had previously attempted. With the formation of the Académie des Sciences, Colbert forged close ties between savants and the absolutist state. Many members of the community of savants, gathered in Paris during the eighteenth century, based careers on their association with various state supported institutions.[44] Louis XIV himself withdrew from Paris to Versailles during the latter part of his reign and the court remained ensconced in the countryside until a revolutionary mob brought Louis XVI and his family back to Paris in 1789. Nonetheless, through the remaining decades of the *ancien régime,* the scientific community remained concentrated in Paris, meaning that the savants of the revolutionary generation often found themselves uncomfortably close to unfolding political events. Ultimately, the coming of the French Revolution not only endangered the lives of members of this community, but destabilized professional identities and closed career paths for aspiring intellectuals.

Revolution and Terror left its mark on the scientific community in Paris. Outram identified the deaths of twenty former members of the Academy of Sciences between

[43] Roger Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666-1803* (Berkeley: University of California Press, 1971), 13.
[44] Hahn, *Anatomy of a Scientific Institution*, 1-34. Hahn's book is still the leading English language description for describing the establishment and early development of the Academy of Sciences in Paris. A summary of the early establishment of the institution can be found in the first chapter of the book.

September 4, 1792 and November 1795. Some of these deaths can be attributed to natural causes, although under such conditions, it is difficult to ascertain what part stress played in hastening their ends. The majority died violently, including six who were guillotined, with other causes including assassination, siege, imprisonment, and suicide. For those who survived, the Terror left other painful legacies including flight, imprisonment, loss of social status and economic security, isolation and the erosion of personal identity.[45] Losses extended beyond individuals into the institutions that had helped knit the scientific community together.

In the early years of the Revolution, as the royal patronage network that supported the scientific community began to unravel, individual savants attempted to renegotiate new relationships with the government to legitimate their roles within society and demonstrate their utility to the state. Such attempts met with varying success.[46] As the weight of mistrust festered during the Terror, pretentions to specialized knowledge drew the rancor of an austere and wrathful form of egalitarianism. Almost all French institutions and educational establishments were disbanded before the end of 1794. Those few institutions that survived, such as the Natural History Museum in Paris, only did so by redefining themselves within the new political context.[47] The turbulent years of the Terror led to the nadir of scientific activity in France. So 1795 represented a year of rebirth. As the flood waters finally began to recede, the

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[45] *Ibid*., 254, 256, 266-268. In pages 266-268 Outram provides a series of tables indicated the impacts of the Terror both on former members of the Academy of Sciences as well as members of the newly formed Institute. For further information on the fates of various Academy members see also William Smeaton. "French scientists in the shadow of the guillotine: the death roll of 1792-1794." *Endeavour, New Series*, Vol. 17, no. 2 (1993), 60-63.

[46] E. C. Spray, *Utopia's Garden: French Natural History from Old Regime to Revolution* (Chicago: The University of Chicago Press, 2000), 158-159.

[47] Spray, *Utopia's Garden*. In her book Spray chronicles the means by which the Natural History Museum was one of the few institutions that managed to survive this difficult time of transition.

community of savants that remained within Paris could begin the arduous process of reclaiming the terrain on which they would rebuild their community.

Science and Identity in Post-Revolutionary France

For those savants who weathered the vicissitudes of the Revolution (including the crisis of the Terror) as well as the Napoleonic wars that followed, it became necessary to adapt to new institutional norms, create new professional identities and reformulate a new understanding of their place in history. Nevertheless, in the decades immediately following the Revolution, including the Napoleonic era and Restoration period, France was able to maintain a position of scientific ascendency that was not seriously challenged until the middle-third of the nineteenth century.[48] Still, the Revolution and its aftermath was quite costly to the scientific community in France. The unfolding events of the Revolution not only reshaped the professional landscape for those with scientific aspirations, but also in many cases compromised people's sense of personal identity. Under the pressures of rapid civic change, dissenting political views and shifting alliances, the scientific community unraveled. Institutions were dismantled, reformed, and created with such rapidity and so little cohesion, that they offered little sense of professional stability to those who were employed by them.

To understand the impact of the Revolution on the intellectual community of France, it is important to recognize how unique the events surrounding it were within the context of the cultural history of Europe. War, civil unrest, political upheaval, regime change: all of these things were familiar events in the chronicles of European history. But the French Revolution

[48] Robert Gilpin, *France in the Age of the Scientific State* (Princeton: Princeton University Press, 1968), 82.

was more than this. It was a social experiment on a national scale, the shockwaves of which were felt across the world, ushering in an era of revolution that would last more than half a century and trigger revolutionary fervor across the globe. Nobody was sure what it meant to reform an absolutist monarchy into a republic, and in fact at the outset of the Revolution it was not clear that a republic was the intended outcome. The successive legislative bodies of the revolutionary government intensely contested the meaning and political structure of the Revolution.[49] In such a civil and political environment, it was often difficult for savants to identify appropriate means of social negotiation, what opportunities might be available for career development, or what personal and political alliances might help them achieve desirable ends.

Concerns over personal safety and anxiety over political indiscretions also formed a dominant issue through the revolutionary period and beyond. Savants were placed in a tenuous position. The changing political climate pushed intellectuals with relevant technical knowledge into increasingly public roles. Expertise was needed for efficient maintenance of the revolutionary and later the imperial war machine. Intellectuals were also needed to fulfill administrative positions within the government, converting men of science into servants of the state and forming an even tighter association than had existed during the *ancien régime*. From a vocational standpoint, this represented a considerable source of internal conflict, both for individuals and the scientific community. From a social perspective, it seemed advisable to maintain low public profiles and convey the appearance of pursuing careers in science as part

[49] A useful overview of the impact of the French Revolution can be found in the Great Courses lecture series by Suzanne Desan. See Suzanne Desan, *Living the French Revolution and the Age of Napoleon* (Chantilly: The Great Courses, 2013).

of an apolitical quest for seeking the truth in nature. From the perspective of career advancement, it became important to seek out state patronage in one form or another and build a popular reputation.[50]

A savant's reputation depended on cultivating a public persona through writing and lecturing, at a time when the tolerance for freedom of speech and expression were being severely tested. Freedom of speech was put forward as a precept of the early Revolution (1789 – 1793). However, even before the Terror (1793 – 1794), prosecution of cases regarding libel and unpatriotic speech demonstrated that a schism existed between free speech and free expression. During the Terror, as political tensions between the revolutionary factions of the Girondins and Jacobins escalated, a revolutionary could be executed for merely being suspected of harboring unfavorable political views. Internal violence decreased during the Thermidorian period (1794 – 1795). Even though the Directory (1795 – 1799) was a period of comparative political stability, freedom of speech was scaled back and greater police surveillance of citizens was instituted; under Napoleon's consulate and empire (1799 – 1815) freedom of speech was further curtailed.[51] Under such changing social expectations, it behooved savants to carefully choose their words.

The revolutionary generation of savants found history as a means of sublimating their sense of loss and fear through the identification with historical figures from the past, one such popular figure being Socrates. Contemplating both personal and civil history became an

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[50] Outran discusses vocational issues for French savants both during and after the French Revolution. Two of the most pertinent sources of this subject are the previously mentioned article, Outram, "Ordeal of Vocation," 251-273 and Dorinda Outram, "Life-paths: autobiography, science and the French Revolution," In *Telling Lives in Science: Essays on Scientific Biography*, Edited by Michael Shortland and Richard Yeo (Cambridge: Cambridge University Press, 1996), 85-102.
[51] For information on freedom of speech during this period see: Walton*, Policing Public Opinion.*

important mechanism for reclaiming a sense of identity and meaning, and reforming a sense of continuity. A precedent already existed for the institutional expression of such history in the form of public éloges that had been presented by the permanent secretaries at the Academy of Science during the *ancien régime*. When the National Institute was established in 1795 to replace the defunct Academy, Jean Baptiste Joseph Delambre and Cuvier were appointed to fulfill the secretarial roles and took on the task of presenting the public éloges.[52] During Cuvier's career in Paris, savants frequently prepared autobiographical material that could be used to help formulate their éloges once they died. Based on the large amount of autobiographical literature produced during this era, such writing seems to have served an important function in working through the impact of social and political upheaval and well as attempting to secure public reputations for the benefit of future generations.[53]

The Ukrainian historian of science, Leonid Zhmud, has pointed to times of social disruption as critical periods when the history of science becomes necessary to working scientists, however it is clear from the context of his comments that Zhmud's primary focus is on protracted chronological discontinuities of scientific activity or the disjunctions that occur when scientific ideas are transmitted from disparate cultures.[54] The French Revolution represented a form of discontinuity that is poorly represented in strictly chronological terms. Instead it manifested in a rift in the social fabric of the scientific community in France, that seems most appropriately expressed in seismic and cataclysmic terms. In her discussion of

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[52] Outram, *Georges Cuvier*, 56 and 67.
[53] Outram, "Life-paths," 85-102.
[54] Leonid Zhmud, *The Origin of the History of Science in Classical Antiquity*. Translated by Alexander Chernoglazov. Vol. 19 of Philologisch-historische Studien zum Aristotelisms. (New York: Walter de Gruyter, 2006), 3-10.

scientist's autobiographies from the French Revolution, Outram also raises the issue of using such autobiographies as "a way of asserting the continuities of existence and identity across the rupture between the pre- and post-revolutionary worlds."[55] In the wake of the Revolution, biography and communal history moved beyond the normal functions of chronicling disciplinary progress, and recognizing the accomplishments of the newly deceased, it became a means of reclaiming meaning in a frightening and uncertain world.

Nature's Historian

From a scientific perspective, Cuvier is primarily remembered for his formative contributions to the fields of comparative anatomy and paleontology. Outram has also built a compelling narrative regarding the significance of Cuvier's administrative career. However, one aspect of his career that has received comparatively little attention is that of Cuvier as an historian of science. The sheer weight of historical material Cuvier produced over the course of his career is comparable to that of his contributions to comparative anatomy and paleontology, indicating that he was not merely an historical hobbyist but weighted these histories as of similar importance to his scientific works. Upon studying Cuvier's histories within the context of his scientific career, I am convinced that Cuvier thought that the methods that historians used to study history complemented the methods natural scientists used to study the natural world. Before building this argument, however, I will lay out the range of his historical contributions.

[55] Outram, "Life-paths," 85.

Between 1799 and 1803 Cuvier served as temporary secretary to the Institute de France. In January 1803 he was than appointed as one of the perpetual secretaries of the Académie des Sciences.[56] Part of the traditional role of secretary within this institutional context was to deliver public éloges on the occasion of the death of members of the scientific organizations.[57] Additional secretarial duties included the preparation of annual *Histoire et Mémoires*, the yearly history of the institution's scientific achievements.[58] In addition to the éloges that Cuvier prepared for the Institute and the Académie, Cuvier wrote biographical sketches of important figures in the history of science for the *Biographie universelle*.[59] To this extent, Cuvier was following in the tradition of prior permanent secretaries of the Académie des Sciences who served during the *ancien régime*. If his contributions ended here, his interest in history would fit well within this precedent.

In 1810 at the request of Napoleon, Cuvier prepared a report on the progress of the natural sciences[60] subsequent to initiation of the French Revolution, covering the years from 1789 to 1808 entitled *Histoire des progrès des sciences naturelles: depuis 1789 jusqu'à ce jour*. In 1826 Cuvier revisited this history, which was published as the first volume in a series on the

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[56] The Institute de France and Académie des Sciences are the same institution, and the replacement for the Académie des Sciences of the ancient regime. The institution went through a number of name changes throughout its history.

[57] For an extended examination of the elegiac tradition at the Paris Academy prior to the French Revolution see, Charles Paul, *Science and Immortality: The Éloges of the Paris Academy of Sciences (1699-1791)*, (Berkeley: University of California Press, 1980).

[58] For further information of the establishment of these traditions during the career of the first perpetual secretary of the Paris Academy of science see: J. B. Shank, *The Newton Wars & the Beginning of the French Enlightenment*, (Chicago: The University of Chicago Press, 2008), 61.

[59] For an extended bibliographical account of Cuvier's elegiac contributions see: Dorinda Outram, "The Language of Natural Power: The "Éloges" of Georges Cuvier and the Public Language of the Nineteenth Century Science," *Hist. Sci*., xvi (1978), 153-178.

[60] Theodore W. Pietsch (ed.), *Cuvier's History of the Natural Sciences: Nineteen Lessons of the Sixteenth and Seventeenth Centuries*. Translated by Beatrice D. Marx. (Paris: Publications Scientifiques du Museum national d'Histoire naturelle, 2015), 9.

contemporary natural sciences. In 1828 three subsequent volumes were published on the subject covering the years 1809 to 1827. Additionally, in 1828 when the first volume of *Histoire naturelle des poissons* was published, Cuvier devoted half of the material in this monograph to the history of ichthyology. Cuvier's final historical offering commenced in December 1829 as part of a lecture series. These public lectures, which covered the history of the natural sciences, were offered on a nearly weekly basis until July 1830 and resumed again in the winter and spring of 1831 and 1832. On May 8, 1832 Cuvier delivered the opening lecture to the final portion of the series, but soon after his speech Cuvier grew ill, and he died five days later, on May 13, 1832.[61] Cuvier apparently presented this material from memory, and his presentation was only substantively preserved through the compilation of lecture notes from members of the audience, which when finally published comprised five volumes.

Cuvier's histories revealed a tenaciously empirical definition of the natural sciences. Furthermore, appropriate methodologies for investigating the natural world drew from the same skill sets employed by historians or even antiquaries. Outram has noted that Cuvier identified himself as an historian rather than a natural historian.[62] By choosing to categorize himself under this broader term, Cuvier embraced a view of the natural sciences where historical approaches were not merely confined to an outlying province of knowledge but were a central activity to the acquisition of knowledge. The primary creative activity in science was not found in hypothesizing, which amounted to premature speculation. Instead, it was the

61 Theodore W. Pietsch (ed.), *Cuvier's History of the Natural Sciences: Twenty-four Lessons from Antiquity to the Renaissance*. Translated by Abby J. Simpson. (Paris: Publications Scientifiques du Museum national d'Histoire naturelle, 2012), 22-23.
62 Outram, *Georges Cuvier*, 151.

work of synthesis, where the expert navigates through the vast store of knowledge to uncover the underlying order and unearth the underlying laws of nature they revealed. Cuvier's approach to history was both disciplinary and polemical. While it is impossible to entirely separate these two functions of history, Cuvier's history of ichthyology particularly highlights Cuvier's disciplinary approach to history, while his lecture series in the natural sciences more clearly revealed his polemical approach.

Opening statements in both Cuvier's history of ichthyology and his history of the natural sciences revealed why he placed so much emphasis on these histories. In both works, Cuvier makes emphatic claims about the character of natural sciences that have important implications regarding what constitutes good science and how scientific knowledge must be organized. In the opening paragraph of the first volume of *Histoire naturelle des poissons*, Cuvier stated that natural history is a "science of facts" that is too large to be mastered by a single person. Therefore, the serious student of natural history must consult the authors who have contributed to the development of natural history. It is not sufficient to merely know what previous authors have said, but to fully appreciate, "the circumstances that governed their work, the times they lived in, the condition in which they found the science, and the facilities procured for them either through their personal position or through the help of friends, patrons, or students."[63] When this information is put into chronological order it constitutes the history of science, and serves as the necessary foundation to gain a

[63] Cuvier, *Historical Portrait of the Progress of Ichthyology*, 3.

comprehensive understanding of natural history as well as a critical step in untangling the issues of synonymy that plague taxonomy.

Cuvier makes similar claims in the first lecture on the history of the natural sciences, again in very emphatic terms:

> There is no science the history of which is useless to the men who pursue it; but the history of the natural sciences is indispensable to naturalists. In fact, the ideas composing the sciences cannot possibly be the result of theories made *a priori*. They are based on an almost infinite number of facts that cannot be known except through observation. Now, our personal experience is so limited by the brevity of our existence that we would know almost nothing if we knew only that which we are able to learn ourselves. Therefore, we are obliged to have recourse to history, where are stored the observations of men who have preceded us. But to the history of facts we must join the history of learned men, for the value of their testimony very often depends on the circumstances of place, of time, and of the position in which they found themselves.[64]

Cuvier makes several important intellectual commitments in these and other such statements, which illustrate his conception of the nature of scientific endeavor. He also shapes his historical narrative to reinforce his contention of the necessary conditions for the natural sciences to prosper.

Cuvier's view of the natural sciences not only placed large burdens upon the individual naturalist, but also had significant implications regarding the institutional resources necessary to support the accumulation of natural knowledge. According to Cuvier, the natural sciences only thrive when appropriate conditions are met by the state. Without adequate patronage, instruments, education, material resources and repositories for collection the natural sciences tend to stagnate. But these resources alone are not adequate to insure progress. Other societal conditions exert considerable influence on the ability of the natural sciences to flourish.

[64] Pietsch (ed.). *Cuvier's History: Twenty-four Lessons from Antiquity to the Renaissance*, 49.

These include adequate social stability, for times of war or other forms of social unrest created a poisonous environment in which the natural sciences were unlikely to take root. Freedom of thought, a culture unburdened by the requirements of religious conformity and a social climate conducive to all kinds of scholarly endeavor provided the conditions under which the natural sciences are most likely to show significant progress.[65]

When these conditions were met, however, the range of the natural sciences was still so vast that it is beyond the capacity of individuals to obtain a comprehensive knowledge of the totality of the sciences. Instead, the study of the natural sciences must be broken down into disciplines and even sub-disciplines. Cuvier identified five primary divisions of the natural sciences: Anatomy, Zoology, Botany, Mineralogy, and Chemistry. Even within these divisions, significant work had to be done to organize knowledge in such a way that it can be more easily assimilated. From Cuvier's view, there may be no shortcuts to the initial identification of the facts on which the natural sciences were built, but once those facts were established, generalizations can be made that could more efficiently guide subsequent naturalists to the next steps of discovery. It was these generalizations, based on the careful accumulation of facts, rather than hastily made hypotheses, that allowed for the rapid advancement of the natural sciences. Cuvier did believe that he was living in a period of rapid advancement. In his 1810 report for Napoleon Cuvier stated, “'The last two centuries have done more for the

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[65] This is an argument that is distributed across the three volumes of Cuvier’s lecture series that I have read, however, there are places where the more argument is more sharply brought into focus such as in the opening of his first lecture. See Pietsch (ed.). *Cuvier's History: Twenty-four Lessons from Antiquity to the Renaissance*, 40-42.

sciences than all the centuries before, and the last thirty years alone might have contributed as much as the last two centuries.'"[66]

Cuvier's view of science required a closely integrated knowledge of history to support the continued development of that knowledge. Essentially, the boundaries between where history ended and contemporary science began were extremely porous—if they exist at all. This perspective on science was compatible with pre-revolutionary conceptions of knowledge. In the early modern period, the disciplinary boundaries that separated many forms of scientific inquiry were considerably more permeable than they are today. It was not uncommon for work in natural history to overlap with civil history and antiquarian studies within a single text.[67] The branch of natural history, known as minerology,[68] showed just such alliances. Evidence of this could be seen in the way naturalists incorporated historical narratives in mineralogical studies during the seventeenth and eighteenth centuries,[69] and also in the way they adopted practices from antiquarian studies and civil history while considering geological evidence.[70] The influence of these practices can be seen reshaped in Cuvier's self-identification

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[66] Pietsch (ed.). *Cuvier's History: Nineteen Lessons of the Sixteenth and Seventeenth Centuries*, 9.
[67] Gianna Pomata and Nancy Siraisi, "Introdution," In *Historia: Empiricism and Erudition in Early Modern Europe*, eds. Gianna Pomata and Nancy Siraisi (Cambridge, Mass: The MIT Press, 2005), 1-38.
[68] According to Rudwick, until the late eighteenth century, minerology encompassed a wider field of study than that understood today and can be considered "roughly the equivalent of 'earth sciences.'" See Martin Rudwick, "Minerals, Strata and Fossils," In *Cultures of Natural History*, eds. N. Jardine, J.A. Secord and E.C. Spary (New York: Cambridge University Press, 1996), 266.
[69] See Rhoda Rappaport, *When Geologists Were Historians 1665-1750* (Ithaca: Cornell University Press, 1997). In this work, Rappaport examines changing attitudes regarding the need to find textual sources to help verify knowledge regarding causation in geological processes over the course of the mid-seventeenth and mid-eighteenth century.
[70] Martin Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: The University of Chicago Press, 2005), 181-237.

as a "new species of antiquarian,"[71] in the opening of the "Preliminary Discourse" that prefaced his four volume work on fossils, *Ossemens fossiles*. Throughout the "Preliminary Discourse," as well as in the inaugural speech of his history of the natural sciences, Cuvier developed his arguments, drawing evidence not only from his knowledge of comparative anatomy and geology, but from ancient texts, philology, archeology, history and even mythology. Both texts blurred the distinctions between geological and civil history as Cuvier portrayed the emergence of human civilization coming in the wake of the last great revolution of the earth.[72]

Early Histories of Science and the Origin of Disciplinary History

History of science originated as part of a long, venerable, but erratic tradition. Unfortunately, there is a significant historiographical gap between histories of science written before and after the early twentieth century, making it difficult to rapidly contextualize histories written before this divide. This is due to the formation of history of science as an academic discipline, which largely occurred after the end of World War II. Evidence of academic interest in history of science can be traced in Europe and the United States to the late-nineteenth and early twentieth centuries, when academics began offering a range of classes on the subject, producing publications, establishing museum exhibits and forming professional societies.[73] In the mid-twentieth century, the production of history of science

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[71] Georges Cuvier, "Preliminary Discourse," In *Georges Cuvier, Fossil Bones and Geological Catastrophes: New Translations & Interpretations of Primary Texts*, ed. Martin Rudwick (Chicago: The University of Chicago Press, 1997), 183.
[72] Cuvier, "Preliminary Discourse," 183-252 and Pietsch (ed.), *Twenty-four Lessons from Antiquity to the Renaissance*, 49-57.
[73] For examples from the United States see, Arnold Thackray, "The Pre-History of an Academic Discipline: The Study of History of Science in the United States, 1891-1941," *Minerva* 18, no. 3 (1980), 448-473. For discussion of events in England see J. A. Bennett, "Museums and the Establishment of the History of Science at Oxford and

transitioned from a body of work primarily produced by scientists to one where more participants were trained in historiographical methods. This new professional class of historians of science, sought to legitimize their work in part by establishing alliances between history of science and the humanities as distinct from being a mere adjunct activity of the production of science. To establish this distinction, it was not uncommon to disparage the work of scientists who chose to write their own historical interpretation of scientific history.[74] As a result, early generations of professional historians of science have tended to ignore histories of science that were not produced by other professional historians, leaving little room to consider anything written before the twentieth century.

Since the subject of science historiography produced before the twentieth century is still not broadly recognized as a significant category of analysis by most active historians of science, the opportunity to identify relevant material has largely been overlooked. However, within recent decades a few historians have begun the pioneering work of uncovering this history. Material so far revealed provides a promising glimpse into this domain, but it is still too early to develop more than a provisional narrative of the genre. Nonetheless, even such a provisional narrative yields insight into the literary and cultural context Cuvier could borrow from to construct his histories of science. Thus, the brief survey to follow is primarily constructed to

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Cambridge," *The British Journal for the History of Science* 30, no. 1 (1997), 29-46. Also, for the larger historical context of the development of the academic discipline see, John Christie, "The Development of the Historiography of Science," In *Companion to the History of Modern Science*, (eds.) R. C. Olby, G. N. Cantor, J. R. R. Christie and M. J. S. Hodge (New York: Routledge, 1990), 5-22.

[74] Anna-K Mayer, "Setting up a Discipline: Conflicting Agendas of the Cambridge History of Science Committee, 1936-1950," *Studies in History and Philosophy of Science: Part A* 31, no. 4 (2000) 665-689. Mayer points out the suspicion exhibited by Herbert Butterfield regarding the practical implications of scientists writing history of science. For further discussions of such early suspicions see also Stephen Brush, "Scientists as Historians," *Osiris* 10, Constructing Knowledge in the History of Science (1995), 214-231.

highlight the traditions that a historian of science working in the early nineteenth century might have used as models or source materials for constructing their own histories. There are three well recognized literary traditions that Cuvier and his contemporaries had to draw on that offered models for understanding the conjunction of history and science. This material included literature from Greek and Roman antiquity, writings from the early modern Republic of Letters, and commentaries and encyclopedic mater from the French Enlightenment.

The ancient Greek and Roman cultures offered formative contributions to the development of history as a genre and were also generally recognized as important players to the development of a scientific approach to studying phenomena in the natural world. There is an inherent logic to the potential for a deep historiography of science based on the observation made by John Christie that, "There is a genuine problem in assigning definitive, ascertainable origins for the historiography of science. This is because any scientist, in his actual scientific work, already has an orientation towards the past."[75] However, when analyzing the categories of "history" and "science" over the broad sweep of history from antiquity to the present day, it should be recognized how people have defined these terms has changed in different temporal and social contexts, and past historiographies of science do not always conform to modern expectations.

Three authors from antiquity stand out as shaping literary traditions that bring together aspects of history and science: Herodotus, Aristotle and Pliny. Cuvier's lecture material from his course on the history of the natural science demonstrated that he was quite familiar with the extant works of these authors. The earliest of these authors was the fifth century Greek

[75] Christie, "The Development of the Historiography of Science," 5.

historian Herodotus (c. 484–c. 425 BC). Herodutus was the first author to write under the category of *historia*, a term from which Western culture has derived the word history. As one recent Herodotean commentator indicated, “Herodotus, however, lived in a time when categories of knowledge had not been rigidly separated, and his work ranges over many fields and includes geography, anthropology, ethnography, zoology, even fable and folklore. His work defies easy categorization: like Homer, Herodotus is a world unto himself.”[76] Although his work focused on the advance of Persian power, a rich subject material relevant to anyone interested in natural categories of knowledge was woven through the text. Within his work, the reader can find references to geography and natural history as well as discussions of material culture that demonstrated a burgeoning historical interest in both technology and the natural world. While it may be a stretch to categorize Herodutus as a historian of science, elements of the genre can be seen to emerge from this work.

Leonid Zhumud traced the historiography of science back to antiquity, focusing on the contributions made by Aristotle (384–322 BC) and a number of his students from the Lyceum.[77] Prior to Aristotle’s historiographic project, as Herodotus’ contributions have shown, fifth century Greek writers who had already demonstrated an interest in the history of culture, and that had manifested itself in the form of histories focusing on invention and discovery.[78] By the fourth century, Greek science had become a multi-generational endeavor, which may have

[76] John Marincola. “Introduction.” In Herodotus. *The Histories*. Translated into English by Aubrey de Sélincourt. (London: Penguin Classics, 1972), xiv.
[77] Rachel Laudan, “Histories of the Sciences and Their Uses: A Review to 1913,” *Hist. Sci*., xxxi (1993), 3-4. Laudan’s essay makes a brief reference to a number of figures from antiquity who wrote about the history of science, focusing primarily on Aristotle and Eudemus of Rhodes.
[78] Zhmud, *The Origin of the History of Science in Classical Antiquity*, 80.

provided incentive to investigate the history of knowledge.[79] Zhmud has conceived of the historiographic project at the Lyceum as being cooperative and rationally implemented, as evidenced by the apparent lack of duplication in work by Aristotle's students such as Eudemus, Theophrastus, and Meno.[80] The most substantive discussion of the text focused on the work of Eudemus of Rhodes, who wrote histories of geometry, arithmetic and astronomy, the knowledge of which now only exists in fragmentary excerpts and references made by other ancient authors. Zhumud concluded that without the influence of Aristotle, the ancient Greek historiographic project would not have been realized, and that the project was not carried on beyond the work of his immediate successors.[81]

Since late antiquity, two sometimes competing, sometimes complementary models have dominated the perception of what it means to be a natural historian, those of Aristotle and of Pliny (AD 23–79). Thus, Cuvier related more to these two authors as exemplars of the path to natural history than as historians of science. There is nonetheless, a certain fluidity contained in natural history, that lends it to consolidating prototypical characteristics of history of science. *Naturalis Historia*, the work of the first century natural historian, Pliny the Elder, showed aspects of this tendency. Pliny, who demonstrated a marked interest in material aspects of the natural world, frequently indicated how natural products ranging across the animal, vegetable, and mineral kingdoms might be used in the context of medicine, as luxury

[79] Ibid, 121.
[80] Ibid, 133.
[81] Ibid, 277.

goods, and in developing technology and craft skills. Thus, he frequently recorded historical aspects of how such natural products or new technologies were initially used.[82]

All three ancient writers, each in their own way, bequeathed to future generations three allied but varying approaches to the genre of *historia*, a concept that would be revisited within the early modern Republic of Letters. Historians Gianna Pomata and Nancy Siraisi emphasized the plurality of ways early modern naturalists conceived of natural history. They stated, "It is well known that a prominent feature of early modern science was the rapid and exponential growth of *historia naturalis*, but it would be more correct to talk of a proliferation of natural histories—in the plural—all with different philosophical pedigrees and correspondingly different notions of what *historia* was about. Aristotelian and Plinian models of natural history, to give the most obvious example, implied very different concepts of *historia*."[83] The authors further indicated that within the early modern context physicians and naturalists often actively contributed to antiquarian and historical cultural studies in ways that infringed on modern disciplinary boundaries, and that such a scholar might move smoothly between practices of natural history, medicine, philology and antiquarianism within a single work.[84] On a more specialized note, early modern natural historians found it necessary to master ancient knowledge in order to make accurate species identifications. Without such knowledge, it was impossible to confirm if a species being examined was genuinely new, or had already been identified. Thus, such naturalists found it necessary to hone the skills necessary for historical

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[82] Pliny, *The Natural History of Pliny*, Translated, with copious notes and illustrations by the late John Bostock, M.D., F.R.S, and H.T. Riley late scholar of Clare Hall, Cambridge, 6 vols. (London: Henry G. Bohn, 1855). Biodiversity Heritage Library, Date Scanned: 10/14/2008, https://www.biodiversitylibrary.org/bibliography/8126#/summary .
[83] Pomata and Siraisi, "Introduction," 2.
[84] Ibid, 6-7.

and philological investigations of ancient texts, combining the skills of an antiquarian and an historian.[85]

The work of the early modern naturalist, Conrad Gessner (1516-1565), who Cuvier particularly points out as having made a lasting contribution to zoology, exemplified the range of historical skills a natural historian from that era might be called upon to exercise. Gessner came to natural history from a bibliographical perspective, attempting to provide exhaustive knowledge that had been gathered about the animals. His interests extended beyond knowledge of species to include a history of knowledge. As such, he brought a chronological dimension to his work, comparing ancient and contemporary descriptions of species as he attempted to preserve previous stages of zoological knowledge. In a similar vein, Gessner's contemporary Ippolito Salviani's (1514-1572) text on aquatic animals included a 120-page table providing historical information about fish, including their names in Latin, Greek and Italian, characters, and textual references to ancient writers.[86] Works such as these literally carried the historiography of natural history with them. With examples, such as these to work from, Cuvier had reason to regard the history of natural history as an integral part of the process of knowledge formation.

Additionally, in the early modern period, disciplinary histories of science began to emerge as an increasingly distinct and recognized genre of literature. One such genre of disciplinary history, that of medical history, possessed an extended, although not always a well

[85] Ibid, 18.
[86] Laurent Pinon, "Conrad Gessner and the Historical Depth of Renaissance Natural History," in *Historia: Empiricism and Erudition in Early Modern Europe*, Edited by Gianna Pomata and Nancy Siraisi (Cambridge, Mass.: The MIT Press, 2005), 241-267.

defined pedigree. In antiquity, the line between medical history and contemporary medical practice was blurry, as practitioners did not always draw distinctions between past and present medical science. One aspect in which medical history made its presence felt was on the tendency for ancient authors to call on the authority of past witnesses to justify their own beliefs. The appeal to ancient authority persisted through the Middle Ages and the early modern period, influencing the way medical history was written.[87] As previously stated, a close alliance existed between medicine and natural history during the Renaissance, and similar empirical and literary practices drawn within the context of medical *historia* showed the tendency for historicizing the process of observation. The production of early modern case histories such as those written by Gaspare Aselli (c. 1581-1626) demonstrated that such works could offer rich historical detail. And such case histories could form the basis of for histories of medical discovery, as in the case of the medical anthology *Biblotheca anatomica* by Le Clerc and Manget (1685).[88] In the seventeenth and eighteenth centuries it was common practice for medical tracts to include introductions covering the history of medicine as an integral component of understanding the science of medicine.[89]

Other branches of the sciences that developed strong traditions of disciplinary history during the early modern period included chemistry, mathematics and astronomy.[90] Regarding

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[87] For a discussion of the influence of ancient authority and its use for justifying medical practice as presented in early histories of medicine see, Rolf Winau, "The Role of Medical History in the History of Medicine in Germany," In *Functions and Uses of Disciplinary Histories*, Edited by Loren Graham, Wolf Lepenies, and Peter Weingart. (Boston: D. Reidel Publishing Company, 1983), 105-108.
[88] Gianna Pomata, "The Uses of Historia in Early Modern Medicine," In *Historia: Empiricism and Erudition in Early Modern Europe*, Edited by Gianna Pomata and Nancy Siraisi. (Cambridge, Mass.: The MIT Press, 2005), 118-121.
[89] Robert Richards, *The Tragic Sense of Life: Ernst Haeckel and the Struggle over Evolutionary Thought*. (Chicago: The University of Chicago Press, 2009), 227.
[90] Regarding early modern histories of mathematic and chemistry see Lauden, "Histories of Science," 4-5 & 23-24. For information regarding the early modern development of the history of astronomy also see Anthony Grafton, "From Apotheosis to Analysis: Some Late Renaissance Histories of Classical Astronomy," In *History and the*

the history of astronomy, Nicholas Jardine provided an English translation and extended analysis of Kepler's *Apologia*, making the claim that this text represented one of the earliest examples of the development of the "history and philosophy of science as a distinctive mode of reflection on the status of natural science."[91] Although Kepler's work was not published until long after his death and consequently exercised no significant influence on later developments in the historiography of astronomy, Jardine's text nonetheless represents a valuable case study in early histories of science, considering how poorly developed is our knowledge of pre-20th century historiographies of science are at the current time. The eighth chapter of the book, "Historiography and validation" provided additional information regarding other early modern histories of astronomy, and Anthony Grafton expanded on the theme in a separate essay entitled "From Apotheosis to Analysis: Some Late Renaissance Histories of Classical Astronomy." These two works provided a taste of the diversity of opinion that existed among early modern astronomers regarding how they viewed the history of their field of study. If these works are seen merely as indicative of the views of early scientists, much could be gained by a deeper analysis of how early modern physicians, chemists and natural philosophers expressed their own sense of how their work fitted into the history of knowledge. As I have argued, early modern naturalists' practices were shaped around multifaceted concepts of *historia*, and it is therefore worthwhile to explore how that sense of history was expressed in a

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Disciplines: The Reclassification of Knowledge in Early Modern Europe, Edited by Donald Kelly. (Rochester: The University of Rochester Press, 1997), 261-276.

[91] N. Jardine, *The Birth of History and Philosophy of Science: Kepler's* A Defense of Tycho against Ursus *with Essays on Its Provenance and Significance*. (New York: Cambridge University Press, 1984), 2.

broad range of literature from the early modern period—recognizing that history and science during that era did not always inhabit disciplinarily confined-spaces.

The proliferation of scientific societies in the seventeenth century led to the alteration in the patterns of the production of history of science. In one sense this was a very self-conscious process, as Lauden indicated that "almost every scientific institution, no matter how small, commissioned its history, which usually described the founding, initial membership, house, and special projects of the society."[92] Scientific societies changed the pattern of relationships among members within the Republic of Letters, and as a result changed the way this community viewed science and its history. Nowhere was this more dramatically expressed than in the context of the Academy of Sciences in Paris. The Academy was more than a scientific institution; it was a legally recognized learned society attached to the state.[93] The unique position the Academy of Sciences held within the scientific community of Europe produced a society that was very self-conscious of its place in history. This self-consciousness manifested itself in a number of ways. In 1667 the *Journal des Savants* was founded in order to share the findings of the Academy. In 1697 Bernard Le Bouyer de Fontenelle became perpetual secretary of the Academy. In 1699 Fontenelle helped lead the Academy through a series of reforms and in the process took on the role as spokesman for French science.[94] Fontenelle's new mandate as perpetual secretary of the Academy was to make the institution more publicly oriented. As part of that process, he wrote a history of the Academie's scientific achievements each year, publishing the best scientific papers. The first installment of *Histoire de l'Académie*

[92] Lauden, "Histories of Science," 4.
[93] Hahn, *Anatomy of a Scientific Institution,* 3-4.
[94] Shank, *The Newton Wars*, 38.

royale des sciences, *avec les mémoires* de *mathématique* et de *physique* was published in 1700. Public outreach also occurred in the form of twice yearly public assemblies at which the public funeral orations, known as éloges, were delivered. As a result of these reforms, the role of perpetual secretary became a decisive position for shaping the public discourse of science in France.[95]

Between 1699—1791 the task of delivering éloges was maintained through the succession of four permanent secretaries, only to be interrupted for a few years during the political turmoil of the French Revolution. These events attracted large audiences and did much to shape the public impressions of scientists from the time period.[96] These éloges helped create the image of natural sciences as "an objective, passionless, and value-free mode of knowledge."[97] Common motifs portrayed scientists as exhibiting the moral values found in ancient Greek and Roman heroes, used pastoral hagiography, or exhibited Christian and Stoic virtues.[98] These éloges were published, and frequently served as important sources for the development subsequent biographies, an important emerging genre in the late eighteenth and early nineteenth century.[99]

Beyond the strict confines of the Academy of Sciences, other voices emerged during the Enlightenment era that contributed to the interpretive landscape of opinion that shaped knowledge of the history of science as it was understood at that time. One such outspoken

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[95] Ibid., 59-61.
[96] Paul, *Science and* Immortality, 12-13.
[97] Ibid., ix.
[98] Ibid., 92-93 and 98.
[99] For an example of the use of such elegiac sources see the way Fontenelle's éloge of Isaac Newton became an important source for later biographies in Rebekah Higgitt, *Recreating Newton: Newtonian Biography and the Making of Nineteenth-Century History of Science*, (London: Pickering & Chatto, 2007), 8-10 and 19.

voice came from the pen of François-Marie Arouet, otherwise known as Voltaire. Voltaire's *Philosophical Letters* offered a French perspective on English science and culture, published several years after a period of voluntary exile in England between 1726 and 1728 that he made in order to avoid legal troubles in France. This work included letters describing the work of important scientific figures such as Bacon and Locke. It also included a comparison of Cartesian and Newtonian Physics, as well as further discussions of Newton's work.[100] These letters portrayed English science and Newtonianism in a favorable light. Voltaire used this work to assert his role as an independent philosopher and to serve as a polemic that supported a new role for men of letters.[101]

Another controversial work from the mid-eighteenth century placed focus on the history of science. In 1751, when Jean-Baptiste le Rond d'Alembert published the *Preliminary Discourse* for the *Encyclopédie*, he also included a substantive discussion of the history of science. The *Encyclopédie* was initially intended as little more than a translation of the *Cyclopaedia* of Ephraim Chambers (1728), however, when d'Alembert and Denis Diderot were eventually recruited to edit the work, the mission of this project expanded into something considerably more ambitious. Richard Schwab, historian and translator of the *Preliminary Discourse*, has stated, "The work was to contain nothing less than the basic facts and the basic principles of all knowledge; it was to be a sort of war machine of the thought and opinion of the Enlightenment."[102] The *Preliminary Discourse* served as an introduction and explanation of

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[100] Voltaire, *Philosoophical Letters: Or, Letters Regarding the English Nation*, edited by John Leigh and translated by Prudence Steiner, (Indianapolis: Hackett Publishing Company, Inc., 2007).
[101] Shank, *The Newton Wars*, 299-323.
[102] In the "Translator's Introduction," Richard Schwab provides a substantive essay explaining the history and significance of the *Preliminary Discourse*. See Jean Le Rond d'Alembert, *Preliminary Discourse to the Encyclopedia*

method for *Encyclopédie* but it became something more than that for d'Alembert's contemporaries. Soon after its publication, many of the leading figures of the French Enlightenment, came to see the *Preliminary Discourse* as a significant statement representing their philosophy and the work became something of a manifesto for the Enlightenment.[103] In the middle part of this work, simply labeled "Part II," d'Alembert offered his perspective on the history of science.

D'Alembert began his narrative of the progress of science with the revival of learning represented by the Renaissance. He argued that before science could again flourish, a linguistic revival was required such that the path of learning would travel through erudition and the belles-lettres before it arrived at philosophy. The high-marks of d'Alembert's narrative followed similar lines to that of Voltaire, as he selected the "immortal Chancellor of England," Francis Bacon, the "illustrious" Descartes, Newton, Locke, Huyghens and other such familiar figures to serve as heroic figures of his story. An aspect in which d'Alembert's narrative varied from Voltaire's was the importance he placed on Descartes' contributions to the advancement of science. D'Alembert acknowledged that Descartes' reputation had suffered based on his contributions to astronomy, but he pointed to other aspects of Descartes' career as a geometer, philosopher, and mathematician as of more lasting value. But d'Alembert believed the progress of the sciences that were "far more indebted to him [Descartes] than his adversaries will allow; his method alone would have sufficed to render him immortal."[104]

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of Diderot translated by Richard Schwab with the collaboration of Walter Rex, (Chicago: The University of Chicago Press, 1995), xxv.

[103] D'Alembert, *Preliminary Discourse*, ix-xi.

[104] Ibid, 78-79.

D'Alembert also did far more than praise Bacon for his contribution to the development of science; the *Encyclopédie* borrowed ideas regarding the way knowledge should be structured from Bacon, which are reflected in the closing sections of the work entitled "Detailed Explanation of the System of Human Knowledge" and "Observations on Bacon's Divisions of the Sciences."[105]

In the time leading up to the French Revolution, both within the general European tradition of natural history and more specifically within the context of French culture, a variety of traditions had been established in which historical narratives were used as means for contextualizing scientific understanding. Cuvier, who as a naturalist at the Natural History Museum in Paris, had access to one of the largest collections ancient and early modern works of natural history in Europe, which served as an important tool in ensuring that his efforts were not simply a duplication of the work of his predecessors. To a certain extent, Cuvier's efforts as an historian can be understood as a means of ensuring disciplinary integrity for the emerging branches of natural history. Cuvier's history of ichthyology will be considered in this context.

***Histoire naturelle des poisons*: Disciplining the History of Ichthyology**

The primary function of Cuvier's history of ichthyology was geared towards addressing the issues Cuvier raised in the early pages of this work and in the opening of his lecture series on the natural sciences. As Cuvier made clear, natural history was a science founded on the accumulation of a vast body of factual material acquired over many generations. The immensity and disorganization of this unruly collection of facts posed a considerable problem

[105] D'Alembert, *Preliminary Discourse*, 143-164.

to the initiate who wished to add to the storehouse of knowledge. The naturalist, finding himself[106] faced with the need to master the history of natural history, or even just a specialized branch of the field faced an almost overwhelming task that had be met before it was possible to make a positive contribution to the field with some confidence that one was not just repeating the work of some past naturalist. Cuvier's history offered a solution to this dilemma. His history literally became an initial step in the process disciplining these facts in a way that made it possible to for a novice ichthyologist to identify what work has already been accomplished and what work still needed to be done in the field. The history united the work of past ichthyologists with that Cuvier was preparing to embark on, making his own text of *Histoire naturelle des poisons* the logical starting place for future ichthyologists to use as the foundation of their own work. Cuvier placed himself in the position to arbitrate the past and direct the future endeavor of ichthyologists working in the second quarter of the nineteenth century.

At the beginning of the text, Cuvier divided the history of ichthyology into three principal eras. The initial phase was one characterized by partial observations. The second phase, initiated by the Greeks, is one in which the foundations of ichthyology and all other sciences were laid down. The third phase was initiated with the establishment of well-defined genera and precisely characterized species. With these criteria in place, ichthyology was finally

[106] In the nineteenth century there was a pronounced male bias towards the production of knowledge in natural history. Works such as Bernard Lightman, *Victorian Popularizers of Science: Designing Nature for New Audiences* (Chicago: The University of Chicago Press, 2007) have shown the role some women managed to carve out for themselves as popularizers of science. The biography of Thomas Huxley by Paul White has shown the valuable assistance Huxley's wife provided him: Paul White, *Thomas Huxley, Making the "Man of Science"* (Cambridge: Cambridge University Press, 2003). Although it may have been acceptable for females to assist in supportive roles, it was more rare for them to directly contribute by the publication of mainstream scientific texts.

on a fully scientific footing and Cuvier informed his readers that, “Since then, ichthyology has gone forward unobstructed toward perfection, approaching it all the more rapidly as each naturalist engaged in it has applied more ardor and more of that sagacity that discerns what is true and presents the truth in a rational way for rational minds.”[107] Cuvier immediately complicated the overall structure of his narrative by the addition of further historical information and qualifications regarding the various contributions of specific authors, but his history roughly unfolds in this pattern. The history took on the form of a literature review, covering all the material from antiquity to the first quarter of the nineteenth century, that in Cuvier’s judgement substantively contributed to the development of ichthyology in western Europe. Considering the exhaustive nature of Cuvier’s history, it is beyond the scope of this dissertation to comment in detail across the entire content of this work. Instead, I will examine key elements of the three major phases of the history.

In keeping with assertions made in his lecture series regarding the foundational character of the natural sciences and the development of human civilization, Cuvier situated the initial interest in studying fish as a very early human activity associated with it serving as an important food source for primitive people. It is this early phase in human history that Cuvier associated with the first era of ichthyology, where humans first learned about their environment in context with the acquisition of natural resources. In addition to archeological and historical evidence, Cuvier pointed to contemporary ethnographic knowledge about the uses that tribal groups made of fishery resources to back up his claim.[108] Cuvier displayed

[107] Cuvier, *Historical Portrait of the Progress of Ichthyology*, 5.
[108] Ibid, 9.

special interest in the contributions made by Egyptians to the development of ichthyology, based on archeological evidence gathered during the French expedition of Egypt led by Napoleon and described in the multivolume *Description de l'Egypt*. He also included material gathered from Hebrew, Phoenician, and Carthaginian sources, although his discussion of these ancient cultures was extremely cursory. The interesting aspect of this section is the willingness Cuvier displayed to move from textual to archeological and ethnographic sources: including monuments, paintings, mummified animal remains, cult artifacts and customs, medals, coins and architectural structures.[109] Overall, this section was intriguing but quite brief, which was understandable considering the scarcity of information regarding the place that fish had played in prehistoric societies at such an early stage in the development of the discipline of archeology.

From there, Cuvier moved to a more familiar theme discussed in histories of science, that of the contribution of ancient Greece to laying the foundations for Western science. Although he discussed other Greek contributors to the formation of ichthyology as a semi-scientific discipline, he reserved for Aristotle the designation of first naturalist.[110] In Cuvier's estimation, Aristotle had earned a superlative place in the history of ichthyology as the first to assemble a library, as he was thoroughly knowledgeable about his forerunners, and that he had laid the foundations of comparative anatomy and identified many of the significant classes within the animal kingdom. Familiar with 117 species of fish, Aristotle made direct observations and displayed knowledge of reproduction and other aspects of animal behavior.[111] Cuvier informed his readers that Aristotle, "is not only the first but also the only one of the

[109] Ibid., 10-13.
[110] Ibid., 17.
[111] Ibid., 17-20.

ancients to have written on their [fish] natural history with a scientific viewpoint and with some genius."[112]

Although Cuvier went on to recognize Aristotle's successors, Theophrastus and Clearchus, in his estimate none of the following Greeks lived up to the quality of Aristotle's contribution.[113] Interesting minor contributions to ichthyology were attributed to the Greeks and Romans, but according to Cuvier's narrative, the new era in ichthyology ushered in by Aristotle experienced an extremely long hiatus. The whole of Roman antiquity merits only a few pages of text and the middle ages only a few hundred words. Cuvier did indicate some interest in the way Roman authors wrote about fish as an aspect of material culture within Rome. He mentioned freshwater and saltwater fishponds that the Romans used to preserve fish as objects of the luxury trade. It was largely in this capacity that authors such as Varro and Columella wrote of fish. He also acknowledged familiar names such as Pliny. But Pliny suffered from the fault of his times, that Roman contributions to ichthyology and natural history were derivate and did not produce original research. The major merit of Pliny's activity of compilation was that he preserved references to other ancient texts that had subsequently been lost.[114] After providing a brief discussion the works of various Roman authors who made minor contributions to ichthyology, Cuvier came to the middle ages. Of this time, he stated, "The nine centuries that followed were scarcely more favorable to the science; the monks in their cells, almost the only depository of knowledge during the long sleep of the human spirit, had no means of preforming observations. Those among them who showed more curiosity and

[112] Ibid., 20.
[113] Ibid., 20-22.
[114] Ibid., 27-31.

intelligence were reduced to making excerpts from the imperfect copies that remained to them of Pliny and Aristotle."[115] He did point out the work of Saint Isidore, Albert the Great and Vincent de Beauvais, and he did accord the last two of these authors some favorable comment despite the lament, stating of Albert the Great that he was "worthy of a better century."[116]

Cuvier marked the late Middle Ages as an important turning point in human history. Of the time, he stated, "Better times came. A great movement had been aroused in the human spirt as early as the thirteenth century and in the fourteenth century such people as Dante, Petrarch, and Boccaccio; the end of the fifteenth century was the moment of its maturity."[117] Along with changes in intellectual life, Cuvier attributed cultural changes in Europe to a few factors such as better knowledge of ancient classics, increased global travel and the invention of printing. These factors helped lead to new work in natural history. He identified three important figures in the early modern period, who help to re-establish the second developmental phase of ichthyology, originally initiated under the work of Aristotle. These are the sixteenth century physicians Belon, Rondelet, and Salvaiani each of whom published works in ichthyology in the 1550s. In a sense, these authors were set up as Aristotle's true successors, despite the eighteen-hundred-year gap that separated them from the great naturalist philosopher. They were depicted as bringing ichthyology back from the commentarial tradition to one of genuine observation and description. Although their work was not wholly scientific

[115] Ibid., 32.
[116] Ibid.
[117] Ibid., 41.

by Cuvier's standards, it was sufficiently scientific to lay the foundation for the development of modern ichthyology.[118]

Further developments in anatomical understanding by Italian physicians in the sixteenth and seventeenth century laid further foundations towards making ichthyology into a truly scientific endeavor.[119] Ultimately however, the initiation of the third and fully modern phase of ichthyology was at first partially established by the joint work of John Ray and Francis Willughby, and later more fully established by the joint work of Artedi and Linnaeus. These two sets of naturalists displayed an odd sort of symmetry in Cuvier's narrative. In the case of Ray and Willughby, the two naturalists had gathered material for the work between 1663 and 1666, and Willughby described and dissected fish.[120] However, although Cuvier fails to mention it in the narrative, Willughby died before the work on ichthyology could be published. Ultimately, Ray had the book *De historial piscium* published under Willughby's name, although it was left to Ray to organize the material on behalf of his dead friend. Cuvier identified the work of the two men as being the first with descriptions written according to nature, due to a lack of clear nomenclature, Cuvier indicated that the work did not exercise significant influence on the immediate successors of the two naturalists.[121]

It therefore fell to the work of Artedi and Linnaeus "to give the natural history of fishes a truly scientific form."[122] Again, Cuvier's narrative came to rest on the publication of a posthumous work, *Ichthyologia, sive Opera omnia de piscibus*. In this case, it was Linnaeus who

[118] Ibid., 41-44.
[119] Ibid., 57-61
[120] Ibid., 71.
[121] Ibid., 74.
[122] Ibid., 95

shepherded the work of his dead friend Artedi to publication. Linnaeus made use of Artedi's work in ichthyology in his own account of taxonomy found in early editions of the *Systema naturae*. However, through successive editions, Linnaeus gained greater confidence in his own expertise, and made alterations that Cuvier sometimes found of benefit, sometimes of detriment to ichthyology. In addition to Linnaeus' own work, Cuvier recognized the contributions of some of Linnaeus' students and other contemporaries. In addition to putting ichthyology on a genuinely scientific footing, Cuvier credited Linnaeus with popularizing natural history by his work in apparently simplifying the subject.[123]

Cuvier's account of the third phase of the development of ichthyology took up the greatest part of his history. Over half of the rest of this account was taken up in describing the work that came after Artedi and Linnaeus. If this was the unobstructed path towards perfection that Cuvier promised at the beginning of his narrative, it was certainly a bumpy one. Although Cuvier offered generous helpings of praise for the forerunners who separated him from the work of Linnaeus, he offered similarly generous helpings of criticism. After he completed his extensive review of his near contemporaries, Cuvier closed his narrative by placing his own work within the context of the history of ichthyology. He indicated that early in his career, "I began to perceive the degree to which all the existing ichthyologies were yet imperfect—in the number of fishes, in their relations, in the criticism of synonyms, and even in the characters assigned to the species."[124] He went on to give an account of the work he had done to augment the ichthyology collection of fish at the Muséum national d'Histoire naturelle,

[123] Ibid., 95-104.
[124] Ibid., 247.

and in the process gave information about the material sources provided that served as surety for the edifice of knowledge he was projecting to build with this and subsequent volumes of *Histoire naturelle des poisons*.[125]

Beyond Disciplinary History

History offered Cuvier more than a means of defining disciplinary boundaries and ordering the long tradition of knowledge. In the wake of the French Revolution, a continuing sense of social instability permeated French culture. During the series of regime shifts experienced over the course of Cuvier's career, which lasted through the first third of the nineteenth century, historical narrative served as comparatively neutral medium, for raising what might otherwise have been interpreted as politically or socially inflammatory subject matter. As part of a community that had lived through the bloody purges of the Reign of Terror, historical subject matter offered a way for both individuals and the community as a body to rebuild their sense of identity, while re-anchoring themselves with the long historical tradition of natural knowledge. As a eulogist and lecturer, even toward the end of his career, Cuvier seems to have embraced history as a form of drama that served a cathartic function within the community for which he served as a public spokesman. Cuvier, as nature's historian, worked to rebuild a sense of order for his own life, and for the community he served, which he believed he could extend to the productions of the natural world, by learning to read the patterns of nature as they could be seen in the living and fossil remains of the animal kingdom.

[125] Ibid., 247-256.

In his lecture series on the natural sciences, Cuvier made broad intellectual claims on the nature of science, best practices, and the conditions under which science best thrived. Cuvier's histories were polemical. Within the context of the lecture series, he made observations regarding how the social, material, and political conditions under which natural scientists were constrained to work over the course of history, either aided or limited the opportunities for discovery. He also could be quite critical of the approach that practitioners took to their work. Nonetheless, Cuvier's arguments were larger and more subtle than one might expect based on typical modern historiographic reviews of nineteenth century histories of science; for example, Cuvier's work demonstrated an awareness of the cultural pressures acting on science. Cuvier's approach to history merged aspects of biography and literature review, the result of which offered a lively narrative on the state of science through various eras of history. While Cuvier demonstrated the prejudices of his own time and his own position within the scientific community of France, these factors should not be used a criterion for dismissing what he had to say. Instead, it should be recognized that Cuvier's histories offer an invaluable tool for better understanding the cultural context of early nineteenth century French science.

Cuvier was not particularly impressed by Greek philosophical achievements, but as a fellow zoologist he had high praise to lay at the feet of Aristotle. This can be seen in the highly laudatory language with which Cuvier described Aristotle's contribution. "Philosophy, before Aristotle, was entirely speculative, losing itself in abstractions deprived of foundations; science did not exist. Science seems to have sprung full-blown from the mind of Aristotle, like Minerva fully armed from the mind of Jupiter."[126] Due to Cuvier's judgement of Aristotle's significance

[126] Pietsch (ed.), *Twenty-four Lessons from Antiquity to the Renaissance*, 221.

he devoted two lengthy lectures to his life and work, a distinction he did not repeat again until the joint discussion of Leibniz and Newton.[127] Cuvier informed his audience that in the 62 years of Aristotle's life, he accomplished more than all the naturalists who came after him for the next 20 centuries. However, Cuvier did not attribute the whole of Aristotle's success to his own genius. Cuvier indicated that Aristotle was substantially aided by his close relationship to the Alexander the Great and was the beneficiary of the imperial ambitions of the young emperor. Cuvier indicated that Alexander the Great had an interest in natural history, and that he sent animals and other natural productions to Aristotle in the course of his military campaign. Cuvier further repeated the claim made by Pliny the Elder, "that Aristotle kept several thousand men constantly busy at Alexander's expense, hunting and fishing and making the observations that he needed."[128] If one is meant to discern the formula by which natural history is meant to flourish, the primary ingredients seem to have been the keen observational skills of a man like Aristotle, backed up by the generous application of the resources from a world empire.

Cuvier was not as generous in his assessment of the progress of science under the Roman empire as he was under Greek leadership, stated bluntly, "The first emperors did not establish the conditions necessary for the prospering of science and letters. Augustus encouraged only a few men of letters, and under his reign the sciences experienced no

[127] Cuvier made scattered references to Newton in the second volume of his lecture series, but there is a more extended discussion of the complex history of Leibniz and Newton in lectures 2 and 3 from the third volume. See Theodore W. Pietsch (ed.), *Cuvier's History of the Natural Sciences: Twenty Lessons from the First Half of the Eighteenth Century*, translated by Fanja Andriamialisoa (Paris: Publications Scientifiques du Museum national d'Histoire naturelle, 2018), 79-91 and 109-117. In contrast, Aristotle is the sole subject of both chapters 7 and 8 from the first volume, and the tone and loquaciousness nature of these lectures suggest that Cuvier was considerably more impressed by the achievements of Aristotle than he was even of Newton. See Pietsch (ed.), *Twenty-four Lessons from Antiquity to the Renaissance*, 221-241 and 265-279.

[128] Pietsch (ed.), *Twenty-four Lessons from Antiquity to the Renaissance*, 224.

growth."[129] Under the administration of a sequence of leaders who neither valued the attainment of scientific knowledge or personal liberty, Cuvier portrayed the climate existing in the Roman empire as one that stifled learning. He declared, "In Italy under the tyrant-emperors, there was a lack of personal safety and a dread of informers that led to the hiding of one's fortune and one's attainments, and this especially impeded the study of natural history, which on account of the equipment required, would draw much more attention to oneself than studying the merely speculative sciences."[130] In the guise of a discussion of Roman history, Cuvier had the liberty to discuss the chilling impact that fear, censorship, and political repression could have on the development of knowledge.

A stark contrast can be drawn between Cuvier's representation of scientific progress in the Roman Empire with that found in early modern Europe. Cuvier opened his lecture series on the sixteenth and seventeenth centuries with a discussion of the revival of learning that occurred during the Renaissance. He attributed the intellectual achievement of this era to three primary factors: the development of the printing press, exploration and discovery of the globe, and the Reformation. These three historical factors often play an important role in the narrative of the changing climate of knowledge production in early modern Europe. But within the context of Cuvier's lecture series, it should be recognized that these three factors would have a very pointed meaning for an audience that had lived through revolutionary turmoil. In the context of his lecture series, Cuvier was making a case for the value of freedom in the production of knowledge. The significance of the printing press related to the freedom of the

[129] Ibid, 395.
[130] Ibid, 396.

dissemination of knowledge. The voyages of discovery related to the freedom of movement. And Cuvier attributed to the eventual outcome of the Reformation the broadening of religious liberty and the freedom of conscience.[131]

Cuvier clearly believed that material, social, and political factors could have a marked impact on the quality and development of science. He also believed that methodological and ideological factors could substantively impact the quality of science, and he revealed aspects of his intellectual predilections in his discussion of science during the early modern period. Cuvier's discussion of Descartes revealed tensions within Cuvier's narrative, as he tried to balance his disapproval of Descartes' system building against his admiration of Descartes' contributions to more stringent scientific methodology. Cuvier's introduction of Descartes displayed aspects of this narrative tension by stating, "Descartes is not remarkable for great discoveries in physics, but the popularity of his hypothesis and the momentum he created among scholars managed to get rid of the scholastic approach that was wrongly called Aristotle's philosophy since it had not much to do with it. The human spirit was finally free of all constraints and started to make at a fast pace the discoveries we are going to talk about now."[132] Cuvier attributed advances in geometry, metaphysics, and medicine to Descartes, but was considerably less favorable in discussing his role in system making in the context of physical astronomy. In his review of this aspect of Descartes career, Cuvier stated, "All of this system interconnects with a lot of subtlety but, as you can see, it has no foundation. . . . Descartes said

[131] Pietsch (ed.), *Nineteen Lessons of the Sixteenth and Seventeenth Centuries*, 37-38.
[132] Ibid, 423.

give me matter and motion and I will create the world and what it contains; but no part of his system lived on."[133]

Cuvier's criticism of system making had applications that were closer to the realm of his own scientific expertise. In his discussion of Leibniz, that was otherwise quite positive, Cuvier provided a negative review of the Great Chain of Being, a concept whose origin he attributed to Leibniz. Cuvier was suspicious of the Great Chain of Being, because even although the concept predated popular discussion of evolutionary theory and was framed in a religious context, Cuvier thought that the basic assumptions contained in the Great Chain of Being could be applied to evolutionary thought. Cuvier indicated that the philosophical principle on which Leibniz built the Great Chain of Being was, "there is no effect without a cause and there is nothing without a reason."[134] From this premise Leibniz assumed that links could be made between the beings that existed in the past and those that would exist in the future on till the end of time. However, Cuvier scoffed at links that subsequent naturalists had attempted to make between resemblances that could be found in the animal kingdom. Cuvier stated that, "It is claimed that mammals are related to birds through bats, that birds are linked to quadrupeds via the ostrich, and that cetaceans constitute the link between mammals and fishes."[135] Cuvier went on to demonstrate the logical absurdity of this argument by stating, "If such relationships were true, there would not be one single line, but two collateral lines leading to mammals: the bird lineage through bats and the fish lineage through cetaceans. To support his system,

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[133] Ibid, 432.
[134] Pietsch (ed.), *Twenty Lessons from the First Half of the Eighteenth Century*, 112.
[135] Ibid, 113.

Bonnet cited the flying squirrels, the flying lemurs, and the bats."[136] Toward the end of the lecture Cuvier attempted to wrap up his case against the Great Chain of Being with the following statement, "Today, I started the discussion of the Chain of Being because it is believed that Leibniz initiated it. I hope to have proven the system false and shown that it is irrational to say that one animal could form a link between two groups if those two groups shared a function."[137]

Cuvier continued his attack on system making as it was applied to the support of evolutionary thinking in the following lecture dedicated to "Origins of the Earth and Advances in Eighteenth-Century Geology." In the case of this lecture, the historical figure who drew the brunt of his attack was the eighteenth-century French diplomat and natural historian, Benoît de Maillet (1656-1738). Cuvier made a point of discussing what he felt were the most ridiculous aspects of de Maillet's book *Telliamed ou entretiens d'un philosophe indien avec un missionnaire françois, sur la diminution de la Mer, la formation de la Terre, l'origine de l'Homme.* Cuvier stated of de Malliet, "He gathered all the elements that he could find in the works of fiction by writers like Obsequens, Lycosthenes, Sorbian, etc. on mermen and mermaids to prove that the human species itself descends from marine beings."[138] Although he was addressing a work of an eighteenth century author, Cuvier went on to make clear that more contemporary naturalists were still subject to the same kind of folly, "He was the first to put forward the possibility of transformation of marine species into terrestrial species. This theory was reproduced in many ways by modern authors. It was based on certain facts but

[136] Ibid.
[137] Ibid, 115.
[138] Ibid, 139.

conclusions were too vague and broad. What is undeniable is that among certain species, individuals submitted to certain external circumstances undergo very remarkable changes."[139] As the lecture proceeded, Cuvier continued his attack on transformist thinking, finally coming to a head toward the conclusion as he criticized the geology and evolutionary ideas of his own former colleague Jean-Baptiste Lamarck (1744-1829).[140]

The spoken word is ephemeral when compared to the published text. Even though Cuvier cloaked his political views and his criticism of the work of his colleagues as subtext within a discussion of history of science, he had more freedom to express his opinion on the public stage than he would have felt if he had been working in a printed media. As previously stated, Cuvier made no attempt to publish his last lecture series. But Cuvier was a charismatic speaker, and what he had to say attracted considerable attention from the contemporary press. While the lecture series was running journalists published extracts of the lectures in *Le Temps* and *Le Globe*. Cuvier expressed concerns about the accuracy of these accounts. While there are no word-for-word accounts of Cuvier's lecture series, we owe the preservation of much of the content of what Cuvier spoke about to the efforts of a student of Cuvier's, Magdeleine de Saint-Agy, who reconstructed the text of Cuvier's lectures from his own notes and those of stenographers who also attended the lectures, which were published in a five volume series.[141] The retired American Icthyologist and museum curator Theodore Piestsch is currently editing an English translation of this work, the first three volumes of which have already been

[139] Ibid.
[140] Ibid, 141-142.
[141] Pietsch (ed.), *Twenty-four Lessons from Antiquity to the Renaissance*, 22-25.

published. It is Piestsch's dual language edition on which I have drawn my account of Cuvier's lecture series.

Cuvier's biographer, Dorinda Outram, wrote a review of Piestsch's version of Cuvier's lecture series. In this review, Outram raised the issue of authenticity, indicating what has been preserved are not Cuvier's exact words,[142] but she does not say more than Piestsch already acknowledged in the Introduction of the first volume of the lecture series. Considering the media of a lecture series, and the French attitude toward science as a collective endeavor, in this era, I believe the issue of authenticity should be considered in another light. In print, Cuvier preserved a rigidly professional public persona, but he dropped his guard a little while speaking to an audience. Madeleine de Saint-Agy's published version of Cuvier's lecture series preserved elements of the lectures that Cuvier would not have committed to print, if he had been supervising the publication of his lecture series. For instance, it is possible to find extempore remarks such as sarcastic jibes comparing the work of his contemporaries with ideas from the past, that Cuvier felt were ludicrous. Although Cuvier's exact words are not preserved, through the eyes of his audience, we are offered a glimpse of who Cuvier was as a public lecturer. Lecture series always are something of a co-production between the speaker and the audience, and considered in this light, an account of Cuvier's history recomposed from lecture notes of the audience has its own kind of authenticity.

[142] Dorinda Outram, "Book Reviews: Modern (Nineteenth Century to 1950)," *Isis* 107, no. 1 (2016), 186-187.

Chapter 2

Comparative Anatomy and the Quest for Nature's Order

Introduction

As the famous nineteenth century naturalist, Georges Cuvier (1769 – 1832), pointed out in the opening of his 22-volume catalog of ichthyology, humans have been interested in fish from the dawn of human civilization, when they first realized what an important food source these creatures represented.[143] Artisanal knowledge of fish, acquired from sources such as fishermen and fish markets, represents a comparatively durable aspect of human culture. If told from this perspective, the history of ichthyology is long and erratic, and included naturalists from both Greek and Roman antiquity, early modern scholars and has continued its development into the present era. However, the formation of ichthyology into a distinct scientific discipline involved applying a higher order of rigor to the organization and production of scientific knowledge about fish, and this process can be characterized as occurring in a more discrete series of events that took place in the nineteenth century. Even though numerous naturalists from the mid-sixteenth century onwards had devoted considerable efforts to describing fish, two factors had to take place before conditions were adequate to transform these collected observations into a disciplinary framework. The first requirement was that fish collections needed to reach adequate sizes to provide naturalists with sufficient leverage to understand fish diversity and to build orderly structures of knowledge. Once those resources were in place, it was necessary for naturalists to determine strategies for organizing fish

[143] Cuvier, *Progress of Ichthyology,* 4.

descriptions and other recorded data into condensed and coherent formats that would facilitate the transmission of knowledge to subsequent generations of naturalists.

The first of these requirements was finally reached in the early nineteenth century at the Natural History Museum in Paris, which contained a collection of fish that was large enough that Cuvier and his assistant Achille Valenciennes (1794- 1865) could assemble a multi-volume catalog that described a little over 4000 species of fish. Prior to the nineteenth century, even the most comprehensive treatments of ichthyology rarely included descriptions of more than a few hundred species. By the latter half of the nineteenth century, the fish collection at the Natural History Museum in London surpassed that of Paris, allowing the ichthyologist Albert Günther to create a catalog describing more than 8000 fish species.[144] These two collections, and the work of Cuvier and Günther, became the foundation on which the modern discipline of ichthyology was built.

In Chapter one, I considered how Cuvier made use of accounts of the history of ichthyology and the natural sciences to summarize the state of scientific knowledge achieved by the early nineteenth century, and to stake claims regarding best practices in science. During the nineteenth century, comparative anatomy became a standardized means of providing animals descriptions among the emerging zoological disciplines, including ichthyology. This chapter will focus on the development of comparative anatomy in the early modern period providing the context for Cuvier's own contributions. Cuvier wrote a number of foundational texts that were widely read by naturalists of the early and mid-nineteenth century, which used

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[144] Albert Günther, *Catalogue of the fishes in the British Museum*, vols. 1-8 (London: Taylor and Francis, 1859-1870). Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/bibliography/8809#/summary .

techniques from comparative anatomy as the foundation for providing taxonomic descriptions of animals. Comparative anatomy was used as the means to build an orderly approach to the study of zoology and was applied to both living and fossil animal species.

Cuvier argued that natural history was a fact-based science, appropriately founded on large quantities of empirical evidence amassed over many generations. Cuvier's conception of natural history incorporated works stretching from antiquity to the early nineteenth century, placing a premium on human memory and the organizational schemes necessary to make sense of this nearly overwhelming collection of facts. While he did believe in the lawful order of nature, he deeply criticized the propensity for "system building."[145] He advocated generalization as the appropriate means for discovering these laws, but made clear that this was the domain of the experts, cautioning others about the risks of generalization on insufficient evidence. His solution to dealing with the factual density of this conception of science came in the form of subordinating natural history to a systematic program of comparative anatomy.[146]

Prior to Cuvier's work on comparative anatomy, naturalists had taken a diverse series of approaches to organizing natural history. This chapter briefly examines some of the ways naturalists prior to Cuvier ordered the natural world, in order to show the natural history tradition from which Cuvier's work arose. Also considered are precedents in the study of

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[145] The term system building originally was used by late seventeenth century naturalists to criticize over-theoretical approaches to describing natural history attributed to Descartes. However, by Cuvier's time the expression had become increasingly ambiguous as French savants used Descartes as a stand in for contemporaries they believed took over-speculative approaches to the study of nature.

[146] Cuvier's first lecture on natural sciences emphasizes the factual basis of the natural sciences and the risks of people who attempt 'system building.' See Theodore Pietsch, (ed.), *Twenty-four Lessons from Antiquity to the Renaissance*, 49.

animal anatomy, with emphasis on animal studies in France during the *ancien régime* that helped form the basis of Cuvier's work. Several of the major works Cuvier published over the course of his career can be seen to characterize the development of his program of comparative anatomy. His work in comparative anatomy provided the methodology on which he founded his last major zoological project, a description of fish diversity found in the work *Histoire naturelle des poissons* (Natural history of fish). The chapter is concluded with a discussion of translation efforts which introduced English speaking audiences to Cuvier's ichthyology in the 1830s. The development of natural history was part of a shared intellectual project both within Europe and its associated colonies, but linguistic and geographical barriers sometimes slowed the transmission of knowledge. During Cuvier's lifetime, the central location for the development of ichthyology knowledge was located within the confines of his quarters at the Natural History Museum in Paris. However, toward the middle of the nineteenth century, the prime location for production of zoological knowledge, including ichthyology, had shifted to the British Museum in London. In subsequent chapters, I will continue to trace the development of ichthyology in Great Britain.

Natural History in Antiquity and Early Modern Europe

Since antiquity a long-standing historical precedent has existed for considering Aristotle (384 – 322 BC) and Pliny (23 – 79 AD) as representative figures in establishing the foundations on which natural history rests. Both of these authors ordered nature both within the framework of a cosmological scheme and in a more personalized approach to natural history. In the case of Aristotle, his interest in animals was primarily as animate beings that moved, grew, reproduced and died. As a result, his zoological works are primarily organized around the processes of movement and reproduction, and his animals are classified in terms of the anatomical and morphological structures that aid these activities. Pliny on the other hand took a more human-centered approach. He viewed plants, animals and minerals in terms of their relationship to natural products such as food, medicines, building materials and luxury goods.[147]

By the early modern period, several more organizational schemes were prevalent such as encyclopedias, collections and early taxonomic systems. Encyclopedic treatments of natural history were common in medieval as well as early modern times. Entries were often, but not exclusively, arranged in alphabetical order.[148] Such alphabetical treatments made individual entries easy to find for someone who already knew what they were looking for, but did not offer much practical insight into patterns of relationships within the animal world. Over the course of the sixteenth and seventeenth centuries, natural history collections, which often stood as status symbols for the wealthy and powerful, became increasingly more common among the aristocracy and other well off families. It is somewhat difficult to characterize the order found in such collections and the written descriptions that they inspired, since they did not conform to modern organizational expectations. However, display was an essential element to the arrangement of these collections, and they followed varied forms of aesthetic logic. Some projects based on such collections, however, did at least somewhat conform to

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[147] For further insights into the ancient approaches to natural history see Roger French, *Ancient Natural History* (New York: Routledge, 1994).

[148] Yeo presents an overview of the encyclopedic tradition in the first chapter of his book. See Richard Yeo, *Encyclopaedic Visions: Scientific Dictionaries and Enlightenment Culture* (Cambridge: Cambridge University Press, 2001), 1-32.

general categories of natural relationship as can be seen in the works of naturalists such as Conrad Gesner (1516 – 1565) and Ulisse Aldrovandi (1522 – 1605).[149]

Traces of the concepts on which modern taxonomy is based can be found in work of early modern naturalists, particularly within the field of botany. The early modern Italian philosopher Andrea Caesalpino (1519 – 1603) suggested botanical classifications based on flowers and fruits. Work by John Ray (1627 – 1705) and Joseph Pitton de Tournefort (1656 – 1708) were also seen as important contributors to the process. By the eighteenth century, Linnaeus was advocating the concept of a natural system of taxonomy, although contemporary and later critics were prone to question just how natural his system genuinely was.[150] Linnaeus actively promoted his work and was quite successful in attracting students and followers[151] although there was substantial early resistance to his ideas in France.[152] As of the mid-eighteenth century there were not strong connections between anatomical approaches and taxonomic ones.[153]

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[149] For an account of the rise of museums and natural history collections in early modern Italy see Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern* Italy (Berkeley: University of California Press, 1994).

[150] S. Müller-Wille, "Systems and How Linnaeus Looked at Them in Retrospect," *Annals of Science* 70, no. 3 (2013): 305-317.

[151] Patricia Fara, *Sex, Botany & Empire: The Story of Carl Linnaeus and Joseph* Banks (New York: Columbia University Press, 2003), 32-34.

[152] Phillip R. Sloan, "The Buffon-Linnaeus Controversy," *Isis* 67, 3 (1976): 356-375.

[153] Most historical narratives of the development of modern biological disciplines trace their heritage through the efforts of early modern taxonomists. While these naturalists made substantive contributions to the development of natural history, they do not serve as the primary subject of this narrative, which is after all, a history of comparative anatomy rather than taxonomy. During the early modern period, taxonomy and anatomy developed from distinctly separate traditions. While the traditions of taxonomy and comparative anatomy did eventually merge, such events are largely beyond the scope of this chapter.

Comparative Anatomy

In current historiography, some definitional ambiguity exists regarding the difference between animal anatomy and comparative anatomy.[154] How systematic and comprehensive must the comparison be to merit the praenomen of "comparative"? Cuvier, who was less fastidious in his definition than more recent scholars, identified Aristotle as the first comparative anatomist.[155] From Aristotle's works on animals, he was known to have dissected or at least been aware of the internal anatomy of around 110 types of animals.[156] Although the Aristotelian work that provided the primary account of these dissections has been lost, it is possible to identify a significant portion of what must have been contained in the text through references made in extant works such as the *History of Animals* and *Parts of Animals*. These works also demonstrated a significant familiarity with fish found in the Mediterranean Sea. Perhaps due in part to their relative accessibility as food items[157] and to a comparatively stable categorization from antiquity to the present, fish have occupied an important position in the development of zoological knowledge.[158] The pattern held true in the development of comparative anatomy as well, in a large part due to Cuvier's own work.

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[154] The historiography of comparative anatomy is quite limited so two of the defining writings in the field are still from the mid-twentieth century. Both of these works make the same distinction saving the term comparative anatomy to describe the sort of systematic programs in animal anatomy of which Cuvier's work is an example. See F. J. Cole, *A History of Comparative Anatomy from Aristotle to the Eighteenth* Century (London: MacMillan & Co. LTD, 1949) and William Coleman, *Georges Cuvier Zoologist: A Study in the History of Evolution Theory* (Cambridge, Mass.: Harvard University Press, 1964), 44-73.

[155] Cuvier makes this claim in his history of ichthyology. Cuvier, *Progress of Ichthyology*, 18.

[156] An early twentieth century estimate of Aristotle's dissection activities indicates that Aristotle demonstrated significant familiarity with the internal anatomy of 110 types of animals. See Thomas East Lones, *Aristotle's Researches in Natural Science* (London: West, Newman & Co., 1912), 105.

[157] Fish markets have served as an important source of research material for those who wish to learn more about this group of organisms both in Aristotle's day and in the present.

[158] For a basis of comparison consider the case of mammals which did not become a recognized category until Linnaeus formed the designation in the eighteenth century. Until that time, most mammals were identified as quadrupeds, that is vertebrates with four feet. For an analysis of the mammalian category see Londa Schiebinger,

Historical Context of Cuvier's Career

Cuvier spent over two decades working on his program of comparative anatomy, from his entry into the Parisian scientific community in 1795 until the publication of his four-volume synthesis of the subject in his 1817 *Le Règne Animal* (The Animal Kingdom). The rise of comparative anatomy in the late eighteenth and early nineteenth centuries was shaped by the complex political events surrounding the fall of *ancien régime* France and the revolutionary era.[159] When Cuvier arrived in Paris in early 1795, France was in the process of reinventing itself. An unanticipated outcome of the French Revolution was the role it would play in museum reform, or the augmentation of a national collection of animal specimens necessary to lay the groundwork for a rapid expansion of zoological knowledge. Nonetheless, as a consequence of the joint motives of early revolutionary fervor and the desire for preservation of vocational status, savants attached to the *Jardin du roi* (King's Garden), re-conceptualized the place that such an institution was meant to play in the ethos of the new Republic. As a result, the *Jardin du roi* was one of the few scientific or scholarly institutions to survive the institutional purges that took place in France during 1793, although members of the *Jardin du roi* did find it necessary to institute significant reforms and take on the more republican designation of *Muséum national d'histoire naturelle* (National Museum of Natural History).[160] When Cuvier as a young naturalist joined the Museum in 1795, he associated himself with one of the first genuinely modernized museums in Europe. Over the course of his career, due to

"Why Mammals are called Mammals: Gender Politics in Eighteenth-Century Natural History," *The American Historical Review* 98, no. 2 (1993): 382-411.

[159] For a discussion of how political change in this time altered the practice of science in France during the Revolution and early years of Empire see Hahn, *Anatomy of a Scientific Institution*, 159-318.

[160] Emma Spray provides account of this transformation in Spray, *Utopia's Garden*.

French imperial expansion and the spoils of the Napoleonic wars, Cuvier found himself as curator of the largest natural history collection of the time.[161] This collection became an essential resource for the advancement of the two sciences to which Cuvier's name is most intimately attached, comparative anatomy and paleontology. Cuvier was one of the Revolution's success stories, but that success did not come as easily as many biographical narratives about him imply.[162] It was the work of decades.

Cuvier's career was focused on establishing order, both within his roles of public administrator and as a naturalist. In many ways the scope of Cuvier's career can be seen as a search for order: politically, educationally, within the domestic sphere and in the animal world. Cuvier's work in comparative anatomy strove to find order both within individual animal bodies and across the domain of the animal kingdom. It is important to recognize Cuvier's objectives in borrowing from a long tradition that he readily acknowledged both in his history of ichthyology (which takes up the first half of volume 1 of the *Histoire naturelle des poissons*) and in the extended lecture series on the history of the natural sciences that he delivered periodically from the years of 1829 – 1832. In these histories, Cuvier offered what amounts to an extended literature review of authors who made contributions to the growth of ichthyology and the natural sciences from antiquity to his own time. The histories of ichthyology and comparative anatomy have attracted little attention by historians of science, since the establishment of the field as an academic discipline in the early twentieth century. Since much of the subject matter Cuvier wrote on has not been extensively updated in the last two

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[161] Elise Lipkowitz, "'The Sciences Are Never at War?': The Scientific Republic of Letters in the Era of the French Revolution, 1789-1815," (dissertation, Northwestern University, 2009), 107-133.
[162] Dorinda Outram, "Scientific Biography and the Case of George Cuvier: With a Critical Bibliography," *Hist. Sci*. xiv (1976): 101-137.

centuries, his histories still represent a valuable resource both in terms of providing historical overviews of a poorly explored subject matter, and in offering insight into how nineteenth century scientific investigators viewed the histories of their own disciplines.

While few writers in antiquity emulated Aristotle's anatomical endeavors, the growth of medical humanism in the early modern era reawakened considerable interest in animal anatomy. Analysis of Cuvier's history of comparative anatomy and a more recent survey produced in the mid-twentieth century[163] revealed that the sixteenth and seventeenth centuries represented a period of active growth in the field of animal anatomy. Many European naturalists during this time period performed dissections and wrote about their results. In this era, animal anatomy was often perceived as a usable proxy for the human body, and such anatomical and physiological research was often put to the use of clarifying human medical understanding. However, the sheer quantity and diversity of animal dissections carried out by a few early modern physicians such as Marcello Malpighi and Jan Swammerdam sometimes belie strictly utilitarian explanations of their research. While there were numerous scattered examples of individuals or scientific societies describing individual specimens or eclectic collections of organisms, there was nothing approaching a systematic or comprehensive treatment of the subject. Before turning to a closer analysis of Cuvier's texts, it is critical to recognize unique aspects of science in *ancien régime* France that helped prepare the way for his work. Under the *ancien régime*, animal studies had developed along a unique trajectory compared to the rest of Europe. Even though the French Revolution represented a

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[163] Cole, *History of Comparative Anatomy*

significant fracture in the scientific community, continuities still existed between scientific practice before and after the Revolution.

Animal Studies in France in the Seventeenth and Eighteenth Centuries

The character of French science was significantly reshaped during the reign of Louis XIV (1643 – 1715). One of the most visible evidences of this change can be seen in the establishment of the Paris Académie des Sciences (Academy of Sciences) in 1666. The leading architect in the formation of the Academy was the French finance minister, Jean-Baptiste Colbert (1619 – 1683). Colbert conceived of the Academy as a means of harnessing the creative cultural potential of the Republic of Letters to both glorify the French monarchy and place the countries most talented minds in the service of the state through the establishment of royal patronage for a community of philosophers and artists.[164] The Academy and other significant intuitions established during the *ancien régime*, such as the Jardin du roi, did much to shape the space and social context of the practice of science during the late seventeenth and eighteenth centuries. Compared to other scientific communities in Europe, French science took on a highly statist and centralized character. For the scientific community in France there were both benefits and detriments to be found in this system of royal patronage. While it did provide direct and indirect means of support for a small group of practitioners, it also meant that the crown exercised a considerable influence on the practice of science during the *ancien régime*.[165]

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[164] For a description of the establishment of Academy of Science and Colbert's intentions for it, see the first chapter of Hahn, *Anatomy of a Scientific Institution*, 1-34.

[165] Voltaire provides a humorous perspective on the impact of royal patronage through the comparison of the Paris Academy of Science and the British Royal Society in a letter entitled "On the Academies." See Voltaire, *Philosophical Letters*, 97-100.

Due to unique patterns of patronage, sociability and institutional organization during the late seventeenth and early eighteenth centuries, animal studies in France developed under significantly different conditions than it did in other European countries. Within the Academy, the sciences were initially divided into two primary groups: mathematics and physics. These two groups met on Wednesdays and Saturdays respectively. Under this scheme, "physics" included the non-mathematical aspects of natural philosophy: anatomy, botany and chemistry. Only thirty-six members were appointed to the Academy during Colbert's initial administration between 1666 and his death in 1683.[166] In this small community, members from different specialties attended demonstrations and even contributed new material outside of the primary area of their expertise. With no clear disciplinary boundaries existing between such a broad range of inquiry, studies of animals might easily borrow ideas and methodologies from the other branches of the physical sciences.[167] A consequence of this only loosely circumscribed conception of science, was that zoology in Paris acquired a very material focus that was frequently lacking in animal studies outside of France. Compared to other parts of Europe, animal classification was distinctly under-represented.[168] Rather than conceiving of an animal as primarily an object of classification or a convenient anatomical proxy for man, animals came to be viewed as unique physical and chemical entities, with France leading the way in forging a new understanding of anatomy, physiology, development, behavior and the relationships between animals and their environment.

[166] Alice Stroup, *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences* (Berkeley: University of California Press, 1990), 47.
[167] Anita Guerrini, *The Courtiers' Anatomists: Animals and Humans in Louis XIV's* Paris (Chicago: The University of Chicago Press, 2015), 92.
[168] Stéphane Schmitt, "Studies on Animals and the Rise of Comparative Anatomy at and around the Parisian Royal Academy of Sciences in the Eighteenth Century," *Science in Context* 29, no. 1 (2016): 33.

The first dedicated project in animal studies at the Academy was led by the physician and architect, Claude Perrault (1613 – 1688). Perrault was one of four anatomists initially appointed by Colbert. When animals from the royal menagerie died, they were sent to this group for description and dissection. Interest extended beyond descriptive anatomy to functional anatomy and physiology, so the group also performed vivisections, dissections of living animals, to understand more clearly how organ systems within the body worked.[169] The results of the groups investigations were published by the Academy with two volumes appearing in 1671 and 1676 under the title *Mémoires pour servir à l'histoire naturelle des animaux* (Memoirs for the natural history of animals). Perrault's approach to the study of animal anatomy was highly empirical. He criticized system building—in other words building theories without sufficient factual evidence—that he felt had been characteristic of a Cartesian approach to science.[170] Perrault's approach manifested itself in two ways within the project of animal anatomy. The first case fell within the nature of sociability of the Academy, in which the production of knowledge was a communal activity that relied on public demonstration within its membership and consensus of determining the factual basis of the work. Perrault demonstrated further empirical caution in the Academies' publications, by emphasizing the individuality of the animals examined rather than generalizing claims to the species level, since Perrault was skeptical regarding the sufficiency of evidence to make such characterizations.[171]

A third volume of the *Mémoires* was planned, but never completed in Perrault's lifetime and did not appear until 1733, when the Academy decided to publish a retrospective series of

[169] Guerrini, *Courtiers' Anatomists*, 54-55.
[170] Ibid., 151.
[171] Ibid, 155-156.

the institution's early work. The new volume, which was edited both to update material and to include additional work by Perrault that had never previously been published, appeared at a critical time for shaping thoughts and practices in French natural history.[172] Anatomical studies had slowed significantly in the years following Perrault's death in 1688. One notable exception to this trend is the work of Réaumur, the Academy's most active contributor to animal sciences during the first half of the eighteenth century.[173] But Réaumur was no anatomical specialist, as his interests ranged broadly across such topics as insect development and behavior, bee farming, agriculture as well as insect anatomy and physiology. Within this narrative, the exact nature of his research was perhaps less significant than the role he helped to play in popularizing French natural history. By the end of Réaumur's career, natural history in France had become a subject of appeal not only to intellectuals but a broad reading public, and while many factors went into developing this public interest, without Réaumur's copious and eloquent endeavors there would have been significantly less material to feed this preoccupation.[174]

Buffon's Natural History

Georges-Louis Leclerc, Comte de Buffon assumed the intendancy of the *Jardin du roi* in 1739, just six years after the re-publication of Perrault's work. At least in the early part of his

[172] Anita Guerrini, "Perrault, Buffon and the Natural History of Animals," *Notes & Records of the Royal Society* 66 (2012): 393-409.
[173] Schmitt provides a table of the *Mémoires* published by the Academy between 1699-1790 that were partially or wholly devoted to animals, this list displays the frequency of Réaumur's contributions. See Schmitt, "Studies on Animals," 25-31.
[174] An informative account of the rage of Réaumur's scientific activities can be found in Mary Terrall, *Catching Nature in the Act* (Chicago: The University of Chicago Press, 2014).

career as a naturalist, this work influenced Buffon to prioritize anatomical work as an essential component of natural history.[175] In 1740 Buffon received a request from his patron, the minister Jean-Frederic Phelypeaux aux de Maurepas (1701 – 1781), that he catalog the natural history collections held in the King's Cabinet. *Histoire naturelle, générale et particulière, avec la description du Cabinet du Roi* (General and particular natural history, with a description of the King's Cabinet) ended up extending far beyond the bounds of Maurepas' or even Buffon's expectations. Buffon was not experienced at animal dissection, and he found it necessary to take on a collaborator for the project. In 1745 Buffon appointed Louis-Jean-Marie Daubenton as Demonstrator for the *Jardin du roi*.[176] Daubenton served as Buffon's collaborator over the course of the production of the first 15 volumes of the *Histoire naturelle*, although Daubenton's contributions do not appear until the third volume. Volumes 4-15 covered the natural history of quadrupeds, four legged vertebrates, and demonstrate a division of labor between Buffon and Daubenton. Buffon provided the general natural history of the animals and Daubenton the anatomical descriptions. It was Daubenton's contribution to the *Histoire naturelle* that provided the first extended comparative anatomy of a large group of morphologically similar organisms. While Daubenton's contributions were scientifically important, his articles were perceived as long and tedious, and when Buffon moved on to the next part of the *Histoire naturelle* on birds, he chose to drop Daubenton's anatomical contributions to the project.[177]

[175] Guerrini, "Perrault, Buffon," 393.
[176] Jeff Loveland, "Another Daubenton, Another Histoire naturelle," *Journal of the History of Biology* 39, no. 3 (2006): 457-491.
[177] Paul Lawrence Farber, "Buffon and Daubenton: Divergent Traditions within the Histoire naturelle," *Isis* 66, no. 1 (1976): 63-74.

An interesting aspect of Buffon and Daubenton's collaboration was the ambiguity that existed between the relationship of comparative anatomy and animal taxonomy. At least toward the beginning of his work, Buffon demonstrated a level of agnosticism regarding the existence of animal species as real objects in nature. While his position on the subject may have relaxed somewhat later in his work, he never came to terms with the Linnaean approach to classifying plants and animals. Within his work Buffon vehemently attacked Linnaeus.[178] While other naturalists in France held Linnaeus' approach in higher esteem, with Buffon occupying such a prominent position in French natural history, it was difficult for Linnaean practices to gain much of a foothold. With the coming of the Revolution so soon after Buffon's death, however, the Linnaean supporter's position strengthened considerably. Since Buffon's work was perceived as closely allied to the *ancien régime*, his reputation declined significantly during the last part of the eighteenth century.[179]

Buffon took on several collaborators over the course of the production of the *Histoire naturelle*, but it was the first and last of these collaborators, Daubenton and Lacépède, that had the most influence on Cuvier's career and whose zoological work that was most closely related to Cuvier's. The nature of the collaboration between Buffon and his last protégé, Bernard-Germain-Étienne de La Ville-sur-Illon, comte de Lacépède (1756 – 1825), is somewhat ambiguous. Lacépède was appointed as Demonstrator at the *Jardin du roi* toward the end of 1784, which conferred on him the role of collaborator with Buffon's ongoing production of the *Histoire naturelle*. Lacépède published eight volumes of *Histoire naturelle* on reptiles, fish and

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178 Sloan, "The Buffon-Linnaeus Controversy," 356-375.

179 Stéphane Schmitt, "Lacépède's Syncretic Contribution to the Debates on Natural History in France around 1800," *Journal of the History of Biology* 43, no. 3 (2010): 437.

cetaceans, the first of which appeared just before Buffon's death in 1788. However, all of these volumes, including the one published during Buffon's lifetime, appear under Lacépède's name alone, begging the question of whether Lacépède genuinely collaborated on the project with Buffon or simply took it over from him.[180] Lacépède's career intersected with multiple aspects of Cuvier's career. Lacépède was one of Cuvier's earliest contacts in Paris and served an important role in easing Cuvier's entry into the scientific community. Lacépède held the chair of reptiles and fishes at the Natural History Museum in Paris from 1794 until his death in 1825, and he worked on the five volumes of the *Histoire naturelle* dedicated to fish from 1798 – 1803. Lacépède's approach to ichthyology showed substantial methodological differences to that of Cuvier.[181] It is unlikely that Cuvier viewed these differences in favorable terms. However, his review of Lacépède's work showed uncharacteristic restraint. Cuvier first praised Lacépède's eloquence before attributing his short comings to historical factors. Cuvier assured his readers that Lacépède, "would have built an impressive monument." However, "writing his book during the stormiest years of the Revolution, when France was separated from neighboring states by a cruel war, he could not profit from the wealth of material in foreign works."[182] Civility seems to have dictated a diplomatic approach in criticizing the work of a long-term colleague, and may have been a factor in Cuvier waiting to work on his catalogue of fish until after Lacépède's death, even though Cuvier found the state of knowledge of ichthyology wanting during his work preparing the *Le Règne Animal.* More than a decade passed between

[180] Schmitt, "Lacépède's Syncretic Contribution," 429-457.
[181] Alan H. Bornbusch, "Lacépède and Cuvier: A Comparative Case Study of Goals and Methods in Late Eighteenth and Early Nineteenth Century Fish Classification," *Journal of the History of Biology*, Vol. 22, No. 1 (1989): 141-161.
[182] Cuvier, *Progress of Ichthyology*, 163.

the completion of the prior work and the publication of the first volume of Cuvier's *Histoire Naturelle des Poissons.*

Vicq d'Azyr Reform Efforts

It is essential to point out the contributions of one further predecessor who played an important role in laying the foundations of Cuvier's career. This is Daubenton's protégé, Félix Vicq d'Azyr (1748 – 1794). Over the course of his career, Vicq d'Azyr participated in major projects of scientific and institutional reform. Trained as a physician, Vicq d'Azyr spent two decades of his life working to reform natural history and medicine by establishing a more rigorous form of practice. The concept at the heart of this project was that comparative anatomy should form the basis of a more lawful and disciplined practice, with medicine and natural history being subordinate to the organizing principles of this central knowledge. Although sometimes vaguely stated, many of Vicq d'Azyr ideas prefigure concepts that Cuvier was later to articulate in more distinct terms.[183] In the work based on his lecture series on comparative anatomy, Cuvier does acknowledge his intellectual debt to Vicq d'Azyr.[184]

In the early years of the French Revolution Vicq d'Azyr participated in another project that Cuvier was to become more subtly indebted to, that of museum reform. French experimentation in republicanism inspired a number of scientists and administrators to contemplate what role culture and public education should play in meeting the needs of its citizenry. The result was an effort to rationalize and modernize museum practices that were

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[183] Stéphane Schmitt, "From Physiology to Classification: Comparative Anatomy and Vicq d'Azyr's Plan of Reform for Life Sciences and Medicine (1774 – 1794)," *Science in Context* 22, no. 2 (2009): 145-193.
[184] G. Cuvier and C. Duméril, *Leçons d'anatomie comparée* (Paris: Baudouin, 1800), Biodiversity Heritage Library Date Scanned: 2/18/2016, https://www.biodiversitylibrary.org/bibliography/114836#/summary , viii.

articulated in a series of four *Instructions Initiales* (Initial Instructions*)*. These instructions focused on a number of issues such as criteria for determining what artifacts were of cultural significance, preservation and restoration methods, labeling, cataloging and other curatorial practices. In 1794 Vicq d'Azyr and Poirer authored a detailed set of instructions relating to the management of natural history collections.[185]

The early revolutionary period was an extremely uncertain time for the scientific community, as by 1793 most scientific, technological and medical institutions had been disbanded. The Academy of Sciences, which was viewed as being too closely allied with the *ancien régime* was unable to avert this fate. However, the members of the *Jardin du roi* managed to more dexterously reposition the purpose of the gardens and museum as a tool for educating the citizenry. Through a twist of fate Vicq d'Azyr never became a member of the *Jardin du roi*, later known as the *Jardin des Plantes*.[186] Dying in 1794 he did not survive long enough to see the results of his work. His efforts along with other notables such as the famous painter Jacques-Louis David, continued to exercise an influence on modern conceptions regarding the purpose and management of museums.[187] A matter of months after Cuvier's arrival in Paris in 1795 he was able to negotiate a place for himself at the Natural History Museum located on the grounds of the Botanical Garden, previously known as the *Jardin du roi*, and later that year he joined the *Institut de France*, the newly formed institution formed to

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[185] Patrick Boylan, "Revolutionary France and the Foundation of Modern Museum Management and Curatorial Practice Part 1: From Revolution to the First Republic, 1789-92," *Museum Management and Curatorship* 11 (1992): 141-152 and Patrick Boyland, "Revolutionary France and the Foundation of Modern Museum Management and Curatorial Practice Part II: David and Vicq d'Azyr, 1792-94," *Museum Management and Curatorship* 15, 2 (1996): 117-131.
[186] Buffon supported Vicq d'Azyr's membership for the *Jardin du roi*, but institutional politics prevented his appointment to the position. See Spray, *Utopia's Garden*, 43-45.
[187] Boylan, "David and Vicq d'Azyr," 117-118.

replace the Academy of Sciences. By joining these institutions, Cuvier became a part of a community working to reformulate its identity and purpose, building a new conception of science laid on what was left of the intellectual foundations of the *ancien régime*.

Cuvier's Use of Comparative Anatomy

Between 1798 and 1817 Cuvier produced four major works that characterized the development of his system of comparative anatomy. Each of these works represented some level of synthesis at a different stage of the evidentiary process. For Cuvier, synthesis—which he termed as generalization--was based on the careful accumulation of factual evidence from historical and contemporary sources as well as personal observation. For Cuvier this was the ideal means of building scientific knowledge into a coherent body of work and providing satisfactory explanations of material realities and physical processes in nature. The building of this knowledge base relied on the activity of an expert in command of the current state of knowledge in his field. There is reason to believe that Cuvier interpreted this work as a post-revolutionary extension of Buffon's project of cataloging the natural world as seen in the *Histoire naturelle*.[188] However, over the course of his career Cuvier's ambition was not to merely emulate but surpass Buffon, as he searched for a more lawful approach to nature study on which to build a scientific methodology that would transform natural history into natural science.

[188] Although, if this is the case, the approach Cuvier took more genuinely resembles Daubenton's contributions to the ancien régime project than those of Buffon.

When Cuvier came to Paris in 1795 he was already an adept natural historian and anatomist. In 1788 he had graduated from the Académie Caroline in Stuttgart and had taken employment as the tutor to the son of the Marquis d'Hericy in Normandy. Working for the d'Hericy family provided Cuvier with significant leisure time, which he employed in the pursuit of natural history. For Cuvier, natural history was more than recreational activity. It became an important step in the process of building an intellectual identity, demonstrating a vocational potential that set him above his current employment as a tutor. During his six years in Normandy with the d'Hericy family, Cuvier developed his intellectual repetition by forming social contacts based on his expertise in natural history, cultivating a correspondence network and writing articles on his experiments and observations.[189] Even toward the end of his career, he believed that the experience he obtained during this period of his life was significant enough to point out as a demonstration of the depth of his expertise. He stated in the *Histoire naturelle des poisons*, "As early as 1788-89, on the Normandy coast, I described, dissected, and sketched almost all the fishes of the English Channel, and some of the observations I made at that time have been used in my *Tableau élémentaire de l'histoire* and for my *Leçons d'anatomie comparée*."[190] Based on these experiences, he did not come to Paris empty handed. He arrived with a good educational pedigree, a notable social network, and a modest but solid reputation as a naturalist.

[189] Outram, *Vocation, Science and Authority*, 165-167.
[190] Cuvier, *Progress of Ichthyology*, 247.

Tableau élémentaire de l'histoire naturelle des animaux

In July of 1795, Cuvier received the position of assistant to Jean-Claude Mertrud (1728 – 1802) the professor of animal anatomy at the Natural History Museum. By December of the same year, he began his first series of public lectures on comparative anatomy at the museum. Sometime between 1797 and 1798, Cuvier produced his first monograph on the subject, *Tableau élémentaire de l'histoire naturelle des animaux* (Elementary table on the natural history of animals). He wrote this work in response to a perceived need for a comprehensive and popular textbook in zoology, basing the book on his lectures on natural history at the *École centrale du Panthéon*.[191]

Putatively a work of natural history, this book rapidly established the central role that the organization of animal bodies played in developing its methodology, by placing the subject of anatomy in the opening chapters of the book. Using the human body as the standard model, Cuvier set out a general description of human anatomy then progressed through various systems and bodily functions including: organs of movement, respiration and circulation, sensation, nutrition and the process of reproduction and growth. It is only after presenting this material that he continued on to more general aspects of natural history. Once he completed his discussion of man, Cuvier discussed the other animal groups, starting with mammals, the group that shared the greatest similarity to humans. He moved in order of decreasing similarity to man, through the following groups: mammals, birds, reptiles, fish, molluscs, insects and worms, and ends with zoophytes (organisms with characteristics of both plants and animals).

[191] Jean Chandler Smith, *Georges Cuvier: An Annotated Bibliography of His Published Works* (Washington: Smithsonian Institution Press, 1993), 195-196 and Coleman, *George Cuvier Zoologist*, 11-12.

Each class of animal received a compressed description of characteristic anatomical and morphological features, before the discussion of its more detailed taxonomic hierarchy. After Cuvier's treatment of man, the *Tableau* became largely a work of animal systematics. Classification within this systematic scheme was based on anatomical and morphological features that were perceived to be diagnostic for the group or species.[192]

While the work does draw on Cuvier's personal observational experience as a naturalist and anatomist, it served largely as a survey of the state of knowledge of across the breadth of animal anatomy and systematics. As the first monograph of his career, Cuvier was careful to point out the sources on which the work was based. Acknowledging these sources—including Parisian colleagues such as Geoffroy Saint Hilaire, Lacépède and Lamarck[193]—helped establish Cuvier's legitimacy by demonstrating his familiarity with the work of his predecessors and ability to collaborate with his contemporaries.

Leçons d'anatomie comparée

Cuvier's first two major works were products of his early career as a public lecturer and covered the subjects of natural history and comparative anatomy. The second series, *Leçons d'anatomie comparée* was produced with considerable assistance by two collaborators André Marie Constant Duméril (1774 – 1860) and Georges Louis Duvernoy (1777 – 1855). The first two volumes appeared in 1800 and were based on the lecture notes of Duméril, who assisted Cuvier on a number of his dissections and spent four years attending the lectures on which

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[192] G. Cuvier, *Tableau élémentaire de l'histoire naturelle des animaux* (Paris: Baudouin, 1798). Biodiversity Heritage Library, Date Scanned: 01/22/2009, https://www.biodiversitylibrary.org/item/42906#page/11/mode/1up .
[193] Cuvier, *Tableau élémentaire*, vi-vii.

material for the text was compiled.[194] Duméril was unable to continue his collaboration after the publication of the initial two volumes, so Cuvier took on the assistance of another able student and dissector, Duvernoy.[195] After a delay of five years the remaining three volumes were published in 1805. While the active role of compiling the series fell to Cuvier's students, Cuvier maintained strict editorial control over the production of the books making corrections and additions that he deemed appropriate and willingly acknowledging the contents of the work as an accurate representation of his lecture series.[196] The material of the work is divided into 30 lessons distributed over the five volumes. The first volume addressed organs of movement, the second sensory organs, volume three and the first part of volume four covered digestion with the remaining portion of volume four discussing the organs of circulation, respiration and voice, and the series was completed with the fifth volume covering the organs of reproduction and excretion.

Cuvier's early work in comparative anatomy emphasized functional aspects of the animal body relating to his perception that conditions of existence were key to understanding how the body was organized. Simply explained, Cuvier believed that the environment in which the body must operate dictated the form the body must possess. Later in his career, Cuvier would adopt an anatomical hierarchy, known as subordination of characters, which pointed to those features he believed were most important in determining issues of animal systematics.[197] However, his work *Leçons d'anatomie comparée* represented an intermediate phase of his

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[194] G. Cuvier and C. Duméril, *Leçons d'anatomie comparée*, vol. 1 (Paris: Boudouin, 1800), xiii. Biodiversity Heritage Library, Date Scanned: 01/02/2008, https://www.biodiversitylibrary.org/item/17708#page/9/mode/1up .
[195] G. Cuiver and G. L. Duvernoy, *Leçons d'anatomie comparée*, vol. 3 (Paris: 1805), ix-x. Biodiversity Heritage Library, Date Scanned: 12/03/2007, https://www.biodiversitylibrary.org/item/17680#page/9/mode/1up .
[196] Cuvier and Duméril, *Leçons d'anatomie comparée*, vol. 1, xiii.
[197] Coleman, *Georges Cuvier Zoologist*, 77-83.

interpretation of the natural laws found within the biological realm. The order of his lessons therefore emphasized the importance of animal motion and sensory systems, two features of animal anatomy that responded most directly to the concept of conditions of existence. Analysis of the internal organization of Cuvier's texts revealed an orderly and hierarchical approach, with individual lessons further divided into articles, and articles sometimes divided into subheadings. Once an organ was generally described, comparisons were made between all relevant animal groups which were typically arranged in the same hierarchical manner of animal groups found in the *Tableau élémentaire*. An aspect of his work that should not be overlooked was that Cuvier took an integrated and methodical approach to the study of nature.

Recherches sur les ossemens fossiles

Coming at Cuvier's work from a zoological perspective, William Coleman, the first historian of science to produce an in-depth review of Cuvier's zoology, perceived systematics to be the next logical step after comparative anatomy. Coleman's analysis of Cuvier's work moved primarily from a discussion of *Leçons d'anatomie comparée* to *Le Règne Animal*.[198] However, another major work, which should be considered as part of his program of comparative anatomy, came out before *Le Règne Animal*. That was the four-volume work on fossil bones published in 1812, *Recherches sur les ossemens fossiles*. Martin Rudwick has persuasively argued that Cuvier's paleontology should be viewed as the practice of comparative anatomy extended to fossil remains.[199]

[198] See chapters three and four, Coleman, *Georges Cuvier Zoologist*, 44-106.
[199] Rudwick, *Bursting the Limits of Time*, 445-448.

In 1805, the same year as the completion of *Leçons d'anatomie comparée*, Cuvier began offering public lectures in geology at both the Athenaeum and the Collège de France. He also began incorporating geological material into his physiology lecture course at the Collège de France.[200] Sometime around middle of the first decade of the nineteenth century, Cuvier had begun a collaboration with the French pharmacist, Alexandre Brongniart (1770 – 1847), studying rocks around the region of Paris. Together they published an essay on the mineral geography of Paris in 1808. It was around the time of his initial collaboration with Brongniart that Cuvier also began publishing articles on animal fossil bones. These articles, most of which were published between 1804 – 1810, formed the bulk of the material found in *Ossemens fossiles*. One new feature of the work is the "Preliminary discourse." It is in the "Discourse" where Cuvier revealed the connections he perceived to exist not only between comparative anatomy and geology, but also between such apparently widely ranging subject matter as civil and natural history and ethnography.[201] Cuvier's work forged new ground in defining the meanings of comparative anatomy and paleontology, but he has a sense of the integration of knowledge that most resembled the early modern concept of *historia*.[202] Cuvier's lecture series on the natural sciences also promoted a unitary conception of knowledge. However, since his approach to studying the sciences is highly empirical, requiring the accumulation of facts by

[200] Martin Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes: New Translations & Interpretations of the Primary Texts* (Chicago: The University of Chicago Press, 1997), 8.
[201] Cuvier, "Preliminary Discourse," 183-252.
[202] For a discussion of *historia* in the allied literature of early modern of medicine, natural history, civil history and antiquarianism see, Gianna Pomata and Nancy G. Siraisi, eds., *Historia: Empiricism and Erudition in Early Modern Europe* (Cambridge, Mass: The MIT Press, 2005).

large numbers of people over multiple generations, he advocated the necessity for disciplinary divisions in the process of acquiring new knowledge.[203]

Le Règne Animal

By 1817, when Cuvier published *Le Règne Animal*, he was approaching his most mature synthesis of knowledge across the animal kingdom. In some ways this work can be viewed as completing the circle, as from a structural perspective this four-volume text most closely reflected the arrangement of his first work, the *Tableau élémentaire*. After presenting his introductory material, Cuvier moved through the animal groups in order of decreasing similarity to man. However, while the overall structure was the same, there were changes in the categorization and arrangement of this information. From an anthropocentric perspective the most striking change was that man, while appearing first in all the descriptions of the animals, no longer was treated separately from mammals. Instead he was simply treated as the first taxonomic group among the mammals. From a philosophical perspective, we see the introduction of Cuvier's *embranchements*, the four major divisions of animal life as represented by four basic body plans: vertebrate, mollusk, articulate and radiate. And from a taxonomic perspective the addition of new material and some rearrangement among previously identified groups.[204]

Le Règne Animal displayed Cuvier's first large scale attempt to apply two methodological tools based on concept of conditions of existence, that he believed represented

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[203] Pietsch, *Twenty-four Lessons Lessons from Antiquity to the Renaissance*, 53.
[204] G. Cuvier, *Le règne animal distribué d'après son organisation : pour servir de base a l'histoire naturelle des animaux et d'introduction a l'anatomie compare*, 5 vols. (Paris: Deterville, 1817). Biodiversity Heritage Library, Date Scanned: 07/21/2010, https://www.biodiversitylibrary.org/bibliography/49223#/summary .

laws of nature: correlation of parts and subordination of characters. The application of these putative laws to comparative anatomy demonstrated use of the morphological type-concept, one of three type concepts that Paul Farber indicated were commonly utilized in early nineteenth century taxonomy.[205] While the morphological type-concept frequently worked well in identifying higher taxonomical divisions, it was often difficult to apply on the level of families, genera, and species. In the nineteenth century there was very little consensus on the exact definition of species, and as a consequence the identification of species was more of an art than a science. Fish, as the most specious group of vertebrates frequently presented subtle variations among species within large taxa. This often rendered accurate identification of species in these large families and genera as particularly difficult. In such lower taxonomic divisions, Cuvier frequently had to resort to the classification type concept.[206] This approach, which can be applied at multiple taxonomic levels, relied on using criteria such as frequency or distribution to designate a species as representative of a genus or a genus to be representative for a family on up the classificatory scale. In cases where Cuvier adopted this approach, he would describe the type in greatest detail and in subsequent descriptions within the same group simply point out characteristics in which non-typical species diverged from the original description.

A second edition of *Le Règne Animal* was published between 1829 – 1830. This updated version, now expanded to five volumes, can be considered Cuvier's most mature integration of comparative anatomy with natural history across the domain of the animal kingdom. Published

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205 Paul Farber, "The Type-Concept in Zoology during the First Half of the Nineteenth Century," *Journal of the History of Biology* 9, no. 1 (1976): 107-113.
206 Farber, "The Type-Concept," 113-116.

after the work *Histoire naturelle des poisons* was underway, this second edition reflected a knowledge of fish contemporaneous with the more comprehensive text. From this perspective, the most striking change to his arrangement of fish is the fish orders. In both the *Tableau élémentaire* the first edition of *Le Règne Animal* Cuvier placed the Order Chondrichthyes[207] first. However, by the second edition of *Le Règne Animal*, he moved the Order Acanthopterygii, or ray finned fish, into that primary position. The rationale for placing Chondrichthyes first among the fishes in older taxonomic schemes was that this group of fish were deemed to most nearly resemble humans. Cuvier's rationale for moving the Acanthopterygii to this position had been that they were the largest group of fish, and therefore most representative of the Class.[208] Here again we see a trend of decreasing anthropocentric interpretation of the animal kingdom in Cuvier's sense of the arrangement of nature. With each step away from this anthropocentric view of nature and towards more systematic and lawful methodology, he refined the distinction between a Buffonian natural history and a Cuvierian natural science.

Translating Cuvier's Ichthyology into the British Context

As the first third of the nineteenth century began to wind its way to a close, there was a perception among some of the men of science in Great Britain that science in the European Continent was advancing more rapidly than it was in England. Within the context of the natural

[207] In current taxonomy Chondrichthyes is the Class of cartilaginous fish that contains sharks, rays, and skates. In Cuvier's time the Order contained not only these fish but a number of other fish types that have been subsequently moved to other Classes. The earlier arrangement was borrowed for Lacépède's work see, Bornbusch, "Lacépède and Cuvier", 141-161.

[208] G. Cuvier. *Le règne animal distribué d'après son organisation : pour servir de base a l'histoire naturelle des animaux et d'introduction a l'anatomie compare*, vo1. 2 (Paris: Deterville, 1829), 131. Biodiversity Heritage Library: Date Scanned: 07/21/2010, https://www.biodiversitylibrary.org/item/99171#page/9/mode/1up .

sciences, there was both envy and distrust of the advances being made in France. Cuvier's work in Comparative Anatomy attracted particular interest among British scientists, both because it was considered superlative and because of his political and religiously conservative stance made him seem less threatening to the British scientific elite during a time of political and social instability. During the 1820s and 1830s translations and descriptions of Cuvier's work became available making it possible for English speaking readers who were unfamiliar with the French language to read material from and about his work. In the closing section of this chapter, I will focus on two projects from this time period that made the work Cuvier had done in ichthyology more accessible to a British audiences.

The first of these projects was a translation effort spear-headed by Edward Griffith to make Cuvier's work *Le Règne Animal* available in English. Griffith poured considerable effort into the project and brought in several collaborators. In the process, Griffith and his collaborators transformed Cuvier's four volume[209] work into a sixteen-volume supplemented translation. This translation was issued in a series composed of 43 parts between the years 1827 - 1835. The 10th volume, which was comprised of parts 37, 41, 42, was on the Class Pisces and was published in 1834.[210] In the case of this volume, Griffith collaborated with Lieut.-Col. Charles Hamilton Smith in the production of the supplementary material. The second work, which featured an aspect of Cuvier's ichthyology, is a summary of the history of

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[209] When Griffith first began publishing his translations in 1827, only the first edition of Cuvier's *Le Règne Animal* was available, and this edition is four volumes, but when Cuvier's second edition came out between 1829-1830, this edition was published in five volumes. Griffith did make use of Cuvier's second edition for some of the later volumes in his series.

[210] Lieut.-Col. C. F. Cowen, F.R.E.S., "Notes on Griffith's *Animal Kingdom* of Cuvier," *J. Soc. Biblphy nat. Hist*. 5, no. 2 (1969): 137-140. In this article Cowen provides a table providing information regarding the content, timing of publication, part numbers, and supplementary authors on page 139.

ichthyology that appeared in William Whewell's *History of the inductive sciences: from the earliest to the present time Volume 3*, which was first published in 1837. Rather than attempting to provide a comprehensive history of zoology, Whewell borrowed from Cuvier's history of ichthyology to serve as a model for the advancement of the zoological branches of the systematic sciences.

The first four volumes of Griffith's translated and edited edition of *The Animal Kingdom* were dedicated to the Class Mammalia. In the opening of Cuvier's discussion of the Class Mammalia, he informed his readers that, "The mammalia are placed at the head of the animal kingdom, not only because it is the class to which we ourselves belong, but also because all the species included in it enjoy the most numerous faculties, the most delicate sensations, and the most varied powers of motion."[211] According to this arrangement, Griffith's ten volumes on vertebrate classes appeared in order of greatest to least complexity: Mammals first, then Bird, Reptiles, and ending with Fish. With the remaining six volumes dedicated to Fossils, Mollusca, Annelids, etc., two volumes on Insects, and ending with a volume for the Index and References. In the first volume Griffith provided insight regarding his motivations for producing a translation of Cuvier's work. Griffith opened his argument for the importance of this work with the observation, "We possess no complete and compendious work on zoology in our language commensurate, at least, with the modern improvements and discoveries in that science."[212] Griffith went on to express concern that zoological knowledge was advancing more rapidly on

[211] Georges Cuvier, *The Animal Kingdom Volume 1: The Class Mammalia 1*, Edited and translated by Edward Griffith with supplementary material by Major Charles Hamilton Smith and Edward Pidgeon originally published in 1827 (Cambridge, MA: Cambridge University Press, 2012), 72.
[212] Cuvier, *Animal Kingdom Vol. 1*, i.

the Continent than in Great Britain. He stated the intention of attracting more attention to the subject among British naturalists. He then provided justification for his editorial decisions with the following statement, "It was thought better to translate the whole of his (Cuvier's) compendium of zoology, the 'Regne Animal,' and to make such additions to it as might appear requisite to render the present work not merely useful to the naturalist as a book of pure science, but also interesting at large as a general biography, and ornamental as containing original and well-executed illustrations."[213]

Griffith stated that Cuvier's content and writing style were focused only on attracting a professional/student audience. Griffith intended to expand the appeal of the English translation of the work by making the content more entertaining and by addressing a popular as well as a professional audience, by adding material relating to the instincts and habits of animals. Another perceived deficiency he intended to remediate by (1) adding supplementary material and (2) by expanding the species descriptions, was to make the work provide a more comprehensive account of the denizens of the animal kingdom. Griffith ended his Preface to the first volume by offering his audience reassurance regarding the religious orthodoxy of Cuvier and the suitability of zoological subject matter. He stated, "Another and more serious charge has been brought against zoological science as delivered to us by the scavans of Germany and France: it is asserted that it has been made a vehicle for the insidious poison of infidelity. That it has no natural adaptation to such an end is certain, that it has been perverted to such a purpose, is we fear too true."[214] Of Cuvier he stated, "Our author at least, in our

[213] Ibid, i-ii.
[214] Cuvier, *Animal Kingdom Vol. 1*, xi.

minds, stands clearly acquitted of such a charge, but as his view of science have been distorted by others to the prejudice of religion, a distortion which has, perhaps, been facilitated by an occasional want of precision in his style, it has been our particular care in every individual instance of such perversion, to show its utter inapplicability to such an end."[215]

The Animal Kingdom Volume 10: The Class Pisces

Griffith's tenth volume of Cuvier's work, which featured the Class Pisces, contained a higher content of Cuvier's own material than supplemental material added by Griffith and Smith. This could not have been the case with all of the volumes, since Griffith took what was initially a four-volume work to create his 16-volume translated and supplemented edition. But Cuvier freely indicated that he took extra time on the fish portion of his *Le Règne Animal*. In the preface of Volume 1, Griffith recorded this quote from Cuvier's original preface. "On the fishes, it will probably be found that I have done more than in the rest of the vertebrated department. In consequence of the great accessions made to our museum in this way, I have been enabled to add many subdivision to those of M. de Lacépède: I have also been enabled to authenticate many species noticed by Commerson and other travelers."[216] Volume 10 began with a brief introduction to the subject of fish, followed by two of the supplemental additions "On the Ichthyological System of Baron Cuvier" and "Supplement on Fish in General." This accounts for the first 99 pages of text. The remainder of the work, comprising almost six hundred additional pages, was devoted to systematic descriptions of fish groups, found under

[215] Ibid.
[216] Ibid, viii.

the headings of Cuvier's Orders: Acanthopterygii, Malacopterygii Abdominales, Malacopterygii Subbrachiati, Malacopterygii Apodes, Lophobranchii, Plectognathi, and the second series of the class of fish, the Chondropterygii. The descriptions of these groups were followed by supplemented additions to the various Orders, although Cuvier's material frequently extended for close to twice the length of the supplemental sections.

Cuvier defined fish as "oviparous vertebrata, with double circulation, whose respiration nevertheless is effected exclusively through the medium of water."[217] In his continued description it became clear, it was the characteristics associated with its aquatic lifestyle that Cuvier identified as the determining anatomical and physiological features that made fish unique among vertebrates. His observation that, "The entire structure of fish is as evidently adapted to swimming as that of birds is for flights,"[218] reflected his teleological point of view that an animal’s form is determined by conditions of life. Accordingly, Cuvier's description of the fishes’ form was conceived as a response to its means of locomotion.

After Cuvier provided a general bodily description of fish, he discussed his division of fish. Cuvier conceived fish as being represented by two distinct series, Chondropterygii, or cartilaginous fish, and the common fish. He defined common fish as "a primary division of those in which the maxillary bone, and the palatine arch, are inserted in the cranium."[219] The common fish were further divided into Orders based on prominent anatomical features, by which Cuvier made his best attempt to represent their natural groupings. Cuvier justified his

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[217] Georges Cuvier, *The Animal Kingdom Volume 10: The Class Pisces*, Edited and translated by Edward Griffith with supplementary material by Lieut.-Col. Charles Hamilton Smith originally published in 1834 (Cambridge, MA: Cambridge University Press, 2012), 1.
[218] Cuvier, *Animal Kingdom Vol. 10*, 1-2.
[219] Ibid, 7.

organization of groups based on, "commencing with that which is most numerous, viz. the common fish, and we will begin these with the order which abounds most in genera and species."[220]

In the first supplementary section the editors chose to provide a more detailed explanation of Cuvier's ichthyological system. They stated that significant improvements had been made to Cuvier's ichthyology between the first and second edition of the *Le Règne Animal*, "for the author having dedicated his time, during the interval between the two publications, to the continued and thorough researches in Ichthyology, the increase of materials and information extended and modified his views, until he prepared the results for publication in a great and separate work, under the title of Histoire Naturelle des Poissons."[221] Even though Cuvier's larger ichthyology project was not translated into English, Griffith's translation of Cuvier's *Le Règne Animal* was based on the second edition. By reading Griffith's translation, English speaking readers in the nineteenth century would have had an opportunity to see a mature form of Cuvier's ichthyological thinking.

"The Progress of Ichthyology"

William Whewell included a summary of the Cuvier's history of ichthyology in the third volume of his *History of the Inductive Sciences: from the earliest to the present*. Volume three of this text was divided into eight books, of which book 16 is identified under the heading "Classificatory Sciences" and the chapter is entitled "History of Systematic Botany and Zoology".

[220] Ibid, 9.
[221] Cuvier, *Animal Kingdom Vol. 10*, 10.

The first five chapters covered the subject of botany, while the remaining two were devoted to zoology. Whewell believed progress in the classificatory sciences would generally follow the same pattern, and that his description of the development of botany would generally suffice as a representation of how this category of scientific endeavor worked. He opened his chapter on ichthyology with the following statement: "If it had been already observed and admitted that sciences of the same kind follow, and must follow, the same course in the order of their development, it would be unnecessary to give a history of any special branch of Systematic Zoology; since botany has already afforded us a sufficient example of the progress of the classificatory sciences."[222] However, since Cuvier had conveniently provided a ready-made description of just such a special branch of zoology, Whewell took the opportunity to present this material in schematic form to his audience.

Whewell organized the narrative he borrowed from Cuvier under a series of headings that he believed summarized the pattern of progress in these types of sciences. He identified the first interval as a "Period of Unsystematic Knowledge." Under this heading he focused on the work of Aristotle and provided a summary of his works. Next followed the "Period of Erudition" for which he identified Belon, Rondelet, and Salviani as leading figures. For the "Period of Accumulation of Materials. Exotic Collections" he discussed the expansion of collection outside of Europe, particularly focusing on the systematic work of George Margrave, based on Dutch collections from Brazil. Whewell identified the "Epoch of the Fixation of Characters. Ray and Willoughby" as the period in which sound classification began to be

[222] William Whewell, *History of the Inductive Sciences: from the earliest to the present: A New Edition, Revised and Continued in Three Volumes: Volume 3* (Lexington: ULAN Press, 2013), 391.

developed. He particularly pointed out the systematic division of cartilaginous and bony fishes. In "Improvement of the System. Artedi" Whewell discussed the collaboration of Linnaeus and Peter Artedi. In this summary he put forward the notion that Artedi was the more original thinker. And even though Artedi's posthumously published book appeared after a number of Linnaeus' books, Whewell suggested that Linnaeus may have borrowed organizational elements from Artedi. In the section on "Separation of the Artificial and Natural Methods in Ichthyology" Whewell carried the narrative up to Cuvier's own work. Whewell included an extensive quotation from the first edition of Cuvier's *Le Règne Animal*. In this quotation he provided information on Cuvier's classification scheme. In this final section, Whewell's description extends modestly beyond Cuvier's own work to provide a comparison with that of Louis Agassiz. Here Whewell took some time to discuss the method Agassiz used to classify fish fossils. Whewell identified the system as artificial since it is primarily based on fish scales. But he still acknowledged the value of such a system, since he recognized instances when the scales of fish can be studied where no skeletal remains can be found.[223]

Cuvier was a reoccurring figure in Whewell's *History of the Inductive Sciences*. Further along in the third volume Whewell dedicated Book 17 to the subject of physiology and comparative anatomy and Book 18 covered "History of Geology". Cuvier's work was further discussed in portions of each of these books, and Whewell revealed the high esteem Cuvier's work still garnered from at least part of the scientific community in Great Britain during the decades immediately following his death.

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[223] The full chapter on "The Progress of Ichthyology" can be found in pages 391-410 of Whewell, *History of the Inductive Science, Vol. 3*. The quoted subheadings appear as sections in the books "Table of Contents."

Much as Cuvier did, Whewell used his discussion of the history of science to make claims about the nature of science and the achievement of best practices.[224] Cuvier and Whewell's interest in the history of science can be seen as exemplars of a dialogue occurring in the late-eighteenth and early nineteenth century Europe over the meaning and value of science that in which other prominent intellectuals from that time period were engaged. Early in his career the British naturalist, Richard Owen (1804-1892), included a discussion of the history of science in his Hunterian Lecture series on comparative anatomy.[225] The Germanic poet and naturalist Johann Wolfgang Goethe wrote his own interpretation of the history of optics in the early nineteenth century after becoming acquainted with a number of professional historians working in Göttingen who were writing their own histories of particular disciplines within the sciences.[226]

These early nineteenth century histories of science were invested with deeply held convictions not only regarding the value and meaning of science but how science fit within the larger cultural landscape of political and religious meaning. As the narrative of this dissertation turns to consider the development on ichthyology in Great Britain, a story emerges that shows that debate inspired by political discontent played a significant part in the development of natural history practice at the British Museum during the mid to late-nineteenth century. During the ferment of war, although French and British savants had attempted to maintain a narrative of the apolitical nature of scientific knowledge, and the continued camaraderie that

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[224] Richard Yeo discussed Whewell's use of history in his book the chapter 6 "Using History" in his book: Richard Yeo, *Defining Science: William Whewell, natural knowledge and public debate in early Victorian Britain* (New York: Cambridge University Press, 1993), 145-175.
[225] Richard Owen*, The Hunterian Lectures in Comparative Anatomy: May and June 1837, Edited, and with an Introductory Essay and Commentary, by Phillip Reid Sloan* (Chicago: The University of Chicago Press, 1992).
[226] Karl Fink, *Goethe's History of Science* (New York: Cambridge University Press, 1991), 75.

still existed within the scientific community. Although some semblance of civility was maintained, the reality remained, that science is an enterprise that is embedded in the geographical and political actualities of time and place and subject to the vicissitudes of history.

Chapter 3

Zoological Catalogs at the British Museum

During Cuvier's lifetime, the Natural History Museum in Paris had served as the location at the leading edge for the advancement for ichthyology. And for a time after his death, thanks to the continuing work of Valenciennes, the ichthyological cataloging project that Cuvier had started in the later part of the 1820s continued until the publication of the twenty-second volume in 1849. However, the 1840s marked a time of rising fortunes for another zoological collection, housed at the British Museum in London, and it is the career of Albert Günther [that would characterize what this phase of ichthyology was like].[227] Born in Swabia in 1830, Günther received advanced degrees in both natural history and medicine before he immigrated to England in 1857. He was hired to work as a naturalist at the British Museum by the end of the same year, and he spent the rest of his career working for the museum, first as a curator and later as the Keeper of Zoology. As a curator he was responsible for the production of zoological catalogs. Between 1857 to 1875 he prepared catalogs on herpetology and ichthyological subject matter. Günther was not only an accomplished naturalist, he was also well acquainted with the geological discussions of his day. His work on ichthyology included paleontological information, and he argued that knowledge of fish fossils might lead to a better understanding

[227] By the later part of the nineteenth century, ichthyology became an increasingly less centralized endeavor, as colonial and ex-colonial locations took on increasing significance in the production of the ichthyological literature. By the mid-nineteenth century, institutions in the United States and Australia were already beginning to serve as important loci of knowledge production In the United States two major centers for ichthyology research by the mid-nineteenth century were represented by the efforts of Agassiz at Harvard and in Washington DC there was a small collection of ichthyologists working at the Smithsonian. Recently, a useful account of the development of Australian Ichthyology has been published. See Brian Saunders, *Discovery of Australia's Fishes: A History of Australian Ichthyology to 1930* (Collingwood: CSIRO Publishing: 2012).

of the history of the earth.   After he became Keeper of Zoology, Günther who produced the first recognizably modern ichthyology textbook in 1880.[228]

Institutional Reform at the British Museum

Ironically, it was the pressure associated with public scandal that placed the British Museum in the position to become one of the leading centers of zoological knowledge production by the mid-nineteenth century. In the first third of the nineteenth century, it seemed far from inevitable that the British Museum would serve such a function. It was only criticism from the British scientific community of the museum's perceived shortcomings that prompted the British government yielded to public pressure to investigate the museum and lay the administrative groundwork for institutional reform in the 1830s.

Three imminent historiographies do much to lay the groundwork of our current understanding of the state of scientific knowledge and the motivation of its practitioners in Great Britain in the 1830s. I name these works, not according to their respective merit, but by the order in which they were published: Susan Faye Cannon's *Science in Culture*, Martin Rudwick's *The Great Devonian Controversy* (and the subsequent geological histories he has

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[228] When this text was first published, it received significant criticism from rival ichthyologists in the United States. An account of the criticism that Günther's book received can be found in the biography written by Günther's grandson: Albert E. Gunther, *A Century of Zoology at the British Museum: Through the Lives of Two Keepers 1815-1914* (Bristol: Dawsons of Pall Mall, 1975), 292. Nonetheless, in 1905, when the eminent American ichthyologist David Starr Jordan published his own textbook, he not only copied much of the structure of Günther's text, he also quoted long passages from Günther's work. David Starr Jordan, *A Guide to the Study of Fishes*, Vol. 1 & 2 (New York: Henry Holt and Company: 1905).

produced since its publication), and Adrian Desmond's *The Politics of Evolution*.[229] Although there are reoccurring characters in all three works, each text focused on different subsets of the scientific community, and between them they covered a lot of ground.

The last of these works, by Desmond, was written in self-conscious dialogue to the previous historiography of the other two authors, and he made a point of presenting something of a counter-narrative by intentionally focusing much of his history on members of the radical medical community who, excluded from the privileged classes, were also largely excluded from participation in institutions and conversations generated by those that Desmond identifies as the scientific elite. For what it accomplishes, Desmond's text must be praised as a piece of scholarship that considerably advances knowledge of a previously overlooked class of contributors to the scientific discussions of the era. By looking beyond the standard narrative, Desmond's work has enriched our understanding of the range of scientific ideas and stakeholders in early nineteenth century England. However, Desmond's book only accomplishes as much as it does due to previous scholarship such as that provided by Cannon and Rudwick, who presented something approaching a standard narrative describing more mainstream activities within the scientific community of its time. Desmond tends to treat this standard narrative with a dismissive attitude, that is unjust to the painstaking scholarship of his predecessors. However, the task of elucidating a comprehensive picture of the scope of scientific activity and thought in the early nineteenth century is far from accomplished. It

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[229] Susan F. Cannon, *Science in Culture: The Early Victorian Period* (New York: Dawson, 1978) and Martin Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge among Gentlemanly Specialists* (Chicago: The University of Chicago Press, 1985) and Adrian Desmond, *The Politics of Evolution: Morphology, Medicine, and Reform in Radical London* (Chicago: The University of Chicago Press, 1989).

would require the work of many dedicated scholars to fill out the narrative in a way that would provide a sense of completion to this story.

The narrative of the events that helped reshape the production of natural history knowledge at the British Museum in the 1830s lies largely between the interstices generated by these three works.[230] Although these books do not help much to generate the account of events as they transpired at the British Museum, they can serve as familiar landmarks, figurative triangulation points, to help map out less familiar territory in the historiography of 1830s science in Great Britain. This chapter will consider how the legislative hearings over the management of the Zoological Department at the British Museum provided an opportunity to reorganize practices at the institution. An important outcome from these hearings was that impetus it provided for the publication of catalogs of the zoological holdings at the British Museum, allowing the museum more authority to arbitrate the production of taxonomic classifications. The context for the museum's transfiguration is discontent found among the London populace who were chafing under repressive government practices instituted during the French Revolution that still had not entirely relaxed by the 1830s, which Desmond also explores. Even though it did not directly lead to institutional reform it helps explain the factors that pressured the government to investigate working conditions at the museum.

Desmond focus on the influence of the 1830s radical press on medical journalism in London provides a good starting point to consider how political and scientific ideas both are shaped by the press and conversely how the press shapes popular opinion regarding the

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[230] Desmond does briefly discuss the British Museum, but within this context he makes no mention of the legislative hearings. See Desmond*, Politics of Evolution*, 145-151.

interaction between science and politics for a given time and geographic location. But it should be understood that the press of the early nineteenth century expressed a broad but ephemeral spectrum of political opinion, and if we are ever to grasp the full extent of the dynamics between science, politics, religion, and popular opinion, a much broader range of studies on this subject would need to be conducted that explore a greater diversity of political opinion. The historian of early nineteenth century political history, James J. Sack, provided analysis of the journalistic expression of political thought during the first three decades of the nineteenth century. This book serves as a valuable prequel to the period that Desmond analyzed. In his narrative Sack enlarges our understanding of the press by discussing the community that was the polar opposite of Desmond's, the right-wing as well as the Jacobite press.[231] Sack's narrative laid the groundwork for future investigation of the transition of political opinion in Great Britain through the turbulent years of the Napoleonic era till the 1830 uprising in France.

By 1830 persistent economic distress and growing social unrest increased discontent with old-fashioned Toryism, the 1830s in Great Britain was a time of political reform. The first reform government which lasted from the autumn of 1830 till the end of 1834 took, the form of a coalition government of whigs, liberals, moderates, and liberal Tories. Although a number of significant social issues were debated by the coalition government, resulting changes in legislation were relatively modest. Divisive issues argued by the legislature at that time included relationships with Ireland, the Catholic Church, reexamination of the Poor Laws, and

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[231] James Sack, *From Jacobite to Conservative: Reaction and Orthodoxy in Britain, c. 1760-1832*, (Cambridge: Cambridge University Press, 1993), 1-15. It should be observed that terms such as 'right-wing', 'ultra', 'conservative' and 'liberal' were still evolving terms in the early nineteenth century so their meaning has shifted between the nineteenth century and the present. Nonetheless, Sack believes it is still justifiable to use such terms in his work as the serve as helpful anachronisms.

rights of factory workers including regulating work hours for children and adults.[232] Toward the end of 1834, the coalition government was dissolved and the Whigs returned to power from 1835-1841. It was during this era that administrative practices at the British Museum came under investigation by the British government.

The most succinct account of events at the British Museum in the 1830s can be found in Gordon Mcouat's article that addressed how John Gray, a young naturalist who was then serving as a temporary employee at the British Museum, benefited from the 1835/1836 legislative proceedings. Gray's testimony at these hearings gave him an opportunity to voice his opinions regarding the how natural history exhibits should be promoted in an institutional context. Based on this outcome, Gray was able to institute a zoological cataloging program at the museum, that the trustees had formerly blocked as a needless expenditure.[233] The Select Committee on the Affairs of the British Museum that was held in two phases before the House of Commons between 1835-1836. The first phase of testimony was heard between May 18-August 3, 1835, and the second phase did not begin until April 1836. During these hearings, Gray's superiors were defensive and offered little suggestion regarding how practices at the British Museum might be reformed. [234]

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[232] Peter Mandler, *Aristocratic Government in the Age of Reform: Whigs and Liberal, 1830-1852* (Oxford: Clarendon Press, 1990), 123-156. This account is based on a summary of chapter 4 of Mandler's book "Coalition Government, 1830-1834."

[233] Gordon Mcouat, "Cataloging Power: Delineating 'Competent Naturalists' and the Meaning of Species in the British Museum," *The British Journal for the History of Science* 34, no. 1 (2001): 1-28.

[234] Gunther, *Century of Zoology*, 78-87. A discussion of the hearings is given in chapter 5 of Albert E. Gunther's joint biography of John Gray and his own grandfather, Albert Günther. Both Gunther and Mcouat agree that these hearings served as an important opportunity to advance Gray's career.

That the British Government would intervene in the management of the British Museum was due to a confluence of political, social, and scientific factors that came to a head in the 1830s due to temporary influx of reform minded radicals in the British Parliament. In the decades immediately leading up to the French Revolution, increased press freedom and increased publication of government activities had helped to cultivate attention to political news among the British populace.[235] Public pressure to combat political corruption encouraged political representatives such William Pitt the Younger (1759-1806) to institute moderate reform, however with the coming of war, political and budgetary priorities shifted.[236] During the French Revolution and the Napoleonic Wars, fearing invasion and internal revolt, the British political practices had become increasingly repressive.[237] Although radical sentiments survived during war time, the combination of repressive political measures and loyalism did much to restrain radical political activity during the late eighteenth and early nineteenth century.[238] Tensions surrounding these political events did not immediately relax following the decisive defeat of Napoleon in 1815, so repressive practices continued to be exercised into the 1820s.[239] While warlike conditions persisted, much of the British citizenry did not feel like they were in a position to push back from political repression within their own country. But by the 1820s discontent began to surface, reaching a climax in the 1830s.[240] It was within this changing

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[235] Michael Turner, *British Politics in an Age of Reform* (Manchester: Manchester University Press, 1999), 15.
[236] Turner, *British Politics*, 34-40. Pitt served as prime minister between 1783-1801.
[237] Harvey Becher, "Radicals, Whigs and Conservatives: The Middle and Lower Classes in the Analytical Revolution at Cambridge in the Age of Aristocracy," *BJHS* 28 (1995): 405.
[238] Turner, *British Politics*, 56-57.
[239] Gunther, *Century of Zoology*, 51.
[240] Turner, *British Politics*, 52. In 1820 George IV succeeded his father George III. George IV was generally viewed as a week and dissolute monarch. During his reign, which lasted until his death on June 26, 1830, the influence of the crown declined, as political parties, government ministers, and public opinion gained greater influence over British politics.

political climate that various reform movements gained enough traction to sway governmental affairs.

The moderate Whigs were in power, however, radical reformers who had made their way into government during the latter part of the decade were a significant presence. According to the British Historian Peter Mandler the Whig government of the late 1830s was moderate but weak and could be swayed by radical interests. Whigs and Tories attempted to rally against the threat from below, and in the process tried to work out a liberal compromise. As with the coalition government, the Whig party brought together a range of people with different interests and ideas. For a time during the Whig government, a temporary alliance was formed between the Whigs and Radicals against the Tories. The period between 1835 - 1837 served as a period of vigorous agitation for reform by the Radicals. A General Election in 1837 due to the death of William IV helped to bring this phase to a close. Whig ambitions for reform were hindered not only by the disruption caused by the transition of the monarchy, but by worries associated with declining employment. Once the new General Election was called for, local reform associations are reported to have requested the central organization to supply Whig candidates who were not Radicals.[241] Although the ascendancy of influence that Radical reformers had on government proceedings was relatively short-lived, it lasted long enough to help prompt events that would change administrative practices at the British Museum.

The Parliamentary hearings regarding activities at British Museum thus fell within the period of most strident agitation for reform by Radical reformers within Parliament. The terms

[241] Mandler, *Aristocratic Government in the Age of Reform*, 157-170.

of Hans Sloane's will provided a clear structure of management through a committee of trustees. However, when the British government accepted the bequest, little provision was put in place to cover the cost of personnel or to supply resources needed for running a national museum. As a result, operations of the British Museum were chronically underfunded and short staffed over the course of the eighteenth and nineteenth centuries. Due to these circumstances, in the years leading up to the Select Committee hearings, access to the museum was limited, and the highly perishable zoological specimens from the original collection had succumbed to the depredations of time to such an extent that many had been deliberately disposed of.[242] With these shortcomings in view, the British Museum was extremely vulnerable to internal complaints and blistering criticism from the outside.

Gray's supervisors at the British Museum, Charles Konig and John Children were placed on the defensive by Parliamentary proceedings, and presented an opportunity for Gray's ascendance.[243] Gray had worked periodically at the museum since the late 1810s. In 1824 Gray received his first paid work from the British Museum in the form of a six-month commission to complete a *Catalog of Reptiles* for which he was paid 15 shillings a day.[244] In 1835 Gray was still working for the Museum on an impermanent basis, assisting the Keeper of Zoology, John George Children, thus when the hearings took place, Gray's position at the museum was still anomalous. Gray's testimony helped provide the vision for how the museum could modernize to accommodate the needs of both the scientific community and an increasingly scientifically

[242] Gunther, *Century of Zoology*.
[243] Günther 's grandson, Albert E. Gunther, wrote a joint biography of John Gray and his grandfather, Albert K. L. G. Günther, that was published in 1975. This biography along with Mcouat's article provide the primary narratives describing the drama the museum staff underwent when they were interviewed by the 1835/36 Select Committee.
[244] Ibid, 57.

engaged public audience. When contrasting Gray's testimony with that of Konig and Children, Gunther stated, "For John Gray, on the other hand, the Committee opened the first considerable opportunity in his career. It afforded a public platform for which he was not reluctant to testify."[245] Mcouat stated it this way: "His testimony is an example of compromise and moderation of the reformist cause."[246]

A central component of Gray's vision for the future of the museum was to institute a cataloging program. Mcouat argues that while naturalists were busy wrangling over the meaning of species, Gray outmaneuvered their efforts. In the 1840s, through the leverage of institutional holdings and provided with the means of publication, Gray's cataloging program dominated the production of new species descriptions in Great Britain.[247] Gray received his first formal appointment in 1837[248] and three years later was promoted to Keeper of the department of zoology.[249] The first catalog produced under Gray's Keepership was *List of Mammalia* from 1843 and between 1844-1845, additional catalogs were published on birds, tortoises, crocodiles, amphisbaenians, and lizards.[250] During Gray's career as Keeper of Zoology from 1840 until his death in 1875, numerous catalogs were produced by him, other staff members, and outside experts. This output included the eight catalogs on fish produced by Günther between 1858-1870. However, when Richard Owen was appointed as Superintendent of the British Museum in 1856, rivalry for publication funds between Owen and Gray led Owen

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[245] Ibid, 79.
[246] Mcouat, "Cataloguing Power," 20.
[247] Ibid, 1-8.
[248] Gunther, *Century of Zoology*,86.
[249] Ibid, 98.
[250] Ibid, 113.

to introduce restrictions on Gray's publication activities. Owen curtailed Gray's use of outside experts to work on catalogs and reserved the right to produce quarto-sized catalogs with pictures to himself.[251]

There are elements of Gray's biography track well with the social, political, and intellectual dimensions of mid-Victorian science as argued in Desmond, Rudwick and Cannon. Although Gray was born into a family with good social connections, an inheritance that under ordinary circumstances would probably have passed to Gray's father went to his great uncle instead. As a result, Gray grew up in impoverished circumstances. He followed a career path that led him into natural history, and as a young man he received a medical education. By young adulthood, Gray's financial circumstances had improved: first at the age of 24 by receiving paid employment at the British Museum, but more substantially at the age of 26, when he married his cousin's widow and as a result not only gained a wife and two step-daughters whom he held in great affection but the ability to recoup his families' financial losses. With his marriage to Maria Emma Gray, Gray gained a partner who was well connected socially. Additionally, his wife's financial resources allowed Gray to travel to the continent on a regular basis. During his travels, Gray made a point to visit other museums and made acquaintances among the scientific community abroad. However, despite changed circumstances, Gray's sympathies were directed toward those who lived in reduced circumstances, and he not only participated in various social causes throughout his life, he prioritized improving accessibility to the British Museum for all classes.[252] Gray's initial life circumstances display affinities with the

[251] Ibid, 131-132.
[252] Ibid. Gray's early life and education is covered in the first chapter of Gunther's book pages 1-38. Gray's marriage is discussed on page 61.

medical radicals described by Desmond. However, as he matured the financial stability, social position, and institutional affiliations that he attained helped place him into something of an intermediate category, as someone who could relate to the medical radicals, but who also could work within the ranks of the scientific elite. His story, and that of the development of natural history at the British Museum, has points of connection then not only to Desmond's work, but also to that of more standard narratives about the scientific community found in Cannon and Rudwick.

Cannon began the penultimate chapter of her book *Science in Culture* with the following statement: "The first half of the 19th century in Britain--and perhaps the second quarter more particularly than the first quarter--was one of the most formative, searching, and basically determinative periods in the history of science. By 1850, many of the great problems had been posed, many of the tools needed to solve them had been invented, and many of the men who were to solve them had been trained in a professional way which their elders had developed satisfactorily only in the preceding generation."[253] The story of the British Museum, Gray's role in it, and the cataloging project he instituted is not one that Cannon addressed, but it is part of the invisible narrative that runs behind the scenes of many of the chapters in Cannon's book. This is because the stories that Cannon did tell of the Cambridge Network, Humboldtian science, professionalization, and the BAAS are all narratives that can be understood in relationship to the British Museum and Gray's career there.

[253] Cannon, *Science in Culture*, 225.

***List of the Specimens of Mammalia in the Collections of the British Museum* (1843)**

The vision that Gray demonstrated in the 1843 *List of the Specimens of Mammalia*, the inaugural work of the new system of museum catalogs, took the form of a virtual tour of the museum exhibit. In the opening paragraph of the catalog's introduction Gray stated, “In preparing the present catalogue, the principal object has been to give a complete list of all the specimens of Mammalia contained in the collection of the British Museum, indicating at the same time the peculiarities of each as regards age, sex, condition, variety of colouring, habitation, and the source from whence it has been derived.”[254] The introduction served as an interpretive guide for how the contents of the individual exhibit cases were meant to be understood. The introduction for example revealed the museums goals when acquiring specimens. Gray indicated the intent to provide the habitat information for each organism. He went further, however, by sharing the reasons behind instances where they would fall short of this idea, as when he stated that it was not always possible to provide accurate information, as, "Many of the specimens having been procured from dealers, some of whom are unfortunately very careless on this point, and even occasionally guilty of willful misstatement, [make] it . . . often impossible to give the habitat except in the most general terms.”[255]

Gray also provided an explanation of the systematic methods he used in order to define his taxonomic technique, although most of this was done by referring the reader to earlier articles Gray had published in natural history journals about how he classified specific

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[254] John Gray, *List of the Specimens of Mammalia in the Collections of the British Museum* (London: George Woodfall and Son, 1843), iii. Biodiversity Heritage Library, Date Scanned: 06/29/2017, https://www.biodiversitylibrary.org/item/228669#page/5/mode/1up .
[255] Gray, *Specimens of Mammalia*, iii-iv.

taxonomic groups. To a certain extent, the catalog addressed the issue of synonymy, the duplication of names or a single species, although Gray drew limits on this discussion when he believed authors were renaming species in a manner that was not accepted by anyone other than themselves. He also pointed out donated collections that served as type collections that had been previously described by recognized systematists. Gray's index included two tables, the first showing the geographical range from which the specimens from various mammal groups had been collected, indicated on a continental level. He also provided a table comparing the contents of the mammal collection at the British Museum with descriptions of two other collections contained in previously published recent catalogs. These were from the Museum of the Zoological Society of London and the Senkenbergain Society at Frankfort. This table indicated that, at the time of Gray's publication, the mammal collection at the British Museum possessed roughly twice as many specimens as did the other two collections. The number of unique species at the Zoological Society of London was roughly three-quarters that of the collection at the British Museum, indicating the British Museum's collection had more duplicates.[256]

Immediately following the introduction, Gray included a section entitled "Systematic List of the Genera of Mammalia, with their Synonyma." This section—which provided page numbers on which the genera could be found—functioned roughly as a table of contents, although the large number of entries suggests it might be more equivalent to an index. The recognized genus name appeared first, followed by an indented list of any mentioned

[256] Ibid, v-xx.

synonyms for the species. Following the name, an abbreviated attribution indicated the author associated with the identification. This concluded the front matter for the catalog.[257]

Primates were the first Order described in the catalog, starting with the Family Simiadae that would have been found in Cases 1-14 in the Northern Zoological Gallery, Room III.[258] The descriptions of the contents of these cases would be useful for anyone interested in obtaining an historical reconstruction of the contents of the Mammal collection held at the British Museum in the 1840s. Gray's catalog would not have served well, however, as a simple reference tool for taxonomists wishing to learn about mammalian taxonomy. An example of the first description should illuminate some of the issues associated with using the catalog as a reference.

> The Chimpanzee. Troglodytes niger, *Geoff.* Homo Troglodytes, *Linn.* S. Agrias, *Schreb*. S. Pan, *Donovan.* Tr. leucoprymnus, *Lesson, Zool. Illust*. t. 31. *Martin* , f. 254 to 263. Pongo, *Buffon*, H. N. *Supp. Shaw, Zool. I.* t.
>
> a. Young. West Africa. — Mus. Sloane.
>
> b . Skeleton. West Africa.[259]

Gray did provide information regarding the synonymy of the chimpanzee, and that would potentially serve the purpose of referring a taxonomist to earlier descriptions, assuming they had access to a fairly comprehensive natural history library and were able to decipher which reference from a given author Gray was referring to. What these kinds of descriptions did provide to a naturalist of the time, was a list of what the British Museum had in its possession.

[257] Ibid, xvii-xxviii.
[258] Ibid, 1-10.
[259] Ibid, 1.

This kind of information would have been of benefit to someone trying to decide if a visit to the museum would provide the opportunity to view individual specimens they were interested in examining in person. The catalogs also would have been useful for anyone onsite who simply wanted information regarding the taxonomic provenance of the specimens in the display cases. In short, as Gray conceived the catalogs at the beginning of his term as Keeper, their utility was directly tied to the materiality of the exhibit, as it was presented at the museum at the time the catalogs were published. Were the display disassembled, even if all the specimens remained in residence at the museum, much of the utility of the catalog would be compromised.

Proceeding through the Primate exhibit, a would-be visitor in the 1840s would have found representatives from the family Cebidae in Cases 15-19.[260] The next display in Cases 20-33 was of the family Lemuridae.[261] The family Galeopithecidae, which was only represented by one species, *Galeopithecus volans*, was found in Case 23 with other lemurs.[262] Representatives from the family Vespertilionidae were to be found in Cases 24-29.[263] Since the Vespertilionidae are a family of bats, presumably Gray believed bats were a part of the order of Primates, since in the catalog they are included as the fifth family under the Order Primates.

On page 39, Gray introduced his second Order, the Ferae. The first family of Ferae described were the Felidae in Cases 1-23 of the Mammalia Salon. The first species exhibited as representative of this family was the lion. The display included nine representatives: two adult males, an adult female, three normal cubs, and three hybrid cubs. The dimensions of this

[260] Ibid, 10-15.
[261] Ibid, 15-17.
[262] Ibid, 17.
[263] Ibid, 17-39.

family encompassed many species a modern reader would not expect to find among the cats, including wolverines and otters.[264] Intermixed among the cats was the family Ursidae—the bears—in cases 20-21.[265] Case 22 held representatives from the family Talpidae, which in the 1840s included species of moles, shrews, and hedgehogs among its denizens,[266] and the family Macropidae occupied Cases 23-31. This seems to be a variation on the family now known as Macropodidae, or kangaroos. At the time, however, Gray also included mice, wallaby, bettong, bandicoot, the Tasmanian devil, dasyure, and opossum.[267]

From the catalog, it is unclear how the marine mammals were displayed. The family of the Phocidae—seals and walruses—are described on pages 102-103, but location information within the Museum was missing from these descriptions. The same was also true for the Order of the Cete including the family Balaenidae (page 104), family Delphinidae (pages 104-107), family Manatidae (page 107) and family Halicoridae (pages 107). However, location information resumed with the introduction of the Order Glires as Gray indicated the family of Muridae, rats and mice, could be found in The Northern Zoological Gallery, Room III.[268] Other families from this order included the Hystiricidae found in Case 33 (pages 122-126), family Leporidae in Cases 34-36 (pages 126-130), family Jerboidae Cases 36-43 (pages 130-148), but again, locational information is missing for family Aspalacidae (page 148-151). The last Order that Gray covered was the Ungulata which included the family Bovidae (page 151-182) again location information is missing for this order and family. It's unclear if the remaining families

[264] Ibid, 39-72.
[265] Ibid, 72-75.
[266] Ibid, 75-82.
[267] Ibid, 83-101.
[268] Ibid, 108-122.

described in the catalog are meant to be affiliated with the Order Ungulata since they are unnumbered. These families included: Equidae (pages 182-183), Elephantidae (pages 183-188), Dasypidae (pages 188-192), and Brandypidae (pages 192-193). The remaining entries were clearly unaffiliated, and they appeared under the heading "Additional Species" (pages 193-195). The remaining content of the catalog consisted of a "Corrections" page (196), an "Index of Donations" (pages 197-199), and an index (pages 200-216).

While Gray's catalog may not have been very useful as a field guide or even in terms of providing useful descriptions for fellow taxonomists, from an historical perspective they offer insight into the development of natural history and museum display in the nineteenth century. The contents of the Orders and Families provide a point of reference that indicate how much the determination of the higher affiliations among the class of mammals were still in a process of transformation. This text seems to fit within the tradition of "paper museums", that is, literary representations of museum displays.[269] Although lacking illustrations, it seemed to serve a purpose more of declaring ownership by the museum rather than providing a means of identification of its contents.

Catalogue of the Specimens of Lizards in the Collection of the British Museum **(1845)**

Examination of a second catalog produced by Gray two years later showed that his conception of the program of catalogs had evolved. This second contribution was a catalog of

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[269] A discussion of the literary genre of the paper museum can be found in the opening chapter of David Freedberg, *The Eye of the Lynx: Galileo, His Friends, and the Beginnings of Modern Natural History* (Chicago: The University of Chicago Press, 2002), 15-64.

lizards, which appeared under the title *Catalogue of the Specimens of Lizards in the Collection of the British Museum* (1845). Many of the elements of the structure developed in Gray's first catalog persist in this later catalog. But Gray introduced innovations that moved the presentation of the catalog from a virtual tour of the exhibit at the British Museum to something more closely approaching a genuine taxonomic guide. The stated purpose sounds very similar to that in the mammal catalog: "The chief object in preparing the present Synopsis, has been to give at one view a complete Catalogue of all the specimens of Lizards at present in the British-Museum collection, and an account of the species known to exist in other collections, but which are at present desiderata in the British Museum, so as to enable travellers, collectors, and others, to assist in completing the national collection."[270] However, Gray went on to reveal a change in procedure, one that did more than discuss only those specimens actually in the possession of the museum. Gray explained that for the purpose of providing naturalists with the full range of known specimens, "a synoptic description has been given of all the genera and species at present known to exist in the different museums and private collections, and at the end of each description is added an enumeration, stating the state, age, country, and other peculiarities of each specimen of the kind in the Museum collection; or when the species is not at present in that collection, the museum in which it has been observed is added after the general habitat of the species."[271] In choosing among the varied names applied to species by different authors, Gray indicated the application of rules of

[270] John Gray, *Catalogue of the Specimens of Lizards in the Collection of the British Museum* (London: Edward Newman, 1845), iii. Biodiversity Heritage Library, Date Scanned: 02/15/2008, https://www.biodiversitylibrary.org/item/25788#page/8/mode/1up .
[271] Gray, *Specimens of Lizards*, iii.

priority. Gray also indicated that the catalog provided synonymy at least for the most recognized variations.[272]

While the front matter for the lizard catalog is similar to that of the mammal catalog, the "Systematic Index" is more clearly organized then in the prior example. At the end of the introduction, Gray indicated that the British Museum possessed 429 of the 612 known species that had been described in European collections. This is a considerably smaller number of species to account for than that covered by the catalog of mammals, as Gray had indicated 1031 species of mammals were to be found in the British Museum's Zoological collection in 1843. Nevertheless, the main body of the text for the lizard catalog is over 80 pages longer than the mammal catalog. Much of this increased length can be accounted for by the fact that Gray devoted considerably more space to the provision of taxonomic description in the later catalog. Gray also structured the catalog with a clear sense of taxonomic hierarchy. Gray began the body of his catalog with a taxonomic definition of the class of Reptiles and a synopsis of the five orders of the reptiles. He provided a taxonomic definition of the Order covered by the catalog (the lizards) and provided a synopsis of the 24 families before launching into the main content of the catalog.[273] As the text continued, Gray provided descriptions of the families and a synopsis of their genera before he gave the species level information. Gray continued to provide descriptions to the genera and species level, although since he had provided longer descriptions at higher taxonomic levels, sometimes by the time he reached description at the species level the additional information was limited to only a line or two of

[272] Ibid, iv.
[273] Ibid, 1-5.

text. With the provision of these hierarchically organized descriptions, a taxonomist would have found the lizard catalog to be of much greater practical value than the mammal catalog when attempting to determine the identity of specimens they examined in comparison to the catalog descriptions.

Since the lizard catalog was no longer solely a description of the museum's collection, the descriptions provided in the catalog were less directly tied to the materiality of the exhibit at the British Museum. However, as for the mammal catalog, Gray wrote brief descriptions of the individual specimens, so the catalog could still be used to direct the reader to the actual physical holdings of the museum. In this sense, the catalog maintained an essential part of Gray's purpose, which was to delineate the sense of possession these holdings represented. As owner of these collections, the British Museum staked its claim in defining the denizens of the animal kingdom.

Albert Günther: Ichthyology at the British Museum

Under the tenure of Gray's leadership as Keeper of Zoology at the British Museum between 1840-1875, the zoology collection went from being an object of public ridicule in the 1830s to the largest zoological collection in the world by the 1860s,[274] continuing to grow in prominence and prestige through the remainder of the century. Despite this accomplishment, historians of nineteenth century natural history have paid inadequate attention to the roles that Gray and his successor, Albert Günther, played in the development of zoological

[274] Gunther, *Century of Zoology*, 470.

knowledge in Great Britain over the course of the last six decades of the nineteenth century. The primary source for biographical information on both Gray and Günther is a joint biography entitled *A Century of Zoology at the British Museum: Through he Lives of Two Keepers 1815-1914* that was written by Günther's grandson and was published in 1975. Shortly before Gray's death in 1875, Günther, who had been working at the museum since 1857, succeeded Gray as Keeper, a position which he held until his retirement in 1895. Between the years of 1858-1870 Günther produced an eight-volume catalog of fish. In 1880 the publication of Günther's book, *An Introduction to the Study of Fishes*, offered zoologists the first recognizably modern ichthyology textbook produced in the English language. These and other accomplishments played a critical role in the development of ichthyology into a coherent sub-discipline of zoology toward the end of the nineteenth century, and Günther was central to these accomplishments.

Günther's Education and Career

In 1830, Albert Günther was born in Swabia, a region of what is now part of southern Germany. If the circumstances of his early childhood were the guiding factor in establishing Günther's career, then much like Cuvier, it would seem highly unlikely that he would end his career as a prominent administrator in a foreign museum. In 1835, the year Günther turned five, his father Friedrich Gotthilf Günther (1800-1835) died, leaving his wife Eleonora Louise Nagel (1806-1899) with the responsibility of raising and seeing to the education of two young children. At the time of their father's death, Albert's younger brother, Carl Theodor Günther, was only a year old. Until the time Albert was old enough to begin his formal education, Louise returned with her two young children to the home of her father, Ludwig Friedrich Nagel (1777-1859) who was a Lutheran pastor in Vaihingen. Due to the straitened circumstances of their mother, Albert and Carl both seemed destined to enter the Lutheran ministry. As the orphans of a civil servant, the boys were eligible for six years of free education, as long as they maintained adequate academic standing through examinations. They would then be eligible to obtain benefactions or stipendia that would aid in the completion of a theological degree, so they would be able to enter the service of the church.[275]

As a student Günther maintained a sufficiently competent standing within the top third of his class and he passed the required entrance examination required for entrance into the Theological College at the University of Tübingen, where he began his theological program in October 1847.[276] Immediately on his arrival at Tübingen, Günther's theological training commenced with an introduced to the study of contemporary German philosophy, a subject that was not well-suited to the interests of the seventeen-year old boy. As he completion of his first year at the university, Günther expressed an interest in studying natural history, to his mother, a course of action she strongly advised against due to her anxiety that he successfully complete the studies that would guarantee her son's livelihood. In the next term Günther ignored his mother's advice, and he began the study of anatomy and physiology with Professor von Rapp (1794-1868) alongside his required theological education. Günther formed a close relationship with his teacher, who did much to encourage his interest in natural history. Günther continued his studies in natural history over the three subsequent years that it took to

[275] Gunther, *Century of Zoology*, 213-219.
[276] Ibid, 218.

complete his theological training. Günther successfully passed the final examination that qualified a candidate for Orders in the Lutheran church in the summer of 1851.[277]

Günther applied for and was awarded a grant that enabled him to extend his studies for a fifth year at Tübingen for classwork that fell beyond the scope of his theological studies at the Stift. During this year he continued his studies in natural history, and in the summer of 1852 began the thesis work that would allow him to obtain a master's degree in natural history in 1853.[278] Günther produced a 136 page thesis on the topic of identification and description of fish in the region of the Neckar river, entitled *Die Fische des Neckar, Untersucht und Beschriben*. In the eight-page introduction Günther discussed the history of ichthyology, location of his study region, and the purpose of his work. The thesis included a bibliography of the sources Günther used as reference for his species identification.[279] The remainder of the text was devoted largely to the description of the external anatomy of the fish that can be found in the region.[280] Such species descriptions fell within the Cuvierian tradition of taxonomic description, but regional studies such as the one Günther provided in his thesis added to a more complete knowledge of local species distribution throughout Europe.

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[277] Ibid, 220-229.
[278] Ibid, 230-235.
[279] Based on what I have seen of taxonomic catalogs and other natural history books, naturalists in the nineteenth century had inconsistent bibliographic practices. Sometimes the names of other naturalists were only mentioned within the main text if at all. As already discussed in the case of Gray's catalogs references to the species descriptions of other naturalists were listed in such abbreviated form, they were hard to identify, and he included no bibliography. Cuvier's catalog of fish included footnotes with abbreviated references as well, but again did not include a bibliography.
[280] Albert Günther, *Die Fische des Neckar, Untersucht und Beschriben* (Stuttgart: Verlag Von Ebner & Seubert, 1853; Kessinger Legacy Reprints).

Günther obtained a subsequent grant that allowed him to spend a 'Wanderjahre' at an outside university, which he used to help finance a year in Berlin, where he was able to study with the famous professor of medicine, Johannes von Müller (1801-1858).[281] Combining career considerations with his interest in natural history, Günther had the object of obtaining a doctorate in medicine. Günther developed high estimate of Müller's contribution to ichthyology and he relied heavily on Müller's system of ichthyology in his 8 volume *Catalogue of Fishes* (1858-1870).[282] The primary publication of Müller's that Günther cited both in his catalog and textbook was the four-volume work that appeared under the title *Über den Bau und die Grenzen Der Ganoiden* from 1846. As the title suggests, the bulk of Müller's study of ichthyology is dedicated to Ganoid fishes.[283] The Ganoid fish were of interest to Günther and other nineteenth century naturalists because the living representatives of these fish were believed to resemble specimens found deep within fossil record.

An influential figure in the development of ichthyology and medicine in mid-nineteenth century, Müller is best-known for his association with a number of successful students such as Theodor Schwann, Emil du Bois-Reymond, Hermann von Helmholtz, Rudolf Virchow, and Ernst Haekel, all of whom did much to shape the direction of the German biological sciences in the next generation.[284] In the nineteenth century, a close association could still be found between medical studies and natural history, and this can be seen in Müller's study of medicine

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[281] Gunther, *Century of Zoology*, 234-235.
[282] Albert Günther, *An Introduction to the Study of Fishes* (Edinburgh: Adam and Charles Black, 1880), 22-26, 33-34.
[283] Ganoid is no longer a recognized taxonomic category in ichthyology, although the ganoid scale is still a recognized term. Fish with ganoid scales include sturgeons, paddlefishes, gars, bowfin, and bichirs.
[284] A discussion of the relationship of the work of Müller and his famous students can be found in Laura Otis's book. Laura Otis, *Müller's Lab: The Story of Jakob Henle, Theodor Schwann, Emil du Bois-Reymond, Hermann von Helmholtz, Rudolf Virchow, Robert Remak,Ernst Haeckel, and Their Brilliant, Tormented Advisor* (Oxford: Oxford University Press, 2007).

therefore relied heavily on the allied field of comparative anatomy. Laura Otis, a former biologist who became a literature professor, has studied the work of Müller and his students. Otis has argued that Müller's linguistic choices revealed much about the way he viewed life, focusing on the diversity of forms, Müller sought those characteristics that helped lead the observer of nature from a state of confusion and doubt in order to solve the riddles offered by the study of life.[285]

Müller studied medicine at the University of Bonn where he completed his doctoral thesis on animal movement in 1822 and where he obtained his first medical degree by the end of the year. His doctoral thesis attracted the attention of Lorenz Oken, who published Müller's research in his newly-established journal *Isis*. During the final step in Müller's medical training, his patron sent him to Berlin to study under the anatomist Carl Asmund Rudolphi (1771-1832). Under Rudolphi's tutelage while in Berlin, Müller became an adept microscopist, and by the winter of 1824 had passed a second medical examination to obtain his second degree. Müller assumed a lecture position in anatomy and physiology in Bonn in 1824, where his research included work on various bodily systems: vision, circulation, reproduction, and the endocrine system. Müller's career at Bonn advanced with relative rapidity, and he obtained the position of full professor by 1830. In 1832, Rudolphi died, leaving his position open at Berlin. The position was prestigious, but Müller was particularly tempted by the fact that the university had its own Anatomical Museum. Although officials at the University of Berlin would have preferred to hire a more established anatomist, their offer to Friedrich Tiedmann (1781-1861)

[285] Otis, *Müller's Lab*, 25-26.

was rejected. Müller assumed the post of professor of anatomy and physiology at the University of Berlin in the spring of 1833, allowing him the opportunity not only to advance his academic reputation but also to curate an anatomical collection that would enhance own studies and those of his students.[286]

Several accomplishments were particularly influential for Günther's own educational development. In the early years of his career at Berlin, Müller wrote the two-volume physiology textbook *Handbuch der Physiologie des Menschen* which was initially published between the years 1833-1840. This book soon became a classic teaching text and remained so for many years. It was translated by an English physician, William Baly (1814-1861), and published under the title *Elements of Physiology* between 1837-1843. Both as a young graduate and later as an established practitioner, Günther attempted to emulate accomplishment of his professor, by producing textbooks relating to his own specialized knowledge of natural history.

Müller had an abiding interest in marine life, for Günther this meant that Müller offered the ideal combination of interests to enhance Günther's medical studies while at the same time feeding his interest in natural history. Müller developed a new classification system during the 1830s and 1840s for a number of fish groups including myxinoids (hagfish), plagiostomes (sharks and rays) cyclostomes (lampreys) and ganoid fish. Müller, who admired Cuvier and with whom he had wanted to work during his student days, aimed at producing a natural system for fish based on their comparative anatomy. During his tenure Müller also gave attention to

[286] Ibid, 8-14.

improving the Anatomy Museum at Berlin which was one of three collections hosted by the university (the other two being a Zoological Museum and a Mineralogical Cabinet.) Müller frequently devoted a substantial portion of his annual income to continued acquisition at the museum. The Anatomical Museum was meant to be opened to the public, although the hours were very limited, but Müller was somewhat jealous of his province, and preferred only serious students to have access to the collection.[287]

By the time Günther arrived in Berlin Müller was no longer working on fish classification, but the professor nonetheless took an interest in Günther, who wanted to continue his natural history studies because they inspired him more than medicine did. Müller allowed Günther to work over the ichthyology collection in Berlin's Anatomy Museum, offered him space to work, and put a microscope at his disposal. It was while he was working on his medical studies at Berlin that Günther first learned that Gray was looking for an ichthyologist to produce a catalog of fish at the British Museum, but Müller advised Günther not to seek the position at this stage of his education.[288] Although Günther only studied medicine at Berlin for a year, the encounter with Müller was a formative experience for him, and Günther remained in communication with him until Müller's death in 1858.

After leaving Berlin, it took Günther three more years to complete his medical studies. During this transitional period Günther's mother, Louise, had emigrated to England. The financial strain of supporting herself and trying to supplement the income of her two sons had drained her resources. As a middle-class woman in the mid-nineteenth century, the

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[287] Ibid, 20-31,

[288] Gunther, *Century of Zoology*, 236-239.

employment prospects were better for her in England than in her native land. Günther moved to Bonn to continue to study medicine, where, due to illness and the need to find work to increase his income, his progress slowed. For the two remaining years of his study, he returned to the University at Tübingen. There he was reunited with old friends, his own brother among them. Carl had taken a similar path to his brother Albert, diverting from the study of theology to medicine. Financial worries were always a factor throughout Günther's education, and in his final year of medical study, Günther began work on a book that he hoped would supplement his income, the *Handbuch der Medicinischen Zoologie*. The book was eventually published, but not until some time after he had completed his medical degree in the spring of 1857.[289]

With his studies finally completed, Günther went to visit his mother in England during the summer of 1857. While there, Louise, who wanted her son to remain with her in England, encouraged Günther to apply for a zoological position at the British Museum. After writing to Gray, who was still Keeper of Zoology, Günther was invited for an interview. At the interview, Günther and Grey negotiated terms for him to begin working on a catalog of snakes. Since Gray had overspent his budget for the year, Günther was not paid until he finished his first assignment in March 1858. Much as Gray's own early catalogs, the work that Günther was meant to produce was only supposed to classify those species of snakes that could be found in the British Museum. In his biography of Günther his grandson indicated that the work that his grandfather produced substantially exceeded the scope of the instructions that Gray had given. He emphasized the achievement stating, "Albert had produced more than a catalogue, it was a

[289] Ibid, 241-257.

handbook by which species could be distinguished. It also contained a new feature, a geographical index of special use to travelers. Because it included all properly described species in the world's museums, and not simply the British Museum, it quickly became an internationally used reference book. Any displeasure Gray may have felt at having his instructions ignored was mollified both by the thoroughness of the job, and by the fact that a snake had been named after him."[290]

After completing the snake catalog, Gray put Günther to work describing frogs, and finished the *Catalogue of Batrachia Salientia* in the British Museum by June 1858. That summer Günther started working on the *Catalogue of Fishes*. The first volume was published in 1859 and the eighth and final volume appeared in 1870. Again, Günther's grandson indicated that his grandfather's vision for what a catalog should be had matured beyond the terms of Gray's assignment. He stated, "*The Catalogue of Fishes* had taken the development of the British Museum catalogue well beyond that of the snakes. Gray had been content that a catalogue should be a list of specimens in the Museum with some synonymy added. But to Günther a catalogue was a frame into which an order of life could be fitted. . . . The synonymy should be complete, the description of the external features of both sexes should facilitate identification by the man in the field; there should be an account of habitat, and a record of origin as a basis for a study of geographical distribution."[291]

Günther's efforts to produce the most comprehensive fish catalog of the nineteenth century had a material component as well as a literary one. In order to build the Museum's

[290] Ibid, 265.
[291] Ibid, 279-280.

collections, he began an active campaign to gather material from all over the world. His ties to scientific societies such as the Zoological Society of London and the British Association helped connect him to a network of interested naturalists.[292] Even after his work on the catalog was done, Günther continued to promote the growth of the zoological collections of the museum, advocating that zoological material collected by expeditions sponsored by the British government should be added to the collections at the British Museum. One such expedition planned in the early 1870s became an important case in establishing the precedent. This was the expedition of the *Challenger*, initially proposed in 1871 and launched on December 21, 1872. The *Challenger* expedition was the first major voyage specially dedicated to oceanographic research, and it involved circumnavigation of the globe. It yielded the first sizable collection of deep-sea fish. When the *Challenger* returned in 1876, the issue of where the specimens were to be housed was decided in the favor of the British Museum, and much of the zoological material was added to their collections. By the time of the *Challenger's* return, Günther had already assumed the position of Keeper of Zoology, replacing Gray, who had retired in 1875 and who died soon thereafter. Because of his new responsibilities, it was some time before Günther was able to work with the expedition material from this expedition, a task he had to accomplish in his leisure hours. This work included a description of deep-sea fishes titled *Challenger Report on Deep-Sea Fishes* in 1885.[293]

In the mid-1860s Günther embarked on a project that can be seen as an outgrowth of his activity in cataloging herpetological and ichthyological collections. This was the

[292] Ibid, 278.
[293] Ibid, 387-391.

establishment of a bibliography of zoological literature. In order to do thorough systematic work, it was necessary for taxonomists to be familiar with species across the range of available scientific literature. Without a comprehensive knowledge of this literature, it was impossible to keep track of issues of synonymy. Prior to Günther's contribution, there was a German natural history journal entitled *Archiv für Naturgeschichte*, produced between 1835-1926, that did offer some level of literature summary, but Günther's plan was to produce an English language report that offered a more comprehensive review of systematic literature than was covered in the prior journal. Günther served as editor of this project for six years. Starting in 1865 with a review of the literature from 1864, Günther not only edited the *Zoological Record*, but wrote the literature review for the sections on fish and reptiles. By 1869, Günther found the responsibility for editing the *Zoological Record*, combined with his other duties at the Museum, was getting to be too stressful, and he requested that Alfred Newton take over the position. Newton, however, was still editing the ornithological journal *The Ibis*, and he declined the added responsibility that year. Günther edited the *Zoological Record* for one more year, and in 1871 Newton assumed the editorship.[294]

The first half of Günther's career at the British Museum was largely dedicated to the production catalogs. However, in May of 1869 Gray suffered from a paralytic stroke and over the next five years, as Gray's health continued to falter, Günther began to assume more administrative responsibility. Initially, it was assumed that Gray's brother, George Gray, who was then assistant Keeper, would replace John Gray after his retirement. But in 1872, George

[294] Ibid, 288-296.

Gray died unexpectedly, and Günther replaced him as assistant Keeper.[295] Despite his physical disabilities, Gray continued to work as Keeper until the beginning of 1875, by which time his health had significantly deteriorated. When Gray's retirement plans became clear, Günther applied to be his replacement and was accepted, serving as Keeper of Zoology from 1875 to 1895. In the early 1880s, he had to oversee the transfer of the zoological collections from the Bloomsbury quarters to a new building in South Kensington specially dedicated solely to the natural history collections.[296]

Günther had a very productive career at the British Museum, and this summary does not attempt to cover everything he accomplished over the course of his 38 years of active employment. My focus in this dissertation is in his capacity as an ichthyologist who did much to lay the foundations for the discipline of ichthyology. For this reason, I will pass over much of the history of Günther's administrative career at the British Museum at Bloomsbury and the Natural History Museum at South Kensington. There is however, one further publication by Günther, that was accomplished during his term as Keeper at the British Museum, that merits significant interest to this narrative. That is the production of the textbook *An Introduction to the Study of Fishes*, published in 1880. An extensive review of the contents of this text will be provided in the next chapter. What is relevant to be stated here, is that this work did much to help define the development and organization of ichthyological information over the course of the nineteenth century. Günther's zoological predecessors did much to compose descriptions of fish that laid the basis of the knowledge contained in the book. But this groundwork was not

[295] Ibid, 311-326.
[296] Ibid, 344-360. A description of the planning of the new museum and the physical logistics of the transfer of the various natural history collections to the new building can be found in chapter 26.

organized in a way that was easily accessible. There are limitations of Günther's work, that his detractors were eager to point out.[297] But in terms of sheer organizational coherence that Günther offered in his textbook, I argue that he rightly should be seen as the founder of modern ichthyology.[298]

***Catalogue of the Fishes in the British Museum*, 8 vols. (1859-1870)**

Gray exercised limited control over the presentation of the catalogs written by his assistants by authoring the Prefaces. Since it was in the Preface where the objectives, philosophy, and methodology of the catalogs were stated, the content of this section presented a significant statement of the meaning behind the naturalist's work. However, Gray gave Günther's intentions voice by allowing him to make statements within the Preface that are presented in quotation. In the case of the Preface of the first catalog in the fish series, Gray only wrote a few sentences of introduction before providing Günther's own explanation of the catalog. What Günther revealed in this section is the extent to which he relied on the prior work of Cuvier through the work of the *Le Règne Animal* and the *Histoire Naturelle des Poissons*. Of the 1177 species described in this first volume, Günther attributed 777 to Cuvier and Valenciennes. Günther provided information regarding the minor collections contributed

[297] Ibid, 288-296. In the *Zoological Record*, Günther often had not been gentle in his criticism of the work of other ichthyologists, when their failed to meet the standards Günther thought were necessary for other ichthyologists to decipher what species were being described. So, when Günther published his textbook in 1880, a number of his fellow ichthyologists took the opportunity to write unfavorable reviews of Günther's book. According to Günther's grandson, the most vehement of these negative reviews was written by the American ichthyologist Theodore Gill in a book review found in an 1881 issue of *Forest and Stream*.
[298] And the next major Ichthyology textbook to be written in the English language by the American ichthyologist, David Starr Jordan in 1905, relied very heavily on Günther's work, including many direct quotes from Günther that extend for pages.

by individual collectors and organizations that the larger collection the museum had been built on. To this point, Günther followed a formula that had been previously laid out by the early catalogs published by Gray. But Günther provided a much more comprehensive explanation of the methods by which he described the fish in his catalog, indicating the greater degree of rigor applied in his taxonomic practice.[299]

A second innovation that could be seen in the opening material of Günther's fish catalog was an "Index of the Works Quoted in this Volume." This bibliography was organized in a roughly chronological fashion starting with the works of Aristotle. Unlike the work of Gray, this bibliography, which was 12 pages long, allowed a reader to understand clearly what prior taxonomic works Günther was drawing upon in the creation of his catalog. More than that, in itself, it presented something of the history of the development of ichthyological knowledge, helping to show how much the discipline had matured the middle of the nineteenth century, as well as giving some indication of the books contained within the library at the British Museum.[300] Following in the tradition of Gray's prior works, Günther next presented a "Systematic Index," the format of which is quite similar to Gray's lizard catalog.[301]

According to the title, the first volume of Günther's fish catalog was devoted to the Acanthopterygian fishes. Günther preserved some elements of the hierarchical structure of taxonomic description. This is demonstrated in the first pages of the body of the text which started with a description of the Subclass Teleostei. It proceeded then to a description of the

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[299] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 1 (London: Taylor and Francis, 1859), iii-iv. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36875#page/5/mode/1up .
[300] Günther, *Catalogue of Fishes*, vol. 1, vii-xviii.
[301] Ibid, xix-xxxi.

first order of the Teleostei, the Acanthoptergii, and then the first family Gasterosteidae. This first family was represented by only one genus—the *Gasterosteus*. Under the genus title, Günther provided abbreviated citations which included page numbers; this allowed taxonomists who had access to the appropriate reference material to easily look up Günther's references. Additional citations were provided at the species level as well. Another innovation included with the species descriptions was a series of measurements that provided the reader with knowledge of the relative dimensions of the fish. Günther's brief descriptions of known species were much in keeping with those found in Gray's lizard catalog, although Günther does seem to have gone to more effort to provide geographical information when available. When examples of the species were to be found within the British Museums collections, telegraphically brief descriptions of these are provided, along with locational information or an indication of which collection it originated from, when relevant. In the case of the first genus, 11 species were listed.[302]

On page 8 Günther proceeded to the next family, the Berycidae. Since this family consisted of more than one genus, in this case Günther also provided a synopsis of the nine genera contained within the family. Within the genus *Trachichtys*, Günther included a description of the species *Trachichtys elongatus*, indicating that this represented a description of a new species. Known species were described in brief while new species received extended descriptions. In the case of this specimen, Günther's description covered almost half of page 10, all of page 11, and ended in the first third of page 12. Another new species description can

[302] Ibid, 1-7.

be found on page 13 and it accounted for the better part of three pages of text. According to the description of both these new species, illustrations of these fish were meant to be included on plates. Unfortunately, however, the intention to include illustrations of new species was never fulfilled.[303]

The Acanthopterygii is a large group of spiny-rayed fishes. They are considered the most modern of the fish, and in current taxonomy comprise a superorder accounting for approximately 14,800 species.[304] Günther could not account for all the Acanthopterygii in one catalog and volume 2 of the *Catalogue of Fishes* was also dedicated to this group. This second volume, published in 1860, described another 1135 species. Since this volume was largely a continuation of the previous one, Gray and Günther provided an abbreviated Preface. However, Günther did take the time to appeal to naturalists regarding the benefits of collecting more fish to be added to those already found at the British Museum by stating "All these Collections contain so many interesting forms, either entirely new to science, or previously not represented in the British Museum, that I cannot forbear directing attention to the great service which may be done to science by collecting fishes, in whatever country or sea an opportunity may occur. If we look at the large accessions to ichthyology during the last fifteen years, we may well conclude that not one-tenth of the existing species are known."[305] In this

[303] Ibid, 8-15.
[304] Helfman, *Diversity of Fishes*, 291.
[305] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 2 (London: Taylor and Francis, 1860), iv. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36839#page/5/mode/1up .

second volume, instead of duplicating his entire bibliographical section from the previous one, Günther merely added a list of works referenced in addition to those of the previous volume.[306]

Volume 3 published in 1861 formed the conclusion of the material dedicated to the Acanthopterygii. In the Preface Günther indicated his reliance on Müller's definition of the Order. He admitted that some naturalists had criticized Müller's taxonomic conclusions but defended his choice of relying on Müller by making the following observation: "But, frequent as are the objections against Müller's modifications of Cuvier's system, no one has proposed any arrangement which would give a more satisfactory result, if put to the test of carrying it out to a detailed subdivision."[307] In this volume, Günther provided descriptions of another 1168 species of fish. In order to ensure the thoroughness and accuracy of the fish descriptions, Günther traveled to a number of continental museums to supplement the material observed at the British Museum.[308]

Günther presented two more Orders of fish in Volume 4, the Acanthopterygii pharyngognathi and the Anacanthini (1862). These Orders were based on Müller's system, but Günther expressed some reservation regarding whether one of these Orders actually constituted a natural group. He stated, "I fully share the opinion of those who do not consider the coalesced pharyngeal bones as a character of sufficient importance to unite acanthopterous and malacopterous fishes into one Order. Placing the structure of the fins above that of the pharyngeals, I have changed the name of Pharyngognathi acanthopteri into Acanthopterygii

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[306] Günther, *Catalogue of Fishes*, vol. 2, v-vii.
[307] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 3 (London: Taylor and Francis, 1861), iii. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36677#page/5/mode/1up .
[308] Günther, *Catalogue of Fishes*, vol. 3, iii-v.

pharyngognathi."[309] Regarding the Anacanthini, however, Günther expressed his confidence that this Order did indeed represent a natural group. The families that Günther included in the Order Acanthopterygii pharyngognathi are marine fish: Pomacentridae (damselfishes and clownfishes), Labridae (wrasses), Embiotocidae (surfperches), Gerridae (mojarras), Chromides.[310] All of these families now are included among the superorder Acanthopterygii, so Günther's reservations regarding whether or not the group was natural have been substantiated by subsequent taxonomists. The Ancanthini is still a recognized Order of ray-finned fish today, residing under the designation of Gadiformes, and includes cod and other allied families.

Volumes 5-7 and part of Volume 8 covered the Physostomi, an Order of fish that is no longer a recognized group. Günther defined the Physostomi as follows: "All the fin-rays are articulated; only the first of the dorsal and pectoral fins is sometimes more or less ossified. The ventral fins, if present, are abdominal, without spine. Air-bladder, if present, with a pneumatic duct."[311] Volume 5 started with the family of the Siluridae, now an Order in its own right, known by the name Suluriformes, or catfish. Also contained within this volume are "those families which, being provided with an adipose fin, were formerly associated with the Salmonoids."[312] The catfish represented a group of considerable size and complexity, and

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[309] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 4 (London: Taylor and Francis, 1862), iii. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36880#page/5/mode/1up .
[310] This does not seem to be a recognized taxonomic designation anymore but seems to map roughly back to the family Pomacentridae.
[311] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 5 (London: Taylor and Francis, 1864), 1. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36882#page/5/mode/1up .
[312] Günther, *Catalogue of Fishes*, vol. 3, iii.

Günther attributed the delayed publication of his Volume 5 to the necessity of revising his work when a new collection of catfish was acquired by the British Museum. He stated, "The publication of the present volume has been much delayed in consequence of a thorough re-examination of the large family of Siluroid fishes; the manuscript was finished, when the Trustees of the British Museum acquired the unique collection of Dr. Bleeker's Siluroids, thus rendering necessary a revision of the descriptions and of the systematic arrangement."[313]

Günther began Volume 6 with another challenging group, the Salmonidae, which included fish such as the salmon, trout, and char. In the Preface to this volume, the usually stoic author made a statement of vehement complaint regarding the difficulty associated with examining this group:

> The Salmonidae and the vast literature on this family offer so many and so great difficulties to the Ichthyologist, that as much patience and time are required for the investigation of a single species as in other fishes for that of a whole family. The ordinary method followed by naturalists in distinguishing and determining species, is here utterly inadequate; and I do not hesitate to assert that no one, however experienced in the study of other families of fishes, will be able to find his way through this labyrinth of variations without long preliminary study, and without a good collection for constant comparison. Sometimes forms are met with so peculiarly and so constantly characterized, that no ichthyologist who has seen them will deny them specific rank; but in numerous other cases one is much tempted to ask whether we have not to deal with a family which, being one of the most recent creation*, is composed of forms not yet specifically differentiated.[314]

Günther covered 10 more families in Volume 7 which appeared in 1867. Among these groups he emphasized the importance of the Cyprinoid (a designation that includes carps,

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[313] Ibid.

[314] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 6 (London: Taylor and Francis, 1866), iii. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36853#page/5/mode/1up .

suckers, and loaches) and Clupeoid (which includes herrings, shads, and sardines) fishes.[315] In 1870 Günther finally completed the *Catalogue of the Fishes in the British Museum* with Volume 8. He spent the first 148 pages of this work finishing up the Physostomi before he introduced the seven remaining Orders recognized at the time: the Lophobranchii, Plectognathi, Dipnoi, Ganoidei, Chondropterygii, Cyclostomata, and Leptocardii. In the final volume, Günther presented a more extended Preface in order to discuss some of the issues associated with the state of knowledge of ichthyology in his day. He discussed the difficulty of determining the number of species that existed, since there was a range of opinion among ichthyologists regarding how much variation justified the determination of a new species. He indicated, "Again, the views of ichthyologists on species diverge so much that one will give a number several times as great as another*. I consider a species to be well established only when it is founded on characters which, from an examination of numerous examples, are found to be permanent, not subject to gradual variation, and not dependent on season, sex, or age — or which are known to be so from the examination of allied forms."[316]

Midway through the Preface, Günther pointed out the importance of fish to understanding the history of life.

> No other class of the vertebrates is of equal importance to the geologist and palaeontologist, the materials for comparing the living with past creations being so numerous and diversified that we cannot help thinking that the question of the relations of the various epochs to one another will be solved in the field of ichthyology. Although fishes are mostly hidden by the element in which they live, so that the knife of the

[315] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 7 (London: Taylor and Francis, 1868), iii. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36727#page/5/mode/1up .
[316] Albert Günther, *Catalogue of the Fishes in the British Museum*, vol. 8 (London: Taylor and Francis, 1870), vi. Biodiversity Heritage Library, Date Scanned: 10/24/2008, https://www.biodiversitylibrary.org/item/36874#page/5/mode/1up .

> anatomist generally first reveals new facts connected with their life, we have sufficient evidence to show that the phenomena of life are more varied in their different groups than in any of the higher Vertebrata, and that their study will form a solid basis for the solution of those general biological questions which, perhaps rather prematurely, agitate the minds of many zoologists.[317]

Günther thus made a provocative claim regarding the importance of fish in solving unresolved debates that were currently agitating discussion among both geologists and biologists during the latter part of the nineteenth century.

Legacy: The Naturalist's Dilemma

In the closing paragraph of the Preface, Günther gave thought to the legacy of his work. He informed his audience, "I am well aware of the many imperfections of this work; many have been already corrected by others; but if it should form the basis for the future development of a collection at present unrivalled — if it should assist my fellow labourers and enlist others — if it should contribute to the advancement of truth, I shall not repent having devoted the best years of my life to its execution."[318] Regarding the issue of imperfections to be found in the work that naturalists perform, there is a certain plaintive quality in this closing remark by Günther. It reflects a much larger issue, that of the uncertainty involved in the study of biodiversity, both relating to the scope of the project of cataloging nature, and to the degree of difficulty involved when one considers variations within a species, and changes that occur through the process of an organism]s maturation. Throughout the process of cataloging fish,

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[317] Günther, *Catalogue of Fishes*, vol. 8, ix-x.
[318] Ibic, xi-xii.

Günther always factored in the number of species descriptions, based on the work of prior authors, that he considered to be doubtful. As one example from the first catalog, of the 1177 species described, Günther indicated that only 917 were well characterized. This meant that he considered 260 of the fish covered in the catalog to be inadequately described, preventing other naturalists of being able to make valid species identifications based on the entries.

Günther's bibliography, which he built through each subsequent volume of the fish catalog, revealed the work of describing species as a multi-generational and spatially-distributed project. When a project is this large, that expertise must be distributed across a community. No matter how adept the individual naturalist, their work is always limited by access to both scholarly sources, and the quality of the collections at the naturalist's immediate disposal, or within the range of more casual access. What becomes clear from Günther's accomplishments, is that the work of a taxonomist involved a constant process of building on and amending the work of one's predecessors. From the manner in which Günther discussed Cuvier's and Müller's contributions to the field of ichthyology, it is clear that he respected them and that he relied heavily on their systematic work. When he judged that their work fell short of his understanding of how fish should be arranged into natural groups, however, he did not hesitate to make corrections as he saw fit.

In the nineteenth century, taxonomy was still on the front lines of the practice of natural history. The scientific community was still deeply embroiled in controversy associated with the appropriate practice of identifying species. In the case of ichthyology, before Günther started his project the number of known species described by Cuvier and Valenciennes only represented approximately 15-18% of current estimates of extant fish species. With the completion of Günther's project, he had singlehandedly increased that number to somewhere between 25-35%. Because of the sheer scope of the challenge of attempting to identify and organize all of life, the development of the practice of taxonomy required much experimentation and much failure. It is perhaps unfair to judge the accomplishment of past naturalists solely on the stability of their species identifications and systems of organization for organismal relationships. The naturalist's legacy is a difficult one, in which the advancement of knowledge goes hand in hand with the advancement of work that future generations will find in error. But not all this error is straightforward, since some of it is based on changing practices, and some on the amendments that systems require when previously unknown species are added to the matrix of perceived affinities. Günther, in approaching the project of fish identification with a focus on procedural and scholarly rigor, did lay a foundation for future work by assembling the information known in his own day in a way that allowed fellow taxonomists to more rapidly assimilate knowledge of the field. Future taxonomists may not have agreed with all of his conclusions, and may have readily amended his identifications, but they are nonetheless indebted to his organizational efforts.

In his concluding volume, Günther told his readers directly of the necessary scope that was required in order to produce the catalog. He stated, "At the respective dates of the preparation of the eight volumes of the present work 4219 species were available for autoptical examination. To these were afterwards added 958 species which were received too late for insertion; so that the Collection of the British Museum contains at the present time altogether

5177 species, represented by 29,275 examples*."[319] While Günther claimed that the ichthyology collection at the British Museum was first ranked, he also pointed to its limitations in containing only two-thirds of species known at the time. Not only was there much unknown material yet to be collected, sometimes the quality or quantity of those specimens that the museum did have in their possession were inadequate for providing the best possible species description. Knowledge of ichthyology, in the simple terms of collecting and identifying species, still had a long way to go to reach completion.

Günther made another comment that should be noted, as it has some bearing on what may have motivated him to publish an ichthyology textbook. He informed his readers, " An interest in Ichthyology is generally diffused in England; but its study is much neglected. Nor could it be otherwise. Where is it taught? . . . In England I have met with many struggling hard to obtain ichthyological knowledge, with not one who was assisted in it by a teacher."[320] Günther's completion of the fish catalog coincided very closely with the period of Gray's final illness, that led Günther to take on increasing administrative responsibilities. As a result, the rate of Günther's scientific publication slowed down considerably over the course of the 1870s. But a decade after finishing his catalog, Günther saw to the publication of an ichthyology textbook. This textbook contains the culmination of his thought, based on his own education in the sciences and the experience he obtained through the production of his fish catalogs. Along with his fish catalogs, this textbook served as foundational works for Günther's legacy as an ichthyologist.

[319] Ibid, vi-vii.
[320] Ibid, x.

Chapter 4

The “First” Ichthyology Textbook: An Historical Perspective

Early Ichthyology Texts

An Introduction to the Study of Fishes can be considered the first English language Ichthyology textbook produced by a professional ichthyologist. Considering the larger scope of the history of Ichthyology, there are a number of books that may be considered as prototypical textbooks. Since the early modern period, with the works of such naturalists as Belon, Rondelet, and Salviani, all of who flourished around the middle of the sixteenth century, ichthyology can be recognized as emerging from the broader field of zoology as a distinct sub-discipline. The works of such early modern ichthyologists as these, however, took the form of descriptive treatises rather than being structured like modern zoology textbooks, since they provided species descriptions but did not include the didactic features found in later textbooks.[321] In the estimate of both Cuvier and Günther, by the end of the seventeenth century, through the posthumous work of Francis Willughby, John Ray’s text *Historia piscium* can be seen as placing ichthyology on a more philosophical footing. However, this work’s contribution rested largely on improving the rational basis on which fish classification was constructed by incorporating fish classification into a system that subsequent naturalists acknowledged represented a natural system.[322] As a result, this text can best be identified as

[321] These early modern works of natural history could be seen as precursors to museum catalogs such as those produced by Cuvier and Günther. Didactic features in early zoology textbooks would include items such as general descriptions of organ systems or schematic explanations of the skeletal system.
[322] Cuvier, *Historical Portrait of the Progress of Ichthyology*, 73-79. Cuvier provides an account of Willughby’s work that serves as the basis for Günther’s briefer account. See Günther, *Study of Fishes*, 8-9.

belonging to the genre of descriptive treatise or being part of the encyclopedic tradition rather than being seen as a textbook.

The posthumous work of Peter Artedi, published by his former friend and fellow student at the university in Uppsala, Carl Linnaeus, might best be identified as a kind of proto-textbook. The book offered a number of stylistic innovations, primarily in the structure of the text, that began to organize zoological information in a manner that ichthyologists of the eighteenth and nineteenth centuries found useful to build upon through the innovation of new organizational features within the text. The text was divided into five sections: 1. "Bibilotheca Ichthyolgica" provided an account of the work of prior authors who contributed to the field of ichthyology; 2. "Philosophia Ichthylogica" contained descriptions of the external features of fish and provided criteria by which differences within genera, species, and varieties were to be determined; 3. "Genera Piscium" provided the description of forty-five genera of fish; 4. "Species Piscium" included descriptions of seventy-two species that Artedi personally examined; and 5. "Synonymia Piscium" worked through the history of species identification as a means of clarifying issues of synonymy. It should be noted that Linnaeus himself was so impressed by the organization of Artedi's work that he adopted the format for texts of his own that were published prior to the "Ichthyologia".[323]

Considering how much Cuvier contributed to the advancement of comparative anatomy and paleontology, as well as to his specialization in ichthyology, one might expect that Cuvier's

[323] A largely factual account of the relationship between Peter Artedi and Carl Linnaeus can be found in the work of historical fiction by the ichthyologist and evolutionary biologist, Theodore Pietsch. Pietsch includes in this work a description of Artedi's text, and the significance he believes it played in helping form Linnaeus own work on a more firm scholarly footing. See Theodore Pietsch, *The Curious Death of Peter Artedi* (Scott & Nix: New York, 2010).

work would have provided an important precedent for the establishment of a textbook. Indeed, Cuvier was a source of considerable inspiration for Günther's work, the style of his series *Histoire naturelle des poissons* had a clear influence on Günther's own ichthyology catalogs. But Cuvier never did produce anything resembling an ichthyology textbook. The closest Cuvier got to providing such a text would be the first volume of *Histoire naturelle des poissons*, which, as previously discussed, did include an extended history of ichthyology, and also used the first fish description as a model on which subsequent fish descriptions were built. Thus, aspects of Cuvier's influence can certainly be recognized in Günther's writing he did little to provide a working model that Günther would find suitable when he built his own textbook.

Another prolific zoologist who one might have expected to provide a model for an ichthyology textbook is Louis Agassiz. But again, while Agassiz was responsible for mentoring many of the leading United States ichthyologists of the late nineteenth and early twentieth centuries, he never memorialized that leadership in textual form. While his writings in fossil ichthyology provided the primary basis for the understanding of fish paleontology available to nineteenth century readers, there is no comparable text summarizing the range of knowledge for extant fish species.

In the "Preface" of Günther's textbook, he indicated that the work on which he modeled *An Introduction to the Study of Fishes* was an article entitled "Ichthyology" written by Sir John Richardson, that was first published in the eighth edition of the *Encyclopedia Britannica* published in 1856.[324] A close reading of this article shows that it is primarily the structure of this text rather than the content of Richardson's work that Günther borrowed. Richardson,

[324] Günther, *Study of Fishes*, v.

who was trained as a physician in England, spent part of his career in the employ of the British Navy, and as such was afforded the opportunity to cultivate his interests in natural history and Arctic exploration.[325] He was also a friend of John Gray, Keeper of Zoology at the British Museum between 1840-1875. It was probably in this capacity that he came to the acquaintance of Günther.

Richardson's work, both served as a model for Günther but also it further served as counterpoint to the differences between the practice of natural history in Great Britain in contrast to that on the Continent. As Günther was extensively educated in the German-speaking states, an education that culminated in the procurement of a medical degree as well as a Masters' degree and Ph.D. in Natural history, he received a more rigorous scientific and medical training that his contemporaries who had been educated in Great Britain. Even though Günther emigrated to England in 1857 at the age of 27 and spent the remainder of his career as a resident of England until his death in 1914, his work in some ways contrasted with that of his British colleagues. For Günther, one aspect of this difference can be seen in his preference for greater empirical caution in the formation of scientific hypothesis.[326] He tended to approach scientific ideas with more empirical caution than his British contemporaries.[327] Another cultural difference between the work of Richardson and that of Günther can be seen in Richardson's

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[325] An account of Sir John Richardson's career can be found in the following book: Robert Johnson, *Sir John Richardson: Artic Explorer, Natural Historian, Naval Surgeon* (London: Taylor & Francis, 1976).

[326] Günther's greater reluctance to scientific speculation is consistent to educational differences between Great Britain and the German speaking states for his generation. For a useful summary of trends in life science education in the German speaking states see, Lynn Nyhart, *Biology Takes Form: Animal Morphology and the German Universities, 1800-1900* (Chicago: The University of Chicago Press, 1995).

[327] Günther's grandson discusses possible motives for Günther's more conservative approach to scientific ideas in Gunther, *Century of Zoology*, 462-463. Günther's attitudes were also consistent with the generation of scientists educated at German speaking universities as discussed in Nyhart, *Biology Takes Form*, 65-102.

embrace of natural theology in describing the functioning processes of natural history.[328] For example, frequent allusions to the Creator's role in the functioning of nature can be found in Richardson's "Ichthyology" article. In contrast Günther's work is largely devoid of any language that can be interpreted in theistic terms, and a reader unfamiliar with his biography would have no reason to suspect he had been trained to enter the Lutheran ministry.

The difference between Richardson's approach to natural theology from that of Günther is consistent with cultural differences between England and Germany in the nineteenth century and should not be seen as an indication that Günther was less sincere in his faith than Richardson. According to the historian of science and religion, John Hedley Brooke natural theology proved to be quite resilient in the culture of nineteenth century England. Even Darwin found it difficult to divest himself of aspects of thinking he derived from natural theology. In contrast, in Germany natural theology had received significant critique by then end of the eighteenth century in the philosophical writings of Immanuel Kant (1724-1804). Kant's concepts regarding reason and proof made him critical of the idea that people should look to nature for proof of God's existence, and instead suggested that belief in God should rest on moral faith. In his critical writing Kant began the process of loosening the threads that bound science and religion together.[329] Therefore Günther's educational background and professional status as a museum worker would have predisposed him to consider that his scientific writings

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[328] In the nineteenth century, scholars and theologians from the German speaking states showed an intellectual preference for maintain a greater distance between religious ideas and those from the natural sciences. Frederick Gregory, *Nature Lost? Natural Science and the German Theological Traditions of the Nineteenth Century* (Cambridge, MA: Harvard University Press, 1992).

[329] A comparison between the fortunes of natural theology in England and Germany can be found in chapter six of the book, John Hedley Brooke, *Science and Religion: Some Historical Perspectives* (New York: Cambridge University Press, 1991), 192-225.

should reflect his scientific understanding not his religious commitments. The relationship between scientific and religious interpretations of the natural world is extremely complex, and when examining a person's scientific beliefs, a reader should be cautious in making inferences regarding how a person's scientific understanding of nature reflects on matters of faith.

"Ichthyology" by Sir John Richardson 1856

Richardson's *Encyclopedia Britannica* article entitled "Ichthyology" spanned pages 204-331 of the 12th volume of the eighth edition of the reference text. The first section of the introductory chapter of the article defined the term fish in the following words: "Fish may be technically defined as vertebrate animals with red blood, breathing through a medium of water by means of branchial or gills."[330] Richardson attributed his definition to Baron Cuvier, in a way that demonstrated his allegiance to Cuvier's empiricism and commitment to his understanding of natural law and formal interpretation of organisms. The section provides an ecological description of the aquatic realm where Richardson included an additional "great class" to Cuvier's four *enbranchements*: the Zoophytes, which he identified with the invertebrates. As an explorer and naturalist, Richardson would have had more opportunity to handle specimens that were newly collected. This is reflected in his exuberant comment claiming that fish were the most worthy subject of study within the aquatic realm, "Nor are any more worthy of our careful consideration, whether we regard the beauty of eccentricity of their forms, the metallic

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[330] Sir John Richardson, "Ichthyoloy," *Encyclopedia Britannica, 8th Edition, Vol. 12* (Edinburgh: Adam and Charles Black, 1856), 204.

splendour of their colors, or the innumerable benefits which, through the foresight of Providence, they confer upon the human race."[331]

Richardson indicated that he had intentionally avoided providing "any biological inquiry, or historical exposition of the progress of Ichthyology" since it would require too much space and since Cuvier had already satisfactorily provided this material in the first volume of the *Histoire Naturrelle de Poissons*. Richardson did, however, take the time to acknowledge the debt that ichthyology owed to Aristotle for the body of doctrine on which the knowledge of ichthyology was built, despite the fact that Aristotle did not recognize the standards by which the distinction of species were properly defined. He then jumped to the contributions of Beleon, Rondelet, and Salviani, identifying them as the true founders of modern ichthyology. His litany of essential contributors rounds itself off with praise for Willughby and Ray, Artedi and Linnaeus and finally rested on Cuvier himself.[332]

Richardson, who viewed of the living world as a product of creation, organized vertebrates in a descending hierarchy of animal classes starting with Mammals, Birds, Reptiles, and Fishes. He provided further subdivisions of the Reptile class into the orders Serpent, an unnamed group whose description seems to indicate he had the order Testudines in mind, Amphibians, and a fourth unnamed group which seems to be describing lung fish. In his discussion of fish, Richardson identified the Lancelet as the lowest known form, since its vertebral column is so unsophisticated. He pointed out a further unusual species, the

[331] Richardson, "Ichthyology," 204.
[332] Ibid, 204-205.

Cheironectes caudimaculatus from the family Lophiidae, because they belonged "to a group of fish which actually walk at times on their four limbs."[333]

The second section of the first chapter focuses on "The External Form and Character of Fishes." Richardson took some effort to clarify what he meant by defining a difference between higher and lower forms among the fishes. He stated, "We do not imply that there is any deficiency in the structure of fishes which constitute the fundamental group, for every creature was perfectly organized when called into existence by the fiat of the Creator for the functions he destined it to perform; but He, having designed the fishes to play a part in the scale of nature requiring less intelligence, has furnished them with a simpler nervous system and less sentient organs, a more obtuse sense of touch, restricted organs of smell and taste, and an acoustic apparatus up within the head, without any exterior ear or auditory canal for collecting and conveying the vibrations by which sound is produced and transmitted."[334] As the section unfolded Richardson further revealed that,

> Palaeontologists have ascertained, moreover, that fishes were the first of the vertebrals which appeared on the theatre of the earth's history, and at an epoch long antecedent to the deposits in which the remains of the higher animals were found. The primitive fish, however, were not types of the lower forms of the class, but, resembled saurian reptiles in parts of their structure, so that they were at least on par with the more highly organized fishes of the present day. We have not learned that the remains of fish having the embryonic vermiform shape, have been discovered in the oldest ichthygenous deposits.[335]

He, nonetheless indicated that for living species of fish, "Indeed, the vermiform type exhibited by embryos of vertebrals in their earliest stage, is persistent in many fishes, which by the

[333] Ibid, 206.
[334] Ibid.
[335] Ibid, 207.

assemblage of the other points of their structure enter totally different groups."[336] Richardson closed the section with some considerations regarding the relationship between animal form and locomotion.

The work proceeded to a third section on osteology, covered in pages 207-218. Richardson cited Richard Owen's work *Lectures on the Comparative Anatomy and Physiology of the Vertebrate Animals* as an invaluable resource for students studying ichthyology. From Agassiz's work he drew a comparison between extant and fossil species by indicating the neural and haemal arches of *Lepidosiren* showed similarity to fossil fish from Silurian and Devonian deposits. Richardson also borrowed Agassiz's terminology for describing the distinction between heterocercal and homocercal tails. Toward the end of section three, Richardson devoted over two pages to the description and illustration of fish scales. He indicated, "Professor Agassiz considered the form of the scales to bear so strong a relation to the rest of the ichthyic structure and the general economy of fish, that he founded upon it his primary divisions of the class, of which he characterized four."[337] These four types of scales were identified as: Cycloid, Ctenoid, Ganoid, and Placoid.

Section IV, which was only two brief paragraphs, covered the subject of the muscular motion of fishes. This section indicated that the motion of fish is facilitated by the spinal column, which allowed side to side motion. The tail was also identified as an organ of movement, and Richardson further indicated that the swim bladder aided in buoyancy.

[336] Ibid.
[337] Ibid, 216.

Section V focused on the nervous system and senses of fishes. Richardson identified the Lancelet as an example of a fish with the simplest nervous system. He indicated that brain sizes vary and that they were lacking in the lowest examples of the class of fish. After the brain, Richardson moved on to the organs of vision and hearing, smell, taste and touch. Richardson hypothesized that the senses of smell, taste and touch are not particularly accurate in fishes. He made a comparison between fish and birds in which he presumed that the sensory systems of birds were much more acute than those of fishes. Richardson compared the cold sexual behavior of fish to the warm sexual behavior of birds; here Richardson appeared to be influenced by humoral thinking, with fish, which inhabit the cold, wet domain of water being assigned phlegmatic characteristics.[338] Richardson stated of fish, "Their sexual emotions cold as their blood, indicate only individual wants. Few species pair, or enjoy connubial gratification, for the male seeks the eggs rather than the females which deposit them, and neither sex recognizes its offspring."[339] Birds, which inhabit the warm, wet domain of the air are sanguine. Of birds Richardson indicated, "They enjoy all of the delights of conjugal and parental affection, and perform their incumbent duties with devotedness and courage; they cherish and defend their offspring, and will sometimes die in their defense; . . . with what deep and continuous affection does the female brood over her cherished treasures!)" Richardson's final depiction of fish in this section is of "the silent dweller of the deep" that "knows few attachments." But there is nonetheless an ecstatic quality to the writing in keeping with the tradition of natural

[338] Ibid, 221.
[339] Ibid.

theology that emphasized the wonder and beauty of nature: “Assuredly, however, the hand of nature has been prodigal in bestowing on their external aspect every variety of adornment.”[340]

Section VI, on “Nutrition” began with a description of fish behavior as it was related to eating and the nutritive process. Richardson informed his audience that “Fish in general are extremely voracious and the rule of ‘eat or be eaten’ applies to them with usual force.”[341] He further indicated that fish morphology dictated the type of prey they are best suited to eat. Richardson emphasized the greed of fish and their lack of discrimination regarding what they are willing to consume. He stated, “They attack and devour crabs and shell-fish, gulping them entire if they cannot otherwise attain their object; they do not object occasionally to swallow the young even of their own species, and the more powerful kinds carry their warfare into other kingdoms of nature, and revel on rats, reptiles, and young ducklings, to say nothing of the ferocious shark, which seldom makes a meal even of the lord of creation.”[342] Richardson discussed the relationship between growth and eating habits. He provided a description indicating the great variety of forms fish teeth come in. Again, there is an association to be drawn between the shape of teeth and the fish’s feeding behavior. It was primarily toward the end of this section that Richardson focused of the structure of the mouth, jaws, and pharynx of the fish.

Sections VII - IX respectively covered the topics of circulation, respiration and the air-bladder of fishes. The commentary on these sections was more strictly anatomical in focus than the proceeding sections. Richardson pointed to the air-bladder as being one of the most

[340] Ibid.
[341] Ibid, 222.
[342] Ibid.

remarkable anatomical features of fish. Richardson indicated that a variety of natural scientists including Owen, Biot, Davy and Humboldt had done work to determine the gaseous contents of air bladders. After giving some more consideration to the structure and function of the air-bladder, Richardson closed section IX and the introduction to his essay.[343]

The largest portion of Richardson's encyclopedia entry is on the "Classification of Fishes." The section spanned pages 226-329, equaling 104 of the 127 pages. Richardson's work on classification is not original, and does not represent a significant influence on the course of mainstream ichthyology, so I do not provide an extended narrative of how Richardson classified fish. For the purposes of this dissertation, I will focus on the introductory sections and concluding remarks from Richardson's essay, where his thinking on in the natural arrangement of fish, which he defined under the terminology of affinities, is most evident. According to Richardson's work these affinities branched off in several directions. He indicated that the nervous system "would be one important basis for classification, but its various modifications of structure in fishes are still too imperfectly know."[344] He went on to make the same complaint for nutrition, respiration, circulation, secretion, generation, and development. Richardson mentioned that Agassiz had been working on embryonic development in order to put together a classification system founded on that basis, but that, at the time of his article, Agassiz had not yet published that system. Richardson stated, "All attempts at classification of fishes which have hitherto been given to the world, violate more or less anatomical affinities; the best on the whole that have been proposed, is that of Professor Johannes Müller, which we shall

[343] Ibid, 221-224.
[344] Ibid, 226.

follow, adopting the modification of Professor Owen."[345] Richardson used the second half of his introductory remarks to attribute advances in the field of fish systematics to Cuvier, Müller, and Owen.

In the closing remarks to "Classification of Fishes" Richardson commented on his sources. He indicated that the bulk of his material is drawn from a series of lectures presented by Richard Owen in 1844 and continued in 1846, at the time when Owen was serving as curator of the Museum of the College of Surgeons of London. He also mentioned *Histoire de Poissons*, the 22-volume work by Cuvier and Valenciennes, indicating that it served as a textbook for the chapters of osseous families and genera. He made reference to a textbook by Müller that he would have liked to have used. However, Richardson indicated that he was unable to find the book in the public libraries, so he was unable to consult it. Richardson stated that there were issues with synonymous species that he had been unable to address, and that without these corrections it is difficult to do good work on the geographical distribution of species.[346]

The closing portion of Richardson's essay focused on the geographical distribution of species. It was of modest length, only spanning two pages. Richardson identified geographical distribution as a topic of great potential but indicated that the state of knowledge prohibited much hope for success in realizing that potential during his lifetime. In Ichthyology, Richardson felt that the poor development of knowledge regarding systematics as well as fish habits and migratory behavior prevented naturalists from deducing general laws regarding their distribution. Richardson did acknowledge one environmental factor that influenced the

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[345] Ibid.
[346] Ibid, 328.

distribution of aquatic organisms was water temperature. The remainder of the opening paragraph, which spanned more than half a page, discussed animal migration in general without specifically focusing on fish. In the next couple of paragraphs, Richardson discussed fish movements, indicating that some fish can travel fast speeds and great distances.[347] He also discussed the temperature tolerances of fish, indicated that according to Davy fish eggs of some species are cooked if they are maintained at a temperature of 80 degrees F. This interested Richardson due to the fact that there are fish species with the capacity to survive in extreme environments such as *Ambassis thermalis*, which inhabits the hot springs of Cannea, and which can live in water that is 115.25 degrees F. Ultimately, his views of the temperature tolerances of fishes led Richardson to believe that may fish species were created for certain types of habitat. He stated, "Fish constituted to brave such heats would speedily perish, there is every reason to believed, in colder regions; and a review of the whole class leads irresistibly to the conclusion that many species have been created solely to meet the conditions of existence which certain limited localities afford, such as *Amblyopsis* of Mammoth Cave of Kentucky, and the siluroids of the mud volcanoes of the Andes."[348] Richardson briefly speculated regarding the creation of fish species and points to multiple, discrete creation events to explain the appearance of new species of fish after large scale extinction events. He states, "And moreover, the new species were created with the change in condition of the ocean and its

[347] Ibid, 329-330.
[348] Ibid, 330.

boundaries lead to the extinction of the older races, and rendered such an exercise of creative power necessary."[349]

It is unclear how sophisticated a taxonomist Richardson was, since he borrowed so heavily from the practice of his predecessors. What he did have, however, was a vision of how ichthyological information should be arranged. Günther recognized and acknowledged this vision, even if he did not emulate Richardson's narrative or taxonomy. Richardson anticipated biogeographic knowledge and the need for a bibliography of zoology. Günther was able to fulfill in his work.

An Introduction to the Study of Fishes

Preface (v-vi)

In the "Preface" to *An Introduction to the Study of Fishes*,[350] Günther states that the book was intended to "form an account of the principal facts relating to the structure, classification, and life-history of Fishes."[351] Günther viewed his target audience to be composed of zoologists and travelers. As the Keeper of Zoology at the British Museum, which by 1880 contained the largest zoological collection in the world, Günther had a vested interest

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[349] Ibid, 330. Regarding his view of creation Richardson seems to be in general agreement with Agassiz's views, which I will discuss at more length in the next chapter.
[350] A search of World Cat for Günther's textbook indicates 314 libraries own copies of 34 editions of the book. See https://www.worldcat.org/title/introduction-to-the-study-of-fishes/oclc/1579385 , Accessed 11/26/19. The initial English language edition of the book was published in 1880 by A. and C. Black in Edinburgh. Six years later Gunther also produced a German language edition of the book. See Albert Günther, *Handbuch der Ichthyologie* (Wien: C. Gerold's Sohn, 1886). I can find no evidence that any additional English language editions of the book were published before 1963 when it was republished in New York by Hafner Pub. Co. In the last couple of decades with the increasing availability of print-on-demand publishing of books that are out of copy right, facsimiles of the book have been repeatedly produced and no doubt account for most of the 34 editions of the book that World Cat refers to. I have been able to locate three reviews of the book produced within the first year of the works initial publication.
[351] Günther, *Study of Fishes*, v.

in having zoologically informed travelers who could efficiently collect animal specimens to augment the museum's collections. Günther's own catalog of fish, published in eight volumes between 1859-1870, provided descriptions of 8525 species of fish, accounting for somewhere between one third and one fourth of 21st century estimates of fish biodiversity. During his time as the British Museum's primary ichthyologist and herpetologist, Günther had made considerable efforts to encourage and aid travelers who were willing to donate their collections to the museum. As groups of organisms and regions under study became better sampled, each new expedition ran a greater risk of primarily duplicating previous efforts. At this point, zoologists were past long past the time when travelers routinely encountered virgin territory[352] and any effort would be valuable to the cabinet naturalist. As more and more species are collected and identified, the level of expertise required in the field to provide new specimens increases. A zoology textbook such as that produced by Günther for ichthyology represented an invaluable tool for the traveling naturalist who wished to make a useful contribution to the advancement of zoology. If this can be interpreted as one of the primary functions of Günther's ichthyology textbook, then he achieved his goal with at least one traveling amateur naturalist. The writings of Mary Henrietta Kingsley revealed how much she relied on and valued Günther's book, which she took on her travels to Africa.[353] During the time she spent in Africa, Kingsley collected reptiles and fish and studied African customs. She wrote of her travels in the book

[352] In the context of collecting the question of virgin territory needs to be considered on different spatial scales. Due to the fact that some endemic species can have very small territorial ranges, on the small scale, it may still be possible to encounter largely unexplored regions in some parts of the world even today. While it is true that by the nineteenth century much of the world had been explored on the broad scale, there were still many microhabitats that had not been sampled.

[353] Mary Kingsley, *Travels in West Africa, Congo, Français, Corisco and Cameroons* (Lexington: Forgotten Books, 2012), 7. In the Introduction of her book, Mary Kingsley acknowledged her gratitude to Albert Günther for the help he gave her with the natural history collection she formed during her African travels.

Travels in West Africa, Congo, Français, Corisco and Cameroons and Günther provided a scientific appendix for the book in which he described the reptiles and fish she had collected.[354]

As previously stated, Günther attributed the plan of his textbook to the article on "Ichthyology" written by Richardson. Günther, however, pointed to a unique contribution he added to the structure of the work that can be found on the chapters on the subject of the geographical distribution of fishes. This he claimed as material that no prior naturalist had ever handled in a comprehensive manner, indicating that he had based his conclusions on the work he had done in composing the "Catalog of Fishes." In the conclusion of his "Preface" Günther provided attributions of prior authors and organizations from whose works he had based the illustrations of his book.[355]

Introductory Remarks (1)

This half page of text in the introduction is noteworthy as it was in this location that Günther provided his definition of Fishes. Here I will only quote the first sentence of the definition, but even this covers nearly half the contents of this passage: "According to the views generally adopted at present, all those Vertebrate animals are referred to the Class of Fishes, which living in water, breath air dissolved in water by means of gills or branchial; whose heart consists of a single ventricle and single atrium; whose limbs, if present are modified into fins, supplemented by unpaired median fins; and whose skin is either naked, or covered with scales

[354] Albert Günther, "Appendix III: Dr. A. Gunther on Reptiles and Fishes," In *Travels in West Africa, Congo, Français, Corisco and Cameroons by Mary Kingsley (Lexington: Forgotten Books*, 2012), 692-717.
[355] Ibid, v-vi.

or osseous plates or bucklers."[356] Günther also provided the observation that the majority of fish were oviparous. He indicated that there is little to distinguish Fishes from Batrachians, that is tailless amphibians. Günther ended this section by providing a definition of Ichthyology as the branch of Zoology that comprised the study of fish.

Chapter 1: History and Literature (2-34)

It is in this first chapter of Günther's work that a reader can most clearly discern the influence of Cuvier on Günther's organization of his textbook. Richardson did not think it worthwhile to reproduce an extended history of ichthyology. However, while Günther's history should be viewed as a schematic overview of Cuvier's own more extended history, he did devote the first 25 pages of this chapter to summarizing and extending Cuvier's account of the history of ichthyology. As a result of its brevity, Günther's account covered only the most distinguished ichthyologists who appear in Cuvier's narrative. Günther's version therefore focused on innovations in classification, and in keeping with this theme, he provided tables of the classification systems of distinguished naturalists such as Linnaeus, Cuvier, and his own teacher, Müller. In pages 17-26, Günther extended the historical narrative beyond that provided by Cuvier. Appropriately, the first entry was on Cuvier himself.

Günther paid considerable tribute to Cuvier's achievement in the works the *Le Règne Animal* and Cuvier's joint work with Valenciennes in *Histoire naturelles des Poissons*. Günther does, however, point out two perceived failings in Cuvier's work. The first deficiency is that as the Cuvier's ichthyology catalog progressed, his descriptions became more nominal, a charge

[356] Ibid, 1.

he also attributed to Valenciennes. A second issue that Günther took with Cuvier's work was a failure to recognize that as fishes develop, they can take on substantially different characteristics. Günther stated, "What is more surprising is, that a man of his anatomical and physiological knowledge should have overlooked the fact that secondary characters are developed in fishes as in any other class of animals, and that fishes undergo great changes during growth; and, consequently, that he described almost all such sexual forms and different stages of growth under distinct specific and even generic names."[357] Next Günther provided a table of Cuvier's system of classification, and in his narrative praised it as offering a considerable advancement on Linnaeus' system. As part of that improvement Günther informed his readers that, "The various characters employed for classification have been examined throughout the whole class, and their relative importance has been duly weighed and understood."[358] Günther also recognized that Cuvier advanced knowledge of fish paleontology, although he stated that Cuvier failed to recognize that a resemblance between fossil and living fish might have merited a closer affiliation within Cuvier's classification system.

Another ichthyologist included in Günther's updated history was Louis Agassiz. The primary innovation Günther pointed to in the work of Agassiz regarded the structure of scales. Agassiz divided his classification into four major groups based on what he perceived as differences in the conformation of their scales which he identified as Placoids, Ganoids, Ctenoids, and Cycloids. However, in Günther's final assessment, this classification failed due to the recognition of later ichthyologists that it represented an artificial system. Günther stated

[357] Ibid, 18-19.
[358] Ibid, 19-20.

his judgement of Agassiz's system in the following terms, "therefore his system could never supersede that of his predecessors, and finally shared the fate of every classification based on the modifications of one organ only."[359] Günther's assessment of Agassiz's contribution to fish paleontology was considerably more charitable. Günther praised Agassiz's work *Recherches sur les Poissons fossiles* with the comment, "In his principal work, . . . he placed them before the world arranged in a methodical manner, with excellent descriptions and illustrations."[360]

Günther devoted to a review of the work of his own teacher, Johannes Müller. Günther acknowledged that Agassiz pointed out that Ganoids represented a unique assemblage of fishes, but he reserved the accolades of the primary advancement of knowledge of this group of fish to the four-part work by Müller entitled *Über den Bau und die Grenzen Der Ganoiden*. Günther also attributed several other minor innovations of Cuvier's classification system to Müller and indicated they offered another step towards the perfection of a 'perfectly natural' system. Günther stated, "Many of the families established by Cuvier were re-examined and better defined by Müller, as may be seen from the following outline of his system."[361] The significance that Günther attributed to Müller's classification system can be seen in the space he devotes to it. Günther's table of Müller's classification system takes up nearly two and a half pages of the historical section of this chapter, accounting for approximately ten percent of this entire section.[362]

[359] Ibid, 21.
[360] Ibid, 22.
[361] Ibid, 23.
[362] Ibid, 23-25

The final eight and a half pages of Günther's first chapter comprised a literature review of works contemporary to or subsequent to that found in Cuvier and Valenciennes's catalog. In practical terms this review included works published between the mid-1820s and mid-1870s. Günther divided this review into three sections. The first of these entitled "Voyages, Containing General Accounts of Zoological Collections" focused on collections made by French, English, and German expeditions.[363] Section two, entitled "Faunae," provided a bibliography of regional studies. Parts A - G include works devoted to European regions, part H is devoted to North America, and part I is simply entitled "Japan" (although this geographical category must be read with considerable latitude since works within this section appear to range from such broadly scattered regions as Japan, North Africa, Malaya, and India.) Additional regions covered included Africa, the West Indies and South America, New Zealand and the Arctic Regions.[364] Günther's third and final section of the literature review covered the subject of "Anatomical Works". Günther acknowledged an extensive list of authors who had advanced anatomical knowledge of fishes, and highlights texts by H. Stannius, Richard Owen, and Thomas Huxley. From the titles of these works, however, it is apparent that the texts of Owen and Huxley were general works devoted to the anatomy of vertebrates, so it might be assumed that the advancement of ichthyological anatomical knowledge was part of a larger project of animal anatomy. This is consistent with the understanding that much of the work on animal anatomy in the nineteenth century was allied with the development of medical education. In addition to anatomical works, Günther acknowledged a number of series devoted to advancing fish

[363] Ibid, 26-27.
[364] Ibid, 27-32

systematics beyond Cuvier and Valenciennes, ending the chapter with a discussion of Günther's own catalog of fish, which he stated, "As regards the systemic arrangement— Müller's system was adopted in the main, but the definition of the families is much modified."[365] And so, through the historical and review sections of this chapter, Günther informed his audience of the works of his predecessors that formed the basis on which he built his own text.

Chapter 2: Topographical Description of the External Parts of Fishes (35-50)

The second chapter of the textbook is focused on a description of the external characteristics of fish. Günther indicated at the beginning of the chapter that the four main external body parts are the head, trunk, tail and the fins. He discussed there how variations in the modes of life of the fish effect the conformation of the body, primarily focusing on the body forms that are conducive to swimming fast and dwelling at the bottom. Günther expressed reservations regarding the efficacy of classification as practiced by early ichthyologists which relied almost exclusively on external characteristics for fish identification, arguing that, "The old ichthyologists, even down to Linnaeus depended in great measure on them for classification; but although often the same form of body obtains in the same group of fishes, similarity of form by no means indicates natural affinity; it only indicates similitude of habits and mode of life."[366] Most of the length of this chapter was focused on a more detailed discussion of the head, fin, and scales of fishes, which again primarily varied according to the life habits of the fish. After he provided a description of the various types of fins found on fishes, Günther

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[365] Ibid, 34.
[366] Ibid, 36.

described how the fins, particularly the tail, caudal, and pectoral fins moved to aid the fish in locomotion.[367] Of scales, Günther indicated they bore little resemblance to the scales of reptiles, and instead were in composition more similar to hair, nails, or feathers. Towards the end of the chapter Günther provided a more detailed description of Cycloid, Ctenoid, Ganoid, and Placoid scales. Although Günther asserted that these scale types did not provide a good enough categorization to define fish classification, he nonetheless found the definitions of the specified types of scales a useful means of describing differences in fishes.

Chapter 3-4: Skeleton (51-92)

Entitled "Terminology and Topography of the Skeleton" (51-62), this chapter served the purpose of vocabulary building, with Günther providing definitions and descriptions of many elements of the fish skeleton so that a student would be in a position to "comprehend the subsequent account of the modifications of the skeleton in the various sub-classes and groups of Fishes."[368] In order to facilitate the ease of description, Günther chose the Perch as a model organism on which to base his explanation of the fish skeleton. Toward the end of the chapter, Günther indicated the problem posed by synonymous vocabulary used to describe fish skulls by making the following observation: "The bones of the skull of the fish have received so many different interpretations that no two accounts agree in their nomenclature, so that their study is a matter of considerable difficulty to the beginner."[369] In order to partially rectify this problem, Günther provided in the final three pages of the chapter a table of skull vocabulary as

[367] Ibid, 44.
[368] Ibid, 50.
[369] Ibid, 59.

it was used by Cuvier, Owen, and Stannius, and leaving the fourth column to the combined vocabulary of Huxley and Parker.

Chapter 4 embraced the subject of “Modifications of the Skeleton” (63-92). In this chapter Günther revealed his sensibility regarding the organization of fish from lowest to highest forms. According to this scheme he started with the “lowest sub-class of fishes,”[370] the Lancelet, which he indicated possessed the most primitive type of skeleton. He followed this with a description of Lampreys and Sea-hags, whose skeletons, Günther indicated, “shows a considerable advance of development.”[371] Next followed the Chondropterygians, the group comprised of sharks, rays, and chimaera. Again, with this group he recognized, “The advance in the development of the skeleton of the Chondropterygians beyond the primitive condition of the previous sub-classes.”[372] Following the Chondropterygians, Günther discussed the Ganoids, a group of fish that he identified as forming one of the largest orders of fish discovered in the fossil record. Next followed the Dipnoi, or lungfish. Günther pointed out the unusual formation of the Dipnoi pectoral fin which he contrasted with that of Ganoid fishes.[373] Finally, almost the last half of the chapter is devoted to the largest fish group, the Teleostei, or ray-fin fish. The organization of the description of fish groups as it is found in this chapter differs from the organization of the “Systematic and Descriptive Part” of Günther’s textbook. While Günther’s arrangement in Chapter 4 does not conform exactly to current arrangements of basal to more derived species of fish, it does conform to evolutionary arrangements of fish groups as

[370] Ibid, 63.
[371] Ibid, 64.
[372] Ibid, 67.
[373] Ibid, 73-74. This feature has been of considerable interest in evolutionary theorizing regarding the development of tetrapods from fish.

it would have been understood in the late-nineteenth century. I will return to this example at the end of the chapter where I discuss the nature of Günther's opinions regarding evolution.

Chapters 5-12: Internal Anatomy of Fish (93-169)

In chapters 5-12 Günther laid out the internal anatomy of fish, starting with "Myology" (93-95) the study of muscle in Chapter 5. Within these chapters, Günther generally preserved a descriptive structure that discussed the lowest fish forms before moving on to more advanced examples, however, he never actively identified the philosophical meaning behind lower and higher forms beyond the strict facts of structural difference. In each of the chapters, Günther looked to *Branchiostoma*, that is Amphioxus as representing the lowest form, although he was more selective in his choice of discussing the ascending structural variations, sometimes only referring to two or three forms in a single topic within his discussion of internal anatomy.

In Chapter 6 Günther covered "Neurology" (96-108), further subdividing the topic into a discussion of the spinal cord, brain, and nerves of fish. In keeping with the understanding that fish are the least advanced form of vertebrate, he informed his readers that in *Branchistoma*, the brain is entirely absent and in other forms, "The brain of fishes is relatively small."[374] The discussion of nerves identified ten nerve pairings from three regions of the fish body: the diverticula of the brain, nerves originating from the brain, and nerves originating from the medulla oblongata. He ended his discussion of the nerves by identifying two nerve pairs absent in fish, the Nervus accessorius and the Nervus hypoglossus.

[374] Ibid, 97.

Chapter 7 treated the subject of "The Organs of Sense" (109-120). Günther began with the organ of smell. In his discussion of the sense organs Günther repeatedly stressed observations of how much diversity could be found in the various characters of fish. For instance, in his discussion of sight he stated, "The position, direction, and dimensions of the eyes of fishes vary greatly."[375] Regarding the sense of taste, Günther indicated that in fish, this sense did not seem to be acute, basing his conclusion on the following observation: "But the majority of fish swallow their food rapidly, and without mastication, and therefore we may conclude that the sense of taste cannot be acute."[376] However, he concluded the chapter with the assertion that the sense of touch seems to be more developed than that of taste.

In Chapter 8 Günther proceeded to the topic of "The Organs of Nutrition and Digestion" (121-134). In the first two pages of this chapter, Günther paused briefly from the strict narrative of descriptive anatomy, in order to provide a discussion of feeding behavior in fish. Günther states that "the rule of 'eat or be eaten' applies to them with the usual force. They are almost constantly engaged in the pursuit and capture of their prey."[377] He further enforced the picture of fish as voracious eaters by stating that, "Fishes show but little choice in the selection of their food, and some devour their own offspring indiscriminately with other fishes."[378] The majority of the ten remaining pages of this chapter was taken up in a discussion of the teeth and intestines of fish. Keeping to the theme of how much variation can be found in the anatomy associated with the sensory organs, Günther claimed that, "With regards to the

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[375] Ibid, 111.
[376] Ibid, 119.
[377] Ibid, 121.
[378] Ibid, 122.

dentition, the class of Fishes offers an amount of variation such as is not found in any of the other classes of Vertebrates."[379]

Chapter 9 covered the "Organs of Respiration" (135-149), and in keeping with the understanding that among fishes the means of respiration was one of the primary distinguishing characteristics of the Class, this is one of the longer chapters on fish organ systems. At the beginning of the chapter, Günther reminded his audience that, "Fishes breathe the air dissolved in water by means of gills or branchiae."[380] Almost the first half of the chapter is devoted to variations of gill conformations among the various groups of fishes. The majority of the remainder of the chapter covered the subject of the air-bladder. Günther identified this organ as "Being compressible, its special functions consist in altering the specific gravity of the fish or in changing the centre of gravity.''[381] Günther indicated that not all fish possessed air-bladders, and of the largest group of fish he stated, "Its occurrence in Teleosteans is most irregular, closely allied species sometimes differing from each other in this respect; it shows in this sub-class the most extraordinary modifications, but has no respiratory function whatever."[382]

Chapter 10 on the "Organs of Circulation" (150-154) and Chapter 11 on the "Urinary Organs" (155-156) are quite brief. After a discussion of blood-corpuscles, Günther devoted the rest of chapter 10 to a discussion of the heart. Chapter 11 consisted mostly of a description of the kidneys. *Branchiostoma* is noted as lacking both a muscular heart and urinary organs.

[379] Ibid, 124.
[380] Ibid, 135.
[381] Ibid, 142.
[382] Ibid.

Chapter 12, the final chapter on the internal anatomy of fish, is devoted to the "Organs of Reproduction" (157-169). As the majority of fish are oviparous, several pages of the chapter are focused on the production, and to a lesser extent, the behavior associated with egg laying. A number of prodigious egg layers such as the Halibut and Cod-fish are pointed out. Another behavioral element discussed is the protection of young, particularly regarding the issue of male participation. Much of the remainder of the chapter is focused on the description of the ova and testicles of female and male fish.

Chapter 13: Growth and Variation of Fishes (170-184)

In Chapter 13 Günther addressed the way fishes change in form during the process of growth. In the opening of the chapter, he indicated that the majority of observed effects related to proportional changes in body parts. However, he also provided the example of the unusual metamorphosis that flat-fishes undergo in the process of development and explained that, "As they grow they live more on the bottom, and their body, during rest, assumes a horizontal position; in consequence, the eye of the lower side moves towards the upper, which alone is colored; and in many genera the mouth is twisted in the opposite direction, so that the bones, muscles, and teeth are much more developed on the blind side than on the coloured."[383] Radical changes occur in other fish species as well and Günther gave a list of fish whose "young are so different that they were described as distinct genera."[384] Another issue

[383] Ibid, 171.
[384] Ibid, 176.

that Günther raises in the chapter was the differences in fish size within a single species related to sexual dimorphism. He ended the chapter with a discussion of fish color.

Chapter 14: Domesticated and Acclimatised Fishes . . . (185-192)

Günther used Chapter 14 to discuss issues associated with fish domestication as spelled out in the long title, "Domestication and Acclimatised Fishes; Artificial Impregnation of Ova—Tenacity of Life and Reproduction of Lost Parts—Hybernation—Useful and Poisonous Fishes." Günther indicated that only a few species of fish had been successfully domesticated, the first of which were the Carp and Goldfish, which were transferred from East Asia to Europe.[385] Günther further indicated that the first attempts at the "artificial impregnation of fish-ova" was attempted by J.L. Jacobi during 1757-63, and that at the time of the writing of the book, the same procedure was still in practice. Günther made the observation that the practice, which was developed to resupply depleted stocks, also aided those students interested in fish embryology.[386] At the time of Günther's writing, the use of aquaria was still a relatively new cultural innovation in Europe and Günther made reference to it in the following statement: "Captivity is easily borne by most fishes, and the appliances introduced in our modern aquaria have rendered it possible to keep in confinement, and even to induce to propagate, fishes which formerly were considered to be intolerant of captivity."[387] Günther ended the chapter with a discussion of poisonous fish.

[385] Ibid, 185.
[386] Ibid, 186.
[387] Ibid, 187.

Chapter 15: Distribution of Fishes in Time (193-201)

Although the chapter on fish paleontology is only of modest length, the significance of this subject to the development of nineteenth-century ichthyology is of great enough importance that I will provide a more extended discussion of the contents of this chapter than I have to other chapters of similar length. In the opening paragraph of chapter 15, Günther expressed his uncertainty regarding the completeness of the geological record. He indicated that it was unlikely that geologists would ever be able to determine what the earliest fish species were or how closely related they were to existing species. He acknowledged that Leptocardii and Cyclostomes were presumed by zoologists to be the lowest members of the vertebrate series. However, he indicated that paleontologists were still searching for the evidence to back up this claim.[388]

In the continued narrative Günther discussed deposits of Conodonts that had been found in Lower Silurian and Devonian deposits in Russia, England, and North America. But Günther revealed that paleontologists of his times were still debating the nature of Conodont fossils. They were still uncertain if they could be attributed to fishes, annelids, or mollusks. Günther identified fragmentary remains associated with the Upper Silurian found in a site near Ludlow as the first examples of undoubted fish fossils. More abundant and more easily identified fish remains could be found associated with Devonian deposits. Regarding the Devonian deposits Günther mad the interesting observation that, "At certain localities of the Devonian, fossil fishes are so abundant that the whole of the stratum is affected by the

[388] Ibid, 193.

decomposing remains emitting a peculiar smell when newly opened, and acquiring a density and durability not possessed by strata without fishes."[389]

Günther's description of fish fossils proceeded through the stratigraphic record, from Devonian to Carboniferous, which he stated showed great similarity to the proceeding fossil record. Again, Günther indicated that the Permian group showed very similar fish types to those found in the Carboniferous. He further stated, "The passage from the Palaeozoic into the Mesozoic era is not indicated by any marked change as far as fishes are concerned."[390] Günther stated that the fossils from the Mesozoic era were well known through the work of Agassiz and Sir Philip Egerton, with 152 species being identified. Lyme Regis was a particularly productive locality, yielding 79 species. Naming some remarkable genera from the Mesozoic, Günther finally identified a significant transition in the fossil record: "These genera offer evidence of a great change since the preceding period, the majority not being represented in the older strata, whilst, on the other hand, many are continued in the succeeding oolithic formations."[391]

Through the Oolithic and Cretaceous groups, Günther perceived further transitions in the fish fauna that more nearly approached modern forms. Of the Cretaceous Günther stated, "But the Palaeichthyes are now in the minority; undoubted Teleosteans have appeared for the first time, on the stage of life in numerous genera, many of which are identical with still existing fishes."[392] In the Tertiary epoch, Günther pointed to a transition in which the Teleostean fish now dominated the fossil record and mentioned minor changes that occurred through the

[389] Ibid, 196.
[390] Ibid, 197.
[391] Ibid, 198.
[392] Ibid, 199.

Miocene and Pliocene. Günther noted that a few fish families, such as the Salmonidae, had appeared in Post-pliocene times, but ended the chapter with the observation that, "the distribution of fishes has not undergone any further essential change down to the present period."[393]

Chapters 16-21: Geographical Distribution of Fish (202-311)

Günther used Chapter 16 "The Distribution of Existing Fishes over the Earth's Surface—General Remarks" (202-207) to introduce the subject of the geographic distribution of fish. This chapter was largely focused on the differences between freshwater and marine fishes as being one of the most fundamental factors distinguishing how fish are distributed. Nonetheless, Günther made it clear that there was a certain degree of interchange in habitats either by accident or choice that might lead one to find freshwater forms in marine environments and marine forms in freshwater environments. Among fish, environmental preferences for marine and freshwater habitats further combined with other environmental factors that were seen to influence fish distribution.

Günther addressed Chapter 17 to the subject of "The Distribution of Freshwater Fishes" (208-250). He identified 2269 species of fish as distinctly inhabiting freshwaters and provided a general description of typical distribution: "As a general rule, a genus or family of freshwater fishes is regularly dispersed and most developed within a certain district, the species and individuals becoming scarcer towards the periphery as the type recedes more from its central home, some outposts being frequently pushed far beyond the outskirts of the area occupied by

[393] Ibid, 201.

it."[394] On pages 209-211 Günther provided a list of freshwater fish species, genera, and families that were observed to have discontinuous distributions. Then on pages 211-213 he offered a discussion of some of the means by which freshwater fish species were believed to become geographically dispersed. As the chapter proceeded, Günther raised questions regarding geological factors associated with the dispersion of fish. Günther also pointed out the issue of geographical provinces as proposed by Philip Sclater. Most of the remainder of the chapter was devoted to providing a more detailed description of the geographical distribution of freshwater fish as Günther broke down three zones—Northern, Equatorial, and Southern—into sub-provinces as discussed on pages 217-250.

Günther looked to both paleontological evidence and the distribution of extant fish species to reveal something of the history associated with fish distributions. However, Günther displayed his preferential commitment to fish paleontological evidence regarding the duration of fish types through his comment that, "Geological evidence is the only proof of the antiquity of type."[395] As Günther laid out his description of the geographical distribution of fish, he would periodically make comments that suggested that he perceived genuine continuity between species, genera, and families. For instance, when he spoke of the similarity between freshwater species in India and Africa he stated that, "As the majority of these groups have many more representatives in India than in Africa, we may reasonably assume that the African species have been derived from the Indian stock."[396] Of freshwater fish species on the two sides of the Atlantic, Günther observed, "On the other hand, the existence of so many similar

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[394] Ibid, 209.
[395] Ibid, 212.
[396] Ibid, 225.

forms on both sides of the Atlantic affords much support to the supposition that at a former period the distance between the present Atlantic continents was much less."[397] Based on comments such as these, found in Günther's discussion of the biogeography of fish, it seems likely that Günther at least entertained the possibility that fish were subject to some level of evolutionary change. This is a topic that I consider in more detail at the end of this chapter.

In Chapter 18, "The Fishes of the Brackish Water" (251-254) discussed fish that either inhabited brackish water or could sometimes be found in either marine or freshwater habitats. Günther indicated that brackish water fish did not serve as good indicators of aquatic biogeographic provinces because their adaptability to a range of habitats allowed them too extensive a range. Accordingly, he made little effort to characterize their distribution. Instead he provided a list of brackish water families and genera.

In Chapter 19 Günther introduced the topic of "The Distribution of Marine Fishes" (255-291). He indicated that there were three distinct categories of marine fishes: shore fishes, pelagic fishes, and deep-sea fishes. Chapter 19 is focused on shore fishes, leaving the pelagic and deep-sea fishes to be covered in Chapters 20 and 21. Günther did not believe as much distinguished the three categories of marine fish as could be found distinguishing marine and freshwater species. Instead, he stated that, "They gradually pass into each other, and there are numerous fishes about which uncertainty exists whether they should be placed in the Shore or Pelagic series, or in the Pelagic or Deep-sea series; nay, many facts favor the view that changes in the mode of life and distribution of fishes are still in progress."[398] In his table indicating the

[397] Ibid, 233.
[398] Ibid, 256.

principle types of Shore-fishes, Günther categorized 3587 species as belong to the shore series. He identified five primary ocean areas in which shore fishes could be found: The Arctic Ocean, The Northern Temperate Zone, The Equatorial Zone, The Southern Temperate Zone, and The Antarctic Ocean, and further divided the equatorial and two temperate zones into subcategories.

The bulk of Chapter 19, pages 261-291, provided a more detailed discussion of the faunal composition of the major ocean areas. In this chapter Günther made a few provocative claims regarding changing oceanic geology/geography that could be potentially detected based on the distribution of fish types. The first of these claims involved the similarity between shore fishes from the Japanese district and the Mediterranean. "Bold as the hypothesis may appear, we can only account for the singular distribution of shore fishes by assuming that the Mediterranean and Japanese seas were in direct and open communication with each other within the period of the existence of the present Teleoseous Fauna."[399] Additionally, based on the similarity between fishes observed on the Atlantic and Pacific sides of the Isthmus of Panama, Günther made the claim that in relatively recent geological history, that there had been an opening between the North and South American continents: "The explanation of this fact has been found in the existence of communications between the two oceans by channels and straits which must have been open till within a recent period."[400]

Chapter 20 provided a discussion of "Distribution of Pelagic Fishes" (292-295). He defined pelagic fishes as those "fishes inhabiting the surface of the mid-ocean."[401] Günther

[399] Ibid, 270.
[400] Ibid, 280.
[401] Ibid, 292.

indicated that pelagic fish assumed a number of modes of life, and therefore exhibited different bodily properties. He stated that most pelagic fish were excellent swimmers, exhibiting rapidity and endurance, but this did not account for all pelagic species. Some pelagic fish were comparatively poor swimmers and might congregate around floating seaweed or other drifting material, or simply drift in response to winds and ocean currents. Other fish such as Sucking fish, had adhesive properties and might attach themselves to other fish, ships, or floating objects. Another group of fish exhibited the habit of nocturnal migration, staying hidden at depths during the day, and ascending to the surface at night. Since pelagic fish were not subject to the same barriers associated with living in freshwater and coastal habitats, individual species could be comparatively widely distributed, and may even have ranges that extended to both the Atlantic and Pacific Oceans.[402]

In Chapter 21 Günther concluded his discussion of fish habitats with the subject of "The Fishes of the Deep Sea" (296-311). Upon the introduction of this subject, Günther indicated that knowledge of deep-sea forms was fairly new, and that the recent expedition of the *H.M.S. Challenger* had done much to increase what was known by the time of the writing of the textbook. In 1880 Günther also prepared his report on the deep-sea fishes from the *H.M.S. Challenger* expedition, so he was able to include the knowledge he had gained from examining these specimens.[403] In the textbook, Günther discussed the physical conditions of the deep sea, and the adaptations deep-sea fishes exhibited to inhabit this region of the ocean. Because

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[402] Ibid, 292-295.

[403] Since the *H.M.S. Challenger* expedition occurred between the years 1872-1876, Günther had not had the opportunity to discuss the specimens collected during the voyage in his fish catalog. However, in 1878 Günther prepared a report on the deep-sea fishes of the expedition, added a report on shore fishes in 1880, and finished his analysis of the H.M.S. Challenger material with a report on pelagic fishes in 1889.

deep-sea fish inhabited a sunless region, Günther noted characteristics such as modification of organs of vision, simplification of colors, and the fact that deep-sea organisms sometimes produced their own phosphorescent light. He postulated that the uniformity of environmental conditions in the deep sea—the cold temperatures, high pressure and quiet waters—meant that deep-sea fish could exhibit unlimited dispersal within their chosen habitat. They were also all carnivorous species, due to the lack of vegetation. Because deep-sea fish lived under high pressure conditions, the withdraw of these species from deep waters often subjected them to significant bodily damage.

Günther indicated that although the *H.M.S. Challenger* expedition was responsible for the discovery of new genera and species of deep-sea fish, no new types of families had been discovered. In fact, Günther viewed deep-sea fishes as modifications of surface-dwelling forms: "The fish-fauna of the deep sea is composed chiefly of forms or modifications of forms which we find represented at the surface in the cold and temperate zones, or which appear as nocturnal pelagic forms."[404] Günther ended this chapter with a table listing genera and species of deep-sea fishes which extended from pages 307-311. When the information was available, Günther indicated the depth at which these fish had been found.

Systematic and Descriptive Part (312-696)

In the opening of the "Systematic and Descriptive Part" of the textbook, Günther divided the class of fish into four subclasses using anatomical features such as the shape of the heart, intestines and skeleton to determine the distinction. These four subclasses included:

[404] Ibid, 305-306.

Palaeichthyes, Teleostei, Cyclostomata, and Leptocardii. Günther then described the first sub-class, Palaeichthyes, which included Sharks, Rays, Chimaeras, and Ganoid fishes on pages 312-372. Günther's descriptions were organized in descending taxonomic hierarchy, moving through sub-classes, orders, sub-orders, and families. The major subheadings ended at the family level, but descriptions of the genera included within these families are provided under small subheadings within the sections on families and sometimes individual species information was included as well. Günther made the following observation of the Palaeichthyes regarding where they fit in the history of life: "Geologically, as a sub-class, they were the predecessors of Teleosteous fishes; and it is a remarkable fact that all these modifications which show an approach of the ichthyic type to the Batrachians are found in this sub-class."[405] This observation indicated that Günther recognized morphological similarities across class boundaries, even if he resisted evolutionary interpretations of these similarities.

In his discussion of the Palaeichthyes sub-class, Günther made it clear that geologically ancient organisms were represented by this group. His subject matter within the text ranged well beyond mere anatomical description of living species. Günther also discussed the fossil remains that showed affinities with living species. He provided descriptions of fish behavior when such information was available. He discussed descriptions of existing fisheries, and even made suggestions regarding the economic benefits that might be derived from extending fisheries. When Günther transitioned from a description of sharks to that of rays, he discussed habit in relation to fish body types in a way that revealed the perceived connection between

[405] Ibid, 313. During much of the nineteenth century the Batrachians were identified as a subdivision of reptiles, but they would now be known as amphibians.

the way fishes lived, and how they were shaped. He stated that, "The mode of life of these fishes is quite in accordance with the form of their body. Whilst the species with a shark-like body and muscular tail swim freely through the water, and are capable of executing rapid and sustained motions, the true Rays lead a sedentary life, moving slowly on the bottom, rarely ascending to the surface."[406] He viewed the Chimaeridae, the only living family of the Sub-Order Holocephala, as the passage between sharks and rays and ganoid fish.[407] The Ganoidea he identified as an ancient order of fish that was in the process of going extinct. He stated, "To this order belong the majority of the fossil fish remains of palaeozoic and mesozoic age, whilst it is very scantily represented in the recent fauna, and verging towards total extinction. The knowledge of the fossil forms, based on mere fragments of the hard parts of the body only, is very incomplete and therefore their classification is in a most unsatisfactory state."[408] As a result, many of the descriptions in this portion of the book are of extinct groups that were only known from fossil remains.

Most of the remainder of the section on the systematics of fish was taken up in his description of the second subclass, the Teleostei (373-690). The Teleostei were identified as the geological successors of the Palaeichthyes. But this refers to their physical location within the stratigraphic record, not to ancestry. Günther made this point when he stated, "there is no direct genetic relation between those fishes, as some Naturalists were inclined to believe."[409] Günther divided the Teleostei into six orders: Acanthopterygii, Acanthopterygii Pharyngognathi,

[406] Ibid, 335.
[407] Ibid, 348.
[408] Ibid, 350-351.
[409] Ibid, 373.

Anacanthini, Physostomi, Lophobranchii, and Plectognathi. As a geologically younger and extremely diverse subclass of fish, the ratio to known living representatives of the Teleostei to extinct species was much higher than that of the subclass of Palaeichthyes. As a result, much more space in this portion of the textbook was taken up in discussion of living fish than fossil fish. Many of those fossil remains that were identified were found in the Tertiary and Quaternary portions of the fossil record, although there were also some cases of fossils found from the Cretaceous period as well.

Throughout this section, Günther continued to provide records of observations of fish behavior that indicated his interest in fish extended beyond systematics and description. In the case of the pilot fish, Günther provided an account of how this type of fish had a mutualistic relationship with sharks. Günther stated that, "The Pilot obtains a great part of his food directly from the Shark, in feeding on the parasitic crustaceans with which Sharks and other large fish are infested, and on the smaller pieces of fish which are left unnoticed by the Shark when it tears its prey."[410] Throughout the systematic and descriptive section, Günther made frequent references to what people from classical antiquity had said about fish. However, within the fish lore there is only one Biblical reference made, regarding the John Dory (*Zeus faber*). Of this fish Günther stated, "The fishermen of Roman Catholic countries hold this fish in special respect, as they recognize in a black round spot on its side the mark left by the thumb of St. Peter when he took the piece of money from its mouth."[411]

[410] Ibid, 445.
[411] Ibid, 451.

Günther singled out the family Pediculati as a group that "contains a larger number of bizarre forms than any other."[412] He also included a provocative statement that indicated it is not easy to pigeonhole his views on ancestry in fish. "A large portion of the genera, therefore, have gradually found their way to the greatest depths of the ocean; retaining all the characteristics of their surface-ancestors, but assuming the modifications by which they are enabled to live in abyssal depths."[413] In his discussion of the division Acanthopterygii Centrisciformes, Günther also made a reference to the term "type" that indicated some ambiguity as to what level Günther identified a typic form to exist, but suggested that it might rise as high as the family or division level.[414]

In his catalog of fish, Günther identified the family Salmonidae as one of the most difficult groups to accurately characterize. He addressed this family toward the end of the portion of the text on the Teleostei, devoting just over twenty pages to the single family (630-651). Of the genus Salmo Günther stated, "We know of no other group which offers so many difficulties to the ichthyologist with regard to the distinction of the species as well as to certain points in their life-history, as this genus, although this may be partly due to the unusual attention which has been given to their study, and which has revealed an almost greater amount of unexplained facts than of satisfactory solutions of the questions raised."[415] He went on to comment on variations in the genus based on differences associated with sex, age, development, hybridization, food, and characteristics of the water in which they are found. In

412 Ibid, 469.
413 Ibid, 469-470.
414 Ibid, 509.
415 Ibid, 631.

order to aid in identifications, he provided a list of variable characters and aspects of life history. He also provided a list and brief descriptions of the species found within subdivision of the genus into Salmones (Salmon and Trout) and Salvelini (Charr). Günther's discussion of Salmo took up 15 pages of his discussion of the Salmonidae, leaving five pages to cover the remaining eight genera within the family.

The two final subclasses of fish that Günther discussed were quite small. The Cyclostomata (691-695) represented a group of eel-like fish and was represented by only two families, the Petromyzontidae or Lampreys and the Myxinidae otherwise known as hagfish. The placement of this subclass presented Günther with a problem in geological terms, because they were presumed to be an ancient group, but Günther was uncertain if adequate evidence existed to confirm this presumption. He states that: "The Cyclostomes are most probably a very ancient type. Unfortunately the organs of these creatures are too soft to be preserved, with the exception of these horny denticles with which the mouth of some of them is armed."[416] He indicated that fossils resembling the dental plates of Myxine could be found in some strata from the Devonian and Silurian periods, but he did not seem to take this as adequate evidence for committing this subclass to a definite placement in the history of life. So instead of assigning this group to a position before the Teleostei or Palaeichthyes, he simply reserved the discussion of these organisms to the end of the systematic section.

The final subclass, Leptocardii. was represented by a single family and genus and only took up one page of the textbook (696). Günther identified this genus, the *Branchiostoma* or Lancelet as the most primitive fish form, although he made no mention of fossil evidence for

[416] Ibid, 691.

this group, so it was also reserved for the end, rather than taking up a known place in the history of life. Of the Lancelet Günther stated, "It is the lowest on the scale of fishes, and lacks so many characteristics, not only of this class, but of the vertebrate generally, that Haeckel, with good reason, separates it into a separate class, that of the Acrania."[417]

Appendix: Directions for Collecting and Preserving Fishes (697-706)

Günther ended his textbook with a ten-page appendix providing instructions to would be travelers and collectors regarding the best practices for collecting and preserving specimens (697-706). Günther recommended preserving fish in the best and strongest spirits that could be procured. While he stated a preference for spirits of wine, he also indicated that the cheaper methylated spirits could be used instead, but he warned that they did not serve as good a preservative. He recommended zinc boxes as the best containers that could be used by a collector, indicating that wooden casks were not suitable, unless used for large specimens that were being preserved with salt or brine. In terms of the mode of preservation, Günther told collectors that they should make an incision along the fish's abdomen, both to evacuate fluid that would lead to rapid decomposition of the fish, and to allow more rapid and through penetration of spirits within the fish's body. In hot climates, it might be necessary to transfer the preserved fish into a new box with stronger spirits, in order to prevent excessive decomposition of fish bodies before they could be shipped to a museum. When decomposition of a specimen could not be adequately forestalled, Günther recommended discarding the fish, to prevent it from spoiling other specimens. And when an adequate number of specimens had

[417] Ibid, 696.

been preserved, Günther directed they should be wrapped within linen or soft paper and the zinc box could be soldered closed so that the fish could be shipped to their ultimate destination.[418]

Günther provided additional instructions for the preservation of large specimens, which could only be preserved as skins or in skeletal form. For these specimens he recommended providing measurements of the specimens before skinning them, so that when the specimens were stuffed and mounted, they could be represented as closely as possible to their living dimensions. Günther gave information regarding which regions of the globe were underrepresented by fish specimens, and that could therefore serve as the most fruitful collection grounds. Additionally, Günther requested observational information from his collectors, which would add to knowledge of these organisms. Among the kinds of observations Günther indicated interest in were issues regarding how the fish were used in trade, which fish were poisonous, observations regarding peculiarities of sex, propagation, and development, fish measurements, accurate coloration of live specimens, life histories of parasitic fish, the temperature of the blood, and microscopic examination of fresh specimens.[419]

Günther's Evolutionary Agnosticism

In the chapter on fish paleontology in *An Introduction to the Study of Fishes*, Günther asserted in the opening sentence that the earliest history of fish life was, and probably always

[418] Ibid, 697-701.
[419] Ibid, 702-706.

would be, irresolvable.[420] This statement is probably as close a representation as one is likely to get in pinning down Günther's thoughts on the subject of evolution, at least within the texts of most immediate interest to the disciplinary development of ichthyology. Throughout his career at the British Museum, Günther demonstrated a reluctance to be drawn into the public debate about evolution. In the penultimate chapter of the biography on Günther, his grandson attempted to provide some explanation for his grandfather's resistance to Darwinian thinking.[421] Bowler provided a breezy explanation of the case when he stated, "If Darwinism made only limited inroads into the museum at first, it was because the keeper of zoology, Albert Günther, was simply indifferent to it."[422] But a close reading of Günther's textbook suggests that both of these authors have oversimplified the case. Günther's position on evolution appeared to be presented with a carefully composed neutrality and disengagement with the subject. This does not mean that Günther was indifferent to the subject—far from it. Instead he seemed to be carefully navigating through treacherous territory in order to avoid being swept up into the controversy.

A brief discussion of an interchange that occurred between Günther and the German entomologist Karl Jordan (1861-1959), who was employed at the Natural History Museum at Tring, sheds some light on Günther's position on evolutionary debate. This account can be found in Kristin Johnson's biography of Jordan's life and work *Ordering Life: Karl Jordan and the Naturalist Tradition*. Johnson writes,

[420] Günther, *Study of Fishes*, 193.
[421] Gunther*, Century of Zoology*, 453-469.
[422] Peter Bowler, *Life's Splendid Drama: Evolutionary Biology and the Reconstruction of Life's Ancestry, 1860-1940* (Chicago: The University of Chicago Press, 1996), 32.

> Years later, Jordan recalled how Albert Günther took him aside during one of his occasional visits to Tring soon after 'On Mechanical Selection' appeared. The sixty-six-year-old British Museum zoologist admonished him 'in no uncertain terms' that he had 'gone over to biology, and made it clear that he did not approve.' Like many naturalists, Günther thought the answer to the problem of distinguishing species from varieties would be achieved only through the careful collection of taxonomic facts, rather than premature philosophical debates. In contrast to those who believed Darwin's greatest contribution had been inspiring the search for general laws in natural history, Günther believed the increasingly vociferous debates over the mechanism of evolution violated the terms of good science.[423]

In a discussion of Günther's mid-career labors, his grandson pointed out a disagreement that occurred between Günther and Thomas Huxley regarding the relationships that existed between fish groups.[424] In *Study of Fishes*, Günther had made the following challenging statement regarding the relationship between Teleostei and Ganoid fish: "But there is no direct genetic relation between those fishes, as some Naturalists were inclined to believe."[425] Günther's grandson indicated that Huxley recognized this comment as being directed at him and took offense. Elsewhere in *Study of Fishes*, Günther made another assertion regarding genetically distinct groups of fish; in this case, Günther was discussing how the tropics served as an impassable barrier to the migration of freshwater species. He stated, "where a similarly temperate climate obtains in the southern hemisphere, fish-forms appear analogous to those of the north, but genetically and structurally distinct."[426] It's worth noting what these statements do and do not indicate about Günther's beliefs. Both interpretations were *case specific*, and Günther does not seem to have been making sweeping statements denying the

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[423] Kristin Johnson, *Ordering Life: Karl Jordan and the Naturalist Tradition* (Baltimore: The Johns Hopkins University Press, 2012), 101.
[424] Gunther, *Century of Zoology*, 335.
[425] Günther, *Study of Fishes*, 373.
[426] Ibid, 215.

possibility that there were groups of fish that are genetically related. The mere fact that Günther went to some trouble of denying relationships in these particular cases, admitted the possibility that there were other cases where relationship may be established. And, as previously stated, Günther went so far as using the term 'ancestors' in his discussion of the relationship between surface dwelling and deep-sea forms of fishes found within the family Pediculati.[427]

Recent historiography just discussed in the works of Günther's grandson, Bowler and Johnson has clearly identified Günther on the anti-evolutionary side of those who could or could not be counted among Darwin's followers. But Günther's views and relationship to Darwin raise an important historiographic issue: what did it actually mean be non-Darwinian in the late nineteenth century? If Günther was prepared to admit some level of ancestry among distinct species of fish, even if only to the genus or family level, it indicates that some blurring of the distinction between evolutionary and anti-evolutionary positions within the nineteenth century could occur. The career of Buffon demonstrated that there was already was already a precedent for considering the possibility of limited ancestry to the family level that stretched back to mid-eighteenth century thinking. And as Desmond's account of mid-Victorian paleontology points out, even among those who are identified as Darwin's supporters, different interpretations of the geological evidence prevailed.[428]

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[427] Ibid, 470.

[428] Adrian Desmond, *Archetypes and Ancestors: Palaeontology in Victorian London 1850-1875* (London: Blond & Briggs, 1982). For instance, on the issue of human evolution Desmond states on page 91, "Lyell was tortured by indecision and never went as far or as fast as Darwin would have liked." Furthermore, Desmond also points out that Huxley frequently disputed Owen's interpretation of fossil evidence, even when agreement might advance Darwinian arguments.

Günther's discussion of ichthyology within his textbook expressed a number of views which, even if they were not directly supportive of evolutionary thinking, could be used to advance evolutionary arguments. One of the basic features of Günther's work was expressed in the means by which Günther organized his discussion of fish. In his anatomical sections, he often discussed structures within the fish in order of ascending anatomical complexity. That Günther refrained from arranging the sub-classes of fish in a similar manner, can be accounted for by Günther's preference for the proven antiquity of fish groups as supported by the fossil record, and he acknowledged the comparative structural simplicity of the sub-classes Cyclostomata and Leptocardii, even though he placed them after the Teleostei.

Another issue addressed by Günther's textbook would have been of interest to evolutionary thinkers was his discussion of fish biogeography. Alfred Russell Wallace had published his book *The Geographical Distribution of Animals* in 1876, which was before the publication of Günther's textbook. Wallace arranged the subclasses of fish differently than Günther had in his fish catalogs, so he probably relied on the expertise of someone other than Günther to develop this section. But in the preface of the first volume of his text, Wallace stated that he had relied on Günther for the classification of reptiles.[429] It is likely, if Günther's discussion of fish biogeography had been available before Wallace published his book on the distribution of animals, that he would have consulted this text as well, even if he had chosen to interpret fish classification in a different way.

[429] A. R. Wallace, *The Geographical Distribution of Animals: With a Study of the Relations of Living and Extinct Faunas as Elucidating the Past Changes of the Earth's Surface*, Vol. 1 (London: Elibron Classics, 2005), xiv.

Based on his biogeographic observations, Günther made several claims regarding the distribution of fishes that carry implications regarding changing geographical patterns over time. These observations imply both geological alteration of the land and water bodies, and some level of continuity between groups of apparently related fish beyond the species level. In his discussion of the distribution of freshwater fish, Günther indicated that South America and Africa must have been much closer to each other. He stated, "the existence of so many similar forms on both sides of the Atlantic affords much support to the supposition that at a former period the distance between the present Atlantic continents was much less, and that the fishes which have diverged towards the East and West are descendants of a common stock which had its home in a region now submerged under some intervening part of that ocean."[430] Günther also claimed that the distribution of shore fish indicated geological changes in the regions of Central America and the region between the Mediterranean Sea and the coast of Japan. In the case of Central America, he noted a high similarity between the genera and species on both the Pacific and Atlantic coasts, associated with the location at which the Isthmus of Panama narrows. Based on this evidence, Günther offered, "The explanation of this fact has been found in the existence of communications between the two oceans by channels and straits which must have been open till within a recent period."[431] Günther also compared the shore fish of the Japanese district with that of the Mediterranean. Günther stated, "We can only account for the singular distribution of these shore fishes by assuming that the Mediterranean and Japanese seas were in direct and open communication with each other within the period of the

[430] Günther, *Study of Fishes*, 233.
[431] Ibid, 280.

existence of the present Teleostean Fauna."[432] To support his claim Günther provided a list of over 100 genera that compared the fish of the two regions.[433]

Observations such as these complicate the portrait of Günther as merely someone who denied or was indifferent to evolution. He acknowledged some level of diversification over time. What seems to be at stake wasn't Günther's belief in descent with modification, but what he believed about the mechanism of evolution, and the limitations of the process. Although she does not discuss Günther extensively, Johnson's view of his beliefs offers a more nuanced understanding of Günther's position on the subject than either Günther's grandson or Bowler. For instance, Johnson pointed out that Günther was willing to support the adoption of trinomial nomenclature for cases when demonstrable geographical differences could be shown between varieties of the same species.[434] On the other hand, Johnson indicated Günther's resistance to evolutionary ideas in the following terms: "Firmly invested in the descriptive work demanded by large collections, Albert Günther pointed out that although many systematists accepted evolution, 'the needs of minds differ' and not everyone needed 'some universal concept into which their daily work fitted.'"[435]

Despite what Günther may have said, it is impossible to work in a systematic framework, without adopting at least modest theoretical commitments. In *Study of Fishes* some of Günther's commitments emerge from the text, when read closely enough. Based on the current evidence, I believe that the best way to characterize what Günther's views were, would

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[432] Ibid, 270.
[433] Ibid, 271-272.
[434] Johnson, *Ordering Life*, 60.
[435] Ibid, 76.

be as an “adaptationist with some level of belief in genealogy.” In other words, Günther believed that over the long periods of time under which geological changes led to environmental changes, species adapted to their environment, and some of those adaptations could be passed on to their offspring, eventually allowing species from the same genera to diversify into new varieties and even species. His belief in this capacity for diversification seemed to extend at least to the family level. What he believed beyond that point, remains unclear.

Chapter 5

Louis Agassiz and Fish Paleontology

Introduction

The painstaking systematic work accomplished in the nineteenth century by naturalists such as Günther provided the rich mosaic of knowledge on which narratives of natural history could be built. When Darwin was preparing the text of *Descent of Man*, he turned to Günther for expert knowledge regarding the sexual dimorphism of fish, amphibians and reptiles.[436] This specialist knowledge offered the promise to either build up or invalidate the sometimes overeager hypothesizing of less empirically grounded naturalists. Karl Jordan, the German entomologist working at the Natural History Museum at Tring, "noted that he repeatedly found statements of fact in arguments for and against evolution that had long since been directly contradicted by the solid observations of systematists."[437] A close reading of Günther's discussion of fish diversity has already demonstrated his interpretation of this variation was more nuanced that other historians of science have acknowledged. Such a reinterpretation suggests that further investigation of the interplay between theoretical and specialist knowledge is merited. In this chapter I will consider more closely the place fish fossils played in the way ichthyologists and geologists interpreted the stratigraphic record. Focusing on the interplay of ideas between Cuvier, Agassiz, Günther and Darwin, a poorly known facet of the story of nineteenth century evolutionary debate emerges.

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[436] Gunther, Century of Zoology, 312.
[437] Johnson, *Ordering Life*, 110.

Günther's views would have been quite similar to what Darwin's were in the early days of his transformist thinking. In his book *The Development of Darwin's Theory: Natural History, Natural Theology, and Natural selection, 1838-1859*, Dov Ospovat explored Darwin's pre-Malthusian adaptationist views. According to Ospovat, in this early stage of his intellectual development Darwin believed that, "Organic changes are also produced in response to great slow changes of conditions, whose causes are fundamentally geological, and these changes may be preserved."[438] While adaptation was an idea that could be modified to suit evolutionary thinking, Ospovat made clear that within the context of natural theology, many naturalist contemporaries of Darwin in the first half of the nineteenth century considered it as a means by which species were perfectly conformed to their environments without driving the process of diversification.[439]

Even Darwin considered that there may have been limits to how far evolution went. Ospovat indicated that in 1837, Darwin expressed skepticism regarding the relationship between vertebrates and invertebrates in his response to the Cuvier-Geoffroy debate. According to Ospovat, "Darwin was not convinced by Geoffroy's arguments for the unity of type of all animals ('I deduce from extreme difficulty of hypothesis of connecting mollusca and vertebrate, that there must be very great gaps')."[440] Ospovat further argued that Darwin did nonetheless find Geoffroy's views to be considerably more congenial to his than the views of Cuvier, and Ospovat indicated that Darwin was critical of Cuvier within the context of the

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[438] Dov Ospovat, *The Development of Darwin's Theory: Natural History, Natural Theology, and Natural selection, 1838-1859* (Cambridge: Cambridge University Press, 1981), 50.
[439] Ospovat, *Development of Darwin's Theory,* 33-38.
[440] Ibid, 28.

debate. The argument continued with the observation that in the 1830s naturalists, like Darwin, who were most amenable to the concept of ancestry were uncertain how many types were represented by these ancestral forms.[441]

The question remains, how long after Cuvier's death in 1832 did Cuvierian *embranchements* persist as recognized categories within the minds of actively working naturalists in countries such as France and England? We know, based on Appel's analysis of the Cuvier-Geoffroy debate that a number of leading naturalists worked to find common ground between the ideas of the obstreperous pair and developed new syntheses in the decades that followed. Appel argued that "homologies and adaptations were not satisfactorily reconciled until the advent of Darwin's theory of evolution in 1859."[442] But in her discussion of Darwin's response to the debate, Appel failed to indicate if Darwin ever revisited his 1837 opinion on the relationship between vertebrates and invertebrates.

Evidence from Darwin's own seminal work, *Origin of Species*, provided evidence that Darwin himself was never entirely convinced that Cuvierian *embranchements* could be wholly dispensed with. In the closing paragraph of his Chapter 6 on "Difficulties on Theory" Darwin discussed his view of the central ideas from the Cuvier-Geoffroy debate. According to Darwin, both Cuvier and Geoffroy's principal ideas could be embraced and reconciled by his own theory of natural selection. He stated, "On my theory, unity of type is explained by unity of descent. The expression of conditions of existence, so often insisted by the illustrious Cuvier, is fully

[441] Ibid, 232.
[442] Appel, *Cuvier-Geoffroy Debate*, 230.

embraced by the principle of natural selection."[443] But between the two ideas, which Darwin referred to as "great laws," Darwin gave the precedence to Cuvier rather than Geoffroy as he concluded the paragraph: "Hence, in fact, the law of the Conditions of Existence is the higher law; as it includes, through the inheritance of former adaptations, that of Unity of Type."[444] Ultimately, while Darwin had a theoretical preference for believing that all of life could be traced to a single line of ancestry, he conceded that this view may not, in fact, be true. In the concluding chapter, Darwin signaled his discussion of the issue with the following question, "It may be asked how far I extend the doctrine of the modification of species."[445] He then provided his answer stating that, "Throughout whole classes various structures are formed on the same pattern, and at an embryonic age the species closely resemble each other. Therefore I cannot doubt that the theory of descent with modification embraces all the members of the same class. I believe that animals have descended from at most only four or five progenitors, and plants from an equal or lessor number."[446] In the next paragraph Darwin observed that, "Analogy would lead me one step further, namely, to the belief that all animals and plants have descended from some one prototype. But analogy may be a deceitful guide,"[447]

Due to changes of terminology over time, there is some ambiguity regarding how exactly Darwin was using the term 'class' in the context of his argument. In the nineteenth century, the term class does not seem to have conformed to exactly the same position within the taxonomic hierarchy as it does today. Part of this ambiguity arises from the fact that there

[443] Charles Darwin, *On the Origin of Species: A Facsimilie of the First Edition* (Cambridge, MA: Harvard University Press, 1964), 206.
[444] Ibid.
[445] Ibid, 483.
[446] Ibid, 483-484.
[447] Ibid, 484.

does not seem to have been a term analogous to our present taxonomic designation phylum intervening between class and kingdom. However, in the case of Darwin's description of the range in which evolutionary inheritance is expressed, he made more than one statement indicating that in that instance, he is thinking of something equivalent to Cuvierian *embranchements*. In his discussion of morphology in the penultimate chapter of *Origin of Species*, when Darwin pointed to the significance of repetitive anatomical structures within the context of evolution he made the following assertion: "An indefinite repetition of this same part or organ is the common characteristic . . . therefore we may readily believe that the unknown progenitor of the vertebrate possessed many vertebrae; the unknown progenitor of the articulate, many segments; and the unknown progenitor of flowering plants, many spiral whorls of leaves."[448]

Fish fossils have an intriguing role to play in the story of how a number of naturalists interpreted Cuvierian *embranchements* and how geologists understood the fossil record. As a leading figure in the development of both ichthyology and paleontology, Cuvier was interested in fish fossils and had collected fossil material at the Natural History Museum in Paris for study. Günther also demonstrated significant interest in fish fossils and the place they played in the geological record. Günther's knowledge of fish paleontology was significantly augmented by Agassiz, who had briefly worked under the tutelage of Cuvier in the months before Cuvier's death. The 1830s and 1840s represented a significant time in the development of stratigraphy and paleontological knowledge, and it was precisely during these formative decades in

[448] Ibid, 437.

geological history that Agassiz preformed an intensive study of the fish fossils found in museum collections across Europe.

The Missing Link: The Untold Story of Paleontology in the Nineteenth Century

When I set out to write this dissertation, the story I meant to tell was one of how naturalists in the nineteenth century used new textual genres to organize zoological information into new formats in order to bring increasing coherence to the emerging discipline of ichthyology. In the process of pursuing this narrative, however, an unexpected secondary narrative began to shape itself and emerge within my dissertation, complicating and enriching my understanding of how the development of ichthyological knowledge took place. That is the story of fish paleontology and the important role it played in how nineteenth century ichthyologists understood the organisms they studied. In the twentieth century, as the practice of ichthyology became increasingly specialized and localized, fish paleontology became less central to the practice of how biologists studied living fish species. But nineteenth century ichthyological practice, emerging as it did within the Cuvierian tradition of comparative anatomy, easily lent itself to the osteological examination that an expert vertebrate paleontologist would need to use in order to make sense of fossil remains. In uncovering this secondary story, I became increasingly aware of a narrative gap that exists within the current historiography of nineteenth century geology.

There are books that highlight the story of nineteenth century paleontology. Two prominent examples are Adrian Desmond's work *Archetypes and Ancestors: Palaeontology in Victorian London 1850-1875* and Peter Bowler's text *Life's Splendid Drama: Evolutionary Biology* *and the Reconstruction of Life's Ancestry, 1860-1940*.[449] While these two texts provide useful narratives linking paleontological practices to evolutionary theory and the morphological medical tradition, they fail to make substantive links to the primary project of British geology in the nineteenth century: geological survey and the process of defining the stratigraphic column. This oversight might be excused in the case of Desmond, since the major historiographic works on British stratigraphy produced by Rudwick, Secord, and Oldroyd between 1985-1990 were not available when Desmond wrote his own book.[450] But in the case of Bowler's work, which was not published until 1996, this oversight represents a more glaring omission. Until more work is done linking the history of nineteenth century paleontology with nineteenth century stratigraphy, our understanding of how nineteenth century geologists interpreted the fossil evidence will remain relatively tenuous. In recent years Rudwick has done much work to marry the narratives of the development of stratigraphic knowledge with interpretation of fossil evidence for the early nineteenth century, but he has only brought this narrative up to the mid-1840s.[451] For the critical years between 1859 when Darwin published *Origin of Species* and his death in 1882, we don't have well established historiographies that explore normative opinions of how British geologists actually understood Darwin's work. Any attempts that have been

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[449] Adrian Desmond, *Archetypes and Ancestors: Palaeontology in Victorian London 1850-1875* (London: Blond & Briggs, 1982) and Peter Bowler, *Life's Splendid Drama: Evolutionary Biology and the Reconstruction of Life's Ancestry, 1860-1940* (Chicago: The University of Chicago Press, 1996).

[450] Here I am discussing the sequence of books, the first of which was Rudwick's *The Great Devonian Controversy* is already cited in Chapter 3. The two remaining books are James Secord, *Controversy in Victorian Geology: The Cambrian-Silurian Dispute* (Princeton: Princeton University Press, 1986) and David Oldroyd, *The Highlands Controversy: Constructing Geological Knowledge through Fieldwork in Nineteenth-Century Britain* (Chicago: The University of Chicago Press: 1990).

[451] In this case, I am referring to two books by Rudwick: Martin Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: The University of Chicago Press, 2005) and Martin Rudwick, *Worlds before Adam: The Reconstruction of Geohistory in the Age of Reform* (Chicago: The university of Chicago Press, 2008).

made to characterize this opinion, therefore, are based on disturbingly tenuous evidence. The fact that the leading European fish paleontologist, Agassiz, believed that fish fossils disproved evolution and that the leading British stratigrapher, Roderick Murchison, believed him, suggests that in 1859 Darwin's evolutionary ideas, were being presented to a less receptive geological community than is clearly emphasized in many accounts of the development of evolutionary ideas in the nineteenth century.[452] By the mid-nineteenth century, membership within the Geological Society of London was quite large, but we only have clearly established accounts of the reception of his work from a few of Darwin's leading supporters, such as Lyell and Huxley, and a few of his leading opponents, men like Owen, Agassiz, Sedgwick, and Murchison.

As it has been told up to now, the story of mid to late-nineteenth century British paleontology, has been given from a skewed perspective. In order to reorient the narrative to one that best represents the interests and needs of the paleontological community from that era, the best place to start would be by providing an account of the work done in the nineteenth century to identify and stratigraphically account for the most important index fossils. Who were the fossil experts that British stratigraphers turned to help determine how individual stratigraphic layers fit into geological history? Which plant and animal fossils

[452] Books like Sandra Herbert, *Charles Darwin, Geologist* (Ithaca: Cornell University Press, 2005) and Mott Green, *Geology in the Nineteenth Century: Changing Views of a changing World* (Ithaca: Cornell University Press, 1982) indicate that Darwin's ideas were not initially part of mainstream geological thinking. But it is doubtful that these books are widely read outside the circle of scholars who do dedicated research in nineteenth century geology and natural history. There are more popular works such as those written by authors such as Stephen Jay Gould that suggest that Darwin's ideas were readily adopted by scientist who were contemporary to Darwin. In the opening of the book Ronald Number, *The Creationists: The Evolution of Scientific Creationism* (New York: Alfred A. Knoff, 1992), 11 Number's indicates that by the late nineteenth century very few American geologists believed in six literal days of creation or Noah's flood, but these aspects of Biblical geology had been suspected in Europe long before Darwin published *Origins*. But it should be understood that opposition to Darwin's views took many forms, and there is reason to suspect that less extreme examples of opposition within the geological community are likely to have flourished for some time after Darwin's publication.

revealed the most about the history of life? We have some idea of the most important invertebrate fossils that served as indices to the history of life were mollusk shells, which were abundant and characteristic to specific stratigraphic layers. And in the process of working on my dissertation it became clear to me that the most important vertebrate fossils were those of fish. Since the fossils from the other classes of vertebrate organisms were almost entirely confined to Tertiary and Quaternary layers, they could only be used to help define some of the youngest geological strata. Once the story of these important index fossils is better known, then historians of nineteenth century geology and natural history will be in a better position to understand how Darwin's ideas about the history of life were generally received by members of the geological community of his day. Index fossils are important elements of the vocabulary of nineteenth century paleontology. Without this language, the story becomes stilted.

Development of Stratigraphic Knowledge

Over the course of the 1830s and 1840s, geologists increasingly came to recognize that fossils could help define the stratigraphic layers, and in the process also helped reconstruct the history of life. It was the paleontological work that helped define stratigraphy, that was of greatest importance to the community of geologists during this period in history.[453] As the most ancient vertebrate group to be found in the fossil record, Agassiz's activity as a fish paleontologist made his contribution eminently valuable to European stratigraphers. So, Agassiz's work was directly supportive of paradigmatic activity during the time he was working on this project. His contribution to paleontology helped clarify understanding of an important

[453] Herbert, *Charles Darwin, Geologist*, 82-87.

controversy relating to fossils and stratigraphy that culminated in the 1830s and 1840s, and had considerable bearing on how fish fossils were interpreted through much of the nineteenth century.

As an historian of the earth, Cuvier used fossils instead of human artifacts to help tell the story of the earth's distant past. Although Cuvier rejected the concept of unlimited time, like many savants of his generation, Cuvier embraced the concept of deep time. Cuvier envisioned earth's history as consisting of long periods of calm, whose evidence was recorded in thick rock beds with well-preserved fossils. Cuvier believed the stratigraphic record also displayed evidence of geologically brief periods of violent change.[454]

In *The Great Devonian Controversy*, Martin Rudwick explored changing perceptions of the stratigraphic record and the role fossils played in geological understanding through the scientifically contentious decades of the 1830s - 1840s. Rudwick asserted that by the time of Cuvier's death in the early 1830s that, "all geologists were well aware that the structural sequence of the strata also represented a temporal sequence of past events."[455] Geologists of the 1830s were reluctant to estimate the age of the earth in firm quantitative terms, for fear of being accused of groundless speculation. Nonetheless, the thickness of layers of strata were assumed to be reliable indicators of the relative length of successive periods. By the early nineteenth century, geologists demonstrated interest not only in local geological phenomena, but recognized the potential for correlation among geographically distant sequences of strata.

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[454] Rudwick pointed out that these revolutions "were often treated as analogous to the traumatic political Revolution in France, which was still fresh in the collective memory of all Europeans." See Rudwick, *Worlds Before Adam*, 13.
[455] Rudwick, *Great Devonian Controversy,* 42.

Over the course of the eighteenth century, geologists had come to recognize three main stratigraphic categories: the Primary, Secondary, and Tertiary layers. These layers were initially distinguished by variations of mineral content and structure as well as fossil content.[456] Regarding the antiquity of the earth, Rudwick stated, "This new and exciting vista into the history of the earth was no fantasy devised by skeptical philosophers to confound the faithful; it was vouched for by leading geologists of impeccable piety as a disclosure that ought to evoke an enlarged sense of awe at the scale and diversity of the created world."[457] Rudwick further discussed the perceptions of nineteenth century geologists regarding the utility of the geological record to determine the history of the earth. He stated, "They claimed that the history of the earth and its inhabitants could be deciphered by learning to read 'the record of the rocks,' and that the succession of layers of strata in the earth's crust were Nature's own historical documents. Imperfect the record might be, but deceptive it was not. Correctly interpreted much of the history seemed plain and straightforward."[458]

The story of the controversy was largely followed through the work of three British geologists: Henry De La Beach (1796-1855), Roderick Murchison (1792-1871) and Adam Sedgwick (1785-1873), although many prominent British and Continental geologists of the era made some contribution to the debate. During the mid-1830s De La Beach started a geological survey in the county of Devon, located in southwest England, and as a result made claims about geological formations and their associated fossils that contradicted Murchison's expectations of the geological record. Murchison called the validity of De La Beach's survey into question,

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[456] Ibid, 42-56.
[457] Ibid, 4.
[458] Ibid.

setting into motion a debate that did not subside until the early 1840s. The issue at stake was the chronology and contents of what were believed to be some of the oldest fossil bearing rocks found in the geological sequence. It took years to bring the controversy to a state of consensus, and geologists on both sides of the argument had to make multiple reinterpretations of their work, in order to come to satisfactory representations of the geological landscape of Britain and the Continent. But by the early 1840s, as the controversy drew to a close, geologists were beginning to confirm that the geological record exhibited comparable formations across the globe and that characteristic fossils served as a reliable means of identifying these formations, when they could be found.[459] During this time, Agassiz examined most of the known fish fossils in Europe in the process of preparing a work on the subject.[460]

The controversy between Murchison and De La Beach was resolved through the recognition that a previously unrecognized fossil layer separated the younger Carboniferous layer of the stratigraphic column from the older, deeper Silurian layer. This intermediate layer, frequently identified as the Old Red Sandstone, was eventually accorded the name, Devonian. But as one controversy was subsiding, a new one flared up between the long-term friends and geologizing companions, Sedgwick and Murchison. In the 1830s, both geologists had conducted surveys in Wales, Sedgwick in the north and Murchison in the south. Initially, they viewed their projects as non-competitive, since Murchison was intent on defining the Silurian system, and Sedgwick was attempting to identify the Cambrian layer of the stratigraphic record.

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459 This narrative provides a broad overview of the story presented in *The Great Devonian Controversy*.
460 Ibid, 390-391.

In 1834 the two geologists had conducted a joint survey dividing territory and the fossil record between them.[461] It was close to a decade before they discovered that the portions of the fossil-record they were examining were largely overlapping, leading to what eventually turned into a bitter priority dispute. Through the 1840s to the mid-1850s, examination of fossil finds across Europe did not seem to yield anything below the Silurian layer. During this time Murchison expanded his definition of the Silurian system, claiming a distinctly primordial position within the stratigraphy. Only with the identification of a few sights such as May Hill in Gloucester, England, did nineteenth century European stratigraphy begin to yield fossils predating the Silurian era. Although Sedgwick attempted to claim such fossils for the Cambrian period, even these fossils were eventually relegated to the Ordovician Period which immediately proceeded Silurian specimens in the fossil record. The compromise represented by identifying these fossils as "Ordovician" was initially proposed in an 1878 paper by Charles Lapworth (1842-1920), a few years after the deaths of both Sedgwick and Murchison.[462]

This brief outline of the development of European geology to the middle third of the nineteenth century helps provide the context necessary to understand the significance of Agassiz's contribution to fish paleontology. However, in order to more fully appreciate the place Agassiz played within the scientific community of Europe during the first half of his career, one must also take into consideration the shape of Agassiz's education and career. In the next section, I will provide a brief biography of the first portion of Agassiz's career.

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[461] Secord, *Controversy in Victorian Geology*, 80-90.
[462] Ibid, 307. Secord provides a description of Lampworth's Ordivician proposal.

Agassiz: Education and European Career

Born nearly 38 years after Cuvier on May 28, 1807, Louis Agassiz belongs firmly to the generation of Charles Darwin (1809-1882) and Asa Gray (1810-1888). Nonetheless, there are number of similarities to Agassiz's story and that of Cuvier, placed him in greater sympathy with the views of the older naturalist than those of these two contemporaries. To start with, Agassiz, like Cuvier, was of Swiss Protestant descent, and received a portion of his early formal education within the German-speaking provinces. In Agassiz's case he received training in both Heidelberg and Munich. Like Cuvier, Agassiz was an accomplished linguist, with knowledge of French, German, Greek, Latin, Italian, and English. And perhaps most importantly, in the early years of his career, Agassiz corresponded and came to work with Cuvier, during the final year of his life, with the result that Cuvier conceded the work of cataloging fish fossils to the ambitious young naturalist.[463] Between the ages of 15-23 Agassiz attended universities in Heidelberg and Munich for medical studies. The level of support that Agassiz was able to win from his teachers, scientific and literary colleagues, students, and the public at large, shows that Agassiz must have possessed considerable personal charisma. The correspondence existing between Agassiz and Alexander von Humboldt, indicates that Humboldt did not merely like Agassiz, but took an almost paternal interest in his career.[464]

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[463] General biographical information for Louis Agassiz in this dissertation is drawn from two main sources. The two-volume biography written by Agassiz's wife provides a balanced narrative, giving equal weight to Agassiz's education and career as described in the first volume, with his American career described in the second volume: Elizabeth Cary Agassiz, *Louis Agassiz: His Life and Correspondence* (London: Forgotten Books, 2015), Volume 1&2. Edward Lurie spends more time discussing Agassiz's time in the United States, but there is still a reasonably descriptive account of Agassiz's education and work in Europe as well. Edward Lurie, Louis Agassiz: A Life in Science (Chicago: The University of Chicago Press, 1960).

[464] Examples of the warm correspondence that existed between Agassiz and Alexander Von Humboldt is provided in the biography written by Agassiz's second wife. Cary Agassiz, *Louis Agassiz*, Vol. 1, 187-188 and 222-229.

In Germany, Agassiz studied biology and allied subjects from a number of distinguished professors. At Heidelberg, where he studied between 1826-1827, Agassiz was introduced to the subject of embryology by the prominent anatomist, Friedrich Tiedemann (1781-1761). It was through Tiedemann that Agassiz first became acquainted with recapitulation theory, an idea that exerted a lasting impression on the young naturalist.[465] He also met fellow students, Alexander Braun (1805-1877) and Karl Schimper (1803-1867), two young botanists who also did much to shape his intellectual development during this stage of his life. Among the topics they discussed were Goethe's ideas concerning the metamorphosis of plants. In 1827, Agassiz continued his studies in Munich, Agassiz came in intimate contact with the teaches of *Naturphilosophie* by studying with the naturalist Lorenz Oken (1779-1851) and the philosopher Friedrich Wilhelm Joseph Schelling (1775-1854). He also received further training in embryology from Ignatius Döllinger, the same professor who trained Karl Ernst von Baer (1792-1876). This association influenced Agassiz's concepts of development through the entire length of his career. "He discovered for himself what Döllinger and Von Baer already knew, that certain forms of animals resemble one another in their embryonic state. Observing the growth of the egg of various kinds of mammals, he also learned to compare different stages of embryonic growth. His experiences here had a lasting effect upon Agassiz's conceptualization of the method and purpose of natural history. Although at different phases in his career he was paleontologist, ichthyologist, or geologist, the science of embryology held such fascination for him that he returned time and again to it."[466]

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[465] Lurie, *Louis Agassiz*, 22.
[466] Ibid, 37.

While still a student at Munich, in May 1829, the same month he turned twenty-two, Agassiz experienced his first authorial success with the publication of the first volume of *Selecta genera et species piscium*. This work, which described fish indigenous to Brazil, was based on the Brazilian travels that one of Agassiz's teachers. The botanist Carl Friedrich Philipp von Martius (1794-1868) had traveled in Brazil with the German biologist, Johann Baptist von Spix (1781-1826). Spix died in 1826, leaving many of the fish specimens collected during that journey undescribed. In the spring of 1828, Martius requested that Agassiz complete the work. With an eye to his future career, Agassiz dedicated this work to Georges Cuvier, and he used this occasion to initiate a correspondence with the celebrated naturalist. That same May, Agassiz completed written examinations in the subject of vertebrate and invertebrate comparative anatomy achieving a doctorate in natural history, so that his degree could be included on the title page of the work on Brazilian fish. The second volume of this work was published two years later in 1831.[467]

By the time Agassiz completed his first volume of *Selecta genera et species piscium* and earned his PhD in natural history, he had lost interest in his medical studies, if they had ever actually served as more than an excuse to study natural history. However, the correspondence from his mother and father expressed considerable anxiety over Agassiz's desire to abandon medicine, and they insisted he complete his medical degree in Munich. Agassiz acquiesced to his parent's expectations. In April 1830, Agassiz took and passed the oral and written examinations required to complete his medical degree, and by December of the same year he

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[467] A description of Agassiz's educational activities and early experience of a naturalist between the years of 1827-1832 can be found in the second chapter of Lurie's book. Lurie, *Louis Agassiz*, 31-71.

ended his studies at Munich. While finishing his medical degree, Agassiz had begun to study paleontology, laying the foundation for his next major publication. A modest correspondence between Agassiz and Cuvier between 1829 - 1831 helped prepare the way for a visit to the Museum of Natural History in Paris. In the fall of 1831, Agassiz and his friend Braun began a tour of natural history museums in Germany, which ended in December, when arrived in France to meet Cuvier. Agassiz made a sufficiently favorable impression on the older naturalist that Cuvier conceded the project of describing fish fossils, despite the fact that he had begun a similar project. His generosity extended to Agassiz the opportunity not only to work in the museum's collections but also to view Cuvier's own notes and drawings on the subject. Agassiz was able to spend nearly six months in the company of the famous naturalist, before Cuvier's death in May of 1832. After Cuvier's death, the publisher of Cuvier's series on fish invited Agassiz to join with Achille Valenciennes to help complete the series. Ultimately, however, instead of accepting this offer, Agassiz chose to return to Switzerland to teach at the university at Neuchâtel.[468]

***Recherches sur les poissons fossiles*: Assessing Agassiz's Contribution to Fish Paleontology**

Between 1833 and 1843, Agassiz began publishing installments of the results of his fish fossil work, the material that would eventually be organized into the multi-volume work known as *Recherches sur les poissons fossiles*. A survey of recent literature in the field of geological history or recent biographical work on Louis Agassiz, leave some question regarding the significance of this work. Martin Rudwick's weighty book on the development of European

[468] Ibid.

geology, *Worlds Before Adam*, which picks up its narrative in the late 1810s and ends in 1845, only devotes roughly a third of a chapter to the topic.[469] Mott Green's book *Geology in the Nineteenth Century*, only mentions Agassiz's work within the context of glacial and mountain theories.[470] Recent biographies such as Christopher Irmscher's *Louis Agassiz: Creator of American Science* and Mary Winsor's *Reading the Shape of Nature* both focus much more substantively on the second half of Agassiz's career in the United States from 1846 until his death in 1873.[471] To be fair to Irmscher, he does spend some time discussing Agassiz's early career in Europe, but again most of this material is devoted to Agassiz's contributions to glacial theory and he devotes even less time to Agassiz's fossil fish than Rudwick.[472] Rudwick does periodically mention Agassiz's fish fossil work in *The Great Devonian Controversy*, but as the narrative primarily follows the course of this controversy through the careers of British geologists, Agassiz is again primarily assigned a peripheral role within this context as well.[473]

To really gain a better sense of the significance of Agassiz's fish fossil work, one must look to older biographies of Agassiz. In Alexander Lurie's work *Louis Agassiz: A Life in Science*, one can find a more coherent portrait of the importance of Agassiz's early career, though even

[469] Rudwick, *Worlds Before Adam*, 437-441. Rudwick starts out chapter 30 with a description of Agassiz's fish fossil work, before considering additional paleontological and stratigraphical work by John Philips, Sedgewick, and Murchison.
[470] Green, *Geology in the Nineteenth Century*. Green briefly mentions Agassiz in relation to glacial theory on page 73 and mountain theory on page 153.
[471] As Mary Winsor's book is exclusively focused on work Agassiz did in the United States, she never even mentions Agassiz's fish fossil research in Europe: Mary Winsor, *Reading the Shape of Nature: Comparative Zoology at the Agassiz Museum* (Chicago: The University of Chicago Press, 1991).
[472] On page 59 Irmscher indicates that Agassiz's first wife help to illustrate *Recherches sur les poisons fossiles* and on page 63 he indicates Agassiz was considering if he should only attempt to print 150 copies of the book. See Christoph Irmscher*, Louis Agassiz: Creator of American Science* (Boston: Houghton Mifflin Harcourt, 2013).
[473] Rudwick discusses Agassiz's importance in asserting that stratigraphic layers could be better identified through the types of fossils found in them than through their mineral composition. See Rudwick, *Great Devonian Controversy*, 102-103

this book devotes over two-thirds of its length to Agassiz's American career. Of this work Lurie indicates, "These volumes were the first modern effort to depict this significant branch of paleontology. No other research or publication effort by Agassiz ever equaled the talent he displayed in this depiction and analysis of over 1,700 species of ancient fishes. This remarkable contribution to natural history was the primary inspiration for a new area of inquiry in the history of organic creation. Agassiz's work was so singular and definitive that its scope and originality were not matched until late in the nineteenth century."[474] Lurie further indicates the significance of this work by mentioning the high praise of Agassiz that the Reverend Adam Sedgwick communicated to Charles Lyell. He stated, "In France, Germany, and England, natural scientists of such rank and differing views as Elie de Beaumont, Alexandre Brongniart, Achille Valenciennes, Leopold von Buch, Humboldt, Bronn, William Buckland, and Sir Roderick Murchison joined in the swelling chorus of praise for Agassiz's achievement. The Geological Society of London, the British Association for the Advancement of Science, the Royal Society of London, the Academy of Sciences of the Institute of France, the Prussian monarchy, and an impressive number of local scientific societies all honored Agassiz with grants, prizes, medals, and similar marks of distinction in recognition of this contribution."[475]

A more intimate portrait of the influence of this and other work Agassiz completed while living in Europe, can be found in the biography by his wife Elizabeth Cary Agassiz, *Louis Agassiz: His Life and Correspondence* (1885). This biography is largely epistolary in nature, with the bulk of the text being made up of letters between Agassiz, his scientific colleagues, friends,

[474] Lurie, *Louis Agassiz*, 78-79.
[475] Ibid, 79-80.

and family members. The text includes correspondence with such notable members of the scientific community as Georges Cuvier, Alexander von Humboldt, Buckland, Charles Lyell, Sir Philip Egerton, Edward Frobes, Roderick Murchison, Charles Darwin, Adam Sedgwick, and Charles Bonaparte, Prince of Canino. This correspondence demonstrating the high regard that Agassiz enjoyed among his scientific colleagues within the European scientific community. The full first volume of the two-part work, which extends to 400 pages, is devoted exclusively to Agassiz's early life and career in Europe, and it provided a more lengthy account of Agassiz's education and work during this part of his life than can be found in subsequent accounts. While the second volume does focus on Agassiz's time in the United States, the correspondence in this work demonstrated that Agassiz maintained active communication with his former European colleagues through the entire extent of his life.

A further sense of Agassiz's contribution can be seen in the work of his contemporaries such as the naturalist, Hugh Miller. In *The Old Red Sandstone: Or New Walks in Old Field* (1851), Miller talks of Agassiz's fossil work in glowing terms. In his book, Miller stated the following comment regarding fossil fish:

> Of these, the greater part yet discovered have been named by Agassiz, the highest authority as an ichthyologist in Europe or the world, and in whom the scarcely more celebrated Cuvier recognized a naturalist in every respect worthy to succeed him. The comparative amount of the labors of these two great men in fossil ichthyology, and the amazing acceleration which has taken place within the last few years in the progress of geological science, are illustrated together, and that very strikingly, by the following interesting fact—derived directly from Agassiz himself, and which must be new to the great bulk of my readers. When Cuvier closed his researches in this department, he had named and described, for the guidance of the geologist ninety-two distinct species of fossil fish; nor was it then known that the entire geological scale, from the Upper Tertiary to the Grauwacke inclusive, contained more. Agassiz commenced his labors; and in a period of time little exceeding fourteen years, he had raised the number of

> species from ninety-two to sixteen hundred. And this number, great as it is, is receiving accessions almost every day.[476]

Agassiz held close collegial connections to a number of active participants within the Great Devonian Controversy. By the mid-1830s, once word got around that Agassiz was busily working on assembling work on fossil fish, British geologists were eager to invite the young naturalist to come inspect the fossils in their collections. In December of 1833, Buckland wrote to Agassiz inviting him to England to view such fossils. Buckland indicated that he wished to show Agassiz "what few materials I possess in the Oxford Museum relating to fossil fishes, and am also desirous that you should see fossil fish in the various provincial museums of England, as well as in London. Sir Philip Egerton has a very large collection of fishes from Engi and Oeningen, which he wishes to place at your disposition. . . . What I would propose to you as a means of seeing all the collections of England, and gaining at the same time additional subscriptions for your work, is, that you should come to England and attend the British Association for the Advancement of Science in September next."[477]

In *The Great Devonian Controversy*, Rudwick discussed a progress report by Louis Agassiz that was read in his absence at the 1842 British Association meeting:

> Summarizing some eight years' work on many fine collections, Agassiz reported that all the species and most of the genera of the fish were known only from the Old Red Sandstone itself. He claimed that the remarkable diversity and elaboration of the fish in this, almost their earliest known occurrence, was a 'great argument against the theory of the successive transformation of species and the descent of all the theory of all living organized beings from a small number of primitive forms' . . . He 'startled his compeers,' however, with the further claim that each such formation had a completely distinct fauna, sharply divided from those older and younger, bearing witness to

[476] Hugh Miller, *The Old Red Sandstone: Or New Walks in an Old Field* (Lexington: Forgotten Books, 2012), 32.
[477] Cary Agassiz, *Louis Agassiz* Vol. 1, 232.

> frequent episodes of sudden extinction and new creation of species."[478] Responding to Agassiz's assessment, "Murchison, Sedwick, De la Beche, and Phillips all spoke up in turn, insisting that many species of fossils had much longer ranges in time than Agassiz allowed. There might be no sympathy for any Lamarckian fantasy of the transmutation of species, but at least among leading British geologists there was now a virtual consensus that faunal change had taken place in a piecemeal fashion. . . . For the Devonian had broken down the almost complete contrast between what had previously seemed to be two distinct major faunas, the Silurian and the Carboniferous, and had replaced it with a nuanced transition that was now taken as a model for the whole fossil record.[479]

In the last section of *Worlds Before Adam*, Rudwick discussed the state of knowledge of paleontology in the 1830s and 1840s. Rudwick contends that by the later part of the 1830s Agassiz's work on fossil fish helped promote a progressive understanding of the fossil record. He stated that, "Agassiz's massive work added powerful support to the opinion of almost geologists other than Lyell, that fossils provided a broadly reliable record of a clearly directional history of life. . . . As Agassiz himself put it emphatically, his latest detailed research was confirming—in the case of fish—the great principle 'of the progressive and organic development of life on earth.'"[480]

In the case of Agassiz, the result of the closure of the Great Devonian Controversy was to fix in his mind the extreme antiquity of the first appearance fish in the fossil record. This interpretation was revealed in Agassiz's 1857 text *Essay on Classification*. In this work Agassiz stated, 'It was formerly believed by geologists and paleontologists that the lowest animals first made their appearance upon this globe and that they were followed by higher and higher types, until man crowned the series. Every geological museum, representing at all the present

[478] Rudwick, *Great Devonian Controversy*, 390.
[479] Ibid.
[480] Rudwick, *Worlds Before Adam*, 440.

state of our knowledge, may now furnish the evidence that this is not the case."[481] As evidence to back up this claim Agassiz referenced a number of works from geologists of his time, such as Rodrick Murchison's *The Silurian System* (1839) and *Siluria*: *The History of the Oldest Known Rocks Containing Fossils* (1854) and ending his list with Adam Sedgwick and Frederick McCoy's book, *A Synopsis of the Classification of the British Palaeozoic Rocks* (1855). At the heart of Agassiz's interpretation was the idea that fish fossils were found in the deepest reaches of the fossil record, meaning that all four of Cuvier's branches of the animal kingdom appeared virtually simultaneously in the fossil record. Based on this understanding Agassiz believed, "Moreover, for the last twenty years every extensive investigation among the oldest fossiliferous rocks has carried the origin of the Vertebrate step by step further back, so that whatever may be the final solution of this vexed question, so much is already established by innumerable facts, that the idea of a gradual succession of Radiata, Mollusks, Articulate, and Vertebrata is forever out of the question."[482]

Agassiz's Response to the Cuvier-Geoffroy Debate

Appel says little about Agassiz and his response to the Cuvier-Geoffroy debate, although what she does mention indicates that Agassiz had an interesting position as spectator to Cuvier's parting remarks. The active debate had ceased in 1830, but Cuvier still made pointed comments in his writings and at public speaking engagements. Agassiz was present for the last portion of Cuvier's lecture series on the history of the natural sciences, given in the opening

[481] Louis Agassiz, *Essay on Classification*, Edited by Edward Lurie (Cambridge, MA: The Belknap Press of Harvard University Press, 1962), 26.
[482] Agassiz, *Essay on Classification*, 27.

months of 1832. Of this experience Appel says, "Alexander von Humboldt whispered criticism of the lectures into the ear of his young protégé Louis Agassiz, seated beside him. He defended unity of composition and his countrymen against Cuvier's slurs."[483] Agassiz's experience of the debate was mediated both through his German education and through his half year apprenticeship with Cuvier. In its final manifestation, we can see Agassiz wrestled with related issues in his opposition to Darwinian evolution.

In the early stages of his intellectual development, Agassiz's encounter with concepts relating to unity of composition came through his study with Oken rather than familiarity with Geoffroy. While Agassiz was a student, Oken made a lively impression on him. During a convalescence in the spring of 1827, while recovering from typhus fever, Agassiz wrote a letter to his friend Braun expressing something of these sentiments. "I am often busy too with Oken. His 'Naturphilosophie' gives me the greatest pleasure."[484] Later in life, Agassiz took a more empirically cautious stance, his youthful enthusiasms were tempered both by his apprenticeship with Cuvier, and decades of working closely with fossils, preserved, and live specimens, in the laborious task of providing taxonomic descriptions, observing behavior, and describing embryological development.

In the early part of the career, one can gain some insight into Agassiz's developing understanding of the issues at stake in the initial volume of *Researches on the Fossil Fishes* (1833). In this work, Agassiz committed himself to Cuvierian *embranchements*, which he identified as the "four great types of the animal kingdom: Radiates, Mollusks, Articulate, and

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[483] Toby Appel, *The Cuvier-Geoffroy Debate: French Biology in the Decades before Darwin* (New York: Oxford University Press, 1987), 170.
[484] Cary Agassiz*, Louis Agassiz* Vol. 1, 34.

Vertebrates."[485] Agassiz also introduced his concept of the prophetic type. Through this non-evolutionary concept, Agassiz recognized features of organisms in earlier portions of the fossil record that seem to anticipate organisms that will be created at later stages in the progression of life. He also identified what he believed were analogies between "embryological phases of the higher present fishes and the gradual introduction of the whole type on earth, the series in growth and the series in time revealing a certain mutual correspondence."[486] In his preface Agassiz stated, "I have succeed in expressing the laws of succession and of organic development of fishes during all geological epochs; and science may henceforth, in seeing the changes of this class from formation to formation, follow the progress of organization in one great division of the animal kingdom, through a complete series of the ages of the earth."[487]

In her biography of Agassiz, his wife Elizabeth hastened to point out regarding this passage, "This is not inconsistent with his position as the leading opponent of the development of Darwinian theories. To him development meant development of plan as expressed in structure, not the change of one structure into another. To his apprehension the change was based on intellectual, not material causes."[488] Later in the same text, Agassiz more clearly stated his opposition to evolution, as developed through his analysis of fossil fish. "More than fifteen hundred species of fossil fishes, which I have learned to know, tell me that species do not pass insensibly into one another, but that they appear and disappear unexpectedly, without direct relations with their precursors; for I think no one will seriously pretend that the

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485 Ibid, 240.
486 Ibid, 239.
487 Ibid, 243.
488 Ibid, 243-244.

numerous types of Cycloids and Ctenoids, almost all of which are contemporaneous with one another, have descended from the Placoids and Ganoids. As well might one affirm that the Mammalia, and man with them have descended directly from fishes. All these species have a fixed epoch of appearance and disappearance; their existence is to an appointed time. And yet they present, as a whole numerous affinities more or less close, a definite coordination in a given system of organization which has intimate relations with the mode of existence of each type, and even of each species. An invisible thread unwinds itself throughout all time, across this immense diversity, and presents to us as definite result, a continual progress in the development of which man is the term, of with the four classes of vertebrates are intermediate forms, and the totality of invertebrate animals are the constant accessory accompaniment."[489]

Agassiz's final pronouncement on evolution can be found in the magazine article "Evolution and Permanence of Type" that was published a few months after his death. Even though this piece was written shortly before his death, Agassiz framed his argument within the context of the intellectual contributions of individuals from Europe who were important to his early intellectual formation. The article opened with the following paragraph: "In connection with modern views of science we hear so much of evolution and evolutionists that it is worth our while to ask if there is any such process as evolution in nature. Unquestionably, yes. But all that is actually known of this process we owe to the great embryologists of our century, Döllinger and his pupils K. E. von Baer, Pander, and others—the men in short who have founded the science of Embryology. It is true there are younger men who have done since, and are

[489] Ibid, 244-245.

doing now, noble work in this field of research; but the glory must, after all, be given to those who opened the way in which more recent students are pressing forward."[490]

In an act of linguistic sleight of hand that is likely to be missed by readers unfamiliar with German or unacquainted with his familiarity with the language, Agassiz chose to associate the English term "evolution" with the German term "entwicklung" and selected only the embryological meaning of development. With this selection he asserted his belief in evolution, while sidestepping the more scientifically contentious Darwinian definition of the term. Agassiz stated, "In the present ferment of theories respecting the relations of animals to one another, their origin, growth, and diversity, those broader principles of our science—upon which the whole animal kingdom has been divided into a few grand comprehensive types, each one a structural unit in itself—are completely over-looked."[491]

Agassiz identified Cuvier as the first naturalist to practice natural classification based on four structural body plans found in the animal kingdom. He attributed additional significance to a four-part system, when he discussed the work of Karl Ernst von Baer as a worker who identified four modes of growth among animals. Agassiz indicated that, "Every living creature is formed in an egg and grows according to a pattern and a mode of development common to its type, and of these embryonic norms there are but four."[492] Agassiz believed it significant that these two investigators, who were not in communication with each other and were studying different aspects of organismal classification and development, should come to similar

[490] Louis Agassiz, "Evolution and Permanence of Type," In *The Intelligence of Louis Agassiz: A Specimen Book of Scientific Writings: Selected, with an introduction and notes, by Guy Davenport, Forward by Alfred S. Romer* (Boston: Beacon Press, 1963), 215.
[491] Agassiz, "Evolution and Permanence of Type," 216.
[492] Ibid, 216-217

conclusions. Agassiz stated, "Staring from diametrically opposite points, they met at last on the higher ground to which they were both led by their respective studies."[493]

Agassiz's Final Assessment of Darwin's Evolutionary Theory

Agassiz took a cautiously respectful tone in his discussion of Darwin's ideas, and framed them within the context of unity of composition, which he pointed out was an idea that did not originate with Darwin. "This idea is not new. Under different aspects it has been urged repeatedly for more than a century by DeMaillet, by Lamarck, by E. Geoffroy St. Hilaire and others; nor was it wholly original even with them, . . ."[494] However, Agassiz granted, "But Darwin has placed the subject on a different basis from that of all his predecessors, and has brought to the discussion a vast amount of well-arranged information, a convincing cogency of argument, and a captivating charm of presentation."[495] Agassiz also granted that Darwin addressed the subject according the best scientific methods, although he indicated that Darwin overstepped the bounds of actual scientific knowledge, relying on his imagination to fill in this deficiency.

At this point, Agassiz went on to make a comparison between Darwin's ideas in *Origin of Species* with those found in Oken's *Naturphilosophie*. Agassiz presents Oken as a cautionary tale of ideas that attracted a great deal of initial enthusiasm, but in the course of the half

[493] Ibid, 217.
[494] Ibid, 219.
[495] Ibid.

century that had elapsed since then had become, "numbered now among the exploded theories of the past."[496]

Agassiz did not limit his discussion of Darwin's work to *Origin of Species*, but made a range of positive and negative critiques of *The Variation of Animals and Plants Under Domestication*, *The Descent of Man*, and *The Expressions of Emotions in Man*. In his discussion of *The Descent of Man*, Agassiz made a comment that revealed his paleontological perspective of Darwin's work, "But here again the reader seeks in vain for any evidence of a transition between man and his fellow creatures. Indeed, both with Darwin and his followers, a great part of the argument is purely negative. It rests partly upon the assumption that, in the succession of ages, just those transition types have dropped out from the geological record which would have proved the Darwinian conclusions had these types been preserved, and that in the living animal the process of transition is too subtle for detection. Darwin and his followers thus throw off the responsibility of proof with respect both to embryonic growth and geological succession."[497]

Agassiz discussed the claim of the Russian naturalist Kowalevsky, that in the Ascidian he had found a transitional form between Mollusks and Vertebrates. In order to provide the context of the claim, Agassiz explained that during an early developmental stage, the Ascidian exhibited a string of cells that resemble the Vertebrate dorsal cord. Agassiz, however, pointed out an argument rejecting this claim written by von Baer. The basis of von Baer's rejection of the relationship of the string of cells in Ascidians that resembled the dorsal nerve cord of

[496] Ibid, 220.
[497] Ibid, 222-223

Vertebrates is in Ascidians this structure is actually ventrally located and so does not represent a true homology. Agassiz asserted that believing such a transposition of this structure between Vertebrates and their ancestral forms is unreasonable.[498]

Toward the end of the article, Agassiz called on his familiarity with fossil fish and their position within the geological column to build his final argument against evolution. He pointed out that the earliest known vertebrates in the fossil record are Selachians, which he identified as sharks and their allies, and Ganoids, which he identified with garpikes. He claimed the these fishes, whose fossil remains can be found in Silurian and Devonian deposits, are more advanced structural forms than fishes such as Amphioxus, Myxinoids, and Lampery-eels, which are not found in the fossil record to similar antiquity, although he does admit a lack of hard parts in these organisms may have prevented their preservation. Still, he argued that, "The presence of the Selachians at the dawn of life upon earth is in direct contradiction to the idea of a gradual progressive development. They are nevertheless exceedingly abundant in Palaeozoic beds, and these fossil forms are so similar to the living representatives of the same group that what is true of the organization and development of the latter is unquestionably equally true of the former."[499]

"Evolution and the Permanence of Type" was meant to be just the first in a series of articles in which Agassiz intended to continue to build on his argument against Darwinian evolution. However, Agassiz died before he could continue the series. Consequently, we are left with his closing remarks in this first article as the primary indication of how he would have

[498] Ibid, 223-224.
[499] Ibid, 230.

continued with his argument. He concluded, "I hope in future articles to show, first, that, however broken the geological record may be, there is a complete sequence in many parts of it, from which the character of the succession may be ascertained; secondly, that, since the most exquisitely delicate structures, as well as embryonic phases of growth of the most perishable nature, have been preserved from the very early deposits, we have no right to infer the disappearance of types because their absence disproves some favorite theory; and, lastly, that there is no evidence of direct descent of later from earlier species in the geological succession of animals."[500]

In Agassiz's mind a rational understanding of the relationships that existed in comparative anatomy could only be achieved through combining information from comparative anatomy, embryology, and paleontology.[501] He believed that it was through the comparison of embryology and the geological record one came to understand the progressive development of life, both as experienced by the individual changes that a young organism underwent, and as seen through the history of life. To understand Agassiz's perspective, it is important to recognize his theistic commitments, because within his scheme of thinking, the development of life was understood within the fossil record depended on the periodic intervention of God, since he believed that the a series of catastrophic events had occurred over the course of deep time, which had completely wiped out life on earth.[502] After each of these events, God recreated a community of organisms, similar to, but for the most part more advanced than

[500] Ibid, 232
[501] This is a central argument that he made in his Lowell Lecture series that he presented in 1848-1849.
[502] Numbers provides a brief discussion of Louis Agassiz's resistance to evolution and interpretation of the fossil record. See Ronald Numbers, *he Creationists*, 7.

those found in the proceeding stratigraphic layer of the fossil record. One can see a certain equivocation regarding the nature of progress when comparing his position before Darwin published *Origin of Species* and afterwards, in his final essay Agassiz did emphasize the advanced state of fish fossils found in what he believed to be the earliest portion of the fossil record.

Twelve Lectures on Comparative Embryology

To gain insight into a mature version of Agassiz's perspective, articulated before he was confronted by Darwinian conflict, the reader can examine Agassiz's publications between the time of his emigration to the United States in 1846 and the publication of *Origin of Species* in 1859. Before departing Europe for the United States, Agassiz had received an invitation from the Lowell Institute to give a series of lectures in Boston. The first series of lectures that Agassiz gave at the Institute during the winter of 1846-1847 was entitled "The Plan of Creation, Especially in the Animal Kingdom" was never published and have been lost.[503] A subsequent series of lectures given in during the winter of 1848-1849 entitled "Twelve Lectures on Comparative Embryology" was published. In the text of this lecture series, Agassiz demonstrated what he believed were the connections that existed between comparative anatomy, embryology, and zoology.

Agassiz was primarily concerned with presenting a view of the animal kingdom that reflected the principles of a natural system. In his opening lecture, Agassiz credited Cuvier with providing the foundation on which such a system could be based indicating, "It was the result of

[503] Irmscher, *Louis Agassiz*, 87.

the brilliant investigations of Cuvier, to show that a natural arrangement of the animal kingdom could be based upon the structure of the beings which were to be classified."[504] However, Agassiz believed there were limitations to how far such an approach could carry the investigator. He stated, "However important these anatomical researches have been, it is nevertheless my belief that in this line of investigation we have gained all the important information that we can gain; and that we have to run new tracks in order to improve our natural method,—that we must even give up this fundamental principle as the ruling principle, if we will make further advance in this science."[505] Agassiz then committed himself to the position that embryological data would provide the means of developing a new methodological approach. He believed that a program of comparative embryology would provide a deeper level of systemization than could be provided by comparative anatomy alone.

Periodically, throughout the lecture series, Agassiz suggested that knowledge of paleontology further augmented understanding of embryology, since there were analogous processes of development that occurred both within the series of the fossil record, and within the maturing organism. Agassiz, however, pointed out what he believed had an important caveat to how far the process of development of the history of life could be perceived to have gone. In the fourth lecture, he stated, "It has been long and generally asserted, especially among physio-philosophers, that the lower animals were first introduced upon our globe, and formed alone the population of the earliest periods in past time; that Polypi existed before Mollusks; these before Articulata, and that Vertebrata were the last to make their appearance.

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[504] Louis Agassiz, *Twelve Lectures on Comparative Embryology Delivered before the Lowell Institute in Boston: December and January, 1848-1849* (Boston: Henry Flanders, 1949), 1.
[505] Agassiz, *Twelve Lectures*, 6.

But the discoveries in fossil Ichthyology, which it has been my good fortune to describe in my researches upon, fossil fishes, have shown that vertebrates animals, fishes, have existed in the oldest epochs, and that such an order of succession, as mentioned before, did not agree with the plan of creation. Indeed, that representatives of the four great divisions of the animal kingdom, Articulate, Mollusca, and Radiate, occur simultaneously with fishes, in all the lowest geological formations, was soon ascertained by the investigations of paleontologists, and the fact of any regular succession was afterwards altogether denied."[506]

Although Agassiz asserted that the fossil record indicated the four basic body plans were autonomously created during the earliest epoch of the history of life, he advocated a progressive understanding of the development of life within these separate types. Agassiz's narrative continued with the following qualification that, "The great difference between this fact and the views entertained before, consists in the knowledge of the independent relation of the different classes, which in the lower types arise all simultaneously, to undergo their metamorphoses simultaneously, through all geological periods, whilst among Vertebrates, the Fishes were found to occur earlier than Reptiles, and these earlier than Birds and Mammalia, which made their appearance last. It was in that way shown that there is a progressive succession of classes among Vertebrata, ending with the creation of Man; whilst Polypi and Echinoderms among Radiata; Acephala, Gastropoda and Cephalpoda among Molluscs; Worms, Insects and Crustacea among Articulata, existed simultaneously during all great periods, and presents each a development of their own."[507]

[506] Ibid, 27.
[507] Ibid.

In the conclusion to this lecture series, Agassiz indicated that once a better knowledge of embryology had been attained for the entire animal kingdom, it would be important to go back and look at the paleontological data. By combining knowledge gained from these two forms of study, it would be possible to replace an arbitrary method of classification with a more natural system. If this was to be achieved by comparing the earliest stages of embryological development with the earliest fossil forms of the four great domains of animal life. Through this process, "the plan of creation will be better understood. Then we shall more fully acquire an insight into these harmonies, by which the whole is combined and carried through ages to the perfection which has allowed man to stand at the head of Creation."[508]

Agassiz's ideas, which identified resemblance between early forms in embryological development with earlier fossil representatives within given classes of organisms, reflect the influence that recapitulation theory had on him. However, Agassiz's recapitulationist ideas strictly denied evolutionary processes that led one type of organism to be transformed into another type of organism. Agassiz, nonetheless, did recognize that some fossil forms seemed to anticipate the progressive trends that he and other paleontologists interpreted occurred over the course of time. In the book *Essay on Classification*, first published in 1857, Agassiz again discussed his concept of prophetic types. In Agassiz's description of the phenomena he stated, "Recent investigations in Palaeontology had led to the discovery of relations between animals of past ages and those now living which were not even suspected by the founders of that science. It has, for instance, been noticed that certain types which are frequently prominent among the representatives of past ages combine in their structure peculiarities

[508] Ibid, 104.

which at later periods are only observed separately in different, distinct types. Sauroid Fishes before Reptiles, Pterodactyles before Birds, Ichthyosauri before Dolphins, etc."[509]

Considering the examples he chose, Agassiz seemed to be referring to analogous, rather than homologous characters within the fossil record. However, the concepts of analogy and homology, a term first coined by Richard Owen in 1843, raised the potential consideration, when does resemblance indicate relationship?

In the early to mid-nineteenth century, the years of Agassiz education and formative experience, paleontology was still a young science that was largely descriptive rather than theoretical in character. In *The Great Devonian Controversy* Rudwick provided a description of how geologists of the 1830s generally interpreted earth history. By the 1830s, scriptural geology, that is insistence on a short timescale for the earth and on a literal Noachian flood, were concepts that were still embraced by some individuals, but were outside the consensus of scientific geological thinking. Many of the most prominent scientific geologists of the time were religiously pious and some even held ecclesiastical positions, but they espoused a form of liberal theology, and their belief was not dependent on strictly literal interpretations of the Bible. They believed in the great antiquity of the earth but were reluctant to assign a specific length of time to the age of the earth, for fear of being accused of groundless speculation. Some members within the community were prepared to accept that the creation of new species may be derived from the natural process of "transmutation," however the community resisted interpretations such as Lamarck's which implied that the final creative cause was

[509] Ibid, 115-116.

entirely natural and did not require any intervention from a Creator.[510] In *Worlds Before Adam* Rudwick extended his portrait of geological thinking into the 1840s, indicating that geologists from that era were inclined to believe in a progressive view of the fossil record, without generally accepting evolutionary thinking. Although Lyell was a notable exception to this thinking, since he found Lamarck's views so repugnant that he shifted from a progressive view of the fossil record to a non-progressive view, primarily to so he could argue against Lamarck's transmutationist ideas.[511]

It was during the late 1820s to mid-1840s that Louis Agassiz did the work that built his reputation as one of the leading naturalists and paleontologists in Europe. During this time period, the work that he is best remembered for is based on his description of fossil fish, and the contributions he made to glacial theory and the promotion of the idea that Earth had experienced a recent ice age. Agassiz's work on glaciers had a sensational character, and it and stirred up scientific controversy. But his work on fossil fish, made him into the leading fish paleontologist of his generation. The scope of his survey of fossil fish was so comprehensive that comparable efforts have not been duplicated even to the present day.[512]

By the mid-1830s, Agassiz's fish fossil work had attracted attention among leading members of the geological community working in Great Britain, who were eager to have Agassiz include their fossil fish in his survey and benefit from his expertise on the subject.

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[510] Rudwick, *Great Devonian Controversy*, 42-46

[511] Rudwick, *Worlds Before Adam*.

[512] In 1990s a German paleontologist Karl Albert Frickhinger produced a photographic survey of fossil fish that was translated into English in 1995. However, this Fossil Atlas contains records of less than a thousand specimens. At the time of its publication, this atlas represented the second largest survey of fossil fish after Louis Agassiz's work 150 years earlier, and to the best of my knowledge, Agassiz's and Frickhinger's work represent the two largest surveys of fossil fish to the present day. See Karl Frickhinger, *Fossil Atlas Fishes* translated by Dr. R. P. S. Jefferies (London: Mergus, 1995).

Invitations to visit England were extended to Agassiz by a number of British naturalists, including Buckland, Lyell, and Murchison.[513] On Christmas Day 1833, William Buckland (1784-1846) wrote a letter to Agassiz that offered to facilitate a tour of important collections, including those found at the Oxford Museum and the collection of Sir Philip Egerton. He also invited him to the British Association meeting that was to be held the following September.[514] On February 4, 1834 Lyell wrote Agassiz to inform him that the Geological Society of London had awarded him the Wollaston prize for his work on fossil fish, which included a cash award of 30 guineas.[515] In August of 1834, Agassiz visited England for the first time, where Buckland provided Agassiz with an extensive tour of the public and private fossil collections that could be found throughout the extent of Great Britain. Agassiz's work presented a considerable financial strain on his limited resources, and during the 1830s he was the beneficiary of much needed financial support from the institutional networks that his British natural history colleagues helped link him to.[516] As an expert in fish paleontology in an era when British geologists were becoming increasingly aware of the need to accurately identify fossils in order to define the comparative age of layers within the stratigraphic column, Agassiz's work was viewed as an invaluable contribution to science. Furthermore, as fish were the one vertebrate group whose fossils could be found extending to the base of the known fossil record, his work had a direct relationship to the controversies surrounding the accurate identification of the Devonian, Silurian, and Cambrian layers as they were known in the mid nineteenth century.

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[513] Cary Agassiz, *Louis Agassiz* Vol. 1, 231.
[514] Ibid, 234-235.
[515] Ibid.
[516] Ibid, 248-267.

Agassiz's Long-Term Reputation

Despite the immense respect accorded to Agassiz by many of his scientific colleagues in his own time, within the last half dozen decades, Agassiz's biographers have handled his reputation with a certain amount of ambivalence. Some of this ambivalence can be justly attributed to resistance to hagiographic narratives and genuine character flaws Agassiz possessed regarding his uncharitable treatment of subordinate colleagues and ideas about race that, although common within the nineteenth century context, make modern audiences uneasy.[517] But there is another aspect of narrative tension surrounding Agassiz's reputation that stems more from modern prejudices than from the quality of Agassiz's scientific work as it was understood within his own time and cultural setting. Namely, as one of Darwin's most outspoken opponents after the publication of *Origin of Species* in 1859, thanks to the benefit of hindsight, Agassiz's scientific opinions toward the end of his career are often tainted with the suspicion of regressive thinking. For instance, Agassiz is sometimes unfavorably compared to his American colleagues, the botanist Asa Gray (1810-1888) and the geologist James Dwight Dana (1813-1895), who are noted as being more favorable to Darwin's ideas. But are Gray and Dana really Agassiz's peers, and consequently are they the best contemporary naturalists by which Agassiz's scientific opinions should be judged? As Agassiz was educated and received his formative scientific experience in Europe, a more just assessment of his position in comparison to Darwin would probably lie with those individuals with whom Agassiz and Darwin both mutually interacted, individuals such as Murchison, Sedgwick, Buckland, Lyell, and Owen. Seen

[517] Irmscher, *Louis Agassiz*, 219-269. Irmscher discusses Agassiz's uneasy relationships with subordinates in chapter 5, pages 168-218, and his views on race in chapter 6.

within the context of this community, Agassiz and Darwin's work can be better understood as representing the range of diversity of opinion relating to how naturalists within the middle third of the nineteenth century understood the history of life.

Buckland, the oldest of these naturalists, died in 1856 and so was never in a position to directly comment on Darwin's evolutionary ideas. However, as a theologian, who served as Dean of Westminster from 1845-1856, it is Buckland, not Agassiz who can be seen as representing the more religiously conservative end of spectrum of main-stream geological thinking during the mid-nineteenth century. In the 1820s Buckland had gone so far as indicating he had found geological evidence supporting the veracity of the Biblical flood. This is not an indication that Buckland was a strict Biblical literalist, for like Cuvier, Buckland believed in the antiquity of the earth prior to the appearance of mankind. But he did look to the Bible as an historical account of events after the creation of mankind. By the 1820s Continental geologists had rejected diluvial interpretations such as those promoted by Buckland, but these ideas were still popular in Great Britain during the 1820s. However, by the 1830s even in Great Britain Buckland, and most of his contemporaries had abandoned diluvial explanations that pointed to the Biblical flood.[518]

Ideas of individual scientists and scientific communities shift over time. As already pointed out, Agassiz's perception of the history of the earth was shaped by his own experience working with fish fossils, and his understanding of the great Devonian controversy. Agassiz's interpreted the paleontological evidence as indicating that fish could be found in the very

[518] Rudwick: *Worlds before Adam*, 73-87. In chapter 6 Rudwick provides an account of Buckland's initial diluvial narratives. Page 502 Rucdwick indicates the shift of opinion away from diluvial thinking by Buckland and his contemporaries by the 1820s.

earliest stages of the history of life. Although a handful of "Cambrian" fossil deposits had been identified in Europe before Agassiz left in 1846, later work reclassified the deposits as Ordovician. The state of fossil knowledge in the 1840s and for some years to come, therefore could not demonstrate that invertebrate life predated vertebrate life, seemingly thwarting a monistic descent of animal life, such as the one adopted by Darwinian supporters like as Ernst Haeckel (1834-1919). Although Darwin's evolutionary thinking was influenced by his experience as a geologist, he recognized that the fossil evidence known at the time of the publication of *Origin of Species* was insufficient to build a strong paleontological argument for descent, so although he addressed geology within the text, he did not make it a central feature of his argument. In her assessment of Darwin's experience as a geologist, Sandra Herbert indicated that Murchison and Sedgwick were among the least sympathetic readers of *Origin of Species* and to find support for his ideas Darwin would have to look to a younger generation of geologists.[519] Although a handful of paleontologists wrote scientific literature supporting Darwin's evolutionary ideas during the 1860s and 1870s, it wasn't until later part of the nineteenth century that many paleontologists actively began seeking evidence for evolution within the fossil record.[520]

Assessing Agassiz's Career in the Shadow of Darwin Historiography

Since Agassiz was one of Darwin's chief scientific rivals during their respective lifetimes, within the context of the history of science, it is difficult to present a fair assessment of

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[519] Herbert, *Charles Darwin, Geologist*, 331.
[520] Desmond, *Archetypes and Ancestors* and Peter Bowler, *Life's Splendid Drama.*

Agassiz's career when faced with the mammoth historiography that has been poured over Darwin's life and scientific contribution. Europe of the nineteenth century produced hundreds of important biologists, natural historians, and geologists, and thousands of minor ones. But within the history of science, Darwinian historiography is so overrepresented, that it is difficult to find adequate intellectual space to tell the story of Darwin's rivals without making some effort to recontextualize the meaning of their scientific ideas. Part of the difficulty lies in the fact that modern readers frequently do not know how to divest themselves of the mythology that has been built around the meaning of Darwin's ideas and career. But this is history written in retrospect, and representing history as it is lived, from a beginning of a person's lifetime to its end, may provide some relief to the distortions of so unbalanced a literary production.

The aspect of Agassiz's career that is of most relevance to this dissertation is Agassiz's contribution to geology, while he was still living in Europe. Within this timeframe, there are interesting parallels that can be drawn between the development of Agassiz's and Darwin's careers, since it was in the 1830s to mid-1840s that both men made their most active contributions to the field of geology. Considering this to be the case, it is Sandra Herbert's work on Darwin's geological career that has shed the most light on the subject. So, I will build my comparison of these two geologists and natural historians on Herbert's discussion of "Darwin's Place" within the geological community during this time frame.[521]

In order to understand Herbert's assessment of Darwin within the geological community of his own time, one must first take into account what Herbert conceived be the primary and secondary interests of that community. Herbert defined primary interests as being

[521] Herbert, *Charles Darwin*, Geologist, 90-96.

paradigmatic, and secondary activities as being part of geology's "list", that is "other questions that geologists wanted answered and all other topics that appeared to them geological."[522] Herbert clearly identified the main paradigmatic activity of the British geologists in the 1830s to be the work of determining succession in the stratigraphic record.[523] This interpretation is well supported by the work of Rudwick, Secord, and Oldroyd, and based on their collective narratives one can see that stratigraphic work continued to be a paradigmatic activity in British Geology throughout the nineteenth century.

In her discussion of Darwin's place in the British geological community, Herbert argues that, at this stage of his career, Darwin was well placed but not a central figure, he fit well in the Geological Society on a social level, but his intellectual position placed him slightly off center from the primary interests of this community.[524] Since the dominant activity of British geology at the time was mapping out local stratigraphy, from a purely locational perspective, since Darwin's primary field activity occurred while he was voyaging on the *Beagle*, much of his scientific publication, while interesting to other geologists, failed to rise to the place of central importance. In Herbert's assessment, during the 1830s and 1840s, Darwin was working from geology's list, rather than its paradigm. Darwin was well enough recognized by the Geological Society, that he was recruited to serve as secretary between 1838-1841, and this did help embed Darwin well within the activities of the society. In short at this time, Darwin was a reasonably well recognized, but not a leading figure in British geology.[525] During a similar time

[522] Ibid, 81.
[523] Ibid, 80.
[524] Ibid, 90.
[525] Ibid, 91-96.

frame, while Agassiz was still based in Switzerland, Agassiz was making a name for himself both on the Continent and in Great Britain. According to Winsor, "Besides a monumental survey of fossil fishes and observations on glaciers that swelled into the dizzying picture of an entire continent once buried under ice, he and his helpers were studying the embryology of fish, geographical distribution, and the classification of echinoderms."[526]

Since Darwin took interest in Agassiz's engagement in arguments regarding glaciation, Herbert addressed this aspect of Agassiz's geological career, but never made mention of his work as a fish paleontologist. In 1840 Agassiz published a book on glaciation entitled *Études sur les glaciers*. The same year, Agassiz also made a tour of Great Britain, in which he interpreted the landscape in light of his glacial thesis. Darwin initially resisted Agassiz's ideas, since accepting them would mean he needed to reinterpret work he had already done. Due to Agassiz's influence, however, Darwin did eventually come to recognize glaciation as a factor that shaped the geological landscape.[527] Although her book is dedicated to a discussion of Darwin's contribution to geology, Herbert saw Agassiz's work on glaciation as significant enough that she concluded her work with the following observation: "Glacial theory, a catastrophist claim, stood, with transmutationism as monumental accomplishments. . . . Thus the careers of Agassiz and Darwin, of catastrophism and uniformitarianism, were intertwined. Both made major contributions to the science of geology.[528] In the 1830s and 1840s, both Darwin and Agassiz were rising stars within the context of European geology. But at this stage of their respective careers, it was Agassiz's star that was rising faster and shining brighter.

[526] Winsor, *Reading the Shape of Nature,* 1.
[527] Herbert, *Charles Darwin, Geologist*, 269-294.
[528] Ibid, 358.

Darwin's Barnacles

To fill out an understanding of the comparative scientific reputations of Darwin and Agassiz in their own time, it is necessary also to consider their reputations as systematic naturalists. Between 1846-1854 Darwin began a project that allowed him to help bridge some of the distance between Agassiz and himself within the domain of natural history and the production of taxonomy. In 2003 the publication of the book *Darwin and the Barnacle* by British historical novelist and writer of creative non-fiction, Rebecca Stott, helped fill a needful gap in Darwinian historiography of science. From a biographical perspective, the eminent historian of nineteenth century biology, Janet Browne, also covered this historical interlude of Darwin's life in the first volume of her two part biography of Darwin, initially published in 1996, but Browne failed to make as strong an argument as Stott's later book did for the significance of Darwin's barnacle work.[529] The same can also be said of Desmond and Moore's biography, *Darwin: The Life of a Tormented Evolutionist*.[530] Stott's book is beautifully written, but it should be understood as a work of historical non-fiction rather than history of science. From the perspective of history of science, there are both advantages and disadvantages to Stott's approach. Throughout the text, Stott spent as much time trying to capture a sense of historical verisimilitude and painted an intimate portrait of Darwin's domestic life, as she did in discussion of Darwin's work on barnacles. For someone looking to find a sense of orientation to what life was like in the nineteenth century, and who Darwin was as a person, this serves as an excellent

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[529] The majority of Janet Browne's account of Darwin's barnacle work can be found in Chapter 20 of her book: Janet Browne, *Charles Darwin: Voyaging* (Princeton: Princeton University Press, 1995), 473-510.

[530] Adrian Desmond and James Moore, *Darwin: Life of a Tormented Evolutionist* (New York: Warner Books, 1991). Desmond and Moore's account of Darwin's barnacle work is distributed in brief passages of text towards the middle of the work. Two of the most extended passages address the subject can be found on pages 355-357 with further discussion appearing periodically through pages 366-374.

approach to entering the world of Darwinian biography. It is also clear from the bibliography of Stott's book that she spent a significant amount of time acquainting herself with the primary literature of the people she discussed, demonstrating the advantages of the skills being educated in Literature and Art History bring to the table. But there are gaps in the strength of her work regarding a similar acquaintance with the secondary literature from the history of science. As a result, Stott's work does not provide as rigorous an account of the chronology and complexity of the development of scientific and religious ideas as a gifted historian of science would be able to provide.[531]

Still, Stott did spend considerable effort acquainting herself with the anatomy of barnacles, so she could talk intelligibly about Darwin's work on these enigmatic marine invertebrates. As such, Stott's work will not be readily surpassed by anyone who does not bring knowledge of the taxonomy of invertebrate zoology to provide a more coherent account of how good a barnacle taxonomist Darwin was or how much light Darwin's barnacle work did provide the famous naturalist in the development of his evolutionary thinking. For this reason, I will rely on Stott's account of Darwin's barnacle work for a discussion of his work on living barnacles. I find however, I am more interested in aspects of what Stott leaves out of her narrative, than what she included. Stott failed to provide as useful an account of Darwin's work on fossil barnacles as she does of living ones. Her bibliography also indicated that Stott had very little acquaintance with relevant secondary literature on the history of nineteenth century geology and paleontology. So, after a discussion of Stott's account of the two volumes Darwin

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[531] Rebecca Stott, *Darwin and the Barnacle: The Story of One Tiny Creature and History's Most Spectacular Scientific Breakthrough* (New York: W. W. Norton & Company, 2003).

devoted to living Cirripedia, I will provide a closer analysis of Darwin's two slim volumes on fossil Cirripedia, because it is this work that provided Darwin's most practical contribution to the development of nineteenth century paleontological knowledge.

Throughout her book, Stott compellingly argued that Darwin used the eight years (1846-1854) he spent working on living and fossil barnacles to demonstrate his technical expertise as a naturalist. She made this argument to serve as a partial explanation for the delay between Darwin's 1844 sketch on his theory of natural selection, and the publication of his ideas on the subject alongside those of Alfred Russel Wallace in 1858. When Darwin did eventually publish *Origin of Species*, Stott claimed that due to his barnacle work, "Even those who denounced his theory could not dismiss Darwin as a mere speculator. He was a man who had classified the barnacles, won his spurs, been awarded the Royal Society medal. He was a man of authority and a man with important contacts and supporters."[532] As evidence for this perspective, Stott provided a number of examples of influential figures in Darwin's life and professional development who suggested that such a project as the one he took on when examining barnacles was a necessary prerequisite for establishing oneself as an expert within the community of British naturalists. Prominently featured among those who gave such advice were Darwin's Cambridge mentor the Reverend Leonard Jenyns[533] and Joseph Hooker.[534] Stott has also claimed that Darwin's concerns over the negative reception of Robert Chamber's anonymously published work *Vestiges of the Natural History of Creation* also made Darwin concerned over demonstrating his expertise to the scientific community of his day before

[532] Stott, *Darwin and the Barnacle*, xxv.
[533] Ibid, 71-72.
[534] Ibid, 81 & 44.

publicly discussing his evolutionary ideas.[535] Stott indicates that a significant aspect of the motivation Darwin had for producing his Cirripedia monographs was that Agassiz had publicly pointed out that such work was called for in 1846.[536] It is Irmscher, however, who provided the more compelling account of this call to action: "Charles Darwin was in the audience when Agassiz, soon to board his steamer in Liverpool, bound for the United States, gave a speech at a meeting of the Ray Society in Southampton on September 15, 1846. On this occasion he said that someone should write a book about barnacles or, in Darwin's words, that 'a monograph on the Cirripedia was a pressing desideratum in Zoology.'"[537]

Stott continued her argument with a discussion of how Darwin used his evolutionary thinking as an interpretive framework for his systematic understanding of the barnacle specimens he studied. While I see no reason to doubt Stott's interpretation of this aspect of the narrative, I do have reservations regarding how much value Darwin actually got out of his systematic work in terms of deepening his understanding of evolution. My reason for this hesitancy lies in a simple test, that of how much space Darwin devoted to the discussion of the sub-class Cirripedia in *Origin of Species*. Going to the index of the first edition of Darwin's controversial work, one finds the book contains only five references to the Cirripedia. In order to provide a basis of comparison it is interesting to note that the index provides nine references to the combination of the two terms 'fish' and 'fishes' and ten references to the term 'birds.' The most evolutionarily relevant thing Darwin has to say about the Cirripedia appeared within his discussion of embryology found in the penultimate chapter of the book. In this section

[535] Ibid, 81.
[536] Ibid, 108.
[537] Irmscher, *Louis Agassiz*, 126.

Darwin argued that the embryonic and larval forms of organisms frequently more closely resembled each other than adult forms within the same class of organisms.[538] While doing his barnacle work, Darwin divided the Cirripedia's into two orders: the Lepadidae or pedunculated barnacles and the Balanidae or sessile barnacles.

In the discussion of embryology found in *Origin of Species*, Darwin made the following observation regarding barnacle classification: "So again the two main divisions of cirripedes, the pedunculate and senile, which differ widely in external appearance, have larvae in all their several stages barely distinguishable."[539] In the closing paragraph on the section on embryology, Darwin further stated, "For the embryo is the animal in its less modified state; and in so far it reveals the structure of its progenitor."[540] A little further down he continued his argument with the following statement. "Thus, community in embryonic structure reveals community of descent."[541] There is a particular significance in this observation in regard to the sub-class of barnacles because before 1830 they had been identified solely by the shells they inhabited which concealed the fact that they were crustaceans rather than mollusks.[542] For eight years, Darwin did his exacting work, which relied on microscopy and dissection to provide the systematic descriptions by which the taxonomy of the Cirripedia were to be defined. During this time, he also grew the correspondence network through which he obtained both access to living and fossil barnacle specimens and information from fellow naturalists on related work. Only a modern expert in barnacle classification would be in a position to say how

[538] Darwin, *Origin of Species Facsimilie First Edition,* 439-450.
[539] Ibid, 440.
[540] Ibid, 449.
[541] Ibid.
[542] Stott, *Darwin and the Barnacle*, xxi.

good Darwin's work was, but his own scientific contemporaries felt Darwin's contribution of sufficient merit to award him the Royal Metal in 1853. Based on this work it would be fair to say that Darwin shored up his reputation as a naturalist to such an extent, that his expertise as a barnacle taxonomist would have been considered to be of similar value to that of Louis Agassiz's expertise as a fish taxonomist by the mid-1850s.

In 1851 Darwin produced two monographs, one on living pedunculated barnacles and one on fossil pedunculate barnacles. The first of these works, entitled *A monograph on the sub-class Cirripedia, with figures of all the species. The Lepadidæ; or, pedunculated cirripedes*. Vol. 1 is the more substantive production requiring just over 400 pages to describe and illustrate the species Darwin had at his disposal. It is this work along with the second volume on living barnacles *Living Cirripedia, The Balanidæ, (or sessile cirripedes); the Verrucidæ*. Vol. 2, published in 1854 which helped win Darwin his reputation as an experienced systematist.

In the context of his barnacle work, Darwin participated in the cataloging efforts of John Gray at the British Museum. In the opening paragraph of the Preface to the 1851 monograph Darwin acknowledged the role played by Gray in facilitating his work on producing the barnacle monographs. Darwin stated, "Mr. J. E. Gray, in the most disinterested manner, suggested to me making a Monograph on the entire class, although he himself had already collected materials for this same object. Furthermore, Mr. Gray most kindly gave me his strong support, when I applied to the Trustees of the British Museum for the use of the public collection; and I here most respectfully beg to offer my grateful acknowledgments to the Trustees, for their most liberal and unfettered permission of examining, and when necessary, disarticulating the specimens in the magnificent collection of Cirripedes, commenced by Dr. Leach, and steadily added to, during many years, by Mr. Gray. Considering the difficulty in determining the species in this class, had it not been for this most liberal permission by the Trustees, the public collection would have been of no use to me, or to any other naturalist, in systematically classifying the Cirripedes."[543] Darwin's project was allied with the efforts that were being made under the supervision of the Keeper of Zoology at the British museum, John Gray, to catalog as many animal species as possible during the term of his administration between 1840-1875. Darwin was indebted both the generosity of John Gray and the British Museum, as well as many active naturalists and geologists who lent him access to their barnacle specimens in order to complete this work, which he did largely at his home in Down House.

As previously stated, by the mid-1850s Darwin was acknowledged as an accomplished barnacle systematist. But Agassiz's reputation was not only that of a superlative naturalist, he was also acknowledged as an accomplished paleontologist and embryologist. So, we must consider the range of Darwin's skills and practical experience beyond those of a naturalist and a physical geologist if we are to understand how contemporaries of these two naturalists would have compared the two men. Understanding the role that Darwin's work with barnacle fossils may have played in boosting his reputation within the field of geology and paleontology presents a different kind of problem than that of understanding his reputation as a naturalist, however. For this reason, I will take some time to describe the contents of these two fossil monographs also produced in 1851 and 1854.

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[543] Charles Darwin, *A monograph on the sub-class Cirripedia, with figures of all the species. The Lepadidæ; or, pedunculated cirripedes*. Vol. 1 (London: Ray Society, 1951), v. Biodiversity Heritage Library, Date scanned: 12/17/2007, https://www.biodiversitylibrary.org/item/18404#page/9/mode/1up .

Fossil Barnacles

The first volume of Darwin's fossil barnacles, published in 1851 was entitled*, Fossil Cirripedia of Great Britain: A monograph on the fossil Lepadidae, or pedunculated cirripedes of Great Britain*, Vol. 1. This work presented Darwin with a number of difficulties that he discussed in the introduction to his work. In the opening page Darwin indicated, "It is unfortunate how rarely all the valves of the same species have been found coembedded; it is evident that, with the exception of some few species, the membrane which held the valves together, decayed very easily, as it does in recent Pedunculated Cirripedes. Hence, in the great majority of cases, the several valves have been found separate. Hitherto it has been the practice of naturalists to attach specific names indifferently to all the valves; and as in each species there are from three to five or six different kinds of valve, there would have been, had not the whole group been much neglected, so many names attached to each species."[544] What Darwin indicated about the pedunculated, or stalked, barnacles was that all that was preserved in the fossil record for these organisms, were pieces of the outside covering, which he identified as valves. To make matters worse, this external feature of these organisms were disarticulated before or during the process of fossilization. The exterior covering of barnacles was composed of multiple valves, which according to Darwin, had, if they were described at all, been misidentified as belonging to different species.

Darwin explained another difficulty posed by these fossil remains, "It should be borne in mind, that the recognition of the Fossil Pedunculated Cirripedes by the whole of their valves

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[544] Charles Darwin, *Fossil Cirripedia of Great Britain: A monograph on the fossil Lepadidae, or pedunculated cirripedes of Great Britain*, Vol. 1, (Bartholomew Close, C. and J. Adlard, 1851), 1. Biodiversity Heritage Library, Date Scanned: 07/22/13, https://www.biodiversitylibrary.org/item/134078#page/9/mode/1up .

and peduncle, is identical with recognising a Crustacean by its carapace, without the organs of sense, the mouth, the legs, or abdomen: to name a Cirripede by a single valve is equivalent to doing this in a Crustacean by a single definite portion of the carapace, without the great advantage of its having received the impress of the viscera of the included animal's body: knowing this, and yet often having the power to identify with ease and certainty a Cirripede by one of its valves, or even by a fragment of a valve, adds one more to the many known proofs of the exhaustless fertility of Nature in the production of diversified yet constant forms."[545] A greater difficulty posed by identifying fossil remains of barnacles, is that the exterior morphology of these organisms by itself was extremely misleading regarding where barnacles belonged in the animal kingdom, since they resemble mollusks more than crustaceans. Consequently, it was largely through comparison with living specimens that Darwin learned anything useful about the species of barnacles that he found in the fossil record.

On the opening page of the main portion of this text, Darwin began with a general description of the Family Lepadidae. Darwin repeated within this description that most of what was known about the structure of this family of crustaceans can only be found by examining the soft parts of the body, which was not an option with fossil specimens, because as he previously indicated in the introduction, it was only disjointed pieces of the external covering of these organisms that was preserved in a fossil state. It should be noted that his second footnote on this page makes a reference to information he obtained from "J. D. Dana."[546] Stott pointed out in her book that during the barnacle years, Darwin was in correspondence with the

[545] Ibid, 2.
[546] Ibid, 12.

American geologist, James Dwight Dana. Darwin completed his description of the family with the following observation regarding barnacles, "When we look at a Cirripede, we, in fact, see only a Crustacean, with the first three segments of its head much developed and enclosing the rest of the body, and with the anterior end of this metamorphosed head fixed by a most peculiar substance, homologically connected with the generative system, to a rock or other surface of attachment."[547]

After Darwin provided the general description of the Family Lepadidae, he immediately began describing the genus *Scapellum*. Part of this description was written in Latin, followed by an English account of the same material. Since Latin had long been the lingua franca of the scientific community in Europe, this feature of the text demonstrated that Darwin intended to make this monograph partially accessible to other members of the scientific community of Europe for whom English was not a familiar language. The initial combined Latin and English description is brief, only accounting for about a page of text, although the full generic description of *Scapellum* extends from pages 13-18. Darwin went on to describe 15 species of *Scapellum* in pages 18-46. Darwin's species descriptions were lengthy compared to other catalog entries I have seen written by other nineteenth taxonomists. They also provided scientifically useful information, by including facts regarding the layer of the stratigraphic column in which these specimens were found, the geographic location, and from which collection they had been obtained. These features would have been considered of particular value to the scientific community, since a complaint that was frequently lodged against taxonomists during this time period was that their species descriptions failed to provide enough

[547] Ibid.

information to fellow taxonomists to verify that their specimens were the same as others that had been described.[548]

Darwin followed the description of the genus *Scapellum* with a description of the genus *Pollicipes*. He identified 22 species within this genus. The final genus Darwin discussed was the *Loricula*.[549] For this genus, Darwin only identified one species *Loricula pulchella*. The description of these three genera rounded out the main textual portion of the monograph. After a two-page index, the monograph included a series of illustrations of the barnacle valves, the fossil remains from which Darwin drew his descriptions. The fossil remains were illustrated in five pages, but since the barnacle valves were small, the illustrations could accommodate as many as 11-13 fossil specimens per page in the first four pages of illustrations, allowing Darwin to represent 37 species plus a number of variations on these pages. The last illustration was dedicated solely to the one species for the genus *Loricula*.[550]

Darwin's second monograph on fossil barnacles *A monograph on the fossil Balanidæ and Verrucidæ of Great Britain.* Vol. 2 was published in London for the Paleontographical Society in 1854. Considering the brevity of the monograph, since Darwin only provided headed descriptions of 16 fossil species of barnacles, in the Preface Darwin acknowledged a surprising number of other geologists and naturalists who lent him fossil specimens from their collections while he was preparing the fossil monographs. Among the 15 people he acknowledges are such familiar figures the history of geology and Darwinian literature as Lyell, Greenough, Forbes, and Henslow. This second fossil monograph provided an analysis of the fossil remains of two

[548] Ibid, 13-46.
[549] Ibid, 47-86.
[550] Ibid. The final pages containing the illustrations are unnumbered.

families named in the title, the Balanidae and the Verrucidae. In the introduction to the second monograph Darwin indicated that, of the 16 fossil species described, 9 species were still represented by living forms. Darwin also included a description of the methodology by which he identified the barnacles. On page 6, Darwin provided a table showing in what stages of the Tertiary fossil record, 15 of the 16 barnacles fossils could be found in. On page 8 Darwin offered a series of illustrations showing the "archetypal" form of a fossil barnacle from the genus Balanus from which 11 of the 16 species of fossil barnacles were derived. The final three pages of the introduction, Darwin used to discuss how he applied terminology to the description of the fossil barnacles in the monograph.[551]

The main body of the second monograph follows the same format as the first one. After providing a brief Latin and English description of the Family Balanidae, Darwin indicated of the two natural subfamilies of barnacles found within this group, only the subfamily Balaninae had fossil representatives in Great Britain. Working his way down the taxonomic hierarchy he then provided descriptions of the subfamily Balaninae, followed by the genus Balanus, before proceeding with the species descriptions for this group. Toward the end of the section on the subfamily Balaninae, Darwin introduced the new sub-genus Acasta, which was represented by a single species *Acasta undulata*. Next came the genus *Pyrgoma*, again represented by only one species, *Pyrogoma anglicum*. Then the genus *Coronula* was represented by the species *Coronula barbara*. The main body of the text ends with the description of the members of the

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[551] Charles Darwin, *A monograph on the fossil Balanidæ and Verrucidæ of Great Britain.* Vol. 2 (Bartholomew Close, J. E. Adlard, 1854), 1-11. Darwin Online, http://darwin-online.org.uk/content/frameset?itemID=F342.2&viewtype=image&pageseq=1 .

family Verrucidae represented by two species from the genus *Verruca*.[552] With so few species to represent, Darwin only required two pages to provide illustrations for the relevant specimens.

What can be learned from Darwin's experience describing fossil barnacles, was that there was an extremely limited number of specimens that he was able to examine. In total across the two monographs, Darwin only described 54 species of barnacles. To make matters worse, when only fossil material was available for a given barnacle species, it was not always in good condition, and he had to rely on a single character, preserved from the barnacles external anatomy, that did not offer relevant information regarding the organism's true form. I know of no reason to doubt that Darwin did his best with the material provided, but the material provided was very poor. He could not have learned much of practical value regarding the validity of his evolutionary hypothesis working with this material. I still do not have sufficient skills to assess the quality of either Darwin's or Agassiz's fossil descriptions. But what I know based on the material they examined is this: Agassiz had much more practical experience as a paleontologist than did Darwin, and he worked with a much more paleonotologically valuable class of organisms.

Agassiz and Darwin: Natural History, Embryology and Paleontology

From what is known of Agassiz's education and career he also had more practical experience working as an embryologist than did Darwin. Although Darwin and Agassiz may have been considered as possessing similar levels of expertise as naturalists, among those who

[552] Darwin, *Fossil Balanidæ and Verrucidæ*, 12-44.

clearly understood the accomplishments of both men, Agassiz would have been considered both a better paleontologist and embryologist than Darwin. This is of relevance to understanding Darwin's work *Origin of Species*, since Darwin considered evidence from embryological and paleontological sources within this text. One can also see the impact of Agassiz's legacy on Darwinian thought, since Agassiz is listed in the index of the first edition of this work 8 times. By the mid-1840s, when Agassiz emigrated to the United States, he was a figure of public adulation as can be attested to by the success of his career as a lecturer. Although the portion of the career he spent in the United States between 1846 and his death in 1873, Agassiz was less productive on a scientific front, it was because he was then fulfilling a role as a statesman of science. Irmscher has indicated, "In his hey-day, about 1854 to 1864, what Agassiz achieved was a synthesis of a remarkable and interesting kind. He did three closely connected things: he articulated an ideal for a new coherent field of study, he founded an institution as the locus and material instrument of that field, and he trained a generation of young practitioners to carry on his vision."[553] Agassiz's career in the United States captured the imagination of a young nation. His death represented such a loss to his adoptive country that it became an occasion for public mourning.[554]

Although Agassiz's posthumous reputation has eclipsed that of Darwin, this should not be seen as a legitimate representation of who these men were to the scientific communities of their own day or the scientifically interested public. Accounts of Agassiz's career that problematize his failure to accept Darwin's evolutionary ideas fail to recognize that Agassiz had

[553] Winsor*, Reading the Shape of Nature*, 3.
[554] Irmscher, *Louis Agassiz*, 36-38

what he believed to be sound scientific reasons for being skeptical of Darwin's views. They also fail to recognize that it took time for Darwin's ideas to gain general acceptance within the geological community of his day. However, it was not uncommon for twentieth century authors to accuse Agassiz of being old fashioned in his perspective, since he failed to assent to Darwin's ideas. Agassiz was not infrequently compared unfavorably to other nineteenth century American scientists such as Asa Gray and James Dwight Dana, who took a more favorable view of Darwin's work and are therefore characterized as being more forward thinking than Agassiz.[555] But such a perspective fails to take into an account that a more accurate representation of Agassiz's peer group could be found among the membership of the Geological Society of London, where his ideas were not considered out of place. In the United States, while Agassiz was acquainted with both Gray and Dana, his preferred companions were drawn from the American Transcendentalist community, where his perspectives on natural history were quite favorably regarded. It is possible to take another perspective on the reasons that Gray and Dana were more favorably disposed to Darwin than Agassiz. Darwin went to the trouble of cultivating personal relationships between Dana and Gray before *Origin of Species* was published.

A significant factor that initially drew Gray and Darwin together was their mutual antipathy for Agassiz. While Agassiz had a gift for charming his scientific superiors and potential patrons, he was not always so adept at maintaining strong personal ties with his scientific colleagues and subordinates. According to Irmsher, "The Swiss scientist served as the

[555] Elaine Wolfe, "Acceptance of the Theory of Evolution in America: Louis Agassiz vs. Asa Gray," *The American Biology Teacher* 37, no. 4 (1975): 244-247 and Paul Croce, "Probabilistic Darwinism: Louis Agassiz vs. Asa Gray on Science, Religion, and Certainty," *The Journal of Religious History* 22, no. 1 (1998): 35-58.

convenient ‘other’ against which Darwin and Gray and their American followers could define themselves, regard-less of the differences they might have had with one another.[556] In Gray, Darwin found a useful informant, since Gray’s knowledge of botany augmented Darwin’s access to a store of knowledge in which Agassiz did not surpass Darwin. Irmshcher’s narrative has indicated that Darwin wrote his narrative of *Origin of Species* with a weary consideration of how Agassiz might object to his claims.[557] Throughout the years of Darwin’s acquaintance with Agassiz, Darwin’s posture to Agassiz was sometimes obsequious and sometimes combative. Once Darwin openly acknowledged his transmutationist views, he knew that Agassiz was an opponent who was unlikely to be swayed to his way of thinking. No matter how Darwin and his supporters may have been inclined to mock Agassiz’s scientific and religious beliefs, he was a force to be reckoned with.

Darwin, Agassiz and Cuverian *embranchements*

During Darwin’s lifetime, six editions of *Origin of Species* were published between 1859-1872. The accumulated change made to the book over its six editions is substantial in some of the chapters. However, between the first and the sixth edition, Darwin maintained the statement regarding the possibility that there existed between four and five separate lines of descent within the plant and animal kingdoms.[558] Within the mid- to late nineteenth century context, a substantive piece of evidence for maintaining the view that members within the animal kingdom had descended from multiple lines of ancestry instead of a single line, rested

[556] Irmscher, Louis Agassiz, 134.
[557] Ibid, 134-147.
[558] Ibid, 642.

on the understanding that fish fossils could be traced to nearly the base of the fossil record. In the view of Agassiz and Murchison, there simply could not have been time for fish to evolve from invertebrate progenitors. In fact, they took the argument further than that by insisting that this was strong enough proof to disprove that evolution happened at all.[559] It is an interesting fact, that Darwin never made direct reference to Agassiz's fish fossil work in *Origin of Species*. Considering the closeness of the association of both Agassiz and Darwin to the Geological Society of London in the late 1830s and early 1840s, it seems highly unlikely that Darwin was unfamiliar with Agassiz's work. In an exposition of the impact on Darwin's knowledge of geology on the production of *Origin of Species*, Sandra Herbert discussed Darwin's thoughts on the comparative genealogy of birds and fish. Herbert showed a sketch from Notebook B displaying Darwin's belief that based on fossil evidence, the most ancient genealogy of fish was known, while that of birds was not. If Darwin believed that fish genealogy was known, this belief should have been based either directly or indirectly on Agassiz's work, since no comparable work on fish fossils had been done at the time.[560]

The work of Agassiz, Murchison, and Günther showed that through the mid to later part of the nineteenth century, there were leading naturalists and geologists who persisted in believing that no ancestral connection could be demonstrated between vertebrates and invertebrates. Although Darwin did not address Agassiz's work on fish fossils, he did acknowledge Murchison's views on the antiquity of the geological record. In the sixth edition

[559] Agassiz's position on the place fish fossils were thought to play in disproving evolution has already been discussed at length in Chapter 3 of this dissertation. For Murchison's views on the subject see Oldroyd, *The Highlands* Controversy, 160.
[560] Herbert, *Charles Darwin, Geologist*, 330.

of *Origin of Species* Darwin stated, "Several eminent geologists, with Sir R. Murchison at their head, were until recently convinced that we beheld in the organic remains of the lowest silurian stratum the first dawn of life."[561] Darwin went on to discuss formations below the Silurian layer based on the what he understood of Canadian geology. At the time Darwin believed that an organic layer had been discovered below the Cambrian layer known as the Eozoön. The organic nature of the Eozoön was only held as a minority opinion during Darwin's lifetime, and was entirely rejected less than a decade after Darwin's death. But the convenience of this evidence seems to have proved too great a temptation for Darwin to pass up. He initially included a discussion of the Eozoön in the fourth edition of *Origin of Species*.[562] Based on this reported discovery, Darwin believed that evidence had been found proving the antiquity of life that went much further back in the time scale than anything Murchison ever admitted existed. Darwin acknowledged uncertainty regarding the reason no more fossil evidence of so great an antiquity had been found: "Although we now know that organic beings appeared on this globe, at a period incalculably remote, long before the lowest belts of the Cambrian system was deposited, why do we not find beneath this system great piles of strata stored with the remains of the progenitors of the Cambrian fossils?"[563] Darwin answered his own question with the following

[561] Charles Darwin, *The Origin of Species* (New York: Random House, 1993), 439. Although this book does not state what edition of Darwin's work it is based on, I have compared passages with a known copy of the sixth edition and have been able to confirm that this printing was based on that edition.
[562] This formation had been discovered in eastern Canada in 1858, for three decades geologists disputed if the Eozoön could be shown to contain any fossils. The dispute was not settled until almost a decade after Darwin's death, when geologists finally came to a consensus that the layer was inorganic in 1890: Charles O'Brien, "Eozoön Canadense 'The Dawn Animal of Canada,'" *Isis* 61, no. 2 (1970): 206-223. When considering this argument, however, it is important to recognize that geological knowledge and opinion has changed a great deal since Darwin's time. Although the Eozoön may have been invalidated by the late nineteenth century, geologists now point to other forms of evidence that they believe validate the existence of life well before Cambrian times.
[563] Darwin, *Origin of Species*, 618. Again, this is from the sixth edition.

remark. "I can answer these questions and objections only on the supposition that the geological record is far more imperfect than most geologists believe."[564]

Because the historiography of mainstream opinion on the quality and nature of paleontological evidence in the later part of the nineteenth century is so poorly developed, it can be difficult to determine how accurately Darwin depicted the geological opinion of his own day. Due to the polemical nature of *Origin of Species*, at times Darwin seemed to be putting the best spin on the evidence, if not being actively disingenuous. Take for instance this comment Darwin made following the list of potential difficulties the geological evidence presented to his theory of natural selection. After admitting that these potential objections were serious Darwin stated, "We see this in the fact that the most eminent palaeontologists, namely, Cuvier, Agassiz, Barrande, Pictet, Falconer, E. Forbes, &c., and all our greatest geologists, as Lyell, Murchison, Sedgwick, &c., have unanimously, often vehemently, maintained the immutability of species."[565] But Darwin then argued that opinion was shifting in his favor. "But Sir Charles Lyell now gives the support of his high authority to the opposite side; and most geologists and palaeontologists are much shaken in their former belief."[566] That Darwin courted Lyell's favorable opinion long before he made his opinions public, is a well known part of Darwinian historiography. What is troubling about this statement, if the picture Darwin was attempting to paint of the impact of his ideas was true, is that Darwin did not seem to be in a position to marshal a longer list of names of prominent geologists who now supported his opinion. So, it is unclear, how successful Darwin really had been in shaking the

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[564] Ibid.
[565] Ibid, 443.
[566] Ibid.

opinion of 'most geologists and palaeontologists' by the publication of this statement in 1872. That the tide of geological opinion did eventually turn in his favor is not the point of dispute. The problem is that based on the limited knowledge we have of the development of paleontology in the last half of the nineteenth century, historians of science are not in a position to claim that we have accurate knowledge of when and how that opinion changed.

Similarly, we are not currently in a position to answer the question of how long belief in Cuverian *embranchements* persisted. But the closing sentence of Darwin's book suggests that the concept remained viable through most if not all of Darwin's career. "There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved."[567] When Darwin penned the words "a few forms or into one," he did seem to have Cuverian *embranchements* in mind. But a recent popular account of Darwin's life and work suggests there is current historical misunderstanding of the significance of the statement. I say this because in a 2008 documentary "The Genius of Charles Darwin" misquoted this sentence from Darwin's book. In the close of the first episode, Richard Dawkins quoted this closing sentence from *Origin of Species*, but deliberately dropped the portion of the sentence, "with its several powers, having been originally breathed into a few forms or into one." This erasure very intentionally ignored Darwin's uncertainty about whether or not all life could be

[567] Darwin, *Origin of Species*, 490. This quote is taken from the first edition, previously cited. There is a variation to the ending in the sixth edition, where Darwin adds a reference to the Creator into the quote of relevance, "with its several powers, having been originally breathed by the Creator into a few forms or into one." In the sixth edition that I cite from this quote can be found on page 649.

represented by a single evolutionary tree. This elision may not matter very much in a popular documentary, but from the perspective of serious historical scholarship in the history of science, it has more troubling implications. When studying the history of scientific opinion, if historians too exclusively focus on only a single side of an argument in any given scientific controversy, they deafen themselves to the nuance and meaning of that opinion. It is only in the dynamic tension of the dispute that nature of the varying opinions can be understood.

Conclusion

As I was writing this dissertation, there came a moment of almost insurmountable despair, that I had made a terrible mistake choosing a topic that focused on how naturalists managed to compose a coherent picture of a branch of biodiversity knowledge. Explaining biodiversity provides humans with a seemingly unending task. It's difficult to even estimate how many types of organisms on earth there are or to keep track of how many species have been described.[568] Towards the end of his history of biological collection practices of the mid-nineteenth to mid-twentieth century, the historian of biology Robert Kohler expressed skepticism that a complete inventory of life would ever be accomplished that would encompass the "millions of tiny and nearly indistinguishable creatures, many confined to minute habitats."[569]

In the preface of her book *Unifying Biology* in which she discussed the history of the "evolutionary synthesis," Betty Smocovitis confessed, "It is also very much a personal project grown out of the chaotic world of lived experience with the diversity of the biological sciences in our modern world." Like Smocovitis, my historical interest in the development of natural history is very much an outgrowth of my own education in the biological sciences. It is ironic that I began my studies in biology in 1996, the same year Smocovitis' book was published.

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[568] Ingi Agnarsson and Matiaz Kuntner, "Taxonomy in a Changing World: Seeking Solutions for a Science in Crisis," *Syst. Biol*. 56, no. 3 (2007): 531-539. This article provides a biodiversity estimate of between 4 – 12 million organisms in the world, and also estimates about 2 million species have been described. It is uncertain how accurate any estimates of the biodiversity on Earth actually are, considering the difficulty of measuring what has yet not been surveyed.

[569] Robert Kohler, *All Creatures: Naturalists, Collectors, and Biodiversity, 1850-1950* (Princeton: Princeton University Press, 2006), 284.

Smocovitis wrote of the, "diversity and heterogeneity of the modern biological sciences."[570] Yet she went on to claim a status for the evolutionary synthesis that was, "at least as deep as the Enlightenment project (or even deeper still) of unifying the branches of knowledge."[571] However in the eight years I pursued my own undergraduate degree in biology and master's degree in biological oceanography, the only architect of the evolutionary synthesis my professors discussed at significant length was the author of the biological species concept, Ernst Mayr.

It seems that scientific and historical narratives evolve more readily than organisms do. It was my Animal Diversity class in which the most extended discussion of evolution took place. The textbook for that class included a 20-page discussion of Darwin and the development of Darwinian theory, then summarized neo-Darwinism and the evolutionary synthesis in less than a page.[572] Of the continuing description of evolutionary theory that was given in the closing pages of the chapter, no clear attribution was given to indicate how many of the ideas originated with the evolutionary synthesis, or what should be credited to subsequent scientists.[573] Instead, the class took a cladistic approach to the study of animal taxonomy, and we spent the semester learning about synapomorphies and sister groups. Some of the differences in my experience from that of Smocovitis might be explained by the differences in our respective specializations. While Smocovitis specialized in evolutionary biology, my concentration was in marine biology. In my biology classes, it was of course assumed that

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[570] Vassiliki Betty Smocovitis, *Unifying Biology: The Evolutionary Synthesis and Evolutionary Biology* (Princeton: Princeton University Press, 1996), xiii.
[571] Ibid, 7.
[572] Cleveland Hickman, Jr., Larry Roberts and Allan Larson, *Animal Diversity* 2nd ed. (Boston: McGraw Hill, 2000), 4-25.
[573] Hickman et al., *Animal Diversity*, 25-32.

evolution provided a unifying explanation for relationships of organisms in the natural world, but primary credit for providing the explanatory basis for evolutionary theory had reverted to Darwin and other nineteenth century naturalists that were his supporters and rivals.

Through the course of my biological studies, significant concern was expressed by several of my professors that taxonomy was a dying art. A kind of nostalgia for nineteenth and early twentieth century expertise suffused conversations that also tended to drift toward problems of the way current funding structures within the sciences incentivized rapidly achieved results and trendy subjects, that may not add lasting value to scientific knowledge. A survey of recent literature reveals that the anxiety over diminishing taxonomic skill was not a strictly insular concern. Lisa Drew, a longtime science writer, illustrated just how troubling the problem is when she interviewed the mammalogist Michael Mares, now Director Emeritus of The Sam Noble Museum of Natural History. In the opening of the article Drew stated, "Mares can find specimens relevant to his work in collections all over the world. But more often than not, the labels are incorrect. During one recent visit to a museum that Mares will not name—'but it's one everyone on the planet has heard of,' he says—he found that every one of roughly 50 specimens, representing seven species and three genera, was mislabeled. And they were all mammals, arguably the easiest life forms to identify."[574] Another article harkening back to a past where amateur naturalists once dominated the field of species collection and identification seeks to find a solution by reviving a role for amateur participation within the taxonomy profession.[575]

[574] Lisa Drew, "Are We Losing the Science of Taxonomy?" *Bioscience* 61, no. 12 (2011): 942.
[575] David Pearson, Andrew Hamilton, and Terry Erwin, "Recovery Plan for the Endangered Taxonomy Profession," *Bioscience* 61, no. 1 (2011): 58-63.

Related issues within the discussion of the future of taxonomy pertain to the status of museums and how taxonomy will transition to the information needs of the digital age. In recent decades museums that house biological collections have been struggling with budgetary issues that threaten the funding needed to maintain these collections. Curators from natural history collections have tried to build strong arguments for why these collections are still valuable and need to be preserved.[576] Meanwhile, among some biologists, there is a perception that internet based platforms will offer significant solutions to maintaining the availability and discoverability of taxonomic information.[577]

Kohler has discussed a perception that has prevailed among some modern life scientists that much of the activity of natural history is prescientific: "In the grand narrative of scientific progress, collecting is what naturalists did before they became scientists and built labs and gardens and learned to experiment, measure, and model. Collecting in this view is mere fact gathering: a routine preliminary to the real scientific business of manipulating and analyzing facts and constructing theories."[578] Kohler suggests, however, that this attitude is shifting, and that there is now a growing respect for natural history. In my biological studies, I did encounter evidence of both attitudes. The advice that made the biggest impression on me, however, came in my Benthic Ecology class, where my professor said that it was important to study theoretical papers, but if a person didn't devote a similar amount of time in learning natural

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[576] Two examples of these kind of arguments can be found in the following articles: Kevin Winker, "Natural History Museums in a Postbiodiversity Era," Bioscience 54, no. 5 (2004): 455-459 and Judith Winston, "Archives of a Small Planet: The Significance of Museum Collections and Museum Based Research in Invertebrate Taxonomy," *Zootaxa* 1668 (2007): 47-54.
[577] For examples of this discussion see articles such as these. H. C. J. Godfray, "Linnaeus in the Information Age," *Nature* 446, no. 15 (2007): 259-260 and Robert Guralnick, Andrew Hill and Meredith Lane, "Towards a Collaborative, Global Infrastructure for Biodiversity Assessment," *Ecology Letters* 10 (2007): 663-672.
[578] Robert Kohler, "Finders, Keepers: Collecting Sciences and Collecting Practice," *Hist. Sci.* 45 (2007): 428.

history they risked doing theoretical work that was ungrounded in what actually occurred in nature. But the practical pressure on a young scientist to publish early and often makes such an investment of time difficult to manage. What I learned in the course of my graduate studies in oceanography was that I was more interested in the narrative and history of what I was studying, than in the day-to-day practice, which pushed me to provide causative explanations of what happened in nature before I had time to adequately observe or even conduct a thorough literature review. I wanted to be a natural historian more than I wanted to be a biologist. In the end, I concluded it would be easier to study natural history as a historian than as a scientist.

I left graduate school with an as yet unexplored interest in fish biogeography, and when I was in the process of choosing my dissertation topic for the history of science, initially I was interested in studying the colonial network of fish collectors who provided the fish collections on which nineteenth century knowledge of global fish distributions was based. But a cursory investigation of the literature in the history of ichthyology revealed how poorly advanced basic knowledge of the development of the discipline was. While some regional histories of ichthyology were available,[579] the last attempt at a comprehensive history of the field was the one written by Cuvier at the beginning of the first volume of *Histoire naturelle des poisons* published in 1828. A broad survey of the literature such as Cuvier had offered was impractical, but the historian of science Paul Lawrence Farber's disciplinary history of ornithology provided

[579] In addition to Brian Saunder's book on Australian Ichthyology *Discovery of Australia's Fishes*, American ichthyologists have written summaries of American ichthyology see George Myers, "A Brief Sketch of the History of Ichthyology in America to the year 1850," *Copeia* 1964, no. 1 (1964): 33-41 and Carl Hubbs, "History of Ichthyology in the United States after 1850," *Copia* 1964, no. 1 (1964): 42-60.

a model that I found useful to adopt. Writing a disciplinary history for ichthyology seemed like a logical starting place to lay a foundation on which future research for the history of ichthyology could be based. It also offered me the opportunity to consider Farber's question regarding how similar different zoological disciplinary histories would be.[580]

Zoological disciplinary histories cut across many elements within the narrative of the development of the natural sciences. My work on the disciplinary formation of ichthyology suggests that there are indeed some standard elements to be found in different branches of zoology, such as the importance of systematics, collection building, and the production of large descriptive works. But it is also true that there are many unique aspects to these histories which are shaped by the individuals who worked on these projects, the timing of major works, their relationship to the development of the life sciences and the cultural contexts under which zoologists worked. For myself an example of an unexpected aspect of the narrative of ichthyological history is the place the that leading ichthyologists I studied played as vocal opponents to the development to evolutionary theory over the course of the nineteenth century. This may not be surprising to other historians of science, but when I began studying in the field, I was initially very resistant to examining the relationship between science and religion. It was only as I began to recognize how necessary it was to take this aspect of the history into account to gain a wholistic view of the development of scientific ideas that I began to more closely examine this aspect of how science functioned.

When organisms become objects of human interest as pets, objects of study, food stuff, ornamentation or in whatever other capacity they are examined or manipulated within their

[580] Farber, *Discovering Birds*, xxiii.

relationship to humanity, they are transformed into cultural artifacts. As cultural artifacts, different groups of organisms are handled in different ways, relating to the unique properties of the organisms. This can easily be illustrated by examples drawn from the various histories of natural history collection.[581] For instance, Farber opened his discussion of the history of ornithology with a description of the place birds played in eighteenth century culture, as food, decorative motifs, and how feathers became high fashion accessories.[582] In Peter Dance's book *A History of Shell Collecting*, the author made clear that even though the collection of mollusk shells was something of a eighteenth and nineteenth century obsession in Europe, most of the collectors knew very little about the lives or anatomies of the organisms that inhabited these shells.[583] In the middle of the nineteenth century, when technological advances such as the invention of cheap glass made the mass production of aquariums possible, it transformed the way people collected and studied fish and other aquatic organisms.[584] The place that animals have played as pets, domesticated livestock, and objects of spectacle have engaged people with the question of what it means to be human and what ethical relationships should exist between humans and the animals they most closely associate with.[585] J. F. M. Clark's discussion of the development of entomology has shown the interest nineteenth century naturalists had in insect behavior and the concerns they had over insects as agricultural pests.[586]

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[581] An instance of an early modern account of how organisms become cultural artifacts as well as objects of study can be found in the following work. Janice Neri, *The Insect and the Image: Visualizing Nature in Early Modern Europe, 1500-1700* (Minneapolis: University of Minnesota Press, 2011).
[582] Farber, *Discovering Birds*, 1-4.
[583] S. Peter Dance, *A History of Shell Collecting* (Leiden: E. J. Brill, 1986).
[584] Jim Endersby, *A Guinea Pig's History of Biology* (Cambridge, MA: Harvard University Press, 2007), 376-378.
[585] Harriet Ritvo, *The Animal Estate: The English and Other Creatures in the Victorian Age* (Cambridge, MA: Harvard University Press, 1987).
[586] J. F. M. Clark, *Bugs and the Victorians* (New Haven: Yale University Press, 2009).

When closely engaging the question of how people learned about the animal world, even though the existing historiography is fairly limited, it has made clear that zoology cannot simply be understood as an intellectual pursuit, but a study that encountered animals as both material objects and as sentient beings.[587] The work that Farber has done in attempting to lay the foundations for understanding of the disciplinary development of zoology provides a good starting place. But this work should be viewed more as a cornerstone than as the basis on which the entire structure of knowledge of the development of the modern zoological disciplines can be built. The foundation needs to be extended to better take into account the individuality of the means by which naturalists attempted to understand organisms, taking on a greater appreciation of animals as parts of living communities, as creatures with distinct behavioral patterns, embracing a better understanding of physiological and developmental aspects of parturition, maturation, and senescence.

Writing such a disciplinary history required me to be ruthlessly selective in determining which naturalists to write about and what aspects of their work to focus on. There is so much that has still gone unsaid about the initial development of ichthyology, so many naturalists who wrote about fish that had to be ignored. In my dissertation, I have made no mention of the connections between ichthyology and the development of early fisheries biology.[588] I have not had the time to pursue connections with the establishment of marine laboratories, coastal

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[587] Clark, *Bugs and the Victorians*, 57-104. Interestingly enough, it was Clark's book on entomology that spends the most time discussing animal behavior. Apparently, the Victorians were fascinated by the behavior of insects.
[588] The rise of fisheries biology and the history of the impact of humans on fish populations is a subject that has attracted the attention of both scientist and historians. Jennifer Hubbard, *A Science on the Scales: The Rise of Canadian Atlantic Fisheries Biology, 1898-1938* (Toronto: University of Toronto Press, 2006). Callum Roberts, *The Unnatural History of the Sea* (Washington: Island Press/Shearwater Books, 2007).

surveys, or the development of the field of biological oceanography.[589] While I made a passing reference to the development of aquaculture while discussing Günther's textbook, there is no serious discussion of the part aquaculture has played in the economics of fish as food items or as objects of scientific study. The point I am trying to make is that the past practice of zoology and various organismal groups that are encompassed by it provide such an abundance of material, that historians attempting to formulate disciplinary histories, have many potential narrative routes that could be used to navigate their way through these histories. These accounts take on an individualist quality, since it is not clear that any given historian of science would always make the same choices when deciding to represent how the particular disciplines such as ornithology, ichthyology, herpetology, mammalogy, entomology, or malacology were initially formed.

There is so much more that could be said about the history of disciplinary development within ichthyology or the broader field of zoology, that I am doubtful that a very comprehensive portrait of the process will soon emerge unless the subject attracts an active community of scholarship. The later part of the nineteenth century, the point at which my narrative leaves off, represents a very active time in the development of ichthyology. From the Renaissance to the early-nineteenth century, European taxonomists had dominated species description and the dissemination of knowledge of fish taxonomy. But that pattern began to shift in the early

[589] Eric Mills history of biological oceanography is largely focused on plankton; a history of larger range of marine fauna including fish certainly would be merited. Eric Mills, *Biological Oceanography: An Early History, 1870-1960* (Toronto: University of Toronto Press, 2012). Alexander Bache, who was central to the expansion of the U.S. Coastal survey was also a friend of Louis Agassiz, for this and other reasons there is room for further development of the relationship to coastal survey, ichthyology and fisheries history. Hugh Slotten, *Patronage, Practice, and the Culture of American Science: Alexander Dallas Bache and the U.S. Coast Survey* (Cambridge: Cambridge University Press, 1994).

to mid-nineteenth century as individuals, mostly of European descent, now living in colonial and ex-colonial regions of the world, began to show greater initiative in collecting, describing, and housing their own specimens. Two regions of the world that showed particular precocity in taking charge of these activities were North America and Australia.[590] Additionally, with the establishment of museums in colonial and ex-colonial regions of the world, naturalists settled in these regions had an alternative to sending their specimens to the major museums in Europe.[591] By the late nineteenth century in the United States, collectors had the option of depositing their specimens in a range of locations, including with university and society collections such as the Academy of Natural Sciences in Philadelphia, founded in 1812, within provincial museums, or in a number of major museums such as the Smithsonian, established in 1846, or the American Museum of Natural History, established in 1869.

Because he was briefly mentored by both Agassiz and Günther, the American ichthyologist David Starr Jordan (1851-1931) presents an interesting case to consider in relationship of the transition between ichthyology practice as dominated by European institutions, and the rise of a class of professional ichthyologists in the United States during the late-nineteenth and early-twentieth century. Jordan attended Agassiz's summer school on Penikese Island in 1873, the final year of Agassiz's life.[592] He also visited Günther at the British

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[590] For an introduction to the history of ichthyology in Canada see J.R. Dymond, "A History of Ichthyology in Canada," *Copeia* 1964, no. 1 (1964) 2-33. For the USA see Myers, "A Brief Sketch of the History of Ichthyology," 33-41. and Hubbs. "History of Ichthyology in the United States after 1850," 42-60. For a history of ichthyology in Australia see Brian Saunders, *Discovery of Australia's Fishes.*

[591] Susan Sheets-Pyenson, *Cathedrals of Science: The Development of Colonial Natural History Museums during the Late Nineteenth Century* (Kingston: McGill-Queen's University Press, 1988). According to Sheets-Pyenson there was a large number of museums built in colonial territories in the late nineteenth century. By 1900 there were 250 museums in the United States.

[592] Winsor, *Reading the Shape of Nature*, 35.

Museum in 1881 and impressed Günther sufficiently, that if adequate funding had then been available, Günther would have offered Jordan a position.[593] It would require a more sustained study of the community of ichthyologists in the nineteenth and early-twentieth century to ascertain how representative the differences between Günther and Jordan's careers were in showing what influence time and geography made to how ichthyologists studied fish. But a cursory look suggests that the differences are telling. An aspect of Jordan's career that is significantly different from his predecessor is the sight of their respective careers. Instead of being a museum worker, Jordan was an academic ichthyologist, holding jobs first at the University of Indiana and later at Stanford University.[594] Three aspects of Jordan's work can be identified that seem to indicate significant differences in practice between the two ichthyologists: 1) Jordan was more of a regional specialist, focusing on fish from the United States and Japan. 2) In the textbook Jordan wrote emulating Günther, he focused less on fish paleontology, and on issues of geographical distribution declined to rely on geological explanations and instead referred to physical geography.[595] 3) Jordan's textbook also demonstrates that he enthusiastically embraced Darwin's evolutionary ideas.[596]

The transition observed between the careers of Günther and Jordan can be seen as part of an ongoing process of change in the practice of zoology in the nineteenth century. Over the course of the careers of Cuvier, Agassiz and Günther, the student of ichthyology history can

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[593] Gunther, *Century of Zoology*, 338-341.
[594] Martin Brittan, "The Stanford School of Ichthyology: Eighty Years (1891-1970) for Jordan (1851-1931) to Myers (1905-1985)," In *Collection Building in Ichthyology and Herpetology*, edited by Theodore Pietsch and William Anderson (Lawrence: Allen Press Inc., 1997), 233-263.
[595] For a sense of Jordan's geographical perspective of fish see chapters 14-17 of, Jordan, *Guide to the Study of Fishes*, Vol. 1, 237-319.
[596] Ibid, 435-459. Chapter 24 is telling entitled "The Evolution of Fishes."

already trace a growing specialization. While Cuvier and Agassiz might more accurately be identified as generalists, Günther clearly specialized in ichthyology and herpetology. Cuvier was well aware of the weight of detail that naturalists needed to master in order to understand the zoological world and anticipated the need for increasing specialization. Biodiversity presents students of nature with an ongoing representational tension. Do we dwell on the details, as Cuvier insisted we must, in the opening of his history of ichthyology where he states that, "Natural history is a science of facts, and the number of facts it embraces is so great that no one person can gather or verify the totality that make up even one of its branches."[597] Or do we try to build encompassing narratives like Darwin attempted to in *Origin of Species*? Within the field of natural history there seems to be a place for both approaches. And yet consider the fact that the work of Cuvier can exist without Darwin's. But what would Darwin have been without Cuvier or all the other members of the veritable army of naturalists who proceeded him?

[597] Cuvier, *Historical Portrait of the Progress of Ichthyology*, 3.

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