The Fate of William Whewell's Four Palætiological Domains: A Comparative Study

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Perspectives on Science, Volume 27, Number 6, November-December 2019, pp. 810-838 (Article)

Published by The MIT Press

The Fate of William Whewell's Four Palætiological Domains: A Comparative Study

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In 1847, the British polymath William Whewell pointed out that the sciences for which he, in 1837, had coined the term "palætiological" have much in common and that they may reflect light upon each other by being treated together. This recommendation is here put into practice in a specific way, to wit, not by comparing the palaetiological sciences that Whewell distinguished himself but by comparing the general historical development of the scientific study of the four broad palætiological domains that he enumerated in 1847: the solar system, the Earth, its vegetable and animal creation, and man.

For wide and various as their subjects are, it will be found that [the palætiological sciences] have all certain principles, maxims, and rules of procedure in common; and thus may reflect light upon each other by being treated together. William Whewell (1847, 1, p. 640)

1. Introduction

In its modern meaning, the term "science" refers to a both diachronically and synchronically multifaceted and heterogeneous subculture. Even the long quest for a delineation of a method that all the sciences supposedly have in common has proven to be futile.[1] Likewise, Thomas Kuhn's historical development model of sciences, including the structure that supposedly is shared by all scientific revolutions, has not withstood critical examination

I would like to thank two reviewers for reviewing this paper and for their helpful comments.

1. For an overview of this quest, see, e.g., Paul Hoyningen-Huene 2013.

Perspectives on Science 2019, vol. 27, no. 6

https://doi.org/10.1162/posc_a_00326

(e.g., Reingold 1980). Michel Foucault's (1970) somewhat similar development pattern has not convinced historians either, even though it was restricted to only a few sciences.[2] However, that does not mean that sciences have nothing at all in common nor that there are no groups of sciences which have some significant features in common.

One example of the latter kind of sciences are the so-called palætiological sciences: the sciences in which, as William Whewell (1837, 3, p. 481) put it, "the object is, to ascend from the present state of things to a more ancient condition, from which the present is derived by intelligible causes."[3] In a table in *The Philosophy of the Inductive Sciences* (1847, 2, p. 117), he defined the fundamental idea by which these sciences are inspired as "historical causation" and distinguished them from other categories of sciences such as the pure mathematical sciences, the pure motional sciences and the mechanical sciences, which each were inspired by their own fundamental idea or conception. His two exemplary palætiological sciences were geology and comparative philology, but he realized that some other sciences also had palætiological divisions, such as astronomy and the science that he, in 1840, began to call "biology." He also distinguished three components in palætiological sciences: a descriptive component, an aetiological component (i.e., the discovery of causes and their limits) and a final theoretical component or "theory of facts" which resulted from "the application of causes well understood to facts well ascertained" (Whewell 1847, 1, p. 664). They were not (to be) practiced in a chronological fashion but each component depended to some extent on advances in the preceding component.

In the said table, he enumerated four palætiological sciences: geology, distribution of plants and animals, glossology (history of languages) and ethnography. Strangely enough, biology was not categorized as a palætiological science. It appeared in the separate category of "organical sciences" and was based on the fundamental idea of organization. This nicely illustrates what will be reiterated below: a synthetic life science was initially not founded upon the idea of historical or evolutionary causation. Put differently: it was, in contrast with the specific study of the post-Deluge distribution of plants and animals, initially not conceived as a palætiological science.

2. Foucault excavated three discrete and discontinuous épistèmês (ἐπιστήμη is Greek for science or knowledge)—sets of rules that were not consciously grasped but shaped and shape what can be thought and said—in the history of Western thought and demonstrated how they corresponded with three distinct phases in the historical development of three sciences: linguistics, biology, and economics. He criticized the history of ideas, arguing that it presupposed continuity, whereas his archaeology or excavation revealed sharp discontinuities between these three different systems of thought.

3. It was a combination of the term "aetiological," sometimes used for the sciences which treat of causes, and "paleontology," the study of beings which formerly existed.

More important for the present paper are the four broad palætiological domains that he distinguished: the solar system—the then known universe as a whole was still deemed to be a steady-state system—, the Earth, its vegetable and animal creation, and man (Whewell 1847, 1, p. 654).[4] Whewell's work on the (philosophy of) palætiological sciences has received some attention from philosophers and historians of science.[5] However, the historical development of the scientific study of these four broad palætiological domains has not yet been investigated from a comparative perspective. Nor have philosophers or historians invested much time or energy in the question whether there is any truth in Whewell's suggestion that the palætiological sciences might reflect light upon each other by being treated together.[6] In the mid-nineteenth century, only one of his four palætiological domains had become the subject of a palætiological master science: Earth. In the ensuing decades, the modern master science of biology would gradually come into being (as a palætiological science), whereas, in the twentieth century, the cosmos became the subject of a third palætiological science, once the realisation dawned that it was a palætiological domain of its own: cosmology (section 2).

These three modern palætiological sciences form the main subject of the present paper. In the conclusion, I will briefly come back to the intriguing question as to why Whewell's fourth broad palætiological domain—man—did not (yet) inspire a fourth palætiological master science (although Whewell himself already distinguished several human palætiological disciplines, such as the aforementioned science of ethnography, in the same way that he also already recognized biogeography as a biological palætiological discipline). The philosophical question as to the ontological nature of the historical development of Earth, life and the cosmos—more or less deterministic, as opposed to contingent or stochastic and therefore predictable, as opposed to unpredictable—also largely falls beyond the scope of this paper.

One thing is crystal clear: the discovery of the deep history of, respectively, Earth, life and the universe played a crucial role in the genesis of geology, biology and cosmology, respectively, as, of course, was to be expected of palætiological sciences. It separates, as we shall see, the prehistory of these sciences from their actual histories. Moreover, in the case of the sister sciences geology and biology, the resemblance doesn't end there. One of the additional parallels is that the discovery of the deep history of

4. See, e.g., also pp. 638–39, 700. For this paper, I have taken the liberty of considering, with the benefit of hindsight, the cosmos as a whole as a Whewellian, palætiological domain.

5. See Quinn 2016, p. 11.

6. O'Hara (1996) demonstrates the continuing validity of Whewell's classification through a study of historical representation in three different palætiological subfields: systematics, historical linguistics, and textual transmission.

Earth and life, respectively, facilitated the integration of various Earth and life sciences into two master sciences (i.e., geology and biology) by providing them with a common and integrating, descriptive (describendum) and/or explanatory (explanandum and explanans) focus. It should immediately be added and emphasized, though, that not all Earth and life disciplines were (and/or are) equally involved in this integrative exercise.[7] Which, in turn, is one of the reasons why the rich and multifaceted history of geology and biology cannot be reduced to this pattern. It merely constitutes—or so it will be argued—the core or the backbone of the historical development of these master sciences (section 3).[8] A look at the history of geology and biology through the lens of this common Bauplan is, in any case, heuristically interesting as it reveals, or sheds somewhat new light on, several peculiarities in those histories.

2. Cosmology

I can be brief about the (pre)history of cosmology. He does not use the specific terms "prehistory" and "history" but in a recent paper, Jacob Pearce (2017) points out that it is only in the early twentieth century, when the cosmos was gradually interpreted as a palætiological or evolutionary phenomenon, that the cosmos as a whole became an object of modern scientific discovery, even though cosmological questions have evidently been around since long before then. It was Einstein's general theory of relativity (1917), the theoretical source of inspiration for the Big Bang model, that marked this birth of modern or scientific cosmology. Although it should be added that "cosmology as a serious scientific discipline began much later, not becoming established until as late as the 1960s" (Pearce 2017, p. 18). The intervening period (i.e., 1920–1970) was characterized

7. Peter J. Bowler and John V. Pickstone point out, in this respect, that we should not assume "that evolution was a major determinant in all biological sciences. Much of late nineteenth century biology can be profitably studied in terms of the changing patterns of work within established areas such as morphology or physiology (…)" (Bowler and Pickstone 2009, pp. 3–4). Many life sciences were indeed only Darwinized in the twentieth century and some, such as medicine, remain to be fully Darwinized.

8. A complete history of these sciences should for example also explicate national differences or peculiarities or investigate the impact of philosophies, cultural movements, new technologies and so forth on their historical development. As Guntau puts it: "the rise of geology as a scientific discipline did not occur on the basis of a single event" (Guntau 1978, p. 287). Rudwick (2005, p. 7) also emphasizes this in his historical survey of the "historicization of the earth, in what became the science of geology": it should not be confounded with a comprehensive history of geology. Elsewhere, he puts it thus: "I must emphasize that [*Bursting the Limits of Time*] and [*Worlds Before Adam*] have not set out to describe the history of the earth sciences as a whole, even during the few decades that the volumes jointly cover" (Rudwick 2008, p. 555).

by a dispute between the Big Bang model and the Steady State model (Kragh 1996). There is, as we shall see, an equivalent for this preparadigmatic period in the history of biology.

Since then (i.e., 1970), the historical style has become the "bedrock of [cosmology] and the condition of its possibility…It has configured and reconfigured the terrain of possibilities for modern cosmology. Approaches that do not build on the foundations laid by the historical style are, by and large, not seen as possible ways of doing cosmology" (Pearce 2017, p. 18). Pearce makes, in this respect, also the comparison with geology and biology: "In the same way that historical explanations are given in geology… features of the universe are now universally understood in terms of historicity" (Pearce 2017, p. 17). And: "It should be noted that the historical style was already present in some other disciplines at the beginning of the twentieth century—such as evolutionary theories in biology in the nineteenth century (Bowler 1989) or historical accounts of the earth in eighteenth century geology (Gohau 1990). Objects of scientific inquiry were interpreted in terms of their historicity" (Pearce 2017, p. 18). Lastly, he also points out that, with recent atemporal "ensemble" type multiverse proposals, "a certain type of ahistorical reasoning has been reintroduced to cosmological discourse…" (Pearce 2017, p.18). Interestingly, this kind of reasoning has also been reintroduced to modern or late-twentieth century geological and biological discourse.

3. Geology and Biology

The aforementioned historical Bauplan of geology and biology consists of three components or phases which will be treated in consecutive order: a prehistorical phase, the emergence of the notion of a science, dedicated to the study of Earth and life (i.e., the conceptual birth of these sciences), and the subsequent history of geology and biology, characterized by a certain integration of various Earth and life sciences, facilitated by the discovery of the deep history of Earth and life.

3.1. The Prehistory

Bernadette Bensaude-Vincent (2003) points out that the standard periodization of nineteenth century chemistry often reflects modern divisions of that science into inorganic, organic, and physical chemistry.[9] Smith (1995, p. 105) likewise rejects a "pillarized" approach to the historical study of the

9. Porter (1980) calls this "tunnel histories": histories that trace "the progress of modern scientific disciplines, rather than exploring the cognitive landscapes of the past" (p. 286). He adds that "It has been all too common to take for granted the nature and distribution of present scientific disciplines, their contents and their parameters, as if they timelessly reflected

human sciences, "an approach that excavates foundations for each of the modern psychological or social sciences, falsely projecting back socially constructed categories into another age."[10] In the case of geology and biology, the opposite occurs: the modern unity is often projected back into a fragmented past. Certain Earth and life phenomena were indeed already known and reflected upon or empirically investigated, long before the invention of geology and biology, but not in an integrated way and not under the specific headings of geology and biology but rather under the general headings, or in the general context of, endeavours or fields like biblical exegesis, travel stories, natural theology and, particularly, natural philosophy and natural history.

Gohau (1990, p. 7) states that what he calls the "prehistory of the earth sciences" was characterized by a "multiplicity of methods within disciplines with little common ground" and a certain aimlessness.[11] This is also what the first geologists thought. Looking back at their predecessors, they were exacerbated by "the aimlessness of previous inquiry: its lack of recognizable order, direction, common goals, research programs" (Porter 1977, p. 208). The prehistory of geology does indeed encompass a wide and heterogeneous array of fields and endeavors. One example are mythological accounts of the origin of the Earth. These were, in the seventeenth century, succeeded by speculative or philosophical cosmogonies and, after the completion of the heliocentric revolution (i.e., when the Earth's status could be detached from that of the whole universe), with mechanical and chemical geogonies. Another field that should be mentioned in a survey of the prehistory of geology is biblical exegesis or "scholarly inquiry into the written word" (Porter 1977, p. 11). A good example of this genre is Athanasius Kircher's *Noah's Ark* (*Arca Noë*, 1675), a painstaking analysis of the Flood, based on all the known versions of the biblical text. Kircher was, however, also the author of *The Subterranean World* (*Mundus Subterraneus*, 1668), a description of the Earth as a complex and dynamic but ahistorical system which was inspired by the contemporary empirical investigation of nature.

nature" (p. 318). And: "Historians still have much work to do in thinking themselves out of 'presentist' disciplinary boundaries, like 'history of geology' and 'history of oceanography'…" (p. 324).

10. He refers, more particularly, to the habit of situating the birth of the human and the social sciences, or at least a certain number of them, in the eighteenth century. In reality, there were not only no disciplines in the modern institutional sense in the eighteenth century, even "the terms and investigative activity making possible such differentiated scholarship did not exist" (p. 105). For the counterargument, see Graham et al. (1983).

11. However, he at the same time also portrays sixteenth- and seventeenth century theories of the Earth as "the first act of our history of geology" (p. 2). Guntau (1978, p. 280) also refers to the eighteenth century as the "*prehistory* of geology."

It was these kinds of investigations of Earth phenomena that delivered the empirical and theoretical material for the nineteenth century realization of the project of geology. Martin S. J. Rudwick (2005), the doyen of historians of the Earth sciences, distinguishes more specifically four eighteenth century ahistorical sciences or fields of expertise, concerned with the Earth: mineralogy, physical geography, geognosy and Earth physics.[12] The first three belonged to the domain of natural history (i.e., they were descriptive). Mineralogy was the main science and studied and classified minerals, rocks and fossils. Physical geography focused on large-scale surface features of the planet such as mountains and volcanoes. Geognosy was, like physical geography, a field science, but studied the underground, laid bare by mining. The fourth ahistorical Earth science, Earth physics, belonged to the field of natural philosophy as it sought to causally understand the phenomena, described and classified by the natural history disciplines (e.g., the reason for the stoniness of rocks or the emplacement of fossils far from the sea). This discipline would, initially, not participate in the integrated study of the Earth that emerged in the late eighteenth century.

Rudwick (2005, p. 59) points out that none of these four disciplines individually, "nor all of them collectively, can be called 'geology' without serious anachronism: the word itself was just beginning to be used regularly, but for yet another kind of scientific project." Or rather, for a specific kind of analyses, called geotheories, theories which "gave accounts of the earth's temporal development deduced mainly from first principles rather than being induced from the particulars of surviving relics of the past: *they described how the earth must (or at least ought to) have developed in the past and how it would necessarily continue to change in the future, given certain initial conditions and unchanging physical principles*" (Rudwick 2005, p. 641; emphasis added).[13] Put differently, theories of the Earth studied the geological (deep) past of the planet but they saw this past as the equivalent of the not very eventful or coincident past of the solar system: certain forces caused the repeated occurrence of the same, predictable phenomena (cyclical geotheories, such as the geotheory of James Hutton or Charles Lyell) or they steered the development of the Earth in a certain, predictable direction (directional geotheories, such as the geotheory of René Descartes or

12. See also Rudwick (2004). Likewise, Taylor (1979) argues for the existence of a "pregeological" set of Earth disciplines. See also Taylor (2008) and Gohau (2003).

13. Laudan (1987, p. 5) calls them genetic causal theories, a subset of causal theories. She points out that "some prominent geologists continue to advocate [genetic causal theories], an advocacy that seems to me well-founded (Bowen 1928)." She believes that there exist two kinds of geology, one that is derived from the tradition of natural history and another that is derived from the tradition of natural philosophy (Laudan 1982). See, in this respect, also note 38.

Buffon). These physical principles not only allowed the savant to predict the future of the planet but also to predict in retrospect or "retrodict" (cf. the retrodiction of the position of a star constellation at a particular point in the past in modern cosmology).

In a similar vein, one cannot use the term "biology" for the seventeenth- or even eighteenth century study of life phenomena: biology did not exist in the eighteenth century. Or, as Foucault (1970, p. 139) put it: the pattern of knowledge that has been familiar to us for a hundred and fifty years is not valid for the previous period. Salomon-Bayet (1981, p. 46) refers in this respect to the prehistory or archaeology of biology. She argues that the history of biology only started from the moment that the term "biology" was coined (1802), because history only starts with the written word.[14] Before 1802, we can only speak of life sciences like physiology, natural history (i.e., inquiry in nature) or anatomy, not of biology. Even the phrase "life sciences" is anachronistic since it was not used at the time: like the prehistory of geology, the prehistory of biology encompassed a wide array of fields but they were not known as life sciences.

Life phenomena were mostly studied under the general heading of natural history. Karl Linnaeus' famous taxonomy of plants, animals and minerals is a paradigmatic example. George Cuvier, the father of paleontology, was professor of natural history in the Collège de France and worked at the Museum of Natural History. The study of the geographical dispersal of animals and plants (what we know as biogeography) also mainly belonged to the domain of natural history, although it started out as an exercise in biblical exegesis. Confronted with a wealth of new creatures from recently discovered parts of the world, seventeenth century naturalists and theologians had to deal with the question whether the Ark could have accommodated all these animals. They circumvented this puzzle by focusing on the Flood: if the Earth indeed had been submerged, all modern species must have been on board the Ark, or they would not exist today. This, in turn, forced them to consider another problem, "namely, the way the earth was restocked with animals and plants" (Browne 1983, p. 10). The question of the causes of this process belonged to the domain of natural philosophy, which, for example, also encompassed plant and animal physiology.

3.2 The Conceptual Birth

The emergence of the notion of a specific science, dedicated to the study of Earth and of another science, dedicated to the study of life, formed part of

14. Strictly speaking, her argument is not entirely correct. The modern concept of an integrated and autonomous scientific study of life was, as we shall shortly see, indeed invented in 1802, but the term "biology" is older than 1802.

the complex transition of eighteenth century natural philosophy and natural history to the modern sciences, also known as the second scientific revolution, which explains why historical studies, devoted to these two sciences occupy a central place in the literature about this revolution.[15] In both cases, the general idea of such a science was preceded and facilitated by an important ontological distinction. One that, so to say, emancipated the phenomena of Earth and life as independent or autonomous subjects.

In the case of geology, that distinction was, as already indicated above, that between Earth and the wider cosmos. Early speculations about our planet referred to "the cosmos as a whole and emphasized cosmology rather than geology. Only after the astronomical revolution of Copernicus and Galileo did thoughts about the earth become dissociated from those about the universe" (Gohau 1990, p. 1). Or, as Porter (1977, p. 11) puts it: "Not till the total triumph of heliocentrism could the Earth's status begin to be detached from that of the whole universe." Long before that total triumph (i.e., the late seventeenth century), predecessors of the term "geology" (geologia or giologia) were already used, though, for specific phenomena like "the science of earthly things" (1344, Richard de Bury), "fossilia" or things that had been unearthed (1603, Ulisse Al-drovandi) and "that which discusses the Earth and its influences" (1687, Fabrizio Sessa).[16] In the following century, the term "geology" subsequently came into use for the non-historical study of the Earth, "with its Furniture", (Anon. 1731, p. 388), as it was formulated in *The Present State of the Republick of Letters*, or, in the case of John Walker, Regius Professor of Natural history at the University of Edinburgh, without its "Furniture."[17] These early definitions "included almost every aspect of natural history dealing with the earth" (Dean 1979, p. 37).[18]

15. See, e.g., Kuhn ([1961] 1977), Cunningham (1988), Brush (1988) and Cunningham and Williams (1993). The term "science" acquired its modern meaning and the first histories of science were published, "as it could only be, if the practice itself had only just been invented" (Cunningham 1988, p. 386). It is undoubtedly also no coincidence that it was in 1818 that the literary genre of science fiction came into being with the publication of Mary Shelley's *Frankenstein*. Or that a few decades later (1834), the term "scientist" was coined. For a counter argument, see Grant 2007, p. 321.

16. See Dean (1979). He claims that de Bury used the term "geologiam."

17. "Geology" was, more particularly, coined as an alternative name for one of the two special parts of natural philosophy "wherein are explained all the particular Phaenomena in Heaven and Earth" (Anon. 1731, p. 388). These two special parts were astronomy and physics. However, as the latter term was often used synonymously with natural philosophy in general, the author proposed an alternative: "geology." See, e.g., also Martin 1735, pp. 10, 11.

18. The term "history" derives, through the Latin historia, from the Greek word "ἱστορία" which meant inquiry or knowing by inquiry. The phrase "natural history" is the only phrase in which this original meaning is retained.

Kenneth L. Taylor (2008, p. 78) states that, speaking strictly, as late as 1776, there was still no geology: "The term itself had not yet been coined, at least not with the scientific meaning it was shortly to acquire." Three years later, Horace-Bénédict de Saussure (1779) was probably the first savant to clearly use the term "geology" in its modern, historical meaning.[19] From the 1780's onward, "geology" also "behaves increasingly as if it were an established English word" (Dean 1979, p. 40). Through the founding of the Geological Society of London in November 1807, the word was given its final and official sanction. Charles Lyell's (1830–1833, 1, p. 1) definition from the early 1830s was particularly influential (his conception of history was not directional and progressive but that aspect of his work was largely ignored):

> Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; it enquires into the causes of these changes, and the influences which they have exerted in modifying the surface and external structure of our planet.[20]

A standard modern definition of geology is "The branch of science concerned with the physical structure and substance of the earth, the processes which act on these, and the earth's development since its formation" (Oxford English Dictionary). It can be misleading though, in that many contemporary geologists believe that the study of the Earth's historical development is not the last goal of their science but either its only or its ultimate goal, i.e., the goal that "integrates all the other subdisciplines of geology" (Laudan 1987, p. 2). All geologists aim at gathering "the data and generalizations necessary *for the reconstruction of the historical record*" (Laudan 1987, p. 2; my italics).

In a similar vein, the status of the phenomenon of life had to be detached from that of inanimate matter before the concept of a science, specifically dedicated to this phenomenon could be conceived. Jacob (1973, p. 33) has, in this respect, argued that the concept of a living organism, or an entity

19. Referring to this work and to the use, in the 1790s, of the word "geology" by Jean André Deluc, David R. Oldroyd (1979, p. 231) writes: "We have here an indication of the establishment of a new science, and moreover one with an explicitly recognized historical field of enquiry." In his account of the historicization of the Earth in the new science of geology, Rudwick uses De Saussure's successful ascent of the Mont Blanc, in 1787, as "a historian's golden spike, plunged into the seamless flow of human history" (Rudwick 2005, p. 22). For other examples of early uses of the term "geology" in its modern meaning, see, e.g., Cuvier (1810, pp. 133–34) and Brongniart (1816, p. xlvi).

20. Dean (1979, p. 43) calls it "the most influential definition of the science ever written…". My aforementioned distinction between the describendum, the explanandum, and the explanans is clearly discernible in this definition.

that contains within itself the principles of formation and regulation, could not arise until the early nineteenth century (when the concept of biology was first formulated): "Until the end of the eighteenth century there was no clear boundary between beings and things. The living extended without a break into the inanimate… There was as yet no fundamental division between the living and the non-living."[21] And, as had been the case with geology, the term "biology" was, in the eighteenth century, already used to refer to some of the prehistorical life disciplines or for certain life phenomena.[22] Johann Planer (1771), for example, used it in the meaning of "botany"; Theodor Georg Roose (1797) for the phenomenon of vitality, in a book on *Lebenskraft*; Thomas Beddoes (1799) for the phenomenon of physiology ("the doctrine of the living system in all its states"); and Karl Friedrich Burdach (1800) for an anthropological science: the study of man from a morphological, physiological, and psychological perspective.

Michael C. Hanov seems to have been the first to use the term biology in its modern meaning, in a subtitle of his *Natural Philosophy or Dogmatic Physics* (*Philosophia naturalis sive physica dogmatica*) (1762–1768).[23] However, it is only in the early nineteenth century that modern definitions of the word biology were formulated. In his multi-volume treatise *Biologie, oder Philosophie der lebenden Natur für Naturforscher und Aerzte* (1802–1822, p. 444, my italics), Gottfried Reinhold Treviranus defined biology thus:

> The object of our study will be the different forms and phenomena of life, those conditions and laws, under which this state will occur, and those causes through which it is influenced. The science which works on these subjects will be called biology, or the science of life. *We shall thus begin to work with material, which has so far been dispersed among many different disciplines, especially in natural history and theoretical medicine.*

This notion of an ahistorical synthetic life science can be seen as the equivalent of the eighteenth century concept (with nineteenth century extensions) of an ahistorical science of geology (with or without "Furniture").[24]

21. See also pp. 74–5, 88–9. See also Foucault (1970) and Roger (1980). Roger wonders whether vitalism was, ultimately, "responsible for the definition, at the end of the century, of a new science, uniquely devoted to the study life, and whose name, accordingly, should be 'biology'?" (p. 276).

22. It had, in the seventeenth century, even been used in the meaning of "biography." See McLaughlin (2002, p. 1n2). For pre-nineteenth century uses of the term "biologie," see also Richards (1992) and Müller (1983).

23. See McLaughlin (2002). Schiller (1980) points out that the term biology continued to be used in various non-modern ways throughout the nineteenth century.

24. Gayon (2004) points out, though, that the total plan of Treviranus' six volume work on the philosophy of living nature clearly shows that his biology wanted at the same time to study the general conditions of the phenomenon of life and to offer an overview of

In the same year that Treviranus coined the idea of an integrated science of life, the French naturalist Jean-Baptiste Pierre Antoine de Monet, Chevalier de Lamarck presented in his *Hydrogéologie* (1802) a "theory of living bodies" or "Biology" as the third part of his "physique terrestre" (next to Meteorology and Hydrogeology, the theory of the external crust of the globe). The observations, he wrote, that he had made about living bodies, the principal results of which he had already announced "in the opening lecture of my lecture series of the year 9 [1801] at the Museum, will become the subject of my Biology, third and last part of the Terrestrial physics" (Lamarck 1802, p. 188).[25] In 1815 (p. 49), he wrote, in his *Histoire naturelle des animaux sans vertèbres*, that

> All that is generally common to plants and animals, as all those features which are, without exceptions, proper to all of these creatures, should be the sole and wide subject of a particular science which has not yet been founded, which has even yet no name and which I shall call biology.[26]

Roe (2003, p. 416) points out that Treviranus, Lamarck and two other naturalists (Karl Friedrich Burdach and Marie-François-Xavier Bichat) all meant something different with the term "biology" but that "all four saw a need to unify the life sciences in distinction to sciences dealing with the non-living world." That unification would eventually prove possible, largely thanks to the discovery and study of evolution.[27] Although this does not imply that biology is generally perceived to be as radically historical as geology is: it is a historical or palætiological science, but, as will be explained below, in a different, somewhat less straightforward way.

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the geographical and historical diversity of life. This may be so, but the deep history of life was not the central unifying notion of the life science that he had in mind. See also note 27.

25. Lamarck never published the text that he wrote between 1800 and 1802 and called *Biologie*, although he incorporated information from it in various works, and in particular in the *Histoire naturelle des animaux sans vertèbres* (1815). In his *Philosophie zoologique* (1809, p. xviii), he mentioned that he had made use, in this book, of a great amount of material for a planned work about living bodies, under the title "Biologie" but that this "work will now remain, as far as I am concerned, without execution."

26. In the text of his "Biologie," Lamarck referred to the "formation successive" of living beings (see Grassé 1944).

27. Richards (2003) points out that, in the work of Lamarck and Treviranus, the word biology "became immediately associated with the theory of the transmutation of species—a new term in recognition of the new laws of life" (p. 16). And: "Biology, as it came to birth at the beginning of the nineteenth century, had evolutionary biology within its genetic depths" (p. 17). Lamarck certainly was already an evolutionist and Treviranus "thought the progressive deposition of fossils evinced a modification of species over time" (p. 17). However, as pointed out before (note 24), it would go too far to claim that evolution was, from the start, the central unifying notion of the biology project.

There can, nevertheless, be no doubt about the importance of evolution as "the overall unifying concept of biology."[28]

3.3 The History

Rudwick (2005, p. 9) defines the aforementioned second scientific revolution as the time that various "basic sciences of nature were shaped or reshaped into recognizably modern forms, reconstituted from mature pre-existing branches of 'natural history' and 'natural philosophy'."[29] Geology was, at that time, indeed shaped into its modern form, but not biology. As Roger (1980, p. 277) puts it: "it is clear that biology did not appear suddenly at the end of the eighteenth century, as Athena sprang from Zeus's forehead" and "from the existence of the word we cannot conclude that the science itself existed (1980, p. 277)."[30] It is therefore only with the benefit of hindsight that we can say that the history of biology started in the beginning of the nineteenth century. Secondly, not only were not all Earth and life disciplines equally involved in this integration, as indicated above, the integrating role and central place of bio- and geohistory has, in the second half of the twentieth century, also become less important to biology and the modern Earth sciences, respectively.

Taylor (2008) states that the late eighteenth century Earth sciences were reorganized into a new and distinct science of the Earth. That reorganization, inspired by a historical turn in the study of the Earth, has been studied in detail by Rudwick (2005, 2008).[31] He examines how, starting from a few scattered essays, the marginal genre of what he calls geohistory "became a routine component of a practice that incorporated all the earlier sciences of the earth and integrated them into a new science" that "came to be known as 'geology'" (Rudwick 2005, p. 291). Geohistory emerged tentatively towards the end of the eighteenth century. It was a time when historicism, or the belief in the efficacy of explaining phenomena by means of their history, was rife and when, consequently, "many aspects of man's culture came to be viewed from an historical perspective" (Oldroyd 1979, p. 191).[32] The

28. See: https://www.livescience.com/44549-what-is-biology.html.

29. See, e.g., also Cunningham and Williams (1993, p. 422) and Cahan (2003, p. 3).

30. He adds: "one might well say that biology did not exist before the time the cell theory was fully developed" (Roger 1980, p. 277). This statement seems problematic to me. The idea of a master science of life did already exist before the development of the cell theory but biology was not yet an integrated science, even after the development of this milestone in the history of the life sciences.

31. See also Rudwick (2004) and Gohau (2003). My short account of that reorganization (i.e., the integration of prehistorical Earth disciplines into the science, called geology) is largely based on Rudwick's analysis.

32. These phenomena encompassed, for example, architectural styles, literature and music. The end of the eighteenth century was also the time that sciences such as archaeology, "with an obvious historical concern" (Oldroyd 1979, p. 191), made their appearance.

historical study of Earth emerged more particularly "by borrowing ideas, concepts, and methods from human historiography" (Rudwick 2005, p. 181). This novel historiography did not concern the methodologically innovative work of nineteenth century German historians such as von Ranke, nor the philosophical or conjectural, large-scale and grandiose histories of eighteenth century authors such as Voltaire or Herder, as some historians have argued, "but rather the Cinderella that was scorned by the philosophes: erudite histories of more limited scope, ..." (Rudwick 2005, p. 182).[33] They were based on a detailed critical study of massive, textual or artefactual (archaeological) evidence and described the particularities of how, where and when human events, during a very specific period and in a specific place, had happened.[34]

This, then, is the moment that the integration of geological disciplines started: when savants increasingly abandoned the aforementioned speculative geotheoretical approach to the Earth's past—although some geotheories already had incorporated some degree of historicity—and began, instead, to use the geohistorical approach to reconstruct the Earth's contingent past (history) with the help of data, techniques and concepts from the "earlier sciences in the study of earth" (Rudwick 2005, p. 291). Hence the modern definition of geology as a "historical, non-experimental science concerned with past configurations of the earth. It deals *with successions of unique, strictly unrepeatable events through time*" (Hallam 1978, p. 3, my italics).[35] It was indeed the discovery, towards the end of the eighteenth century, that Earth not only has an incredibly long past (deep time) but also a largely contingent past (deep history), that was instrumental in forging a number of separate guilds of savants into a more or less integrated community of geologists.[36] The key factor in their reconstruction was the enrichment of static

33. Like the historian Alexander M. Ospovat, Laudan (1987, pp. 111–12) ascribes the historical turn in the history of the Earth sciences more specifically to Abraham Werner, known as the father of German geology. He was inspired by the new historical school, centred on Göttingen. It gave "pride of place to universal history and insisted that history be based on a critical interpretation of original sources ... His insistence on an examination of the rocks was the geological equivalent of the historian's examination of the texts." His big contribution to historical geology was the central concept of rock formation (Gebirgs-formation). The essential differences between rocks of various kinds were their mode and time of formation, not their mineral composition, as the mineralogists emphasized. See also Oldroyd 1979, p. 233.

34. Exciting new discoveries in archaeology (thanks to the excavations of Herculaneum and Pompeii) also played a role in the emergence of geohistory. Rudwick (2014, p. 93) also refers to "outstanding scholarship in the writing of human history, as for example in Edward Gibbon's celebrated *Decline and Fall of the Roman Empire* (1776–88)."

35. Hallam reacted to vocal demands that geology departments should give a larger role to causal theories in their syllabi (in the wake of the success of plate tectonics).

36. As Rudwick (2014) puts it: "... what was far more significant than the stretching of the bare magnitude of the Earth's timescale was the character of the Earth's history that was reconstructed within this greatly extended span of time. As already suggested, deep

descriptions of three-dimensional rock structures (geognosy) with fossils (mineralogy): stratigraphy, the description of geological formations in specific areas, correlated by the recognition of the same fossils in equivalent formations. This was not itself historical, but it provided the framework for the empirical reconstruction of the Earth's history.

This budding geohistorical and integrating practice soon gathered steam. Physical geography did initially not contribute much to the genre. Nor was there, as already noted above, made much progress with causal problems, such as the formation of rocks or the frequent occurrence of earthquakes and the existence of volcanoes ("Earth physics"). It was only in the first half of the nineteenth century that the geohistorical and the causal were increasingly brought together and integrated and that geologists reconstructed an outline of the history of Earth with plausible explanations of many of its main characteristics, thus realising Whewell's ideal of applying "causes well understood to facts well ascertained."[37,38] "The

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history mattered far more than deep time" (p. 101). And: "Mountains and volcanoes, rocks and fossils, were recognized as being the products of nature's history; they could not be understood solely in terms of causes governed by the timeless 'laws of nature'" (p. 299).

37. This was, as we saw, the third phase in the development of a palætiological science, after a descriptive and an aetiological phase.

38. Not everybody agrees, though, with the idea that the geohistorical and the causal were, in the nineteenth century, brought together and integrated. Laudan (1982, 1987) believes that the history of geology is, since its origin, characterized by two different and never fully reconciled geologies: causal (or process) geology and historical geology. Causal geology came first and was later, at the end of the nineteenth century, complemented by the emergence of a strictly historical geology. Both did not often or usually reinforce each other although they were rarely in direct conflict. She also admits that "geologists wanted consistency between their causal and historical theories" and "wanted a fully integrated causal-historical story …" (Laudan 1987, p. 16), i.e., they wanted to reach Whewell's third phase. It seems to me, though, that 18th century causal geotheories may not be confused with the more coincident causes which were later discovered or postulated by geologists during their reconstruction of geohistory and which cannot be completely separated from that descriptive reconstruction of geohistory. The main distinction in the history of geology is (contra Laudan) probably not that between causal geology and historical geology but that between (ahistorical) geotheories (which form a part of causal geology) and geohistory. Geotheories were, in contrast with geohistory, more concerned with law-like causes than with coincident causes. It is true, though, that, in the course of the history of geology, geologists always established the reality of a (contingent) event, "well before its cause or causes were fully understood; again and again, those arguing that the events did happen have had to insist that the lack of a convincing cause for them was no reason to deny their historical reality" (Rudwick 2014, p. 298). Also, the success of plate tectonics, in the 1960s and 1970s, inspired some geologists "to insist that causal theories [i.e., law-like causes] were more central to geology than historical reconstruction" (Laudan 1987, p. 3). However, Laudan points out herself that these (modern) causal theories have a temporal dimension (i.e., they are, like more coincident causes, part and parcel of geohistory). This is a second reason why the dichotomy between causal and historical geology is, or can be, misleading.

chief tool for integrating history and causation was the 'actualistic' method of using the observable present as the key to the unobservable deep past" (Rudwick 2005, p. 558). Whereas in the mid-seventeenth century, the Earth had been investigated and conceptualized "by a multiplicity of methods within disciplines with little common ground," by the early nineteenth century, the "study of strata, fossils, landforms and minerals could be integrated within geology" (Porter 1977, p. 218).

This unity did not last, though. Geology was so intrinsically associated with the detailed reconstruction of the Earth's contingent past that the establishment of the (less contingent) plate tectonics paradigm—and, ipso facto, the addition of a deeper causative dimension to the study of the Earth's crust—became, in the last decades of the previous century, one cause of the increasing designation of the study of Earth with alternative phrases like Earth sciences, a concept that dates from the late 1950s and refers to the study of the whole Earth.[39] A recent analysis of the names of 270 college-level departments in the US revealed that only 45% now still describe themselves as "Departments of Geology" (or equivalents like "Geography and Geology").[40] The plate tectonics paradigm was definitely not the only cause of this significant shift, though. Robert Wood (1984) refers in this respect to the important place that the ahistorical disciplines of geophysics and geochemistry take in the modern study of the Earth.[41] Not only are these disciplines not concerned with the detailed reconstruction of the Earth's contingent past, they also use a different methodology and different instruments. Last but not least, modern Earth scientists of course also study (again) much of the Earth's Furniture, such as its atmosphere and oceans: there has, as Wood (1984, p. 193) puts it, "been a paradigm shift from Geology's little Earth to the whole Earth of the Earth Sciences."[42]

39. See Oldroyd 2003, p. 88.

40. See Heaney (2007). The department of Earth Sciences at the UCL in London, for example, "spans the entire Earth system from the atmosphere to the inner core," see: https://www.ucl.ac.uk/earth-sciences.

41. "Such name-changing provides a powerful demonstration of a new purpose and direction to the science" (p. 181). Wood argues, in general, that the modern Earth sciences did not emerge from (historical) geology but "from a revival of interest in the alternative, causal approach made possible by new techniques for studying the earth's interior" (Bowler 1980, p. 102). Oldroyd (2009, p. 396) points out that, apart from Wood's "useful conspectus," historians "have not yet formed a synthesized view of the metamorphosis of geology into 'earth science'."

42. Oldroyd also refers to "a broader understanding of the earth and its history—deploying new instruments, very different from the geologist's traditional hammer, hand lens, microscope, and other implements" (2009, p. 396). Likewise, Heaney (2007, p. 301) suggests that the reason why the term geology has become out of fashion is that it is "simply too narrow to encompass the incredible breadth of what modern Earth scientists do. For the past two decades, we have been as likely to find an atmospheric scientist or an oceanographer

As indicated above, there exists an equivalent for this relatively recent schism in the study of Earth in the modern history of biology. Let us, however, start out with the beginning: the integration, thanks to he discovery of the deep history of life, of various life sciences or branches into one master science of life. In the conclusion of *On the Origin* (1859, p. 455), Charles Darwin already foresaw "a considerable revolution in natural history." "When we no longer look at an organic being as a savage looks at a ship, as at something wholly beyond his comprehension; when we regard every production of nature as one which has a history …; when we thus view each organic being, how far more interesting, I speak from experience, will the study of natural history become!" (p. 485). Biohistory—the discovery of which was facilitated by the study of geohistory—did, eventually, indeed revolutionize the study of life: it forged, in the course of a century after the publication of *On the Origin* (1859), the life sciences into a new, integrated science.[43] And as had been the case with geohistory, biohistory was preceded by a speculative, philosophical and ahistorical biotheory: for Lamarck, evolution was "not a historical phenomenon: it starts everyday anew, as new 'monads' are spontaneously generated" (Roger 1980, p. 282).[44]

It is maybe surprising that this project was such a long time in the making. As Caron (1988, p. 226) puts it: "… biology as a science was not considered a reality by the scientists of the early nineteenth century. It was at best a project, but a very poorly organized one if it did indeed exist." This explains why the life sciences "displayed a remarkable tendency to be institutionalized separately rather than to remain together as an internally differentiated whole" (Harwood 2009, p. 90).[45] The biology project had not occupied an important place in Lamarck's oeuvre (see note 25) whereas Treviranus' work does not seem to have been very influential. It has even been said that as soon as the ideal of a biological science had been formulated, scholars began to abandon it (Theunissen and Visser

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occupying the adjacent office as someone who hammers on rocks, and nobody who boasts the mathematical expertise required for tornado dynamics wants to be labelled a 'geologist'."

43. This helps to explain why historians of biology have devoted more pages to the study of the history of the idea of evolution "than to any other subject falling under the rubric of biology" (Richards 2003, p. 17).

44. I do not agree, though, with his claim that "neither Darwin nor the present synthetic theory of evolution nor modern genetics are interested in history" (Roger 1980, p. 282). See, in respect with Lamarck's ahistorical or "biotheoretical" theory of evolution, also Tanghe (2019).

45. He adds that it is not clear why this has occurred "but its historiographical implication is that 'biology' is best conceived as a collection of loosely connected areas of inquiry … sharing little more than their concern with living organisms" (Harwood 2009, p. 90). This may be true for much of the history of biology but it is remarkable that he does not mention the later, integrating role of "the overall unifying concept of biology," called evolution.

1996, p. 54). That, however, is clearly exaggerated. Schiller (1980) even notes a strong interest, in the nineteenth century, in the construction of a synthetic life science. However, it was, initially, not primarily based on the notion of evolution (or presented under the term biology). "Many attempts were made [in France] to found such a science, 'physiology' having certainly the greatest success" (Caron 1988, p. 236). Comte, for example, tried to establish a philosophy of living organisms and of life, "based primarily, but not solely, on physiology" (Caron 1988, p. 235). As Schiller (1980, p. 85) points out, all these attempts seem to have been inspired by a common (but mistaken, physics-inspired) motif: that of ascertaining "'die Lehre von dem Leben', 'les lois de la vie', and 'the laws of organic life'."[46] The publication of *On the Origin* was therefore indeed "the climax of half a century of searching for the philosophical [i.e., explanatory] foundations of the new science, 'biology'" (Rehbock 1983, p. 6). However, it would, as said, take another century before these integrative foundations were complete.

Intriguingly, once Darwin put the notion of evolution firmly on the scientific agenda, the biohistorical integration of the life sciences began in very much the same, Whewellian way that the geohistorical integration of the Earth sciences had started out in the previous century: with a descriptive phase. Bowler (1996, p. 24) has pointed out that the reconstruction of life's ancestry that followed the publication of *On the Origin* (1859) was "so extensive a project that it necessarily affected a wide range of existing disciplines. … Specialists in many different areas were forced to interact because they were all concerned with similar questions of origins." It primarily concerned morphology, systematics and paleontology. This is one of the reasons why the conscious attempt to construct a complete science of biology "received its strongest impulse … from Darwin" (Huxley 1884, p. 4).[47]

46. John Jamieson Carswell Smart (1963) was the first scholar to emphasize that there are no laws in biology.

47. Huxley himself did not believe, though, that the science of life that he envisioned could or should be founded upon the notion of evolution. In 1860, biology became a university level subject in the newly created science degree curriculum at the University of London, thanks to the efforts of Huxley and Joseph D. Hooker. However, it served merely to train teachers and lacked a research program. This maybe also explains why it was not evolutionary inspired. The Darwinists, and particularly Huxley, had, at the time, "very little interest in seeing evolution raised to the level of a fully mature, objective, culture-free science (Ruse 1996)" (Ruse 1999, p. 77). Huxley's comprehensive biology "united a study of plants and animals on the basis of their common protoplasmic structure and function. It was formed not from natural history but from physiology, structural botany, and pre-eminently comparative anatomy, which gave the new 'biology' its distinctive morphological aspect" (Desmond 1996, p. 273n20). Huxley refused to "mix up" evolution with his morphology, "fearing that it would 'throw Biology into confusion'" (Desmond 1996, p. 39).

And why the word biology "took root in the 1870s" (Desmond 1996, p. 420).[48]

This has also been called the short term effect on biology of Darwin's theory of evolution (Theunissen and Visser 1996, p. 150). The long-term effect concerned the causal dimension of biohistory (i.e., Whewell's second component and phase): it was only in the mid-twentieth century, with the development of a consensus theory about the causes of evolution—the so-called modern evolutionary synthesis—, that the life sciences became more integrated.[49] This theory also encompassed an application of evolutionary causes to the paleontological facts (i.e., the realization of Whewell's third phase). Before this happy event, the question of the causes of evolution divided, rather than united the life sciences.

As late as 1929, J. H. Woodger (1929, p. 11) observed that the process of fragmentation in the biological sciences had, in contrast with what had happened in other sciences, "not been compensated by the help of any principle of … unifying power, and the possibility of a unified biology seems to recede more and more from our grasp." Ironically, this despairing statement marked the eve of the emergence of biology as a (more) unified science. In 1942, Julian Huxley (1942, p. 26) observed that biology had "become a more unified science" and that it was "coming to rival the unity of older sciences like physics." A few years later, the Society for the Study of Evolution (1946) and the American Institute of Biological Sciences (1947) were founded. In 1957, George Gaylord Simpson, an important architect of the evolutionary synthesis, could proudly introduce a biology textbook with the assertion that he and his co-authors strongly believed that there had come into being a unified science of life.

It is of course during these crucial decades (the 1930s and 1940s) that the modern evolutionary synthesis was created and that evolutionary biology became an epistemically mature science (Ruse 1996). This was, essentially, accomplished by establishing the compatibility of a Darwinian population genetic interpretation of evolution "with the findings of all of the sciences

48. Whewell (1840, 1, p. 544) pointed out, in 1840, that it had already become "not uncommon among good writers." See, in this respect, also Google's n-gram viewer (https://books.google.com/ngrams).

49. Bowler (1980, p. 102) even compares the modern evolutionary synthesis with the advent of the plate tectonics paradigm in geology: "… it is significant that both geology and evolutionary biology were revolutionized in the twentieth century through a revival of interest in the causal approach. Here plate tectonics and the genetical theory of natural selection play parallel roles, overtaking and absorbing an earlier, historical approach to the past." As pointed out before: the theory of plate tectonics added a new, causal dimension to the study of the history of the Earth's crust, but it did not initiate the causative study of that history.

dealing with evolution" (Burian 1988, p. 250). The evolutionary synthesis was, confusingly, indeed the result of two syntheses: one between Darwinism and Mendelism and a second synthesis of empirical data and concepts from a wide variety of life sciences around that first synthesis. It is that second synthesis or the synthesis *sensu lato* that unified many life sciences. "Evolution ... became the 'central science' of biology which bound together, and grounded, the heterogeneous practices of biology into a unified and progressive science" (Smocovitis 1992, p. 3).[50] Or: "the evolutionary synthesis signaled the unification of the biological sciences" (Smocovitis 1992, p. 3).

The reason why it unified these sciences is that it provided an explanation for contemporary life phenomena. Whereas geohistory mainly served as a common describendum and explanandum for geologists, evolution, as explained by the modern evolutionary synthesis, indeed primarily constitutes a common explanans of modern biological phenomena.[51] It is this idea of evolution as explanans of a wide variety of life phenomena, studied in various biological disciplines, that is expressed in Dobzhansky's famous saying that "nothing makes sense in biology except in the light of evolution." Or, as Raven and Johnson write in their classic textbook *Biology* (1992): "biological principles do not exist in a vacuum; *there is almost always an evolutionary explanation that explains why things are the way they are*. From the outset of writing *Biology*, our goal has been to describe biology in its evolutionary context" (p. vi, my italics) because "the theory of evolution provides the conceptual framework that unifies biology as a science" (p. 7). And: "Presenting biology in an evolutionary framework enables the student to *understand* principles, and so actually makes teaching, and learning, easier" (p. vi).

Evidently, evolution could only meaningfully fulfill this integrating, explanatory role, once there had emerged a broad agreement, among biologists, about the mechanisms behind evolution, i.e., the hidden and complex mechanics behind the origin of new adaptive features and species and macroevolutionary trends.[52] This is a second reason for the extraordinarily

50. See also Smocovitis (1996). This does not seem to have been a conscious goal of the architects of the synthesis, though. Smocovitis quotes Ernst Mayr as saying that it wasn't until the 1950s that "one could begin to think seriously about the role of evolutionary biology to achieve a unification of the previously badly splintered biology" (Smocovitis 1996, p. 202).

51. Not everybody agrees with this assessment. For paleontologists like Stephen J. Gould, "the autonomy of biology and the role of evolution as the 'central organizing principle' would come from an argument they inherited from Simpson—chance and contingency in the form of unique historical events" (Smocovitis 1992, pp. 50, 153). For paleontologists, evolution or biohistory has indeed the same status that geohistory has for geologists: it is something that must be described (describendum) and explained (explanandum).

52. Depew and Weber (1988, p. 317) point out that the synthesis "has been rightly construed more as a treaty than a theory ..." Its main merit was that it ended seemingly

long lag between the first formulation of the biology project and its actual realization. Not only did it take a long time before the idea of evolution was scientifically mature (1859) and could begin to unify the life sciences, it also took a long time before evolution could subsequently fulfil its main integrative function as a generally agreed upon explanans of modern life phenomena.

The unification was not perfect, though. The evolutionary synthesis remains, up to this day, a contentious paradigm.[53] Also, not long after the establishment of this synthesis as an integrative paradigm, a war broke out between, on the one hand, classical or organismic biology and, on the other hand, molecular biology (and biochemistry).[54] Ernst Mayr observed at the time that the word biology suggested a unified science but "recent developments have made it increasingly clear that biology is a most complex area—indeed, that the word biology is a label for two largely separate fields which differ greatly in method, Fragestellung, and basic concepts" (1961, p. 1501). One concerns the functional (how?), the other the evolutionary (why?). This distinction between two biologies evidently corresponds quite well with the distinction, in the modern study of Earth, between, on the one hand, geology and, on the other hand, geophysics and geochemistry. Like this last split, the rift between the two biologies also had an important methodological dimension. Molecular biologists are, like the geophysicists, methodologically much closer aligned to the physical sciences.[55] Hence the danger that some biologists felt at the time of being engulfed by these sciences and of losing their autonomy: "With the articulation and refinement of the molecular basis for genetic change, biology faced its greatest threat of complete engulfment by the physical sciences" (Smocovitis 1992, p. 58). At some places (like Harvard University),

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endless preparadigmatic disputes, by showing that it could explain "virtually all of the known phenomena and patterns that ought to be explained by an evolutionary theory" and that it "was not necessary to contemplate or turn to any rival theories" (1988, p. 317).

53. See, in this respect, Tanghe et al. (2018). As Burian (1988, p. 248) puts it: "the synthesis offered a *modus vivendi* that allowed theorists, experimentalists, and field naturalists coming from different disciplines to work together on various problems from within a common framework."

54. See chapter 12, The Molecular Wars, (Wilson 1994). See also Smocovitis (1992, pp. 57–60) and Harwood (2009, pp. 94–95).

55. The evolutionary synthesis was criticized for not having "the predictive and explanatory virtues and the testability of Newtonian mechanics" (Burian 1988, p. 259). It is often (still) not understood that evolutionary theory "cannot escape the essential historicity of biological evolution" (p. 261) and that "the basic principles of historical theories do not play the same role or have the same character as the basic laws of mechanics or other 'ahistorical' theories" (p. 262).

the situation became so dire that a formal division of biology departments took place between these two branches.

It were, not coincidentally, primarily the architects of the unifying evolutionary synthesis who came to the rescue of the recently attained peace and unity within the biological sciences. It was, for example, in this context that Dobzhansky argued forcibly for the unifying power of evolution and that he coined his aforementioned phrase "nothing makes sense in biology except in the light of evolution." "If the living world has not arisen from common ancestors by means of an evolutionary process," he wrote, "then the fundamental unity of living things is a hoax and their diversity is a joke" (Dobzhansky 1964, p. 449). Without the light of evolution, he later stated, biology "becomes a pile of sundry facts, some of them interesting or curious but making no meaningful picture as a whole" (Dobzhansky 1973, p. 129). Whereas a significant segment of the community of modern Earth scientists does not seem to consider geohistory to be the central unifying concept of the Earth sciences, many modern biologists generally still see evolution as the central unifying concept of their science.[56] The fact that this unification is far from perfect does not undermine this belief: an important idea in Betty Smocovitis' *Unifying Biology: The Evolutionary Synthesis and Evolutionary Biology* (1996) is that the unification of the life sciences on the basis of the notion of evolution is very much a work in progress.

4. Concluding Remarks

I have tried to shed new light on the modern palætiological sciences of cosmology, geology and biology by studying their historical development from a comparative perspective, as recommended by William Whewell more than a century and a half ago. The discovery of the deep history of life, Earth and the universe played a crucial role in the historical development of these three sciences: it separates their prehistory from their actual history. In the case of geology and biology, the resemblance doesn't end there: the prehistorical phase of these master sciences was characterized by the existence of an unorganized and unfocused diversity of fields of knowledge or disciplines. The concept of an independent science of geology and biology emerged during the second scientific revolution. The historicization of Earth and life subsequently played a crucial role in the actual construction of these master sciences, thanks to its integrative function: it

56. Even though the actual study of evolution can hardly be called a central goal of modern biology. Ruse (1996, p. 3) points out, in this respect, that the 1994 edition of Peterson's *Guide to Graduate Programs in Biological and Agricultural Sciences* is very suggestive: it advertises about 325 programs in molecular biology but only 45 in evolution. "Overall in the *Guide*, cell and molecular biology get over three hundred pages whereas ecology, environmental biology, and evolutionary biology get barely fifty."

glued together various Earth and life disciplines. Perhaps, this simple Bauplan should become the explicit backbone or core of historical accounts of the development of both geology and biology, although I immediately want to reiterate that the history of both sciences can, evidently, not be reduced to this pattern.

A look at the past of geology and biology through the lens of this common Bauplan revealed, furthermore, several other intriguing similarities and differences between both sciences. The most intriguing similarity is maybe the ontological distinction that was antecedent to the birth of geology and biology. A crucial difference between both sciences is that geology (*sensu stricto*) was and is much more focused on the reconstruction of geohistory than biology is on the reconstruction of the history of life—that is the job of one particular life science, paleontology—, which, in turn, helps explain why the integration of the life sciences took a much longer time than the integration of geological disciplines: evolution could only fulfil its integrative function as explanans of life phenomena with the mid-twentieth century development of the so-called evolutionary synthesis.

Lastly, let me come back to the question why Whewell's fourth broad palaetiological domain, man, has, in sharp contrast with his other three domains, not become the subject of a separate palaetiological master science (even though some of the sciences that study man are, evidently, palaetiological in nature). The idea of a broad science of man is ancient and there have been attempts to integrate the human sciences or certainly certain human sciences, from a historical or an evolutionary perspective, for example by the French school of "Les Annales," founded by Lucien Febvre and Marc Bloch. Why have such tentative attempts to turn the study of man into a palaetiological master science failed? Or, more precisely, why has the discovery and exploration of the deep biological and cultural history of man not facilitated the construction of an equivalent of cosmology, geology and biology? This simple question is maybe the main dividend of the here presented comparative study of the scientific fate of Whewell's four palaetiological domains. It seems to me, in any case, to be a question that deserves more historiographic attention.

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