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Evolutionary Philosophy of Science: A New Image of Science and Stance towards General Philosophy of Science

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Abstract: An important question facing contemporary philosophy of science is whether the natural sciences in terms of their historical records exhibit distinguishing developmental patterns or structures. At least two philosophical stances are possible in answering this question. The first pertains to the plurality of the individual sciences. From this stance, the various sciences are analyzed individually and compared with one another in order to derive potential commonalities, if any, among them. The second stance involves a general philosophy of science in which a thorough theory of the natural sciences is developed. The latter stance strives to account for more than possible commonalities among the sciences but also to provide a broad-spectrum philosophical framework to account for, or to explicate, the nature of science itself and its progress. In this paper, the second stance is taken in which an evolutionary philosophy of science is proposed. To that end, Thomas Kuhn's evolutionary philosophy of science is initially discussed and critiqued. An evolutionary philosophy of science is then proposed based on a revision of Kuhn's evolutionary philosophy of science in terms of George Gaylord Simpson's various tempos and modes for biological evolution. Next, two historical case studies from the biological sciences are reconstructed to illustrate the robustness of the proposed evolutionary philosophy of science for explicating the progress of the natural sciences. A concluding section discusses the proposed evolutionary philosophy of science with respect to providing a broad-spectrum framework or general philosophy of science for understanding the nature and progress of the natural sciences.

Keywords: evolutionary philosophy of science; general philosophy of science; George Gaylord Simpson; microbiological sciences; pluralistic philosophy of science; Thomas Kuhn

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1. Introduction

In this special issue of *Philosophies*, a very critical question is asked. Do the natural sciences with respect to their historical records exhibit distinguishing developmental or progressive patterns or structures? This is an important question and can potentially be answered in terms of the sciences' history; but it also is subject to philosophical scrutiny and analysis. There are at least two possible philosophical stances to answering this question. The first is in terms of the plurality of the individual sciences [1]. In this stance or pluralistic philosophy of science (PPoS), the various sciences are analyzed individually and compared to one another in order to derive possible commonalities among them. The second is a general philosophy of science (GPoS) stance in which an extensive theory of the natural sciences is developed [2,3]. The latter stance attempts not only to account for more than possible commonalities among the sciences but also to provide a wide-ranging philosophical platform to account for, or to explicate, science's nature and its progress. In other words, one does not lose sight of the forest for the trees with the second stance as compared to the first. In this paper, the second stance is taken in which an evolutionary philosophy of science (EPoS) is proposed.

The EPoS proposed in this paper claims that the natural sciences are not only products of evolutionary processes but that they are also evolving in terms of their technical and social practices and communal knowledge. Thus, the image of these sciences is one of evolving or emerging specialties and subspecialties in terms of methodological practices and with respect to theoretical knowledge and explanations. But the proposed EPoS also represents a stance in terms of GPoS that incorporates the current pluralism of contemporary philosophy of science or PPoS. To that end, Thomas Kuhn's EPoS is initially examined and evaluated. An EPoS is then developed from revising Kuhn's EPoS in terms of George Gaylord Simpson's diverse tempos and modes for biological evolution. Two historical case studies from the biological sciences are reconstructed next to exemplify the proposed EPoS's facility in accounting for scientific progress. In the paper's concluding section, the proposed EPoS is discussed with respect to providing a broad-spectrum framework or GPoS for fathoming the nature of the natural sciences and their progress.

2. Kuhn's Evolutionary Philosophy of Science

Kuhn [4] is best known for a historical philosophy of science (HPoS), which was first articulated fully in *The Structure of Scientific Revolutions* (*Structure*). Briefly, normal or paradigmatic science is punctuated by revolutions or paradigm shifts (for an introductory commentary on *Structure*, see [5]). Kuhn is not as well known for having undergone, later in his career, a shift from a historical to an evolutionary philosophy of science—even though the seeds of his EPoS are present in *Structure*. Specifically, he distinguished between traditional philosophy of science in which nature sets the goal for science to provide a true picture of the world and an EPoS in which science is not progressing or advancing closer to the truth but away from what is an inadequate worldview. Rather than the goal of truth for a teleological philosophy of science, Kuhn's non-teleological philosophy of science is "marked by an increase in articulation and specialization" [4] (p. 172). In other words, science evolves through a finer description and explanation of the world based on the emergence of new scientific specialties and subspecialties.

These seeds were to germinate over the next several decades in the Kuhnian corpus, resulting in what is called an "evolutionary turn" in his image of science [6]. In the 1991 Rothschild Distinguished Lecture, Kuhn [7] provides motivation for an EPoS, by analyzing the problem with the earlier HPoS, and he then explicates the conceptual features of the EPoS. The problem with the HPoS, as Kuhn admitted, is that it demolished two supporting pillars for the traditional image of science, without offering any alternative support for it. The pillars were, first, that facts are prior to and independent of the beliefs for which they are said to supply the evidence, and, second, that what emerges from the practice of science are truths, probable truths, or approximations of the truth about a mind- and culture-independent external world [7] (p. 18).

The result from the demolition of these pillars, as he goes on to admit and lament, is that philosophy of science no longer enjoyed a consensus view of science. To recover a consensus, Kuhn proposed an EPoS [8].

In the EPoS, Kuhn makes a shift in what he considers to be the agenda for historians and philosophers of science. For HPoS, he claims the agenda was to explain major changes in scientific practice and knowledge. Unfortunately, this agenda led to the problems associated with this philosophy of science undermining the two pillars of traditional philosophy of science. But now, according to Kuhn, the agenda should be the explanation of "small incremental *changes* of belief" [7] (p. 11). Rather than the cataclysm of world-catastrophic revolutions or paradigm shifts in the wake of science's progression, scientific advancement should be viewed as the gradual proliferation of scientific specialties—much akin to biological speciation. Briefly, for Kuhn, science advances by gradual emergence of a specialty's practice and knowledge. As the members of a specialty practice their trade, a new specialty emerges from the older one because of novel and anomalous results to which the older specialty gave rise. This necessitates modifications in the specialty's lexicon—the substitute for Kuhn's earlier notion of paradigm. Instead of the unity of science, he now envisions science pluralistically—which has important implications for his influence on a contemporary philosophy of science.

Accompanying Kuhn's shift to an EPoS were changes in both the notion of and the role for the incommensurability thesis (Incommensurability allows for the isolation of a new specialty's lexicon from an older one so that the new one can evolve into a separate and distinct specialty. For a discussion, see [9]). Specifically, for Kuhn [7], gradualism represented the rate of change for his EPoS, while incommensurability represented its mechanism for specialization. And he now defined incommensurability in terms of modifications in the lexical taxonomy or linguistic structure of a scientific specialty—i.e., "taxonomic incommensurability" [10]. Rather than no common meaning, as Kuhn initially defined incommensurability, he now defined it as no common taxonomy. In other words, as science progresses with respect to increased specialization, the lexical taxonomy of referring terms to objects is modified dramatically by adding or deleting terms and concepts within the original lexicon. Particularly, novel terms and concepts are introduced that result in the emergence of a new lexicon with an appreciably dissimilar mapping of objects and the terms referring to them. Kuhn also altered incommensurability's role for HPoS in terms of scientific revolutions and their attendant paradigm shifts, to a mechanism for isolating lexicons of different scientific specialties for EPoS. The consequence is that a new specialty can arise from the parent specialty so as to evolve into an independent specialty.

3. Proposed Evolutionary Philosophy of Science

Kuhn's EPoS has its limitations. Specifically, Kuhn [7] accounts for the evolution of science with respect to a single tempo and mode of evolutionary change. The tempo is Darwinian gradualism and the mode is speciation. But evolutionary tempo and mode are far more diverse than these two options [11,12]. The twentieth-century paleontologist, George Gaylord Simpson [13], provides a functional taxonomy of evolutionary tempos and modes for developing a robust and comprehensive EPoS, compared to Kuhn's EPoS. Simpson identified three types of tempos, which refer to the rate of evolutionary change. The first is bradytelic tempo and represents one end on the tempo spectrum. It is the slowest rate of evolutionary change in which there is little, if any, evolutionary change, such as exemplified by coelacanth fish. The next type of tempo is tachytelic and represents the other end of the spectrum. It is the fastest rate of evolutionary change, as exemplified by the nematode worm *Caenorhabditis elegans*. Often the rate is so fast that there might not be any specimens preserved in the fossil record. The last type of tempo is horotelic and represents an intermediate position between the two poles of bradytelic and tachytelic. He considered the horotelic tempo the "standard" or "ordinary" rate of evolutionary change.

Simpson [13] also identified three types of modes, which refer the pattern of evolutionary change and which loosely parallel the three types of tempos, although each of these modes can be coupled to some extent with each of the tempos. The first type of mode refers to the pattern of phyletic evolution. For this mode, an entire population gradually shifts over time to a new taxonomic unit. This mode is often connected with a bradytelic tempo and referred to as phyletic gradualism. These are the mode and tempo often mistakenly associated with classical Darwinian evolution. Quantum evolution is the next type of mode and is generally associated with a tachytelic tempo. For this mode, a novel taxonomic unit appears rather suddenly. Simpson's quantum evolution was preceded by the traditional conception of saltatory evolution in which evolutionary changes proceeds through jumps. Niles Eldredge and Steven Gould championed a modern version called punctuated equilibrium in which periods of rapid evolutionary change are followed by long periods of stasis or little change [14]. Speciation is the final type of mode. It is generally linked to a horotelic tempo such that a novel taxonomic unit splits off from a parent taxonomic unit, resulting in local variations within groups of a taxonomic unit.

Simpson's taxonomy of evolutionary tempos and modes can be used to formulate a robust and comprehensive EPoS that can more adequately describe and explicate the emergence or evolution of the natural sciences and their specialties and subspecialties, than Kuhn's EPoS. Moreover, it can serve as a GPoS, which is discussed in a concluding section. The proposed EPoS specifically takes into account Simpson's distinct tempos and modes, in order to afford a wide-ranging approach to science's evolution. Moreover, it provides a dynamic approach to describe and explicate the nature of science and its growth of knowledge.

As for science's nature, the proposed EPoS does not constrain the natural sciences to a set of methodological principles, procedures, or even rules, especially logical rules or algorithms, which are static and unalterable. Rather, as evident from the history of science's record, significant methodological principles have emerged during the evolution of the natural sciences, especially since the scientific revolution of the seventeenth century (for a general discussion of the historical development of the scientific method, see [15]). For example, the development of controlled experiments has been crucial for investigating natural phenomena and establishing the veracity and accuracy of scientific statements [16,17]. There have also been important technological innovations that are crucial for the appearance of scientific specialties. For example, microscopic and staining technologies were critical for the emergence of various specialties in the biological sciences [18,19].

For the advancement and growth of scientific knowledge, the proposed EPoS affords a variety of approaches for describing and explicating how such knowledge evolves and is incorporated in a specialty's lexicon. Importantly, the growth need not be in terms of either gradual (bradytelic) or rapid (tachytelic) tempos only. Rather, it can display a variety of intermediate tempos in between these two spectral poles. And these intermediate tempos might be the general or common rates of growth. In other words, both bradytelic and tachytelic tempos do occur, but like biological evolution most growth—with respect to conceptual evolution—is horotelic [11]. Moreover, the evolution of science and scientific knowledge involves not just speciation but also phylogenesis. Not only do novel specialties as speciation emerge but so do whole new areas of science as phylogenesis.

Finally, the proposed EPoS is based on the following cognitive evolutionary mechanism. As scientists investigate natural phenomena, they encounter aspects of the phenomena, or anomalies in Kuhnian terms, which cannot be explained by current theory. New theories are then proposed to account for the anomalies. This is comparable to morphological variations due to genetic mutation in the biological evolutionary mechanism. Scientists then investigate the anomalies and test the newly proposed theories to determine whether the theories account for the anomalies. In Kuhnian terms, this represents extraordinary science in which various proposed scientific theories compete for the community's acceptance, especially in terms of guiding normal science. The theory that accounts for the anomalies survives and guides research of a newly emerging specialty. This is comparable to natural selection of the fittest biological species. Finally, in contrast to Kuhn's HPoS, the proposed EPoS does not champion just replacement of an older theory or paradigm by a competitor but also speciation from parental stock.

4. Historical Case Studies

The proposed EPoS, based on Kuhn's EPoS and Simpson's tempos and modes of evolution, provides a general philosophical approach for analyzing and charting the evolution of the natural sciences and the growth of their knowledge, as well as the emergence of scientific specialties or disciplines and subspecialties or subdisciplines. In this section, the evolution of the microbiological sciences, including the emergence of the specialties of bacteriology and virology, and of the subspecialty of retrovirology, and the emergence of the specialty of evolutionary developmental biology (evo-devo) from evolutionary biology and developmental biology are investigated and reconstructed to illustrate and support the generality of the proposed EPoS (for a general overview of the history of the microbiological sciences, see [20], for a general history of evo-devo, see [21]).

4.1. Microbiology Sciences

As shown in Figure 1, bacteriology is the first of the contemporary microbiological sciences to emerge and forms the backdrop on which both virology and retrovirology later emerge. The tempo and mode for bacteriology's appearance are bradytelic and phyletic evolution, respectively. The tempo is bradytelic because bacteriology took well over a century to evolve. The reason for the gradualness was the protracted debate over the miasma and contagion theories of epidemics and infectious diseases (The miasma theory of disease accounted for infectious diseases through dirty or infected air. The theory was prevalent and influential from the ancient Greeks to the late nineteenth and early twentieth centuries. The contagion theory of disease, however, explained infectious diseases through the spread of an infectious agent via physical contact. It was also influential throughout history and represented a rival theory to the miasma theory. For additional discussion of these theories, see [22]). Also contributing to the slow tempo was the fact that bacteriology's emergence was intimately connected to the establishment of the germ theory of disease [23], which fundamentally replaced the miasma and contagion theories [24,25]. Bacteriology's mode was phyletic evolution since it represented a shift along the epistemic path for understanding the etiology of infectious diseases. In other words, bacteriology and its germ theory of disease represented the gradual emergence of a new phyletic specialty associated with describing and explaining the role of bacteria in epidemics and infectious diseases. As mentioned earlier, technological developments in microscopy and staining protocols were important in the evolution of this specialty [18,19].

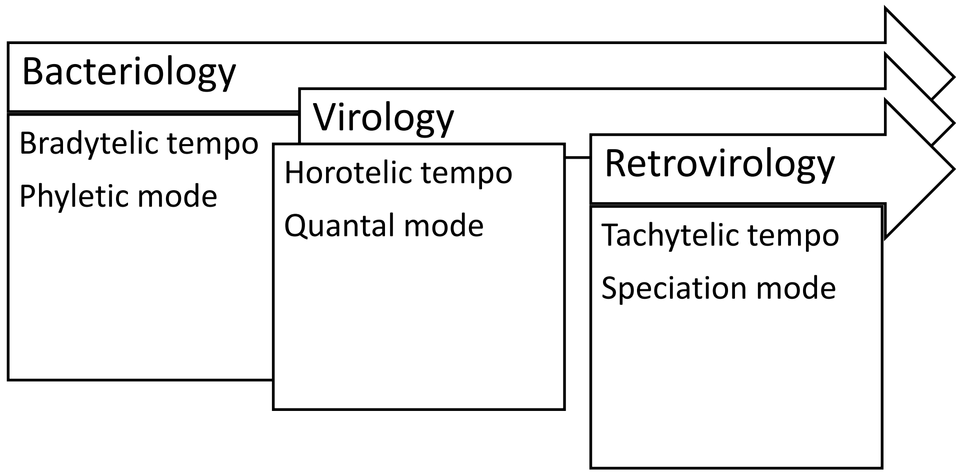

Figure 1. The evolutionary relationship of microbiological specialties of bacteriology and virology, as well as the subspecialty of retrovirology, in terms of tempos and modes (see Section 4.1 for details).

Virology, on the other hand, emerged relatively quickly in comparison to bacteriology [26,27]. Its evolution exhibited a horotelic tempo and a mode of quantal evolution (Figure 1). Part of the reason for the quicker tempo was technological in nature. Methodologically, the physical isolation of bacteria depended on a filtration protocol that retained bacteria on a filter's surface, after disrupted tissue and cells were passed through it [28]. Viruses, instead of being retained on the filter, passed through it and consequently were called filterable infectious agents. For example, Felix d'Hérelle [29] discovered a filterable agent from the fecal material of cholera-infected patients who survived the disease. This agent destroyed the cholera bacterium and was called a bacteriophage (Considerable controversy exists over who discovered the first bacteriophage. For a review of the controversy, see [30]). Moreover, the visualization of viruses required the introduction of the electron microscope, which was developed shortly after research was conducted on these filterable agents [31]. Quantal evolution was the mode for virology's appearance. For its evolution represented a major or quantal leap in the nature of a novel and unanticipated class of infectious agents. So novel were viruses that the question arose over whether they were living organisms or chemical toxins [32,33]. Subsequent research demonstrated that the infectious agents were more akin to living agents than chemical toxins, but that major differences existed in terms of their replication and composition of genomic material—than compared to bacteria [34].

Finally, the appearance of retrovirology represents a mode of speciation in that a new type or species of RNA virus was discovered that replicated by a completely different mechanism than other viruses (Figure 1). In other words, it represents a subspecialty of virology [35,36]. Although the genomes of some viruses are composed of RNA, they replicate by simply transcribing more RNA, which is then assembled along with other components as the virus [37]. Retroviruses, however, replicate accordingly [38]. First, the RNA genome is transcribed by reverse transcriptase into DNA, as a DNA provirus. The provirus is then incorporated into the host's genome. The DNA provirus is later re-transcribed into RNA and then assembled with other components as the retrovirus. Thus, a new microbiology or virology subspecialty—retrovirology—emerged in the latter part of the twentieth century. Moreover, the tempo of retrovirology's emergence was tachytelic. In 1911, Peyton Rous reported the first retrovirus—later named the Rous sarcoma virus—and although he did not receive the Noble Prize in medicine for its discovery until 1966 [39], within a single generation retrovirology was established as a distinct subspecialty within the microbiological sciences [40].

In sum, the contemporary microbiological sciences emerged from the debate over the miasma and contagion theories of infectious diseases. Bacteriology evolved first providing the parental stock from which both virology and retrovirology eventually emerged (Figure 1). Importantly, not only does a new subspecialty as speciation emerge, as in the case of retrovirology, but so do whole new areas of science as phylogenesis, as illustrated with the emergence of bacteriology and to some extent virology. Finally, the lexicons of these microbiological sciences were at times drastically different from one another, reflecting the particular type of infectious agent and its replication. For example, retrovirology's lexicon contained terms such a DNA provirus and reverse transcriptase. Although these terms could be part of the virology lexicon [41], they could not be considered part of the bacteriology lexicon.

4.2. Evolutionary Developmental Biology

In a 2000 *Nature* Opinion entitled, "Evo-devo: The evolution of a new discipline," Rudolf Raff proclaimed, "A revolutionary synthesis of developmental biology and evolution is in progress" [42], p. 74. Indeed, as depicted in Figure 2, evo-devo is a new specialty in the biological sciences that has emerged, within the latter part of the twentieth century, from the convergence of evolutionary and developmental biology. This depiction is rather simplistic, however, since other natural sciences, such as genetics, molecular biology, and paleontology, have also been instrumental in evo-devo's emergence. In this section, utilizing both Kuhn's EPoS and Simpson's tempos and modes of evolution, the parental stocks of evolutionary and developmental biology are briefly discussed before reconstructing the appearance of evo-devo.

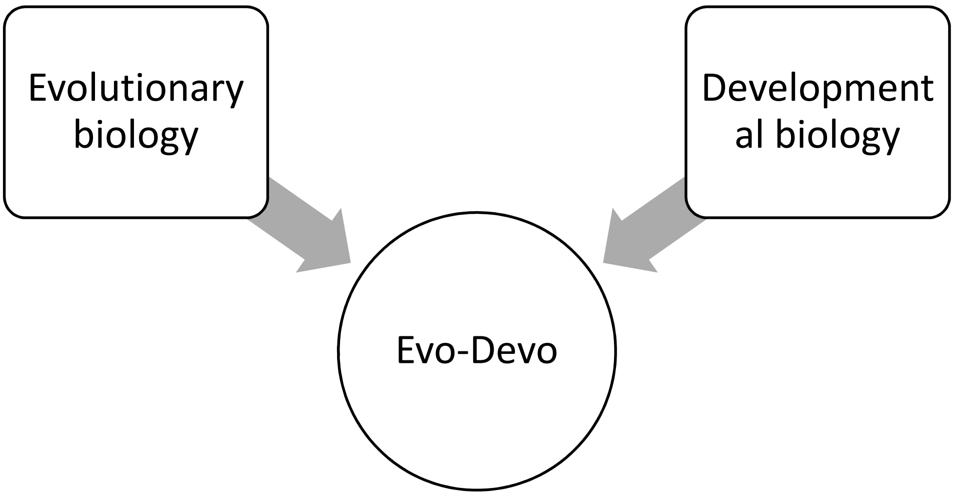

Figure 2. The emergence of evo-devo from the convergence of evolutionary and developmental biology (see Section 4.2 for details).

Charles Darwin's *On the Origins of Species by the Means of Natural Selection*, published in 1859, represents the naissance of contemporary evolutionary biology. Briefly, Darwin's theory proposed that morphological variation occurs within a population from which those that are best adapted to the environment survive and reproduce. Speciation is the result of gradual changes in morphology until a new species emerges. In Kuhnian terms, Darwin introduced a new concept into the lexicon of evolutionary biology—natural selection—that was revolutionary in nature [43]. Evolutionary biology's next major advance came in the mid-twentieth century with the neo-Darwinian modern synthesis in which Darwin's evolutionary theory was integrated with modern advances in the biological science of genetics, systematics, paleontology, and embryology [44]. In Simpson's terms, the tempo of contemporary evolutionary biology is horotelic in which steady progress or change in its conceptual framework has occurred over the last 150 years, while its mode is quantal with respect to major shifts in explaining biological evolution in terms of Darwinian natural selection and then of neo-Darwinian population and molecular genetics and developmental biology.

Developmental biology has a long history extending back to the Greeks [45,46]. Two major theories dominate its historical landscape. The epigenetic theory, first attributed to Aristotle, states that the embryo gradually emerges during gestation from an undifferentiated fertilized egg. The second theory, preformationism, claims that the sperm contains a miniature copy of the organism, which grows into the fetus during gestation. The former theory prevailed during the nineteenth century and became the foundation for comparative embryology. But during the twentieth century, experimental developmental biology was to emerge and lead the charge to understanding the relationship between an embryo's genetic program and its development. Like evolutionary biology, the tempo of developmental biology is horotelic in that steady progress has been attained gradually in its conceptual framework within the last century. In contrast to evolutionary biology's quantal mode, however, developmental biology's mode is phyletic in that there was a shift from comparative embryology to experimental developmental biology.

Darwin's acknowledgement of the importance of embryological evidence for supporting his theory of evolutionary change tethered comparative embryology to evolution. "Community of embryonic structure reveals," asserted Darwin, "community of descent" [47] (p. 311). Ernst Haeckel's notion of "ontogeny recapitulates phylogeny," i.e., evolution of the species is recorded in its development, was the source of Darwin's allegiance to comparative embryology. Although evolutionary biologists continued to use comparative embryology to support evolutionary changes, experimental developmental biology, especially with its incorporation of molecular genetics and biology, eclipsed comparative embryology in terms of the emergence of evo-devo. With the version of evo-devo that emerges in the late twentieth century, the developmental pattern of the embryo is not simply a record of speciation but the embryo itself becomes a unit of selection. In other words, the embryo itself is subject to selection pressure. This version of evo-devo is sometimes referred to as developmental evolutionary biology—although there is a fair amount of discussion concerning viability of this version [48].

In sum, evo-devo is now an established specialty in the biological sciences. As Manfred Laubichler and Günter Wagner announce:

> By all accounts 'evo-devo' has arrived. It is now solidly entrenched in the conceptual framework of modern biology and has all the markings of a new discipline, such as representation in professional societies, scientific journals devoted to the field, academic programs and job searches, panels at funding agencies, textbooks, etc. [49] (p. 1).

In terms of Simpson's tempo of evolution, evo-devo is tachytelic in that once the molecular tools—especially with respect to molecular genetics and biology that were instrumental in the important discovery of the homeobox genes—were available, its emergence was rather rapid. Evo-devo's mode of evolution is comparable to speciation, not so much in terms of the splitting from a parental stock but rather with respect to the synthesis of several parental stocks—particularly evolutionary and developmental biology (Figure 2). Finally, as evo-devo evolves its future promise is "to transform and unify diverse aspects of biology," ranging from molecular biology to agriculture [50] (p. 198).

5. Conclusions

Can the proposed EPoS function as a GPoS? It can function as a GPoS but not in the conventional or traditional way of approaching the unity of science. Traditionally, the unity of science depended on a reduction of the various sciences, such as the behavioral, biological, and chemical sciences, to the physical sciences [51]. In other words, physics served as the template for what constitutes a science; and the non-physical sciences had to be expressed ultimately or at least potentially in physical terms, concepts, and theories. But this traditional attempt to unify the sciences in terms of a GPoS failed [3,52]. As the philosophy of the various individual sciences or PPoS advanced during the latter part of the twentieth century, especially after the historiographic and sociological turns in science studies, philosophy of science fragmented into the philosophy of the sciences [1,53,54]. The disunity of science or PPoS became the consensus among students of science studies, although it is lately being challenged [3,55].

Recently, Stathis Psillos [3] has distinguished four characterizing dimensions for a GPoS candidate. The first is an epistemic dimension. A potential GPoS should account for both the discovery and justification of scientific knowledge, especially in terms of a scientific world image and the veracity of that image. Consequently, the epistemological question is what the world must be like in order that we may know it [56]. The next dimension, closely associated with the first, is metaphysical. It involves ontological categories, such as natural kinds, and the scientific image of the world's deep ontic structure—particularly with respect to causal mechanisms and processes. The third dimension is conceptual, i.e., how scientific theories represent the world. Also included in this dimension is the experimental contribution to theoretical content. The final dimension for a GPoS candidate is practical in terms of cultural, ethical, political, and social factors pertaining to the natural sciences and their knowledge and practice. This dimension also involves the epistemic and cultural values that animate scientific practice as a social institution, among other social institutions.

The proposed EPoS exhibits the four dimensions of a GPoS, as outlined by Psillos [3]. With respect to the epistemic dimension, the proposed EPoS accounts for the discovery and justification of scientific knowledge in terms of the evolution of our cognitive faculties as the world itself evolves. There is an evolutionary link between the world's deep ontic structure and our evolved cognitive faculties to understand it scientifically. In other words, we are epistemically adapted to the world in terms of sensing or perceiving and understanding or conceiving the world. The proposed EPoS also exhibits the metaphysical dimension of a potential GPoS. Specifically, the world is divided into metaphysical or ontological categories that reflect the dynamics of change associated with the world's evolution. Moreover, the scientific world image reflects the conjoint evolution of our metacognitive faculties and the world's deep ontic structure [57]. The proposed EPoS especially captures this dimension of GPoS in terms of the proliferation of scientific specialties, as illustrated with the historical case study from the microbiological sciences. Just as we are epistemologically adapted to the world, so we are metaphysically adapted to it and our natural sciences reflect this adaptation. The proposed EPoS exhibits the conceptual dimension of a GPoS in terms of the representational success of theories. This success, again, is established in terms of the adaptive nature of our cognitive and metacognitive faculties in terms of the world's ontological categories and deep ontic structure. As for the practical dimension, the proposed EPoS accounts for the functional value of its world conception, since it reflects not only our epistemological and metaphysical adaptation to the world but also our adaptation to it in terms of our social institutions of which science is one among many.

In summary, the proposed EPoS—through taxonomic incommensurability and the diversity of evolutionary tempos and modes—advances a unity of science in terms of the historical relationships of the various natural sciences as they evolve. In this way, it accounts for the pluralistic and perspectival stance of contemporary philosophy of science, i.e., PPoS, by explicating the relationships among them, especially in terms of their common ancestry—what Darwin called "unity of descent" [47] (p. 153). The goal is not to force the various sciences into a single science, like physics, with respect to their essential properties, but to account for how these sciences advance and progress as a holistic system in which the various sciences interact and emerge from one another [58]. For example, the microbiological sciences were closely associated with advances in the physical sciences in terms of optics and in the chemical sciences with respect to staining technology.

Finally, the proposed EPoS in terms of the relationships among the various scientific specialties is illustrative of the evolutionary tree structure in which the contemporary specialties or species evolve from a parental stock. Not only did the various organisms, for example in the biological sciences, evolve according to a tree-like structure but the biological sciences also evolve in terms of increasing specializations, i.e., the emergence of finer branches from parental stocks. In other words, the various branches of the evolving biological specialties map onto evolving organisms. And such an illustration is true not only of the evolving biological world but also of the universe's evolution in terms of evolving complexity with respect to the initial Big Bang.

Conflicts of Interest: The author declares no conflict of interest.

Abbreviations

EPoS	evolutionary philosophy of science
GPoS	general philosophy of science
HPoS	historical philosophy of science
PPoS	pluralistic philosophy of science

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56. Kuhn had asked a similar question when discussing the appropriateness of evolutionary theory for understanding science: "What must nature, including man, be like in order that science should be possible at all?" [4] (p. 173). Although he did not answer this question fully, even when articulating his EPoS, the question is central to establishing EPoS as a GPoS. In other words, the natural sciences are an adaptation of *Homo sapiens sapiens* to its environment and only the evolving of these sciences can determine whether they lead to the species' survival or extinction.
57. Metacognitive evolution refers to an ability to step back and evaluate how well cognitive, especially scientific, processes represent the world. In a very real sense, the proposed EPoS represents such a metacognitive process. In other words, if the proposed EPoS allows for a better evaluation of scientific cognitive processes, then it opens up the possibility of enhancing the overall representation of the nature in terms of scientific practice and knowledge.
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