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Ernst Mayr's Critique of Thomas Kuhn

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In the early 1960s, American philosopher of science Thomas Kuhn contributed to a "crisis of rationality" with his hypothesis that science develops by means of paradigm shifts. He challenged the positivist concept of cumulative and continuous scientific progress. According to Kuhn, the relation between two succeeding scientific traditions 'separated by a scientific revolution' is characterized by conceptual incommensurability that constrains the interpretation of science as a cumulative, steadily progressing enterprise. Thomas Kuhn's philosophy was heavily criticized by German-American biologist Ernst Mayr as unapplicable to the history of biology. Mayr, one of the most outstanding evolutionary biologists of the 20th century and a "co-architect" of the so-called Modern Synthesis (contemporary Darwinism), published extensively on the history and philosophy of biology as he thought that theoretical biology cannot progress without proper philosophy of science. Being convinced of the progressive development of Darwinism, Mayr pointed out that Kuhn's concept of scientific revolutions does not reflect conceptual changes in evolutionary biology. Here we summarize Mayr's critiques of Kuhn and, based on our own research, take Mayr's side in the controversy between two great thinkers.

Keywords: Ernst Mayr, Thomas Kuhn, history of evolutionary theory, Darwinism, alternative evolutionary theories, philosophy of biology

Критика Томаса Куна Эрнстом Майром

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В начале 1960-х гг. американский философ Томас Кун, с его гипотезой парадигмальных сдвигов, стал одной из причин так называемого «кризиса рациональности». Он бросил вызов позитивисткой концепции кумулятивного и непрерывного научного прогресса. Согласно Куну, отношения между двумя научными традициями, разделенными научной революцией, характеризуется понятием «несоизмеримость», именно оно и ограничило возможность интерпретации науки как стабильно прогрессирующего, кумулятивного предприятия.

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Философия Куна была подвергнута жесткой критике немецко-американским биологом Эрнстом Майром как неприменимая к истории биологии. Майр, будучи одним из самых выдающихся биологов XX столетия и «архитектором» Современного Синтеза (современного дарвинизма), был также автором многочисленных трудов по истории и философии биологии и считал, что прогресс в теоретической биологии невозможен без соответствующей философии науки. Будучи убежденным в прогрессивном развитии дарвинизма, Майр указывал на то, что концепция Куна не отражает концептуальных сдвигов в истории эволюционной биологии.

Ключевые слова: Эрнст Майр, Томас Кун, история эволюционной теории, Дарвинизм, альтернативные эволюционные теории, философия биологии

Introduction

The Canadian philosopher Ian Hacking wrote in his classic introduction to the philosophy of science: “Philosophers long made a mummy of science. When they finally unwrapped the cadaver and saw the remnants of an historical process of becoming and discovering, they created for themselves a crisis of rationality. This happened around 1960s” [Hacking, 1983, p. 1]. Thomas Kuhn was the major contributor to this “crisis of rationality” with his hypothesis that science develops by means of historically sudden paradigmatic shifts. He challenged the positivist concept of cumulative and continuous scientific progress [Levit et al., 2014]. According to Kuhn, the relation between two succeeding scientific traditions “separated by a scientific revolution” is characterized by conceptual incommensurability that constrains the interpretation of science as a cumulative, steadily progressing enterprise [Hoyningen-Huene, 2005, p. 152]. The most fundamental aspect of incommensurability is that “the proponents of competing paradigms practice their trades in different worlds” [Kuhn, 1996, p. 150].

Simultaneously with this “crisis of rationality”, the 1960s saw the ultimate victory of Darwinism in all biological disciplines, even in those initially experiencing strong non-Darwinian influences. It was the time when Michael Ghiselin declared “The Triumph of the Darwinian Method” [Ghiselin, 1969] and there was little disagreement with his claim. The triumph of Darwinism resulted from the decades long struggle between selectionism and its scientific alternatives. The heavy price paid for this achievement needed not only to be preserved within biology, but also protected from the crisis of rationality descending upon evolutionary theory from the philosophy of science, nourished mostly by the history of physics. Wittgenstein, Hempel, Nagel and Popper, Mayr emphasized, proceeded exclusively from the analysis of physics, mathematics and logic; the specificity of biology was completely ignored

[Mayr, 1997a]. Mayr assumed the role of philosophical patron over Darwinian biology, being at once a crucial figure of the Modern Synthesis and its chronicler. Mayr recognized the threat coming from physics-based philosophy of science early on: "The people who come from the physical sciences have an enormous amount of difficulty with evolutionary biology" [Lewin, 1982]. The first major threat for biology was not being recognized as a science at all. For a while, Karl Popper promoted a view that Darwinism is a metaphysical research program and not a scientific theory, but this issue was settled due to Mayr's effort and Popper ultimately changed his mind: "At first, he [Popper – *auth*.] said the 'just so' stories of natural selection cannot be proven, and evolutionary biology is not really scientific. He said this again and again. But in the last 2 or 3 years he has taken it back because he finally realized that evolutionary biology is a different kind of science from the functional sciences, from the experimental sciences, but it is nevertheless science" [Mayr's interview in *Science*: Lewin, 1982].

The second major threat was Kuhn's theory of paradigm shifts as it would potentially make Darwinism into a "puzzle-solving" game in-principle equal with anti-Darwinian biology. It was to protect his brainchild (Darwinism) that Mayr came up with a devastating critique of Kuhn from the biological perspective. The importance of Mayr's anti-Kuhnian arguments is strengthened by the fact that they apply not only to Kuhn himself, but also to other theories insisting on disruptions in the history of science: "Some historians of science like to distinguish different periods, each with a single dominant paradigm (Kuhn), episteme (Foucault), or research tradition" [Mayr, 1982, p. 113]. Mayr argued against all disruptive philosophies of science.

Although Mayr's influence both in biology and its philosophy cannot be overestimated, his critique of Kuhn did not make the latter unattractive for historians and philosophers of biology; Kuhnian terminology is employed even in very recent publications in these fields. For example, in answering the question whether the Modern Synthesis was an institutional or theoretical event, Gayon & Huneman appeal to Kuhnian notions: "To use Kuhn's dual characterization of a paradigm, as either an 'exemplar' or a 'disciplinary matrix,' I am tempted to say: the main feature of the historical Modern Synthesis that remains today is the exemplarity of a group of people who created a disciplinary matrix for evolution" [Gayon & Huneman, 2019].

This paper proceeds as follows. The next section provides an explanation why Ernst Mayr's opinion matters. Then we will reconstruct Mayr's critique of Kuhn, providing Mayr's very own example from the history of evolutionary biology. Thereafter we will articulate our support of Mayr's critique and explain how our historical research contributes to strength of Mayr's view. In the "Conclusions" all our arguments will be summarized.

Fig. 1: Ernst Mayr and one of the authors (U.H.)
of the present paper in Woods Hole, MA at June 6, 1999

Why Ernst Mayr Matters?

Ernst Mayr was one of the most important evolutionary biologists of the second half of the 20th century, a crucial figure of what is now known as the Modern Synthesis. Being a leading expert in evolutionary biology and biological systematics, he advocated a new philosophy of biology based on his own historical studies. His contributions to modern biology are undisputable, and numerous articles and books he wrote became a landmark for generations of biologists [Junker & Hossfeld, 2005a; 2005b, 2005c; Junker et al., 2006; Kolchinsky, 2006; Haffer, 2008]. His path-breaking historical reconstructions remain controversial though [e.g., Levit & Hossfeld, 2006; Winsor, 2006] as he was simultaneously a proponent and a historian of the Darwinian movement and in that sense was a chronicler of his own achievements.

Historical and philosophical studies occupy a very significant part of his scholarly output. Of more than 700 publications that he has written, approximately 150 debate topics related to the history and/or philosophy of biology [Junker, 1996]. The history of the theory of evolution takes up the largest share of his historical writings at about 60 percent of these publications. He focused, as might be expected, on the history of Darwinism in the 19th century and on the synthetic theory of evolution

(the Modern Synthesis) in the 20th century. Other important topics included the history of ornithology and systematics. To his most crucial historical publications belong *The Growth of Biological Thought* [Mayr, 1982] reflecting on the whole history of biology, *The Evolutionary Synthesis* (co-edited with William B. Provine, 1980) reconstructing the history of the synthetic movement, and *One Long Argument: Charles Darwin and the Genesis of Modern Evolutionary Thought* [Mayr, 1991a] written for a broader audience and arguing that there were two Darwinian revolutions, both in line with Darwin's initial insight. Among his philosophical publications the most influential are: *Toward a New Philosophy of Biology: Observations of an Evolutionist* (1988), *This is Biology: The Science of the Living World* (1997b), and in 2004: *What Makes Biology unique? Considerations on the Autonomy of a Scientific Discipline* [Mayr, 2004].

By the early 1970s, as Mayr seriously turned to the history and philosophy of biology, he was already a star biologist with an international reputation. His historical interest not only awakened relatively late, but he continued to publish regularly on genuinely biological topics. For him, history was a constitutive part of an all-embracing research program in evolutionary biology, where historical accounts go hand-in-hand with current biological research. History of evolutionary biology was for him an instrument of Darwinian self-reflection, the way to make to genuine theoretical advances. He did not see the past and present of biology as separate fields, but related them to one another. The interferences that occur thereby are very informative; they become particularly evident in areas in which Mayr addresses his own biological work.

A critic of Mayr could say that for him historical reconstructions mattered only as far as they could be related to current advances in biology. Indeed, Mayr looked at the past through the prism of modernity and, in doing so, stood in opposition to an influential group of science historians around Thomas Kuhn who compromised scientific advances.

Being greatly influenced by Arthur O. Lovejoy's *The Great Chain of Being* (1936), Mayr employed in the history of ideas the same method he employed in biological systematics. He was interested in the "phylogenetic" development of certain concepts, in their evolution among other competing ideas: "In the end, the history of biology is always primarily a history of ideas" [Mayr, 1993, p. 99]. The task of the history of science is to explain the survival of the "fittest" scientific concept placing it into a dynamic historical panorama. Mayr found his panorama "incommensurable" with that of Kuhn.

Mayr's Critique of Thomas Kuhn

Taken broadly, especially considering Darwin's most influential disciple on the continent, Ernst Haeckel, Darwinian theory not only revolutionized biology, but irreversibly changed the worldview of the modern human, tending toward a new universalist evolutionary epistemology [Levit & Hossfeld, 2019]. In that sense, the Darwinian revolution seems to be an even more striking example of a Kuhnian paradigm shift than the revolution in physics sparked by Einsteinian relativity theory, but Mayr nevertheless claimed that "scientific revolutions in biology do not conform to the description of such revolutions as given by T. Kuhn" [Mayr, 1994]. Mayr argues as follows.

As early as 1972, Mayr formulated his major objection against Kuhn, arguing that evolutionism is actually a complex movement that started in the 18th century and that its many major components were proposed at different times, by different actors, becoming victorious independently of each other: "Even though a revolutionary climax occurred unquestionably in 1859 [with the publication of *On the Origin of Species – auth.*], the gradual acceptance of evolutionism, with all of its ramifications, covered a period of nearly 250 years" [Mayr, 1972].

The Darwinian revolution included the replacement of a considerable number of concepts and therefore requires a lengthy period of time [Ibid.]. Illustrating what he meant by "concepts", Mayr discussed six major elements of biological theory replaced in the Darwinian revolution. First, the biblical idea that the Earth is 6000 years old was definitely refuted; second, both catastrophism and the concept of the steady-state world were abandoned and replaced by the idea of the slowly evolving world; third, the obligatory steady evolutionary progress towards perfection was replaced by adaptation and specialization; fourth, the idea of creation was bracketed and for explanatory purposes replaced by natural causes; fifth, essentialism was replaced by population thinking (more details on this are below); and, finally, anthropocentrism was abolished and humans became a part of the evolutionary stream [Ibid.]. The first three elements Mayr labelled "specific replacements", i.e., purely scientific claims which can be established by means of empirical science; the last three elements he called "metascientific consequences/credos" as they deal with the revolution of the whole *Weltanschauung* and not only with biological issues. All these "elements" in their entirety would, in any case, lead to a Darwinian-like theory, but if only some of them were adapted they would bring about alternative evolutionary theories (if evolutionary at all); for example, the observation of evolutionary changes, combined with essentialism, would lead to various saltationist theories, but combined with population thinking, it leads to Darwin's theory of evolution by natural selection [Ibid.]. The Darwinian revolution was so

slow, Mayr argued, because it required not merely the replacement of one scientific theory by another, but the rejection of at least the six basic beliefs listed above along with some methodological innovations [Mayr, 1972]. Darwin's seminal publication in 1859 was the midpoint of this gigantic, slow revolution, not its beginning nor end.

The sluggish growth of evolutionary thought is only a part of the issue, and maybe not the most important one. Many more troubles for the Kuhnian picture arise from the asynchronism of the Darwinian revolution. This asynchronism is key to the history of certain biological disciplines as well. Mayr gave as an example the history of biological systematics, a discipline in which Darwin's of 1859 produced no decisive change, as one might have expected on the Kuhnian picture [Mayr, 1982, p. 144]. This biological discipline was Darwinized only during the Modern Synthesis by, among others, Mayr himself [Mayr, 1942]. But even now, the ordering system of Willi Hennig (cladistics) co-exists with the Darwinian methodology of evolutionary classification [Mayr, 1994]. Another example is paleontology which became fully Darwinian only in the post-synthetic period [Levit & Hossfeld, 2013].

The thesis of the asynchronism can be applied to the structural components of Darwin's theory as well. Mayr famously distinguished five theories constituting the core of the Darwinian theoretical system: (1) Evolution as such (the very fact of evolution), (2) evolution by common descent, (3) gradualness of evolution, (4) natural selection and (5) populational speciation [1982, p. 505 ff.; Reif et al., 2000]. These five parts of Darwinism became dominant at different times. To illustrate this idea, Mayr introduced the notion of two Darwinian revolutions.

The first Darwinian revolution occurs around the time of Darwin's discovery of natural selection and includes other crucial actors like Wallace and Haeckel. In this period, the very idea of evolution, i.e., the rejection of species fixism (the constancy of species) and the monophyletic concept (the theory of common descent) dominated discussions within biology. The theory of common descent provided a long-term research program for all taxonomists, comparative morphologists, paleontologists, general naturalists, and so on. The first Darwinian revolution also had philosophical consequences as it, for example, deprived humans of their self-proclaimed unique position in the universe, instead placing them into the stream of animal evolution [Mayr, 1990]. The common descent concept was "rapidly adopted and formed perhaps the most successful research program of the immediate post-Darwinian period" [Mayr, 1982, p. 330]. Yet, Mayr insists that even this was not a drastic paradigm shift as many evolutionary theories continued to exist in parallel and the theoretical building of Darwinism was not complete (e.g. genetics failed completely).

The second Darwinian revolution centers around the Modern Synthesis, at the core of which was the detailed and genetically based elaboration

of the theory of natural selection. Natural selection as the only adaptive directing force in evolution was not a generally accepted concept until the late 1930s–1940s [Mayr, 1994]. Darwin's publication resulted in the wide circulation of the very idea of natural selection, but alternative evolutionary mechanisms circulated as well and in the late 19th and early 20th centuries they eclipsed the purely selectionist methodology [Bowler, 1983]. The exclusive role of natural selection came in a bundle with population genetics and the rejection of typological thinking. The Modern Synthesis opened the way for a discussion of entirely new problems and thereby founded a set of completely new research programs inspired by genetics and populational thinking [Mayr, 1982, p. 560ff]. These research programs, however, developed with different velocities in different geographical regions, for example, in France, Germany, the Soviet Union (because of the strong influence of Lysenkoism) and some other countries there was considerable opposition to "synthetic" concepts. Thus, there is also a geographical dimension added to the concept of asynchrony within the Darwinian revolutions. The Modern Synthesis, Mayr concludes, "was definitely not a revolution, since it was clearly only the final maturation of Darwin's theory of evolution" [Ibid., p. 569].

Mayr introduced one more anti-Kuhnian argument, one which targets the methodological roots of Kuhn's theory. To grasp this argument, one should first understand Mayr's notion of essentialism. Mayr interpreted the "population thinking vs. typological thinking" controversy as a key issue in the entire history of Western philosophy and science [Levit & Meister, 2006]. For him, essentialism is "the belief, going back to Plato, that the changing variety of nature can be sorted into a limited number of classes, each of which can be defined by its essence. Variation is simply the manifestation of imperfect representation of these constant essences. Also referred to as typological thinking" [Mayr, 1991a, p. 179]. Typological thinking is based on the essentialist philosophy/ideology [Mayr, 1997, p. 428], which Plato made into a theory of cognition by postulating that "the world consisted of a limited number of classes of entities (eide) and that only the type (essence) of each of these classes of objects had reality, all the seeming variations of these types being immaterial and irrelevant. These Platonian types (or eide) were considered to be constant and timeless, and were sharply delimited against other such types" [Mayr, 2001]. As a consequence, the basic objective of essentialist philosophers was to discover this hidden nature of things. Nearly all philosophers up to Darwin's time, Mayr argued, were essentialists and "all of Darwin's teachers and friends were, more or less, essentialists" [Mayr, 1991b, p. 41]. Essentialism had direct and harmful consequences for biology, since species were considered to be clearly discontinuous "natural kinds" with fixed characteristics [Levit & Meister, 2006]. One of theoretical consequences of essentialism in evolutionary

biology was the adherence of some scientists to saltationism, i.e., to the view which denies the Darwinian idea that slow, gradual divergence of characters is the only source of evolutionary progress. As various "essences" cannot transit to one another, saltationists claim that cardinally new "body plans" come into being as a result of saltations (sudden, discontinuous and crucial changes, for example, a series of macromutations) [Levit et al., 2008].

It was Darwin, Mayr claimed, who radically improved the situation by emphasizing the uniqueness of every individual in the organic world and, especially, in every sexually reproducing species. This view became a cornerstone of a new mode of thinking – population thinking – and laid the foundation for the natural selection theory. Population thinking proceeded from the assumption that biological reality consists of uniquely different entities, while the statistical mean value is an abstraction [Mayr, 1982, pp. 46–47]. Essentialist thinking in its societal implication shared, in Mayr view, responsibility for mass atrocities such as racism as humans were categorized in kinds, and these kinds were characterized by certain fixed attributes (essences).

Mayr applied the essentialism/population thinking dichotomy to Kuhn's theory as well. The latter reflects essentialist-saltationist thinking which denies the notion of gradual evolution [Haffer, 2008, p. 373]. An essentialist mind invented the type, "normal science", and attempted to attribute it to the real history of science. For essentialists, there is little alternative to the suggestion that certain types of science will be replaced by other types in a sudden leap, i.e., by saltation. Thus, the essentialist methodology rooted in Neo-Platonism and banned from biology found its supporters in the philosophy of science. The accusation of essentialism was, for Mayr, the worst accusation to which any contemporary scientist or philosopher could be exposed.

To sum up, neither the first nor the second Darwinian revolution were revolutions in the Kuhnian sense. The actual Darwinian revolution was a 250 year long (or even more) process of slow theoretical development which was both temporally and spatially asynchronous, and which resulted in a significant number of changes including the birth of new sciences (e.g., genetics) and a transformation of worldview in science-based societies. Several scientific paradigms in biology could co-exist at the same time and revolutions in biology are not inevitably separated by long periods of "normal science" [Ibid.]. The evolution of science follows the same pattern as biological evolution, whereby new concepts will undergo a kind of scientific "natural selection". In this process of selection, a new conceptual structure in its entirety is much more important in biology than solitary new empirical discoveries; new discoveries alone will barely affect an existing paradigm as strongly as will a new integral concept [Ibid., p. 374].

Why We Support Mayr's Arguments

Viewed from the 21st century, Mayr's arguments look even stronger than they did in his time. The major addition to the history of Darwinism is the notion of the "non-Darwinian revolution", coined by Peter Bowler to describe post-1859 developments in the 19th century and further elaborated by other historians [Bowler, 1983; 1988; 2005; Kolchinsky, 2002; Delisle, 2017; Levit et al., 2008; Levit & Hossfeld, 2011; Meulendijks, 2021]. Bowler's claim that "Darwin's basic theory does not express a central theme of 19th century thought" [Bowler, 1988, p. 21] and that Darwin's seminal publication led to the flourishing of general evolutionism, but not of the theory of natural selection is now commonplace. The very notion of the "non-Darwinian revolution" became obsolete in the current historiography as "the intellectual space seems quite limited, if non-existent, between, on the one hand, 'Darwinians' who would deny the centrality of natural selection in evolutionary explanations and, on the other, 'non-Darwinians' who use it in company with a number of other evolutionary mechanisms" [Delisle, 2021]. We have suggested employing the term "alternative theories of evolution" (ATE) to describe scientific alternatives to strict selectionism [Levit et al., 2008; Levit & Hossfeld, 2011]. The controversies over Darwinism after the publication of the *Origin of Species* in 1859 nourished the self-confidence of alternative theories of evolution. Therefore, the first third of the twentieth century became the heyday of ATE, which were flourishing at the same time in various countries, achieving clarity and conceptual maturity [Levit et al., 2008]. The Swedish historian of biology Erik Nordenskiöld noted in this connection: "The history of biology might really close with the establishing of the dissolution of Darwinism" [Nordenskiöld, 1928, p. 574].

The problem is, however, that the meaning of the term "Darwinism" differed in different times.

The difficulty with defining Darwinism in its historical context lies in the fact that the theory of natural selection achieved its logical consistency and conceptual maturity decades after Darwin's death [Levit & Hossfeld, 2011 *et sec.*]. The situation with Darwinism differs in this respect from theories paradigmatic for Kuhn such as those in physics, where a quotation, for example, from Einstein's relativity theory would provide an immediate and strong argument in favour of "Einsteinianism". Contemporary (post-Synthetic) Darwinism possesses a prerogative of retrospective classification of concepts as "Darwinian" or "non-Darwinian", irrespective of Darwin's own views. The almost-perfect logical consistency of this complex theoretical system, achieved by generations of experimental biologists and theoreticians during the second half of the twentieth century, legitimizes this prerogative. Below we offer a general overview of the major historical forms of Darwinism.

Classical Darwinism. This is Darwin's own theory, which advanced the idea of organic evolution and common descent, and introduced the principle of natural selection within a broad theoretical context. This context encompassed a multiplicity of evolutionary mechanisms, including the inheritance of acquired characters, direct environmental influence on organisms' heredity, sexual selection, and some mutationism (Darwin's famous "sports") [Darwin, 1872]. Neo-Lamarckism belongs to the realm of non-Darwinian theories from the contemporary perspective, but Ernst Mayr saw no conflict between various evolutionary mechanisms within Darwin's own theoretical system: "For Darwin inheritance of acquired characters and a direct effect of the environment were compatible with natural selection" [Mayr, 1997c]. Positions in favor of or against the pluralism of evolutionary mechanisms in Darwin's heritage determined the subsequent split of classical Darwinism into two major rival selectionist movements, namely old- and neo- Darwinism [Levit & Hossfeld, 2011].

Neo-Darwinism and Old-Darwinism. At the end of the nineteenth century the Canadian-born English psychologist George John Romanes recognized the crucial importance of the question of "whether natural selection has been the sole, or but the main cause of organic evolution" [Romanes, 1895, p. 1]. Discussing this issue, Romanes opposed Darwin, who admitted that natural selection had been assisted by subordinate principles, and sided with Alfred Russel Wallace and August Weismann, who maintained that natural selection should be regarded as the only cause of evolution. The term neo-Darwinism was coined to denote pure selectionism without neo-Lamarckian elements and without the theory of sexual selection. The original Darwinian line of thinking, which preserved the priority of natural selection but still combined Lamarckian and selectionist factors, was continued by the "old-Darwinian" school, represented primarily by the "German Darwin" Ernst Haeckel and his successor at Jena University, Ludwig Plate.

The synthetic theory of evolution (STE) or the Modern Synthesis originated in the early 1930s, after a period characterized by the dominance of alternative theories of evolution, which we address below [Levit & Hossfeld, 2011]. According to Ernst Mayr, the Synthesis was completed in 1947 and a period of so-called "postsynthesis" then began [Mayr, 1999]. The STE proposed a logically coherent and empirically well-substantiated theoretical system that incorporated several branches of biology such as classical genetics, population genetics, molecular genetics, systematics, evolutionary morphology, developmental biology, paleontology, etc. Within the STE, non-selectionist factors of evolution, especially isolation, chance events, and population size are emphasized. Natural selection is regarded as the only force directing major evolutionary change though, it is the sole driver of adaptations; this key difference distinguishes it from classical Darwinism.

The "extended" or "expanded Synthesis" or "integrated synthesis". Today we are living at the times of "expansion" or "extension" of the STE, incorporating new evolutionary mechanisms into the theoretical framework of the Modern Synthesis [Noble, 2015; Fabregas-Tejeda & Vergara-Silva, 2018]. The extension goes in two dimensions: Both new scientific disciplines such as molecular biology and evolutionary psychology appear, and evolutionary mechanisms forbidden by the STE experience a comeback, although completely revised. Thus, the "Lamarckian perspective has re-emerged in the context of the study of epigenetics, that is, developmental processes that are promoted indirectly by a series of events that are not directly dictated by gene products" [Kutschera & Niklas, 2004]. As the extended version of the synthesis embraces many new evolutionary mechanisms such as niche construction, epigenetics, evolutionary plasticity, genomic evolution, etc. [Noble, 2015], one can talk about a new kind of Darwinism, much more embracing then the STE and therefore not reducible to any earlier forms of Darwinism.

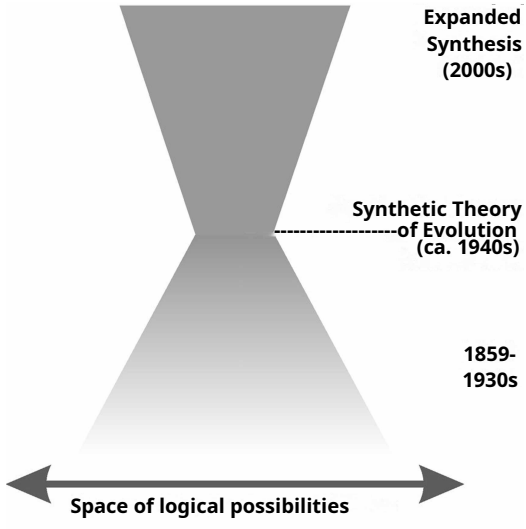

Fig. 2: Hourglass model

Crucial for our current thesis is also the period between the first and the second Darwinian revolutions. The first third of the twentieth century became the heyday of ATE as they flourished simultaneously in various countries and achieved clarity and conceptual maturity relatively quickly [Levit et al., 2008]. At the beginning of the twentieth century, natural selection remained just one of the many equally plausible hypotheses of how evolution proceeds. Together with strict (neo-Darwinian) selectionism, the diversity of ATE filled out the entire 'space of logical possibilities' available for explaining phylogenetic history.

The term "space of logical possibilities" was introduced into discussions in the life sciences by microbiologist Georgii Zavarzin (1979) to designate the range of functional niches actually or potentially available to microorganisms. Certain combinations of functional characteristics are forbidden for microbial communities, whilst certain others are expectable within a given conceptual framework. Actual bacterial communities, for example, may or may not occupy the entire 'space of logical possibilities' reconstructed for a given environment. Here, we apply the same notion, replacing 'microorganisms' with 'mechanisms of evolution' [Levit & Hossfeld, 2011; 2021]. By using the idea of 'the space of logical possibilities', we imply for a moment that the ATE can be described as solitary theoretical entities, i.e., as 'ideal types'.

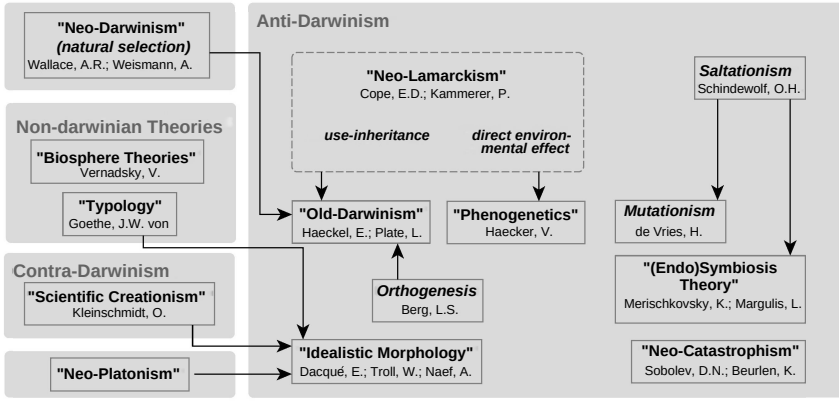

Fig. 3: The Space of Logical Possibilities

There is no space for more detailed reconstruction of the theoretical history of evolutionary biology here, but our main point in introducing the notion of the space of logical possibilities is that all possible combinations of all possible concepts of evolutionary change can be found in the historical record. In other words, all thinkable theories were suggested and discussed.

The picture we have outlined strengthens Mayr's anti-Kuhnian thesis as it shows that the gap between the first and the second Darwinian revolutions was even greater than he thought, as Mayr wrote a history of the Darwinian movement viewed through the eyes of one of its crucial figures (himself). The period between the two Darwinian revolutions was in no way a period of "normal science"; it was instead a time in which many different research programs appeared and sparred for superiority. One of these programs was selectionism, which survived by merging with genetics. At that time, genetics was known as mutationism, i.e., a non-Darwinian movement called "genetic anti-Darwinism"

[Kolchinsky, 2015, p. 93]. Selectionism persisted in the form of neo-Darwinism and was in no way compatible with what we understand today by the "theory of natural selection". In other words, selectionism and genetics not only hybridized, but were crucially modified in this process of theoretical hybridization. The story following the modern synthesis does not look Kuhnian either. Concepts considered extinct re-entered the theoretical landscape but in a strongly modified form, along with completely new conceptual instruments (e.g., molecular biology) which formed the cluster of methods and ideas known today as the extended synthesis.

Conclusions

Ernst Mayr was one of the most crucial figures in the history of Darwinian biology, and was at the same time an outstanding historian and philosopher of science. Mayr maintained that science in general, and biology in particular, is a rational enterprise advancing to a more precise picture of the world. Mayr thus saw Kuhn's concept of scientific revolutions as a threat to the Darwinian worldview he co-established, and he developed a critique demonstrating the inapplicability of the Kuhnian process of theory change in biology. Mayr demonstrated that several "paradigms" can co-exist in biology for a long period of time and there is no necessary "incommensurability" between these paradigms nor any obligatory theoretical leaps. The very idea of sudden drastic changes comes from the kind of essentialist-saltationist thinking which is banned from Darwinian biology. There are events in the history of biology which can be described as revolutions, for example, the first and the second Darwinian revolutions, but they are not separated by any "normal science". In addition, new empirical discoveries alone would be unable to corrupt an existing paradigm in biology; the real challenge comes only from new conceptual structures.

Post-Mayrian research in the history of non-Darwinian biology, including our own research, only strengthens Mayr's critique of Kuhn. The "Darwinization" of various biological disciplines proceeded asynchronously and there was no single dramatic paradigm shift. The period between the two Darwinian revolutions can in no way be labeled as "normal science" and a series of minor revolutions in special biological disciplines can be detected before and after the Modern Synthesis. Research programs which appeared between two revolutions filled out the "space of logical possibilities" and selectionism was only one many competing concepts. Evolutionary biology advanced by means of gradual conceptual evolution and the selection of theories, and in this respect is congruent with its very subject: organic evolution.

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Figure legends

Fig. 1: One of the authors (U.H.) discusses with Ernst Mayr the history of evolutionary biology in Woods Hole (MA, USA) in 1999.

Fig. 2: The history of evolutionary biology can be schematically presented as an 'hourglass' with an extremely broad range of possible explanations at the beginning, significant narrowing at the time of the second Darwinian revolution and the 'extending' of the evolutionary theory nowadays [Levit & Hossfeld, 2011].

Fig. 3: The first half of the twentieth century was the heyday of ATE. In the absence of detailed descriptions of evolutionary events, biologists suggested all thinkable evolutionary mechanisms and their combinations, which we schematically outline above (names of scientific schools are given in quotation marks, whilst single evolutionary mechanisms are given in italics). The appearance of the STE at first excluded a number of logically acceptable mechanisms and narrowed the 'space of logical possibilities'. The scheme distinguishes between scientific anti-Darwinism and contra-Darwinian theories that violate the very fundamentals of scientific evolutionism in that they exclude continual causality in their mechanisms of evolution. Non-Darwinian theories propose additional evolutionary mechanisms (such as theories dealing with higher systemic levels: Zavarzin, 2000), which, in principle, operate parallel to the Darwinian machinery, but under certain circumstances can come into conflict with rigid selectionism [Ibid.]. Theories are presented here as abstract units disregarding their historical dynamics. For example, endosymbiosis theory is currently regarded as fully compatible with today's inclusive Darwinian evolutionism, although it contradicts the logic of strict Darwinian gradualism.

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