Ernst Mayr's Philosophy of Science: Its Connections With Logical Empiricism, the Unity of Science Movement, and the Scientific Revolution[1]

Richard G. Delisle[2]

Abstract: Ernst Mayr is a major figure of the neo-Darwinian movement in the twentieth century. His contribution to this movement largely centers on his development of a strong organismic biology which resists the reductionistic conception of a gene- and molecular-based evolutionary biology. Perhaps less well known, however, are Mayr's significant and sustained efforts to construct a philosophy of science which would take into account the specificities of organismic biology. Unsurprisingly, this endeavor prompted him to build a case against the physicalistic epistemology of the logical postivists and others, which they hoped would serve as a universally valid basis for philosophy of science. Mayr's goal consisted in finding the proper place for biology within science, a quest which he especially pursued in relation to the physical sciences. It is argued in this paper that Mayr's philosophy of science should be taken seriously, since it provides a way of envisioning what a scientific revolution deprived of its physicalistic components might look like. In contradistinction to Mayr's rhetoric and self-understanding of the situation, however, it will be further argued that his philosophy of science achieves its aims only because Mayr himself shared a number of epistemological commitments originally conceived within the context of a physicalistic scientific revolution: a plea againts metaphysics, a theory-based approach to science, a reductionistic and corpuscular philosophy, and the search for an unified knowledge. Mayr's connections to such epistemological commitments are made more obvious when a rapprochement is established between his view of science and the one promoted by the logical empiricists. It seems that these four commitments are neutral enough, epistemologically speaking, to encompass both the physicochemical and the biological realms.

Introduction.

The zoologist Ernst Mayr (1904-2005) is well known for his contribution to the evolutionary synthesis in the realm of evolutionary biology, a synthesis based upon a commitment to two key notions: (1) All phenomena in biological evolution are explained by the action of natural selection on small genetic changes (Gould 1980, 119-120; Mayr 1980, 1). (2)

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[1] In this paper, the expression "logical empiricism" is also used to include "logical positivism". This paper is part of a much broader project on the evolutionary synthesis published as a book under the title: *Les philosophies du néo-darwinisme: Conceptions divergentes sur l'homme et le sens de l'évolution* (Paris: Presses Universitaires de France, 2009). For Ernst Mayr, see especially chap. 5.

[2] Philosophy and Liberal Education, University of Lethbridge, 4401 University Drive, Lethbridge, Alberta, Canada, T1K 3M4; email: richard.delisle@uleth.ca

While several scientific disciplines, including genetics, zoology, and paleontology, contribute different observational bases and realities to evolution, all are assumed to be consistent with the common theoretical foundation of the synthesis (Ruse 1973, 48-49; Caplan 1978, 272-275; Burian 1989, 155-157; Delsol 1991, 123-126). Among Ernst Mayr's notable publications on the evolutionary synthesis are his *Systematics and the Origin of Species* (1942) and *Animal Species and Evolution* (1963). Far from restricting his scientific quest to evolutionary biology, Mayr went on during the second half of his career to reflect upon philosophy of science from the vantage point of his understanding of biology (Beatty 1994; Hull 1994). In fact, he went well beyond making passing comments on philosophy of science, attemping to make a significant contribution to the field by incorporating "organismic biology" into what he perceived to be a philosophy wrongly biased toward physicalism. Unsurprisingly, Mayr's appraisal of the contribution made by the "classical" philosophy of science – that is, the one typically promoted by logical empiricists, according to Mayr – was a harsh one.

It will be argued in this paper, however, that Mayr's philosophy of science shares more similarities with logical empiricism than he has been willing to recognize. It is not that Mayr can be said to have a *direct* connection with the logical empiricists, considering his disregard for logical analysis as a means of pursuing genuine advancement in science. The connection is rather an *indirect* one, and owes to the fact that both Mayr and the logical empiricists he criticized hold in common epistemological commitments inherited from the scientific revolution. Two complementary goals are therefore pursued in this paper: (1) To show that at least one organismic biologist conceived of science in ways that were not uncongenial to logical empiricism, irrespective of his stance against physicalism; (2) To argue that Mayr's philosophy of science should be taken seriously if one wants to envision the scientific revolution as not exclusively defined by its physicalistic components.

Mayr's Organismic Biology.

From the outset, Mayr's assessment of the physicalistic epistemology which arose with the scientific revolution – and most clearly associated with Newton's name – was a critical one. He goes on to enumerate the "tenets" from which Charles Darwin had to break free in order to build an organismic biology. Under the heading "Tenets of Classical Mechanics", Mayr lists the following propositions (Mayr 1995, 321):

1. Universal laws are the cause of all phenomena and processes.
2. All processes are strictly determined (Laplace), hence total prediction is possible.
3. The structure and variation of all phenomena must be explained in terms of essentialism.
4. Full explanation requires consistent reduction.
5. Theories are truly scientific only if expressed in mathematical terms (Galileo, Leibniz, Kant).
6. The experiment is the foremost (and perhaps only legitimate) method of science.

Against this epistemology, which he believed to be ill-adapted for the investigation of biological phenomena, Mayr mounts a systematic counterargumentative strategy. Taking each proposition in turn, he replies in the following way:

(1) *Criticism of an epistemology based upon universal laws* (Mayr 1985, 44). To those physicists hoping to explain all natural phenomena by appealing to a few universal laws, Mayr

sceptically replies that it is highly unlikely that science will ever be able to explain the exceptional diversity of natural phenomena in such a compact and concise form. To grasp the difficulty of the task, he insists, one needs only to think about the inherent complexity involved in the differentiation process during the ontogeny of living organisms, assuming that such an objective is desirable to biologists in the first place.

(2) *Criticism of an assumed universality of determinism* (Mayr 1961, 1504-1505; 1985, 47-49). The notion of a world under the control of universal laws logically leads to a conception of phenomena as rigidly determined, thus implying their predictability. The field of biology, Mayr argues, is by contrast characterized by indeterminism, thus rendering the formulation of predictions difficult or impossible. For instance, it is not possible to predict the sex of a child whose parents are sexual organisms, nor to predict the respective genetic contributions of such parents to their child. If some physiological processes (particularly molecular interactions) have quasi-predictable physicochemical reactions, continues Mayr, it is because these reactions are indeed physicochemical ones. In complex biological systems, however, there remains always a strong indeterminate aspect in both the component's interactions and the developmental sequences. It is possible to speak of probabilistic predictions, but only in the best possible cases. One of the most fundamental problems with the notion of universal laws for biologists stems precisely from the fact that all generalizations concerning complex biological systems suffer exceptions, which is by definition a negation of the universality of laws. The belief in the universality of laws in classical physics, Mayr argues, promoted the notion of predictability to the rank of supreme explanatory criterion. Rejecting this criterion, Mayr argues that it lacks heuristic value in the field of evolutionary biology in which historical factors play a genuinely creative role

in determining events thus breaking the rigid association between explanation/prediction. In this view, Mayr adds the following comment:

> At one time Karl Popper said something he would no longer say today: 'Darwinism does not really predict the evolution of variety. It therefore cannot really explain it'. As Scriven and others have shown, however, prediction is not a necessary part of causality. In complex systems, and in systems involving a great deal of stochastic perturbation, one can give a posteriori explanations of events which one could not have predicted with complete certainty (Mayr 1985, 49).

To put it differently, in an indeterministic world the causal sequence going from cause to effect is maintained, but is deprived of the predictability which normally accompanies deterministic causation. Whereas nobody could have predicted the extinction of the dinosaurs in the early Cretaceous period, to take Mayr's example, the fact remains that such an event rests on causation, since it did in fact occur. In the field of evolutionary biology, which is characterized by a historical epistemology, the explanation/prediction/causality triad of classical physics is broken apart.

(3) *The criticism of essentialism* (Mayr 1985, 55-56). The basic entities in the physical sciences, such as elementary particles, atoms, and molecules, constitute large classes of stable and identical objects. Typological thinking or essentialism is based upon the analysis of this area of reality. Reality in the living sphere, Mayr observes, is characterized by the universality of uniqueness. All sexual organisms are unique, even in their distinct and individual cells. Moreover, the uniqueness of biological realities only increases as the taxonomic hierarchy is climbed toward ever more inclusive entities, such as species, phyla, or entire ecosystems. One can only grasp the universality of uniqueness by replacing typological thinking with population

thinking. According to Mayr, the implications of this uniqueness in the living world are numerous (Mayr 1985, 56):

> It explains the almost incomprehensible diversity of the living world. It explains why in the course of evolution so often different organisms adopt different pathways to achieve the same adaptation... It explains why the response to a selection pressure is only probabilistic. Indeed, it is one of the reasons why predictions in biology are so often impossible. We will not have an acceptable philosophy of science until all the consequences of the uniqueness principle in the living world are properly accommodated by such a philosophy.

(4) *The criticism of reductionism and ontological monism of elementary components* (Mayr 1982, 53-54, 59-64; 1985, 44-45, 57-58; 1988, 14-15). To the physicists' pursuit of a unified vision of nature through the reduction of all phenomena to their common material constituents – elementary particles and their interactions – Mayr replies that this reductionistic approach can contribute nothing to the growth of our knowledge of complex biological systems, owing to their self-organizing or homeostatic nature: "[I]n view of the known frequency of repair mechanisms and feedback devices, disturbances at the level of elementary particles are ordinarily of no effect whatsoever at the higher levels of biological integration" (Mayr 1985, 45). Biological systems are inherently open, which preserves their stability regardless of the input/output exchanges between themselves and the external world. In fact, biological systems do not possess a random complexity, since it is a highly organized one: structures of a single organism are useless when cut off from the whole. Each part of an organism plays an adaptive function necessary to that organism, contrary to what is seen in the inanimate world. Thus, continues Mayr, there exists a biological reality which transcends the elementary constituents. Even if it were possible to explain the isolated components and processes of complex biological systems solely in terms of known physicochemical laws, this is generally not the case when it comes to

understanding the interactions between the various components. There is no equivalent in the inanimate world – even among inanimate complex systems – of the internal order and cohesion of biological systems. Such systems are able to reproduce, grow, differentiate, associate, generate metabolic energy, and respond to an external stimulus. New, unpredictable features at the level of isolated components emerge at higher levels of organization, the whole being more than the sum of its parts. Mayr (1985, 58) writes: "Recognition of the importance of emergence demonstrates, of course, the invalidity of extreme reductionism. By the time we have dissected an organism down to atoms and elementary particles we have lost everything that is characteristic of a living system". In Mayr's view, one of the most interesting features associated with the concept of a "total organism" is that it can result in *downward causation*, whereby the organic integrity of higher levels can influence the organization of lower levels.

(5) *The criticism of an excessive mathematization of science* (Mayr 1982, 54-55). To proponents of such an approach to science, Mayr replies that quantification does not exhaust biological reality in its entirety. Qualities (as opposed to quantities) are neither beyond the confines of science, nor exclusively restricted to descriptive and classificatory realities. Mayr stresses the difficulty of expressing in quantitative terms the relational properties so common in the biological realm:

> The physical world is a world of quantification (Newton's movements and forces) and of mass actions. By contrast, the world of life can be designated as a world of qualities. Individual differences, communication systems, stored information, properties of the macromolecules, interactions in ecosystems... One can translate these qualitative aspects into quantitative ones, but one loses thereby the real significance of the respective biological phenomena, exactly as if one would describe a painting of Rembrandt in terms of the wave lengths of the prevailing color reflected by each square millimeter of the painting... [Qualitative aspects] are particularly important in relational phenomena, which are precisely the phenomena that dominate living nature. Species, classification, ecosystems, communicatory behavior, regulation, and just about every other biological

> process deals with relational properties. These can be expressed, in most cases, only qualitatively, not quantitatively (Mayr 1982, 54-55).

While Mayr recognizes that quantification constitutes an important aspect of several biological fields, he believes that this in no way diminishes the significance of qualitative realities in biology.

(6) *Criticism of the experimental method* (Mayr 1985, 50; 1988, 17). To the physicists who assert that experimentation constitutes the only true method in science, Mayr responds that it is not possible, for example, to test the various theories proposed to explain the extinction of the dinosaurs. Biology is no less a scientific pursuit as a result, however, since this implies only that the experimental method applies to certain specific kinds of research areas. Observation and comparison are, in biology, the privileged methods of investigation, whether in comparative anatomy, systematics, evolutionary biology, ecology, or ethology. This is not to say, however, that according to Mayr the experimental method is to be entirely excluded from the biological realm, for it may have a role to play in specific fields, especially in physiology, ecology, and ethology.

Mayr's Criticisms of Logical Empiricism, Broadly Construed.

Not content with his criticisms of the so-called tenets of the physicalistic epistemology, Mayr goes on to criticize the philosophers of science who, in his view, have subscribed to such an epistemology, and have even attempted to apply it to biology. Mayr formulates two main criticisms against these philosophers. The first one concerns the "classical" philosophy of science which, he holds, has fallen into disuse: "[T]he basic philosophy of biology, as it developed in the last 50 years, has become quite different from the classical philosophy of science as it prevailed from the Vienna school of Carnap and Neurath to Popper and Kuhn" (Mayr 2000, 896). This list of names is sometimes extended to include Cassirer, Russell, Nagel, Hempel, Oppenheim, Bunge, and the neo-positivists (Mayr 1982, 75; 1991, 135; 1996, 99). Three problems seem to afflict this brand of philosophy, in Mayr's view. First, it is essentially a philosophy of the physical sciences wrongly applied to biology (Mayr 1969, 197). Indeed, insists Mayr, many generalizations extracted from the study of physics are not applicable to biology. Secondly, when this brand of philosophy is not directly oriented toward physicalism, it concerns itself with outdated biological problems such as vitalism, orthogenesis, and dualism (Mayr 1982, 75). Thirdly, Mayr questions the methodology of the approach:

> What I do not understand is why most philosophers of science believe the problems of the philosophy of science can be solved by logic. Their interminable arguments, documented by whole issues of the journal *Philosophy of Science*, show that this is not the best way to reach a solution. An empirical approach... seems to be a better way (Mayr 2004, ix).

The second main criticism raised by Mayr is aimed at the philosophers of biology themselves (Mayr, 1986, 233; 1997, 36-37; 2004, 2-3, 14-17). Here, Mayr focuses his attention on one problem. Whereas several such philosophers address relevant biological issues, they still have the tendency to work within the methodological framework of classical philosophy of science, which is largely oriented toward logical analysis. On his view, these philosophers are not properly addressing the realities unique to the biological sciences.

The Scientific Revolution.

After this sustained attack against physicalist epistemology and the philosophers who presumably subscribe to it, one might have expected that Mayr's connection to the epistemology arising out of the scientific revolution and logical empiricism, broadly construed (including analytic philosophy), would be minimal at best. Nothing could be further from the truth. In sharp contrast with Mayr's rhetoric and self-understanding of the situation, I argue that he attempts to position biology within the scientific revolution, a move which requires him to broaden the epistemological basis of that revolution by promoting epistemologies other than physicalism. It is precisely by subscribing to the spirit of the scientific revolution that Mayr, without noticing it, crosses into the epistemological territory of the logical empiricists. Historical analyses of logical empiricism have laid particular emphasis on the origins of this movement, situating it within the intellectual context of the nineteenth- and early twentieth-century period (Ayer 1959, 3-10; Feigl 1969; Suppe 1977, 6-15). In so doing, such analyses have closely followed the founding members of the Vienna Circle in their manisfesto of 1929, who claimed to be inspired by scholars like Comte, Duhem, Helmholtz, Marx, Mill, Russell, Spencer, Whitehead, and Wittgenstein (Hahn, Neurath, Carnap [1929] in Neurath 1973, 304). The claims of these founding members notwithstanding, logical empiricism has deeper historical roots and a more diversified epistemological basis within the scientific revolution than is usually acknowledged, as Neurath (1938) later makes clear. These various sources are part of what the latter calls a "mosaic of empirical science":

> Continual scientific activity throughout the centuries gives rise step by step to a distinctive intellectual environment. The history of this evolution of empirical science and scientific empiricism can be regarded as the history of a "mosaic," the pattern of which has been formed by combining new observations and new logical constructions of diverse character and origin. The generations of the "mosaicists" are not only inlaying the stones but also

> changing certain stones for others and varying the whole pattern... Science as a whole can be regarded as a combination of an enormous number of elements, collected little by little (Neurath 1938, 3).

Other scholars who have contributed to this mosaic of empirical science, Neurath adds, are Da Vinci, Galileo, Bacon, Newton, Huyghens, and Euler. The thesis held here is certainly not that Mayr should be placed among the scientist-philosophers who contributed to logical empiricism; Mayr is too much of an empiricist and too little of a logician to be considered part of this movement. Nonetheless, Mayr wanted to complete and expand the scientific revolution by incorporating biology into it, while the logical empiricists were looking to erect a unified view of science founded on a common empirical-logical approach. It is this convergence of interests toward unification within the context of the scientific revolution which binds Mayr and the logical empiricists together. This can be seen in four common and largely complementary methodological and epistemological commitments.

***Hypotheses Non Fingo*: Against Metaphysics**.

Because of its mathematical nature, the scientific revolution carries within itself a criticism toward the postulation of hypothetical entities and realities. The term "hypothetical" is being here understood in its 17th and 18th century meaning, which points to the role of speculation and conjecture in science. The paradigmatic case of such a hypothetical approach in this period is the vortex theory of the Cartesians, which postulated that invisible swirling corpuscules were responsible for the movement of the celestial bodies. In contradistinction to the Cartesians, proponents of classical physics preferred to restrict the legitimate area of scientific knowledge to simple relations between phenomena – regularities and constant connections –

leaving aside explanations concerning the true nature behind the phenomenological manifestations (Yakira 1994, 8-10). The quintessence of this methodology can, of course, be seen in Newton's decision not to engage in conjectures over the essence of the gravitational force. "I feign no hypotheses" (*hypotheses non fingo*), he writes in his *Principia* of 1687, preferring the formulation of laws which are deduced from principles such as mass, distance, and trajectory of bodies. The Newtonian synthesis is constructed in such a way as to allow the prediction of the position and the speed of celestial bodies, while the causes underlying this celestial mechanics remain unkown. The spirit of this epistemological choice is nicely captured in the following characterization of logical empiricism:

> A scientific description can contain only the *structure* (form of order) of objects, not their 'essence'. What unites men in language are structural formulae; in them the content of the common knowledge of men presents itself. Subjectively experienced qualities – redness, pleasure – are as such only experiences, not knowledge; physical optics admits only what is in principle understandable by a blind man too (Hahn, Neurath, Carnap [1929] in Neurath 1973, 309-310).

And again, formulated differently: "Schlick and Russell (and there are also hints of this in the early Carnap) maintained that knowledge proper can concern only the *structural* features of the world, and must necessarily remain silent as regards its purely qualitative *contents*" (Feigl 1969, 15). Since the actual essence of phenonema is difficult to understand, proponents of this epistemology hold, it is preferable to build science on what is more readily explainable. This is a message that the heirs of the scientific revolution will remember, those of the past as well as those of today. Newton himself will express this idea in a famous passage of the *Principia*: "We ought to admit no more causes of natural things than such as are both true and sufficient to explain their appearances. For nature is simple and does not luxuriate in superfluous causes of things" (translated in Koyré 1968, 265). Posterity retained from this statement the notion that only real causes which are known to exist and are sufficient to explain postulated effects are to be accepted as valid, thereby excluding metaphysics from science, that is, hypothetical causes and the postulation of unknown entities and realities. The British philosopher Thomas Reid reformulated Newton's methodology in his *Essays on the Intellectual Powers of Man* (1785) in terms which are now familiar to us:

> When men pretend to account for any of the operations of nature, the causes assigned by them ought, as Sir Isaac Newton has taught us, to have two conditions, otherwise they are good for nothing. *First*, they ought to be true, to have a real existence, and not to be barely conjectured to exist, without proof. *Secondly*, they ought to be sufficient to produce the effect (cited in Laudan 1981, 92).

As Reid interprets Newton, valid causal explanation requires the postulation of entities and mechanisms whose existence can be directly ascertained (Laudan 1981, 93; McMullin 2001, 302-305). In order to meet this epistemological requirement, the kind of science which arose from the scientific revolution defined itself as being grounded in "empiricism" and "positivism", meaning that "there is knowledge only from experience, which rests on what is immediately given", in the words of the manifesto of the Vienna Circle (Hahn, Neurath, Carnap [1929] in Neurath 1973, 309). There is no need to reiterate here the well-known stance of logical empiricists against metaphysics (Hahn, Neurath, Carnap [1929] in Neurath 1973, 305-308; Carnap [1932] 1959; Neurath 1938, 5-7; Hempel [1950] 1959, 108-109). By centering knowledge in evolutionary biology on the Darwinian mechanism of natural selection, while at the same time explicitly criticizing hypothetical entities in biology (e.g. vital force, entelechy), Ernst Mayr also follows the epistemological imperative underlying empiricism and positivism, and more generally the scientific revolution. In this, Mayr is a direct heir of Charles Darwin. Indeed, by grounding the credibility of the concept of natural selection on an analogy with artificial selection, Darwin wanted to show that natural selection is a mechanism that is known to exist (as seen in breeders's techniques and results), in addition to demonstrating that past evolutionary events can be explained by a cause which is known today, that is, natural selection (Gildenhuys 2004; Hodge 1977; Ruse 1975, 1999). At the end of his life, Mayr wrote: "I was determined not to accept any principles or causes that were in conflict with the Newtonian natural laws. The biology for which I wanted to find a philosophy had to qualify as a genuine, bona fide science" (Mayr 2004, 2). For a scholar who adopted such a strong position against physicalism, this last statement may come as a surprise. He goes on to declare: "Science, as we understand it, dates from the Scientific Revolution" (Mayr 1996, 97). It is clear, then, that Mayr intended to incorporate organismic biology within the tradition of the scientific revolution. To achieve this, however, he had to enlarge the epistemological basis upon which the scientific revolution had normally been thought to rest.

Mayr's strategy consists in reinterpreting the history of science from the 17th century onwards in order to incorporate the development of the field of biology. In so doing, he explained what sort of epistemological arrangements had been required to give it its rightful place (Mayr 1985, 43-47). Was it by accident that science was first incarnated in the form of the laws and principles of Galilean mechanics, Mayr asks? Probably not, since mechanics is undoubtedly the most simple of scientific disciplines (Mayr 1996, 97). The epistemological thesis here submitted by Mayr is that any lag in the formulation of biological laws and principles can be explained by the complexity of realities in biology. Thus, the study of ever-more complex realities explains why the earlier epistemological accounts lacked in universality:

> When the other branches of physics developed, exceptions to the universal laws and to the expected determinism of mechanics were found again and again, requiring various modifications. Indeed, in everyday life the laws of mechanics are often so completely

> thwarted by stochastic processes that determinacy appears to be totally absent (Mayr 1996, 97-98).

Mayr's strategy is clear enough: to show that the study of complex phenomena in physics opens the door to epistemological requirements other than those originally conceived by physicalism. A complete epistemological break between physics and biology is therefore avoided, in favor of a transition from simple phenomena in physics to complex phenomena in physics, and from simple phenomena in biology to complex phenomena in biology (Mayr 1988, 8). Given the physicalistic thesis which incorporates biology within the physical sciences and the vitalistic thesis of a complete autonomy of biology, Mayr chooses the middle ground of "organicism". If living beings are not mechanical entities, neither are they characterized by the action of hypothetical entities unique to biology (such as vital forces or entelechies). Mayr's position consists in keeping biology in the same material sphere as physics, although the specificity of living matter is entirely ascribed to the inherent order of its organization. While this position constitutes a middle ground, it is in no way equidistant between physicalism and vitalism: "organicism, in its rejection of immaterial forces and metaphysical explanations, is actually closer to physicalism than to vitalism" (Mayr 1996, 99). Mayr's attacks on metaphysics and vitalism throw light on his commonalities with logical empiricism. Indeed, the manifesto of the Vienna Circle contains the following comment about biology:

> Metaphysicians have always been fond of singling out biology as a special field. This came out in the doctrine of a special life force, the theory of *vitalism*... Since these concepts do not satisfy the requirement of reducibility to the given, the scientific world-conception rejects them as metaphysical... [If] one digs out of this metaphysical vitalism the empirically graspable kernel, there remains the thesis that the processes of organic nature proceed according to laws that cannot be reduced to physical laws. A more precise analysis shows that this thesis is equivalent to the assertion that certain fields of reality are not subject to a uniform and pervasive regularity (Hahn, Neurath, Carnap [1929] in Neurath 1973, 314).

Mayr carefully avoids this criticism by grounding biology in ontological reductionism:

> [M]ore and more biologists recognized that all processes in living organisms are consistent with the laws of physics and chemistry, and that the differences which do exist between inanimate matter and living organisms are due not to a difference in substrate but rather to a different organization of matter in living systems (Mayr 1988, 12).

According to Mayr, there is nothing in the functions, processes, and activities of living organisms that conflict with the laws of physics and chemistry (Mayr 1982, 52). For him, the vitalists's metaphysical interpretations and appeals to immaterial forces are simply incompatible with the conception of science inherited from the scientific revolution (Mayr 1996, 98).

The Ideal of a Compact and Universal Explanatory Structure.

Another rapprochement can be found between Mayr and the logical empiricists in their common ideal of a compact explanatory structure in science capable of dealing with numerous phenomena. Once again, it is the Newtonian synthesis which provided the inspiration for this conception of science, since it was capable of accounting for a wide range of phenomena – such as the celestial motion of bodies, the fall of objects on earth, and the oscillation of the tides – by the universal action of gravitation. Epistemologically speaking, Newton managed to erect this explanatory structure by oscillating between induction and deduction, that is, by gradually getting a better empirical fit for his theory's predictions by modifying the theoretical assumptions upon which it rests (Burtt [1932] 2003, 213-214; Cohen 1980, 61-68; Losee 2001, 81; McMullan 2001, 307). Again, it is the philosopher Thomas Reid who extracts what is often considered the essence of Newton's method, in his *Essays on the Intellectual Powers of Man* (1785): "The whole object of natural philosophy, as Newton expressly teaches, is reducible to these two heads: first, by just induction from experiment and observation, to discoverer the laws of nature; and then, to apply those laws to the solution of the phaenomena of nature" (quoted in Laudan 1981, 108). Reid saw in Newton's method three explanatory components: (1) the observation of facts and experimentation; (2) the extraction of rules or laws out of them; (3) the formulation of further conclusions derived from such generalizations (Laudan 1981, 98). The British philosophers of the 19th century, especially John Herschel and William Whewell, would later fully expose the methodological implications accompanying the Newtonian doctrine. In more sophisticated terms than those of Reid, Herschel presented them in his *Preliminary Discourse on the Study of Natural Philosophy* (1831):

> [T]he whole of natural philosophy consists entirely of a series of inductive generalizations... carried up to universal laws, or axioms, which comprehend in their statements every subordinate degree of generality, and of a corresponding series of inverted reasoning from generals to particulars, by which these axioms are traced back into their remotest consequences, and all particular propositions deduced from them... (quoted in Ruse 1975, 159).

Whewell would later add to this that the value of an explanatory structure increases in proportion to its capacity to explain or predict ever more distinct phenomena (Butts, 1970; Laudan 1981, 163-180).

Although Mayr and the logical empiricists share a common interest in compact explanatory structure or theories, they differ in their development of this notion. Leaving the investigation of empirical realities to the scientists, the logical empiricists concentrate on the philosophical task of the logical analyses of scientific concepts and theories (Giere 2000, 516). Along with the objective of eliminating vague concepts and metaphysical entities in science, logical analyses have the corresponding function of ensuring that empirical theories are constructed to properly address what they claim to be addressing. Thus the need to understand fully the meaning of observational terms, the cognitive content of concepts, the nature of the relationship between theoretical components, and more generally the explanatory structure between the observational/experimental terms and the theoretical predictions/conclusions (Hahn, Neurath, Carnap [1929] in Neurath 1973, 305-307; Mormann 2007). While it is true that the logical empiricists were often attracted to axiomatized theories for their logical and syntactic elegance and clarity – thereby strongly stressing the deductive portion of theories, since the remaining content of a theory can be deductively derived from its initial axioms – the fact remains that they were not entirely neglecting the inductive portion of scientific knowledge:

> At times the Received View is construed analogously as characterizing the way science develops: initially science consists of empirical generalizations formulated using observation terms. Later, as the science advances, theoretical terms are introduced by definition and theoretical laws or generalizations are formulated in terms of theoretical terms. Thus science proceeds "upward" from particular facts to theoretical generalizations about phenomena, this upward process proceeding in an essentially Baconian fashion (Suppe 1977, 15).

On this view, logical empiricists replicated at the logical and syntactic level the explanatory structure inherited from the Newtonian synthesis and made explicit by Thomas Reid and John Herschel.

For his part, the scientist Mayr elects to contribute not to the philosophical aspect of a compact explanatory structure in science but rather to its empirical content. To fully understand the nature of Mayr's contribution, one needs to return to Charles Darwin. From the outset, Darwin attempted to erect his theory of evolution by natural selection by complying with what he perceived to be the most rigourous methodological prescriptions of his time, prescriptions inherited from the Newtonian synthesis and formalized in the nineteenth century by Herschel and

Whewell themselves (Gildenhuys 2004; Hodge 1977; Ruse 1975, 1999, 56-59, 174-180, 197-198, 238-239). It is unsurprising, therefore, to find in Darwin's theory the main structural components of the theories he assumed to be legitimate. First, induction is useful to Darwin for observing the effects of artificial selection on living populations, as well as for assessing evolutionary facts supporting the notion of common descent, including the geographical proximity of related species, and the morphological similarities binding related species. Secondly, it becomes possible to formulate generalizations leading to the postulation of an universal mechanism of biological evolution – natural selection – based upon an analogy with artificial selection within living populations. It is this evolutionary mechanism which explains the evolutionary facts mentioned above. Thirdly, although in evolutionary biology deduction does not permit the prediction of future courses of individual evolutionary lines, more general predictions such as "populations will continue to change if the environment continues to do so" are possible. Using this explanatory structure, Darwin was able to explain a whole range of different phenomena throughout various fields such as geology, biogeography, comparative anatomy, embryology, zoology, systematics, and ethology. On this view, the explanatory structure of the Darwinian theory is not entirely dissimilar to the Newtonian theory. The differences between the two are largely attributable to the nature of the objects they study:

> As Darwin formulated it, evolutionary theory did not permit verification or falsification by the simple expedient of deducing a single observational consequence and checking it. Given Newton's equations and a few reasonably unproblematic simplifying assumptions and boundary conditions, a physicist could deduce some fairly precise observational consequences which could be used to confirm or disconfirm his theory. He could deduce where Mars should be at a precise time. Darwin's theory was neither mathematical in notation nor deductive in form. Given evolutionary theory and the kind of data available to a biologist, no precise, unequivocal inferences were possible. One could not predict how an extant species would evolve or retrodict how an extinct species did evolve. At best, only a range of some more or less possible outcomes could be generated (Hull 1973, 32).

Because the Darwinian theory is concerned with evolutionary processes involving the interaction of numerous factors unknown in advance – the meeting of a population's unique adaptive path and the unpredictable changes of the environment, for instance – it is impossible to predict the outcome of the evolutionary process.

As argued elsewhere (Delisle in press a; in press b), Mayr not only inherits Darwin's explanatory structure in evolutionary biology, he actively contributes to its development. Perhaps nobody was as close to Darwin as Mayr himself; both were neontologists (working on evolution from the perspective of living populations) and organismic biologists. Mayr did much to reinforce the actualistic foundation of Darwinism. Darwin's *On the Origin of Species* (1859) already provided concepts like domestic and natural variations, hybridization, geographical distribution, embryological and morphological similarities explained by common descent. As much as Mayr thought these concepts were fundamental to the understanding of the evolutionary process, he felt they were still insufficient to the task. Indeed, insists Mayr, they could not help Darwin to arrive at a clear distinction between phyletic (gradual) and cladogenetic (splitting) processes of evolution:

> A species, as we now see it, is characterized not only by being different, but also by being distinct from other species (separated by a gap, reinforced by isolating mechanisms). In his more nominalistic treatment of species in the later 1850s Darwin was concerned only with difference, the first criterion of this dual characterization. As a result he apparently never fully realized that there was a fundamental difference between the phyletic evolution of a lineage... and genuine speciation. Darwin's description of the change of a variety into a species is a description of phyletic evolution... There is no question as to Darwin's focus on phyletic evolution ('vertical speciation'), even though in a few passages... he also refers to the speciation of geographically isolated 'varieties' (Mayr 1992, 349-350).

For Mayr, only the study of population diversity in today's time horizon can lead to a proper understanding of how the gene pool of populations are broken up. Without this understanding, he insists, the impressive diversity of life forms remains unexplained. It is to this end that he exploits and develops an array of concepts, including: population thinking, polytypic species, population structure, biological species concept, founder effect, isolating mechanisms, gene flow, allopatric and peripatric speciation, genetic revolution, and the gradual action of natural selection (Mayr 1942, 1963). The significant conceptual contribution of Mayr to the Darwinian theory not only added to its actualistic foundation, but also solidified its explanatory structure in the form originally conceived by Darwin. Indeed, what Mayr did with the help of supplementary concepts is to increase the operationality of natural selection among living organisms and populations.

A Reductionistic Approach and a Corpuscular Ontology.

Yet another commonality between Mayr and the logical empiricists is a commitment to a reductionistic approach to science founded on a corpuscular ontology. Before explaining how an organismic biologist like Mayr so openly opposed to physicalist reductionism could have ascribed to this view of science, let us first briefly consider its rise within the context of the scientific revolution. The 16th and 17th centuries saw the gradual abandonment of a science founded on final causes – the product of an Aristotlean view – in favor of a science based upon efficient causes. Scholars of the time were less interested in knowing what the Creator aimed to achieve than how things worked, how the world machine was actually working (Duflo 1996, 22-23). This new epistemological attitude gave rise to a mechanistic worldview whose goal was the investigation of efficient causes behind macroscopic phenomena (Yakira 1994, 26-54). It is in this context that the ancient philosophical tradition of atomism was revived and recasted in the empirical spirit of the age (Charbonnat 2007, 227-233). Whether they used the terms atoms, particles, or corpuscles, the major scholars of the period, Galileo, Hobbes, Locke, Bacon, Descartes, Boyle, Gassendi, and Newton, all believed that phenomena could ultimately be explained by appealing to the interactions of tiny, invisible, and indivisible material constituents. In other words, physicalist reductionism constitutes the means by which the ultimate source of causality is reached. In fact, even the notion of action-at-a-distance in Newton's physics – which is not properly a mechanism resting on interactions, considering that gravity is a force – was analogically conceived as an efficient cause of mechanistic nature (Kuhn 1971, 12-13). And although Newton was against the postulation of hypothetical entities in science, he was truly optimistic that improved microscopes would eventually revealed the inductive and observational foundation of the corpuscular philosophy (Laudan 1981, 48, 57).

Although both were proponents of a reductionistic approach to science which rested on a corpuscular ontology, Mayr and logical empiricists differed on this issue in terms of character of their respective interests: empirical for the former and logical/syntactic for the latter. Here again, the logical empiricists replicated at the logical and syntactic level the epistemological choices inherited from the scientific revolution. This fact was made clear by an inspirational figure for the logical empiricists, Bertrand Russell, who explained the nature of logical atomism in the following way:

> [Logical atomism] has gradually crept into philosophy through the critical scrutiny of mathematics... It represents, I believe, the same kind of advance as was introduced into physics by Galileo: the substitution of piecemeal, detailed and verifiable results for large untested generalities recommended only by a certain appeal to imagination (Russell 1914, 14).

This passage was quoted in the manifesto of the Vienna Circle (Hahn, Neurath, Carnap [1929] in Neurath 1973, 306). Just as empirical science must proceed by ontological reductionism in order to avoid the premature and speculative syntheses which typically accompany a holistic approach, its discourse must also be subject to logical atomism. Ernst Mayr subscribes wholeheartedly to this epistemological attitude in the empirical realm of biology. Indeed, a mechanistic and corpuscular philosophy can be applied to biology if biological evolution is conceived as the transmission of distinct entities in time from one generation to another, whether these are called molecules, genes, or organisms. In addition, the action of natural selection on such biological entities satisfies the requirements of a science founded on efficient causes. As an organismic biologist, however, Mayr wanted to be sure that his brand of reductionism was suited to the biological reality. In order to avoid the kind of determinism typical of the physicochemical sciences, as well as a physicalist reductionism which negates emergent properties at the biological level, Mayr rejected the notion of an evolutionary biology founded on the phenomenological levels of the molecules and the genes (Mayr 1975, 2000). For him, it is the evolutionary processes at the organismic level (individual organisms and species) which determine what is happening at the genetic and molecular levels, not the other way around. It is unsurprising, then, that Mayr invested the bulk of his scientific career in further developing concepts which apply mainly at the organismic level: population thinking, polytypic species, population structure, biological species concept, isolating mechanisms, etc. (Mayr 1942, 1963). Here, Mayr genuinely promotes reductionism, but one that applies at the level of biological individuals (organisms and species). This reductionism might best be called "organismic reductionism". It is not that Mayr opposes ontological reductionism, for he fully agrees that organic entities are composed of the same stuff as inorganic ones. Rather, the issue is an organizational one. Methodological reductionism is inappropriate in biology, Mayr insists, precisely because it negates the emergent properties at the organismic level. Interestingly, by placing the threshold of his reductionism at this phenomenological level, Mayr denies the value of a holistic conception of the tree of life. Indeed, for a number of scholars, such as Henri Bergson, Julian S. Huxley, and Theodosius Dobzhansky, the tree of life on earth is conceived as an integrated unit whose ontological reality goes beyond its constitutive parts, that is, isolated individuals and species (Delisle 2008; in press b, chap. 1-2). In denying that the tree of life is more than the sum of its parts, Mayr applies a methodological reductionism of organismic nature against this holism.

The Unity of Science.

The fourth epistemological commitment shared by Mayr and the logical empiricists is their ideal of a unified science. The scientific revolution had already exemplified this ideal to a degree, both implicitly and explicitly: implicitly, by the repeated attempts to apply the so-called proper methodological prescriptions to an increasing number of distinct research domains; explicitly, as illustrated by the power of the Newtonian synthesis to explain a range of distinct phenomena. As one might have expected, this ideal found its way in the writings of the earliest logical empiricists in the form of a search for unified logical and syntactic analyses, a unified language of science (Carnap 1938, 49; Neurath 1938, 18-19). It is not perfectly clear whether the quest for a unified language at the time necessarily included a commitment toward the unity of science as well. Soon enough, however, it became clear that a number of logical empiricists were actively pursuing this goal, as seen most notably in the notion of theory reduction (Oppenheim and Putnam 1958; Hempel 1966, chap. 8; Nagel 1979, chap. 11):

> Nevertheless, that ideal continues to leaven current scientific speculation; and, in any case, the phenomenon of a relatively autonomous theory becoming absorbed by, or reduced to, some other more inclusive theory is an undeniable and recurrent feature of the history of modern science. There is every reason to suppose that such reduction will continue to take place in the future (Nagel 1979, 336-337).

On the empirical front, Mayr, too, was busy conceptualizing a model for a unified science, but one which could accomodate organismic biology. To achieve this, Mayr stresses, the scientific revolution must be envisioned from a more universal perspective: "To achieve a more universal concept of science, it is necessary to remove the specialized, purely physicalist, features from the science of the Scientific Revolution. This still leaves intact the most characteristic aspects of genuine science" (Mayr 1996, 99). It is in this context that Mayr criticizes the unity of science movement, composed mainly of philosophers, for trying to reduce all the disciplines to a common physicalistic denominator (Mayr 1996, 101). What they failed to appreciate, Mayr asserts, is the heterogeneity of the sciences, a diversity which exists even within the field of physics itself. But here again, one must bypass Mayr's rhetoric and self-understanding of logical empiricism in order to insist on the plurality of the views within this movement. This latter viewpoint will make Mayr's connections with logical empiricism clearer still. There is little doubt that Rudolf Carnap had from the outset been pushing for an agenda which included the unity of science, based upon physicalism:

> In the meantime the efforts toward derivation of more and more biological laws from physical laws... will be, as it has been, a very fruitful tendency in biological research... It is obvious that, at the present time, laws of psychology and social science cannot be derived from those of biology and physics. On the other hand, no scientific reason is known for the assumption that such a derivation should be in principle and forever impossible... [T]here is a *unity of language in* science, viz., a common reduction basis for the terms of all branches

> of science, this basis consisting of a very narrow and homogeneous class of terms of the physical thing-language. This unity of terms is indeed less far-reaching and effective than the unity of laws would be, but it is a necessary preliminary condition for the unity of laws. We can endeavor to develop science more and more in the direction of a unified system of laws only because we have already at present a unified language (Carnap 1938, 60-61).

On the other side of the spectrum, Otto Neurath eventually came to embrace a vision of the unity of science which was not based on a vertical organization going from physics to psychology, but rather on a horizontal network of disciplines characterized by multi-directional exchanges (Creath 1996, 161; Reisch 1996, 135-139; Cat et al. 1996, 347-354). Richard Creath explains Neurath's conception of the unity of science in the following terms:

> But everyone would have to listen to everyone else, for no one's evidence could be discounted as utterly and permanently irrelevant. Relevance is after all a two-way street. Physical theory might explain biological evidence, but that biological evidence might just as easily bring down a physical theory or tip the balance between one physical theory and another. In any case the unity cannot be imposed *a priori* but would emerge only to the extent that it reinforces theories from the various fields. As far as I can see this is the unity-as-cooperation view that was championed by Neurath (Creath 1996, 168-169).

Once this pluralism of views within the group of logical empricists is established, we are now in a better position to assess Mayr's position. Interestingly enough, over his career, Mayr's position on the question of the unity of science moved from one extreme to another. At first, Mayr justified his opposition to a physicalistic approach to unification by quoting a passage from the paleontologist George Gaylord Simpson (Mayr 1982, 35). This original passage reads as follows:

> In fact, the life sciences are not only much more complicated than the physical sciences, they are also much broader in significance, and they penetrate much farther into the exploration of the universe that *is* science than do the physical sciences. They require and embrace the data and *all* the explanatory principles of the physical sciences and then go far beyond that to embody many other data and additional explanatory principles… I suggest that both the characterization of science as a whole and the unification of the various

> sciences can be most meaningfully sought in quite the opposite direction, not through principles that apply to all phenomena but through phenomena to which all principles apply… Biology, then, is the science that stands at the center of all science… And it is here, in the field where all the principles of all the sciences are embodied, that science can truly become unified (Simpson 1963, 87-88).

After quoting this passage, Mayr refrained from making any comment on the extraordinary claim that the unity of science must be realized through biology. It seems not unreasonable, therefore, to interpret his silence as tacit approval of this statement. If such is the case, Mayr's view at the time would be rather similar to that of Carnap, with the difference only being that for Mayr, it is not biology that must be subordinated to physics, but the other way around. In both cases, the conception of the unity of science is identical, in the sense that the epistemological imperialism of one discipline is imposed upon all others. A few years later, however, Mayr again quoted the same statement of Simpson, but asserts this time that this position constitutes a "somewhat extreme interpretation" (Mayr 1988, 20), while adding the following comment:

> We may not need to accept all these sweeping claims. However, Simpson has clearly indicated the direction in which we have to move. I believe that a unification of science is indeed possible if we are willing to expand the concept of science to include the basic principles and concepts of not only the physical but also the biological sciences (Mayr 1988, 21).

More than a simple qualification, this comment tends to suggest that Mayr gave up on the model for the unity of science proposed by Carnap in order to embrace a model closer to the one promoted by Neurath, and based on the epistemological equality of disciplines and their complementary relations. Now whether Mayr adopted the perspective of Carnap or Neurath, the fact remains that his connections with several significant ideas defended by logical empiricists are stronger than he was ever prepared to admit. Perhaps this should not surprise us, considering that all were direct descendents of the scientific revolution.

Conclusion.

Mayr attempted to erect a philosophy of science which could take into account organismic biology while remaining within the confines of the scientific revolution. This intellectual quest resulted in proposals for expanded epistemological prescriptions, as part of a scientific revolution believed to be open-ended and still in progress. His proposals can be characterized as follows: (1) an endorsement of epistemological pluralism in a complex world that cannot be reduced to a few universal laws; (2) the recognition of indeterminism at the organismic level and above, thus creating epistemological room for a historical narrative; (3) the restriction of essentialism to the physicochemical sphere, on the grounds that uniqueness constitutes a universal feature at higher levels of matter; (4) the acceptance of reductionism in biology, but only at the phenomenological level of individual organisms and species; (5) the legitimacy of studying quantitative as well as qualitative scientific realities; (6) the pursuit of knowledge not only through experimentation but also with the help of observation and comparison.

At this juncture, it is tempting to ask what is left of the scientific revolution once its physicalistic components have been excluded. Perhaps what is most essential, if we are willing to take serioulsy Ernst Mayr's philosophy of science. When considering the key epistemological commitments shared by Mayr and the logical empiricists – commitments largely inherited from the scientific revolution – a reasonable case can be made in favor of a scientific revolution conceived as transcending its exclusively physicalistic components. Therefore, it seems that commitments such as the rejection of metaphysical entities (materialism), the desire to build a science around compact and universal explanatory structures (theories), the application of a reductionistic and corpuscular philosophy, and the ideal of an unified science, are all "neutral" enough, epistemologically speaking, to encompass both the physicochemical and the biological spheres.

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