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Reclaiming the History of the Epigenesis of Scientific Knowledge: From Aristotle's Theory to Kant's Abstract Epigenesis of Pure Reason and Piaget's Genetic Epistemology

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Scholarly debate persists over whether Aristotle explicitly used the term epigenesis (ἐπιγένεσις). What is beyond doubt, however, is that he originated the concept itself, already implicit in his distinction between potency (dynamis, δύναμις) and act (energeia, ἐνέργεια). Aristotle conceives the generation of an organism as a staged process emerging from an embryo that contains the possibilities of a future being, but not a preformed one. This generation from something that already exists is epigenesis: "upon" (epi) what is given, a new form arises. The concept became increasingly important in the history of thought, especially after the English biologist Conrad Hal Waddington coined the term epigenetics, now a discipline of immense scientific relevance. In this article, we emphasize the fact that Immanuel Kant, in a brief but remarkable moment of his work, took Aristotle's notion of epigenesis and transformed it into an abstract model for the generation of knowledge, one capable of reconciling the opposed presuppositions of Rationalism and Empiricism in the history of ideas. As he writes in the Critique of Pure Reason:

> *There are only two ways in which a necessary agreement between experience and the concepts of its objects can be conceived: either experience makes these concepts possible, or these concepts make experience possible. The former cannot apply to the categories; consequently, only the latter remains (which presents us with a system, as it were, of the epigenesis of pure reason.*

This expression has received remarkably little attention in the nearly 400 years since its appearance and, when discussed, is usually interpreted as a mere analogy to organic epigenesis, a biological concept formally established only in the seventeenth century by William Harvey. Against that prevailing tendency, we do not interpret Kant's phrase assertion as an allusion to the biological development of the human organism, as he himself does in the Critique of Judgment (§81), in discussing Blumenbach. Rather, we understand the "epigenesis of Pure Reason" as a genuine epigenesis: singular, abstract. Kant does not describe the process in detail; he merely indicates it for posterity. This abstract epigenesis cannot imply physical development or transformation. Rather, it signifies an expansion in the field of application of the a priori structures of Reason. For Kant, what is given a priori to human nature, namely the categories and forms of judgment, does not change, evolve, or alter. Here, the prefix epi should be understood in its etymological sense: that which grows out of an immutable origin. The set of possibilities for predication and for the construction of judgments, always identical and always given a priori in Pure Reason, never modifies; it only expands its domain insofar as the Verstand (german word that does not equates to English "Understanding") deepens its structuring engagement with the world of phenomena. What is given a priori to the human being encounters in experience, in the world of phenomena, that which can be assimilated in light of its own a priori possibilities. Much later, Niels Bohr would demonstrate that Pure Reason can

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construct models of physical reality even in the absence of phenomena accessible to immediate observation, thereby extending Kant's concept of the a priori at its core. The great physicist preserves, above all, Kant's interpretation of the construction of knowledge as a "Copernican inversion": it is not phenomena that determine the origin of scientific knowledge; rather, our capacity and possibility of knowing determine what we can know—just as it is not the Sun that revolves around the Earth, but the Earth that revolves around the Sun, as Copernicus demonstrated. In this sense, Kant's theory of scientific knowledge reaches into the realm of quantum physics, a fact acknowledged by distinguished physicists in the twenty-first century. Thus, the dynamis (δύναμις) conceptualized by Aristotle around 400 BCE attains its Energeia (ἐνέργεια) in the twenty-first century, accompanied by his master Plato, who created the concept of dialektikē (διαλεκτική), which explains how a thought can depart from ancient Greece and arrive, unbroken, in our own time. It is in the twentieth century, finally, that Jean Piaget's Genetic Epistemology emerges: as a theory that shows how the epigenesis of scientific though recapitulates phylogeny, synthesizing Aristotle's organic epigenesis with Kant's abstract epigenesis.

Keywords: *Organic Epigenesis; Epigenesis of Pure Reason; Genetic Epistemology; Theory of Knowledge*

Method

In constructing this text, we employed the method of structural analysis, applied to a corpus of writings by Aristotle and Immanuel Kant that address the concept of epigenesis and are listed in the bibliography.

Aristotle Organic Epigenesis

Friedrich Wilhelm Joseph von Schelling (1775–1854) *reminds us that great care must be taken when interpreting thinkers such* as Aristotle. In Historical-Critical Introduction to the Philosophy of Mythology (1842), he writes:

> Aristotle cannot be understood by remaining statically attached to him. One must also know what he does not say and walk for oneself along the paths he walked, grapple with the difficulties he grappled with; in short, one must go through the whole process he went through and perceived in order to understand what he says. Mere historical knowledge is not possible in relation to any philosopher, least of all in relation to Aristotle.

Aristotle is one of the pillars of Western civilization. Much has been written about him, and even more has been studied concerning his doctrines, methods, reflections, and creations. A large part of science has been developed either with Aristotle or against him, but in either case his presence remains fundamental to the construction of scientific thought. Hence the relevance of Schelling's remark.

So why turn to Aristotle? Bertrand Saint-Sernin, philosopher, professor emeritus of Philosophy of Science and Theory of Knowledge at the Université de Paris-Sorbonne (Paris IV), and member of the Collège de France, underscores the importance of

Aristotelian thought for modernity in his book Reason in the 20th Century:

> Husserl subverted chronology, he legitimized a kind of philosophical ubiquity that allows one to go from Kant to Descartes and from Descartes to Hume, or to look for a hero of modern philosophy in a thinker of Antiquity. For this reason, he justifies a return to Aristotle. If we have made this about-face, it is because it seems to us that the Stagirite is modern in his way of approaching the problem of categories, causality, action, and justice. But, above all in the treatise On the Soul, he analyzes, with a clarity and precision never surpassed, the way in which we try to think simultaneously in the world of the senses and in the universe of forms. For the reason of Aristotle or Plato up to our in these days, it is the faculty of imagining Forms. Aristotle established an open list of categories; his aim was to apply them to the knowledge of Being; he showed, however, that our mind cannot form ideas without our body being touched by sensations. For this reason, he remains to this day an incomparable guide for reflection on science and action. He does not fixate on anything, he prescribes nothing; what he does is to clear before our eyes the natural history of the mind. (Bertrand Saint-Sernin 1998, p. 180)

A summary overview of Aristotelian philosophy within the context of life sciences. Before turning directly to Aristotle's treatment of epigenesis, it is useful to *consider what knowledge, science, experience, and reason mean within Stagirite's* philosophy.

Aristotle addresses these themes in works such as *Metaphysics, Analytics, Physics, and On the Soul.* Let us consider what he teaches:

> By nature, animals are born endowed with sensation; however, this does not engender memory in some, although it does in others. And for this reason, these are more prudent and more apt to learn than those who cannot remember; those incapable of hearing sounds, like the bee and other similar animals, if these exist, are prudent without learning; those who, in addition to memory, have this sense, learn instead. The other animals live with images and recollections and participate little in experience. But humankind possesses art and reason. And from memory arises experience for men, for many recollections of the same thing lead to the construction of experience. (Meth. 980b – 981a).

In the Metaphysics, Aristotle sets out the foundations and methods of his philosophy. He begins with reflection on natural phenomena perceptible to the senses, such as those mentioned above. In Book I, he further clarifies the role of knowledge grounded in experience and the role of knowledge arising from proper reflection. Consider what Aristotle says about the relationship between experience and reflection:

> Experience seems, in a certain way, similar to science and art, but science and art come to men through experience. For experience makes art, as Polus of Agrigento said, and inexperience leads to chance. Art is born when, after many experimental observations, a universal notion arises about similar cases. For having the notion that Callias, afflicted by such an illness, was well treated by such a remedy, and the same with Socrates and many others considered individually, is proper to experience; but knowing that it was beneficial to all individuals of such a constitution, grouped in the same class and afflicted by such an illness, for example, the phlegmatic, the bilious, the febrile, corresponds to art. (Meth. 981a -10).

The passages above answer the familiar claim often attributed to Aristotle that "all knowledge is derived from experience. A close reading of the Stagirite shows, on the contrary, that he observes nature, establishes relations among observable phenomena, and defines a reality grounded in thought and in scientific rigor. Let us continue with Aristotle:

> Well, for practical life, experience does not seem to be in any way inferior to art; it is known that experts are even more successful than those who, without experience, possess theoretical knowledge. And this is because experience is the knowledge of singular things and art of universals; and all actions and generations refer to the singular. It is not man, in fact, whom the doctor heals, except accidentally, but rather Callias or Socrates, or another of those so-called, who is also a man. Consequently, if someone has theoretical knowledge without experience and knows the universal, but ignores its singular content, he will often err in the process of healing, for it is the singular that can be healed. (Meth. 981a – 981b 25)

Let us continue with Metaphysics:

> We believe, without doubt, that knowledge and understanding belong more to art than to experience, and we consider those who know the art wiser than those who are experienced, thinking that wisdom corresponds to knowledge for all. This is because some know the cause and others do not. For the experience, know what, but not why. Those, on the other hand, know why and the cause. (Meth. 981b)

Still in Metaphysics, Aristotle demonstrates, or rather, exemplifies the categorical relationship between experience and thinking:

> Thus, we do not consider foremen wiser because of their practical skill, but because of their mastery of theory and their knowledge of causes. Ultimately, what distinguishes the wise from the ignorant is the power to teach, and therefore we consider art to be more of a science than experience, for the former can teach and the latter cannot. (Meth: 981b 5).

In our view, Aristotle treats categories as indispensable instruments for apprehending reality, reflecting upon it, and discerning the truth contained within it in universal form. In that sense, categories enable the *anima* to conceive Being. For the philosopher, categories make it possible for being to achieve cognitive expression. As Aristotle writes:

> In essence, Being receives as many meanings as there are categories, for the significations of Being are as numerous as the categories. Now, among the predicates, some indicate substance, others quality, others relation, others action or passion, others place and time. Being is therefore found in the sense of each of these modes" (Meth. V 7, 1017a 20 – 30).

Aristotle enumerates the categories as substance, quantity, quality, relation, place, time, position, possession, action, and passion. In his account, substance is something fixed and unchangeable, whereas the others form an open list and are therefore susceptible to extension and variation.

Aristotle may rightly be described as a polymath, given the extraordinary range of subjects he addressed with such depth. In the field of the empirical sciences, and

especially the natural sciences, Stagirite produced a long chain of propositions grounded in field research, careful observation, and the objectification of phenomena. In that sense, one may say that he laid the foundations of the philosophy of science. Our purpose in this article is to highlight the Aristotelian concept of epigenesis and its relevance to science, especially to the biological sciences.

Organic Epigenesis (επιγένεση) by Aristotle

According to biologists such as Waddington and to several historians of science, the concept of epigenesis was introduced by Aristotle (384–322 BCE) in ancient Greece. Aristotle proposed that organisms do not emerge fully formed from the outset, as preformationism would later claim, but develop gradually. The form of a living being emerges progressively from an initial undifferentiated substance. The concept was subsequently advanced and reinterpreted over the centuries. In the modern period, the English physician William Harvey (1578–1657), famous for describing the circulation of the blood, reinforced the epigenetic approach by asserting that all living things come from an egg (ex ovo omnia). Studying embryos of different species, Harvey concluded that the structures of organisms are formed gradually through an ordered developmental process. Mazliak (2013, p. 153) summarizes Harvey's view of epigenesis as follows:

> The epigenesis of embryos was stipulated by William Harvey regarding the following aspects:
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> 1. The parts of the fetus are formed one after another.
> 2. The most important parts of the embryo develop first from a functional point of view.
> 3. Each organ is formed a new, without prior miniature development in the embryo.
> 4. Epigenesis therefore rejects the idea of any preformed adult characteristic already present in the egg. In all these respects.

William Harvey aligns himself firmly with Aristotle. Epigenesis is a concept created by Aristotle and later reinforced by Harvey to explain the developmental process of a being after its constitution or origin.

Today, once syngamy has been conceptually and experimentally understood, that is, the evolution of something that already exists, Aristotle's intuition may be restated in modern terms: only what exists can change. This process is built gradually, in stages, within a teleological perspective and therefore toward a definite end, unfolding within the mathematical magnitude called time.

With the idea of epigenesis, Aristotle sought to explain what he observed in the study of animals, namely their origin and development. The result of those investigations contributed to what later came to be called embryology; indeed, many scholars of biology regard Aristotle as one of the founders of embryology. His studies of the life sciences are contained chiefly in On the Generation of Animals, History of Animals, On Generation and Corruption, On the Soul, and On the Parts of

Animals. Guided by these texts, and by relevant chapters of Physics and Metaphysics, the present reflection on epigenesis has been developed. Aristotle classified beings as animate and inanimate, oviparous and viviparous; he described species and organized them in ways that anticipate taxonomy.

Through several lines of reflection, he displayed an extraordinary capacity for observing nature and transforming observation into science in the modern sense. For him, animate beings, endowed with anima, possess their own locomotion, reproduce, grow, develop, and, in some cases, think at different levels. Epigenesis explains how living beings are to be studied through their physical, instinctive, and intellectual characteristics in a developmental process unfolding gradually along the axis of time.

In Arthur Platt's 1912 translation of On the Generation of Animals, Aristotle describes the four causes, hylomorphism, and the transformation of potentiality into actuality within the realm of the life sciences. In the History of Animals, across ten books and 237 chapters, Aristotle records the breadth of his knowledge of living beings and reflects on what a being is and on the stages of its development. According to Aristotle, living beings are not formed all at once; rather, they pass through a developmental process that culminates in their final form. He argued that the characteristics of an organism arise from a complex combination of environmental factors and inherited traits, and that they develop according to an organizing principle he called anima, the form of living beings.

Against preformationism, Aristotle holds that living beings develop gradually from simple and undifferentiated forms to complex and specialized ones. Their elements are not preformed in advance; they emerge over time through growth and differentiation until they reach their final form in a teleological trajectory determined by the anima proper to each type of being. In these writings, which result from careful reflection on biological phenomena, Aristotle follows a teleological path oriented toward a result, and in so doing establishes the critical and demonstrative gaze of science. In De Generatione Animalium (GA 727b 17–18), for example, he emphasizes the four causes involved in the formation of the individual: formal cause (the form of the organism), material cause (menstrual blood/female fluid), efficient cause (semen), and final cause (the completed organism). Although these biological notions are obviously outdated after more than 2,400 years, Aristotle's account remains conceptually important, especially in the way it relates form and matter and conceives form as the source of each being through *anima*. In his works one can observe his method of thinking: establishing relations, comparing, verifying, and objectifying the phenomenon under study. His only research tool was his intellectual capacity (nous).

How does Aristotle describe the evolution of living beings from the conceptual Perspective of epigenesis?

> Now it would appear irrational to suppose that any of either the internal organs or the other parts is made by something external, since one thing cannot set up a motion in another without touching it, nor can a thing be affected in any way by another if it does not set up a motion in it." De Generatione Animalium – On the Generation of animal's trad. Arthur Platt 1912, p.23.

The philosopher points to two distinct aspects of reality: first, the contingency of things *(contingentia rerum);* second, the interconnection of things *(colligatio rerum).* In the first case, he emphasizes that things touch one another *(cum et tangere);* in the second, that things are linked or associated *(cum et legere).* The first circumstance points to what is fortuitous or accidental; the second to what is necessary.

> Something then of the sort we require exists in the embryo itself, being either a part of it or separate from it. To suppose that it should be something else separate from it is irrational. For after the animal has been produced does this something perish or does it remain in it? But nothing of the kind appears to be in it, nothing which is not a part of the whole plant or animal. Yet, on the other hand, it is absurd to say that it perishes after making either all the parts or only some of them. If it makes some of the parts and then perishes, what is to make the rest of them? Suppose this something makes the heart and then perishes, and the heart makes another organ, by the same argument either all the parts must perish or all must remain. (De Generatione Animalium – On the Generation of animals -trad. Arthur Platt 1912, p. 23).

Here both temporality and reflective logic are evident, since any explanation of things that move and consequently move others must involve something other than chance and must confirm, through experience, the truth of what is being proposed. Human development has long been studied, and since the conceptual construction of syngamy it has been understood as a continuous process. It unfolds in stages: cell division, cell migration, growth, and cellular rearrangement. Differentiation, which begins at the molecular level, also plays a fundamental role. These steps transform the fertilized egg (zygote), a totipotent stem cell, into a multicellular organism the human being. All of this is modulated over time:

> Therefore, it is preserved and does not perish it is a part of the embryo itself which exists in the semen from the beginning; and if indeed there is no part of the soul which does not exist in some part of the body, it would also be a part containing soul in it from the beginning. How then, does it make the other parts? Either all the parts, as heart, lung, liver, eye, and all the rest, come into being together or in succession, as is said in the verse ascribed to Orpheus, for there he says that an animal comes into being in the same way as the knitting of a net. That the former is not the fact is plain even to the senses, for some of the parts are clearly visible as already existing in the embryo while others are not; that it is not because of their being too small that they are not visible is clear, for the lung is of greater size than the heart, and yet appears later than the heart in the original development. Since then, one is earlier and another later, does the one make the other, and does the later part exist on account of the part, which is next to it, or rather does the one come into being only after the other?" (De Generatione Animalium – On the Generation of the animals Trad. Arthur Platt 1923, p. 24).

How is the origin of humankind explained today? Consider the sequence ordered along the axis of time and causality. The process begins with fertilization, preceded by several events before the union of the oocyte with the spermatozoon. The oocytes produced through ovulation are received by the Fallopian tube and settle in the ampulla where they are fertilized by the spermatozoa expelled during sexual intercourse. Hundreds of millions of spermatozoa are deposited in the vagina

around the uterine opening. Several thousand spermatozoa reach the fallopian tube, and many of them reach the vicinity of the oocyte. When a spermatozoon penetrates the oocyte, it completes the second meiotic division. This results in the so-called mature oocyte and the polar body. The nuclear structure of the oocyte forms the female pronucleus. The formation of the male pronucleus occurs after the spermatozoon penetrates the oocyte and the sperm's tail separates from the head. Fertilization occurs with the fusion of the pronuclei, and the male and female chromosomes unite in metaphase of the first mitotic division of the zygote. During the passage of the zygote through the fallopian tube, it divides and forms approximately 32 smaller cells, the blastomeres, which will constitute the morula. Next, a cavity forms within the morula, transforming it into a blastocyst. This is composed of the embryoblast, which will form the embryo, the blastocyst cavity, and the trophoblast, that is, the outer cell layer. The trophoblast covers the embryoblast and the blastocyst cavity and forms extraembryonic structures such as the placenta. Soon after, this structure adheres to the endometrial tissue and becomes fixed. From the formation of the zygote, the epigenetic process begins. When we compare the description of the origin of the embryo in the Aristotelian description and in the present day, we see causality and temporal modulation expressed in such a way that we can understand the concepts of genesis and epigenesis. The notion of microscopic and macroscopic structures is also perceptible in the Aristotelian text, something that shows the high degree of reflection of the Stagirite, since he realizes that in addition to the visible structures there were invisible ones that could only be known at that time through the reflection contained in the scientific syllogism. Obviously, the stages of human development in the Aristotelian description are outdated. The philosopher, however, described the general conceptual sequences in the temporal and inferential aspects. The Stagirite's reflection on the generation of animals also contemplates the concepts of inference and causality that organize the proper reading of the concepts contained in the phenomena of generation and the understanding of the microscopic and macroscopic worlds.

Thus, the philosopher tells us:

> That the former is not the case is clear even to the senses, for some parts are clearly visible as already existing in the embryo, while others are not; that it is not because they are too small that they are not visible is clear, for the lung is larger than the heart and yet appears later than the heart in the original development. Since, then, one is prior and the other posterior, one makes the other, and the posterior part exists because of the part that is beside it, or rather, one only arises after the other? I mean, for example, that it is not the fact that the heart, having arisen first, then makes the liver, and the liver again another organ, but that the liver only arises after the heart, and not by the action of the heart, as a man becomes a man after being a boy, not by his action. One explanation for this is that, in all the productions of Nature or art, what already exists potentially is brought into existence only by what actually exists; Therefore, if one organ were to form another, the form and character of the later organ would have to exist in the earlier one; for example, the form of the liver in the heart. Otherwise, theory is also strange and fictitious. (De Generatione animalium – On the Generation of animals – trad. Arthur Platt 1912, p. 24)

The sequential explanation of inherited epigenetic structures organizes the logic of demonstration and therefore of causality, which lies at the heart of the reflective process, as Aristotle states:

> Yet again, if the whole animal or plant is formed from semen or seed, it is that any part of it should exist ready made in the semen or seed, whether that part be able to make the other parts or no. For it is plain that, if it exists in it from the first, it was made by that which made the semen. But semen must be made first, and that is the function of the generating parent. So, then, it is not possible that any part should exist in it, and therefore it has not within itself that which makes the parts. But neither can this agent be external, and yet it must needs be one or other of the two. We must try, then, to solve this difficulty, for perhaps some one of the statements made cannot be made without qualification, e.g. the statement that the parts cannot be made by what is external to the semen. For if in a certain sense they cannot, yet in another sense they can. (Now it makes no difference whether we say 'the semen' or 'that from which the semen comes', in so far as the semen has in itself the movement initiated by the other)." Aristotle, (De Generatione Animalium, - Trad. Arthur Platt 1912)

The idea of movement is linked to the function of the *anima*. Movement exists only where something exists; change is possible only where substance exists. In this sense, *anima* is what gives form to the being of what exists. Aristotle, from an axiological perspective, adapts the scientific syllogism to the conceptual construction of epigenesis.

> It is possible, then, that A should move B, and B move C; that, in fact, the case should be the same as with the automatic machines shown as curiosities. For the parts of such machines while at rest have a sort of potentiality of motion in them, and when any external force puts the first of them in motion, immediately the next is moved in actuality. As, then, in these automatic machines the external force moves the parts in a certain sense (not by touching any part at the moment, but by having touched one previously), in like manner also that from which the semen comes, or in other words that which made the semen, sets up the movement in the embryo and makes the parts of it by having first touched something though not continuing to touch it. In a way it is the innate motion that does this, as the act of building builds the house. Plainly, then, while there is something which makes the parts, this does not exist as a definite object, nor does it exist in the semen at the first as a complete part. But how is each part formed? We must answer this by starting in the first instance from the principle that, in all products of Nature or art, a thing is made by something actually existing out of that which is potentially such as the finished product." (Aristotle, De Generatione Animalium, trad. Athur Platt 1912, p. 24)

The philosopher also describes in detail the process of formation and development after birth, as well as the persistence of this development in the adult individual, always modulated by time. Aristotle (GC 320a 10–15) explains what he calls growth in living beings, especially in human beings. Growth, as is evident, arises from what exists at least potentially:

> Thus, it remains to undertake a discussion about growth, investigating how it differs from coming to be and from alteration, and how it occurs in each thing. Likewise, regarding diminution, how it occurs in each thing that diminishes. Let us begin by examining whether what differentiates them is restricted to the respective domain of each one, providing examples: their differentiation occurs because the change from this

> to that, as a substance in act arising from the substance in potentiality, is coming to be (generation), while that which involves magnitude is growth, and that which involves a passive property is (alteration), with the latter two involving the change from being in potentiality to being in act.(Aristotle (GC 320a 10–15))

Aristotelian epigenesis therefore demonstrates expansion and growth based on a being that exists not only physically but also within cognitive, social, and affective dimensions.

Freire (2022), in an article on epigenesis and epigenetics, presents epigenesis from another perspective, namely in "Doctrinal Forensic Medicine in an Epistemological Biopsychosocial Study of the Concepts of Epigenesis and Epigenetics."

> According to Aristotle, there would be an initial element, something simple, unique, therefore a "principle" that would promote the generation of something more complex. One could argue, as a thesis, that he described autocatalytic RNA, or rather, ribozymes, which are RNA molecules with a nucleic acid structure associated with an enzyme. These substances are RNA molecules that act as catalysts, that is, they slow down the activation process of an energy reaction and, like protein-based enzymes, have a structure that specifically binds to a substrate and facilitates its conversion into a product. This primitive RNA played the role of both producing protein and conducting information, as well as leading to RNA maturation, which produced new nucleotides and thus, as is understood, enabled DNA. (FREIRE 2002, e220613 – DOI 10.47005/220610.)

The complexity of the doctrinal construction of epigenesis. From these complex conjunctions there emerges the possibility of subsequent relations for example, the genotype/phenotype relation which, through fractionation, repetition, further fractionation, copying, translation, and alteration over time, may have generated the earliest living organisms, moving from molecule to cell. If there was movement, it unfolded in time, here understood linearly in terms of antecedent and consequent; hence Aristotle's famous definition: "*this, then, is time: the number of a movement according to the preceding following"* (Phys. 219b 1–2). From a geometric point of view, this can be represented by a line segment. Time would thus have been the driving force of the evolutionary process, allowing the structuring, regulation, and transformations that gave rise first to molecular organization, then to the cell, and finally to complex structures such as organs and living beings, produced by long chains of interaction and communication. In naming and reflecting on form, matter, causes, act, and potency, Aristotle speaks of the "principle" and of its indemonstrability, that is, of something primeval and immediate, prior to later demonstrations and immediate causes.

The Stagirite established a "principle of development" when he observed the embryo's evolving form, its internal movement, its nourishment, and its growth under the direction of the form and matter of the similar being that generated it. A plant generates another plant just as an animal generates another animal like itself. It is also worth emphasizing the ordered and caused character of alteration, which shows that development occurs in continuity with its origin rather than as a mere copy. There is evolution toward another identity while preserving origins and hereditary traits. Reflection on the persistence of original characteristics alongside alterations modulated by time has given rise to numerous later propositions concerning epigenesis.

The Treatise on the Soul (Perí Psychês – Περὶ Ψυχῆς) in the reflection on epigenesist Another Aristotelian work in which concepts related to epigenesis are present is On the Soul (De anima). There epigenesis is approached through reflective and psychological methods, and once again its syllogistic character becomes apparent. But what, after all, is the soul in Aristotle's terminology? Aristotle (DA 415b 8) teaches: *"The soul is the cause and principle of the living body"* In the context of Aristotle's philosophy, epigenesis may also be related to the idea that the capacity to think, or to reason, develops and expands over time. Aristotle holds that the human soul possesses different faculties, including the rational soul, which is responsible for thought and reasoning. Just as the body develops from a simple initial state, so too can the capacity for thought be understood as something that develops and becomes refined over time. Aristotle (DA 40415b21) writes that *"alteration and growth exist according to the soul."*

The capacity to think, according to Aristotle, is characteristic of the rational soul and proper to human beings. This faculty is not innate in fully developed form; rather, it unfolds through experience, education, and interaction with the world. Here one may also introduce Piaget's concept of reading experience. Summarized in the briefest terms, reading experience is the process by which the individual interprets, organizes, and modifies knowledge through interactions with the world, using assimilation and accommodation to construct and expand cognitive structures. It is a continuous and progressive activity, occurring in stages corresponding to the development of human thought. This reflection brings us back to epigenesis. Intellectual development can be compared to epigenesis insofar as it involves the passage from an initial potentiality to a realized actuality. Epigenesis, then, applies not only to the physical development of organisms but also to the intellectual and moral development of human beings. Through experience, education, and reflection, individuals cultivate their rational capacities, attain deeper understanding, and develop greater critical power. This dynamic view of human development reflects the complexity, potential, and consequent action inherent in human nature, as Aristotle describes it. As noted above, Aristotle approaches epigenesis from a broad perspective that includes embryonic origin and development as well as the evolution of organic and cerebral functions, all attributed to anima, the principle that gives form to the being.

It is important to stress that when epigenesis, understood as a general principle of development, fails to occur, the result may be underdevelopment and/or pathology. How, then, is the evolutionary process of the ability to think described today, from its beginning after existence? The answer lies both in embryology and in neuroscience, especially in the period of parental imprinting and in the critical period of human development. Is there, then, an epigenesist of Pure Reason, as Kant suggested?

The soul is the cause and principle of the living body. But these things are said in many ways, and the soul is similarly a cause according to three definite modes, for the soul is from whence and in view of which this movement proceeds, being also a cause as the substance of animate bodies. Now, that it is a cause as substance is clear. For, for all things, the cause of being is substance, and being for those who live is living, and of this the soul is the cause and principle. Moreover, actuality is a determination of what is in potency. In the context of Aristotle's philosophy, epigenesis can be related to the idea that the capacity to think, or reason, develops

and expands over time. Aristotle proposes that the human soul possesses different faculties, including the rational soul, which is responsible for thought and reasoning. Just as the body develops from a simple initial state, the capacity to think can also be seen as something that develops and refines itself over time.

Aristotle (DA 415b21) shows the movement, alteration, and growth that exist through the soul: *"But, in fact, the soul is also where local movement first originates, although this power does not subsist in all living beings. But even alteration and growth exist according to the soul."*

The capacity to think, according to Aristotle, is a characteristic of the rational soul, exclusive to human beings. This faculty is not innate in its complete form, as it develops through experience, education, and interaction with the world. One could add here the concept of reading experience created by Piaget (1996). To paraphrase and summarize Piaget in extremis, reading experience would be the process by which the individual interprets, organizes, and modifies their knowledge based on interactions with the world, using the mechanisms of assimilation and accommodation to build and expand their cognitive structures. It is a continuous and progressive activity, occurring in stages corresponding to the development of human thought. This summary reflection on the Piagetian concept reflected above takes us back to the process of epigenesis, which has already been discussed. The process of intellectual development can be compared to epigenesis, insofar as it involves the progression from an initial potential to an actuality, that is, fully realized action. Epigenesis, therefore, applies not only to the physical development of organisms, but can also explain the intellectual and moral development of human beings. Through experience, education, and subsequent reflection, individuals cultivate their rational capacities, achieving a deeper understanding and greater ability for critical reasoning. This dynamic view of human development reflects the complexity, potential, and consequent action inherent in human nature, as described by Aristotle. As we saw above, Aristotle addresses the concept of epigenesis from a broad perspective that involves both the origin and embryonic development, as well as the evolution of organic and brain functions, which he attributed to anima, that is, the one that forms the being, conceptually speaking. It is important to emphasize that if epigenesis as a general principle of development does not occur, it can lead to underdevelopment and/or pathology. How is the evolutionary process of the ability to think described and conceptualized today, from its beginning after existence (epigenesis)?

The answer to this question lies in the embryological perspective and extends to the parental imprinting period or the critical period of human development from the viewpoint of neuroscience. Is there an Epigenesis of Pure Reason as Kant suggested? The structure of thinking is constituted within the central nervous system. It is important to highlight that the term structure here specifically carries the meaning defined by Piaget (1896/1980) who states:

> In an initial approach, a structure is a system of transformations that incorporates laws as a system (as opposed to the properties of its elements) and that preserves or enriches itself through the very process of its transformations, without exceeding its boundaries or resorting to external elements. In short, a structure consists of the characteristics of totality, transformations, and self-regulation." (Piaget 2003, p. 8).

Modern embryology explains the initial structure of the central nervous system as the instrument that later makes possible various brain functions and thoughts. This system originates in the ectoderm, where a dorsal thickening forms the neural plate around the third week of intrauterine life. This plate is induced by another neural structure, namely the notochord and the paraxial mesoderm. The process then unfolds in an orderly sequence: the neural plate folds to form a neural groove with folded structures on both sides; around the fourth week these folds fuse to form the neural tube. The brain develops from the upper end of the neural tube, which initially gives rise to the forebrain, midbrain, and hindbrain. Here a causal chain becomes visible: the forebrain gives rise to the cerebral hemispheres; the midbrain remains as such in the adult; and the hindbrain gives rise to the structures at the base of the brain, namely the pons, cerebellum, and medulla oblongata. This embryological description of the early central nervous system is intended to show the evolutionary and organizational process of a biological structure that begins in syngamy and persists throughout the formation and definitive organization of that system.

Based on Aristotle's reflections on causality, his logic in describing biological phenomena, and modern neurophysiological and embryological explanations, we can consolidate the concept of epigenesis in the modern era.

Kant's Epigenesis of Pure Reason

Kant's use of the term epigenesis in reference to Pure Reason was certainly inspired by the concept of epigenesis first articulated by Aristotle as the passage from potentiality (dynamis) to act (energeia), though transformed in a distinctive way. An epigenesis of Pure Reason cannot imply development or transformation in the biological sense; rather, it signifies an expansion in the field of application of what is already given. For Kant, what is given a priori to human nature Pure Reason does not change, alter, or evolve.

The epigenesis of Pure Reason (Vernunft), therefore, signifies the expansion of the field of application of Reason's possibilities for constructing judgments in the world of phenomena through the *Verstand,* that aspect of Pure Reason which communicates with experience. It is, in Kant's own terms, an abstract epigenesis distinct from Aristotle's, except insofar as it traverses a necessary path in the construction of the knowing subject. In our view, this is not, as many claim, merely an analogy or metaphor.

This abstract epigenesis preserves the literal meaning of the Greek term: (epi) plus genesis, that is, a development that continues after the constitution or "birth" of the being, yet without introducing anything new beyond the possibilities already given a priori, namely the categories of Pure Reason, which are the product of transcendental deduction. In the Critique of Pure Reason, Kant explains that he characterizes the way in which concepts can refer *a priori* to objects of the world as a transcendental deduction because he wishes to distinguish it from an empirical deduction, which shows only how a concept was acquired from experience and not its necessity, since necessity is given a priori in the categories. The twelve categories contain all the *a priori* possibilities available to the human being for constructing judgments, and thus for constructing concepts within the domain of scientific knowledge.

They are:

1. Quantity: Unity, Plurality, Totality.
2. Quality: Reality, Negation, Limitation.
3. Relation: Substance, Causality, Community.
4. Modality: Possibility, Existence, Necessity.

Kant is speaking here of the possibilities of predication that is, of affirming something about the knowledge of the world. This totality of possible predications, and thus of possible judgments, remains always identical; it does not expand. What do expands is *Verstand's* capability multiplies its structuring operations. What is given a priori to the human being, Pure Reason (Vernunft), encounters in experience, in the world of phenomena, that which can be assimilated according to the possibilities enclosed within the *Verstand.*

What distinguishes *Verstand* within Vernunft as a whole is its capacity to unite subject and predicate in the formation of judgments in encounter with experience. These judgments, let us emphasize, are possible a priori, without deriving their form from experience. Hence the expression "categories of the Understanding." Pure Reason is thus an organon that provides a priori the principles of all possible scientific knowledge. In Kant's time this meant classical physics. It is important to note that for Kant the universality of physical knowledge means its necessary validity for all knowers, not for every domain whatsoever. In ethics, it is Practical Reason that comes into play. There are domains of life to which theoretical reason does not apply. In our own time, classical physics *has been joined by quantum physics, yet classical physics remains valid for* the objects to which it applies. When speaking of the conditions of all possible knowledge in Kant, we must also emphasize the role of mental representation, without which such knowledge would be impossible.

The *Verstand* does not operate in isolation; it requires the faculty of *Einbildungskraft,* the capacity to form images of what is perceived in experience. Kant distinguishes *bild,* images of what exists in the phenomenal world, from *Vorstellung,* images merely imagined. Imagination, understood as the faculty of representing what is perceived in experience, is responsible for the "necessary unity of the synthesis" of phenomena observed in empirical reality. In this respect it is called the transcendental function of imagination.

Sensibility and *Verstand* must be linked through this transcendental function; without it we would have phenomena but not objects of empirical knowledge not what Kant calls experience. For Kant, a representation is not yet knowledge, but knowledge always presupposes representation. In Kant's abstract epigenesis, experience, the world of phenomena, constitutes the other pole by virtue of which knowledge becomes possible. For that reason, it is crucial to emphasize the place of experience within the epigenesis of Pure Reason. Kant states explicitly: *"The possibility of experience is what gives objective reality to all our a priori cognitions."* In other words, the knowledge attained through Pure Reason is knowledge of the empirical world the world we experience. Chronologically, although none of our cognition is derived from experience, but they arise only in

relation to experience. Experience shows that a thing is in a certain way, but it does not tell us that it could not be otherwise. It does not supply logical necessity. Up to Kant, epistemology in the history of Western thought had repeatedly discussed the relation between reason and experience, identifying one or the other as the source of knowledge. Thus, arose rationalisms and empiricisms, beginning with the birth of Greek philosophy in Thales of Miletus and Pythagoras and continuing into modernity with Hume's empiricism and Descartes' rationalism.

Would have the demonstration of an epigenesis of Pure Reason overcome this millennial dichotomy, as Kant believed? In what way, and why? Kant believed that it could, and he expresses this view clearly:

> There are only two possible paths along which a necessary concordance between experience and the concepts of its objects may be conceived: either experience makes these concepts possible, or these concepts make experience possible. The former has no place with respect to the categories (nor, indeed, with respect to pure sensible intuition), since they are a priori concepts (to assert an empirical origin would be tantamount to a kind of *generatio aequivoca*); accordingly, only the latter remains (as it were, a system of the epigenesis of pure reason): namely, that the categories contain, on the part of the *Verstand*, the grounds of the possibility of all experience in general. (Our translation of p. 167 of the French edition of the Critique of Pure Reason)

The difference between epigenesis, Pure Reason, and *generatio aequivoca* may be stated as follows: Pure Reason is given and does not change. Epigenesis is the general principle governing the development of living structures, already present in Aristotle, *generatio aequivoca*, is not given because it does not exist; by definition, it is erroneous. Pure Reason and epigenesis are therefore different. The former does not change. The latter develops and therefore, by definition, changes. Equivocal generation does not exist; accordingly, it neither changes nor develops.

The passage above is one of those hidden treasures in the works of great thinkers. We take it to be such because it offers a way of overcoming the age-old dichotomy between Rationalism and Empiricism. That is no small matter, for it addresses a controversy that has persisted for more than two millennia. Yet this passage has often been dismissed as no more than a metaphor derived from organic epigenesis. In our view, however, the epigenesis of Pure Reason overcomes the dichotomy between Rationalism and Empiricism precisely because it shows how scientific knowledge necessary and universal is constructed from the possibilities of judgment as they come into contact with experience, with the world of phenomena. These are two indispensable poles without which knowledge would be impossible: Reason on the one hand and the world of phenomena on the other.

To make this entirely clear, we must return to Kant's celebrated assertion that *"Reason without experience is empty; experience without reason is blind."* What does this mean? It means that Pure Reason (Vernunft) contains a priori, independently of experience, all the possibilities available to the human being for forming the judgments that constitute necessary scientific knowledge. These possibilities may or may not be actualized; they can remain merely possible. In that case, Reason would be empty of knowledge. Reason ceases to be empty only when it encounters the world, that is, experience, through the Verstand, the aspect of Pure

Reason capable of contact with the empirical world and of synthesizing sensations and representations into judgments and concepts.

This encounter is gradual. Without it, Reason remains empty; without Reason, experience remains blind. The *Verstand* brings with it the a priori possibilities of Pure Reason, articulated in the categories, and through them engages experience, forming judgments and concepts that constitute necessary and universal knowledge. The categories thus provide the a priori form that, through the *Verstand,* apprehends a content namely what is given in experience, the totality of phenomena, structured through judgments whose predicates are concepts. Phenomena are immersed in space and time, which are also given a priori, and it is this encounter that enables the *Verstand* to generate knowledge. Judgments whose form is given in the categories may be either analytic or synthetic. Analytic judgments are necessary and universal, but they do not expand knowledge because the predicate is already contained in the subject; for example, a triangle has three sides. Synthetic judgments, by contrast, expand knowledge, but taken in themselves are not necessary; for example, "this tree is in bloom."

According to Kant, however, our capacity to form judgments grants us, through the epigenesis of Pure Reason, a third and extraordinary possibility: the discovery of synthetic judgments whose connection between subject and predicate is both necessary and knowledge-expanding. If the connection is necessary, it is a priori; it does not come from experience, for logical necessity is not found there. "Heat expands bodies," for instance, expresses a necessary relation posited by Reason. This is the type of synthetic a priori judgment that, for Kant, constitutes science. Why? Because science arises when human intelligence discovers in experience that which cannot be otherwise, and when that "cannot be otherwise" is demonstrated with mathematical clarity.

With Galileo Galilei, this became explicit, and modern physics was born. From then on, we enter a universe of necessary judgments that expand our knowledge of the world and interweave to explain the cosmos. The principle of inertia and the law of falling bodies are standard examples. The synthetic a priori judgment is thus the extraordinary concept in which the epigenesis of Pure Reason culminates and through which scientific knowledge is constituted.

To understand Galileo's principles as examples of synthetic a priori judgments, one must at least grant that Kant is right to begin with the claim that every human being possesses a priori possibilities of judgment. Here we are concerned with Kant's theory of the epigenesis of Pure Reason, not with truth in itself. It seems clear that Kant sought to show that just as an organism has an epigenesis and not merely a genesis, so too necessary and universal knowledge has its own epigenesis, insofar as its application to the world of phenomena expands indefinitely. Yet this is an epigenesis in which the already existing categories do not themselves develop or evolve.

What expands is the meaning of the phenomena organized by the *Verstand,* in proportion to its increasing contact with the data of the sensible world. We therefore understand the whole system of the epigenesis of Pure Reason as Kant's own model of the construction of human intelligence.

In modernity, Jean Piaget would develop an entire theory of how necessary and universal knowledge is possible, based on what he himself called "evolutionary Kantianism" (1960). Before turning to that development, however, one must note the enrichment that Niels Bohr brought to Kant's theory of knowledge. The epigenesis of Pure Reason, understood as a model of the acquisition of knowledge, received unexpected confirmation in the history of ideas when Bohr created his model of atomic structure. The construction of that model extends Kant's concept of the *a priori*.

Kant had shown that knowledge arises from the possibilities of Reason as applied to the world of phenomena that constitute observable physical reality. Bohr showed that such physical reality need not be directly observable by the senses, for example, the position and velocity involved in electronic transitions within the atom. Human reason can nevertheless construct a model of that structure and thereby make it, as it were, cognitively observable through a theoretical construct. Bohr's model thus extends the a priori by showing that the possibilities of Reason apply not only to sensible experience but also to invisible and directly unobservable realities that may nonetheless be disclosed through abstract models. As two prominent contemporary physicists have noted, Bohr was, without explicitly naming Kant, profoundly Kantian. Why? Because he embraced Kant's revolutionary thesis concerning the very possibility of knowledge. Until Kant, speaking broadly, knowledge was often understood as the grasping of worldly phenomena. Kant proposed instead a Copernican inversion: it is not phenomena that determines the origin of scientific knowledge; rather, our own capacity for knowing determines what we can know. Bohr's model of atomic structure confirms this insight. If a phenomenon cannot be completely observed, one may nonetheless construct a model of its structure. Such a model is not the ultimate truth but an instrument, one that can and must be continually refined to expand our capacity to know and understand nature through the advancement of physical science.

Piaget's Ontogenetic Epigenesis

We may now turn to Jean Piaget's evolutionary Kantianism, which transposes Kantian theory into the domain of contemporary biology through his conception of epigenesist a notion that preserves the essence of the Aristotelian concept and reveals what he inherited from the philosopher of Königsberg.

In order to understand how Piaget's epigenetic ontogenesis translates the epigenesis of Pure Reason into biology, we must also recall the essential role of imagination in Kant the *Einbildungskraft* which provides the necessary unity, namely the synthesis of phenomena. Sensibility and Understanding must be linked through this transcendental function; otherwise they yield phenomena, but not objects of empirical knowledge, and therefore not experience. The manifold can be perceived only through an exhaustive synthesis carried out by imagination within consciousness. Pure synthesis is the foundation of the possibility of empirical synthesis and thus of perception itself. The categories, when applied to the physical world, correspond to the *Verstand,* our intellect or intelligence operating according

to the possibilities of the brain in its relation to experience.

According to Piaget, the link between experience and intelligence is the semiotic function, the capacity to distinguish signifier from meaning and, more broadly, the ability to represent the world. This function emerges in human beings at around two years of age and corresponds, in Kantian terms, to the *Einbildungskraft,* the transcendental faculty of representation. For Piaget, intelligence produces judgments and concepts whose form arises from the functioning of the brain while their content derives from lived experience. The decisive difference from Kant is that, for Piaget, the construction of judgments and concepts unfolds within the organic ontogenesis of the human being, beginning with the infant's sucking reflex and developing through a continuous exchange between organism and environment, culminating in the acquisition of logico-mathematical reasoning. Each stage of this ontogenetic development constitutes the a priori condition for the next. Piaget calls this process "evolutionary Kantianism."

Thus, Piagetian organic epigenesis begins with sucking and ends with the brain's possibility of attaining higher logic and mathematics. This possibility is not necessarily actualized in every individual; its realization depends heavily on environmental conditions, and only some reach that stage. The environment therefore plays a decisive role, precisely because the process is an epigenetic exchange between organism and environment. At the same time, the logico-mathematical capacity of the human brain is not confined to formal logic or mathematics alone. It is visible, for instance, in the expertise of surgeons, who apply spatial, inferential, and systemic reasoning with extraordinary precision. Much of this capacity remains unconscious in non-mathematicians.

Conclusion

Human beings deploy it in many domains without explicit awareness, just as most remain unaware of the way their own brain's function. Piaget's theory does not incorporate dozens of Kantian concepts in a direct or systematic manner, in part because it remained tied to the state of neuroscience in his time, a field that even today leaves many Kantian notions insufficiently explained. One instructive example is the Kantian schema: the subtle human capacity to represent mentally a triangle defined by three edges with no thickness, an object representable only in thought. Kant grappled precisely with this possibility of Reason. The schema of the triangle does not exist outside thought; it is a synthesis of imagination, a figure of pure *a priori* imagination. This example shows the representation of something never encountered in experience and therefore points to *a priori* knowledge arising solely from what Piaget calls the endogenous functioning of the human species. That is a crucial insight for epistemology and for the philosophy of science. According to Piaget, the mental structures specific to the act of knowing are not given in advance, not even as a pre-established program. Rather, as he explicitly states, they depend directly on the **endogenous and hereditary functioning of the human species,** which is itself *a priori* to all possible knowledge.

We therefore believe that Piaget brings about a synthesis between the aristotelian concept of epigenesis and Kantian epistemology. In this way, Jean Piaget's evolutionary Kantianism carries into the twenty-first century both the epigenesist of Pure Reason and the epigenesis of our organic capacities, a notion Aristotle had proclaimed some 2,400 years earlier.

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