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The Concept of Nature between Heraclitus and Prigogine

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Abstract

In the Greek tradition, "physis" denotes both the "nature" (the "essence") of an entity and its accomplishment, that is to say, its "development". For example, the embryo is the "essence" of the unfolding organism and, at the same time, the process leading to it. The egg is a symbol of wholeness, but this totality cannot be perceived out of its self-organizing process. In this way, according to Heraclitus, the living being "hides." Essentially, the Self can only be recognized as an outcome rather than a starting point. This stance, endorsed by Heraclitus and Aristotle, has been left aside by modern scientific research since Bacon's time when the less noble Stoic inheritance was tacitly assumed. In Stoics' belief, *physis* means power (God or otherwise), i.e. the causal principle (*causa prima*), which is involved in generating any natural process. Having emphasized the "cause"—even in absence of a clear definition of such a concept—the "real process" lost its relevance and its intelligibility was impaired. The description of the process began to be confused with the description of the "entity" (the thing-in-itself), and this representation eventually ended up identifying the "essence" with its (presumed) "primary" causes. This way, natural things and/or processes were re-absorbed into their presumptive causes, missing the true complexity of the natural system.

Keywords: nature, Heraclitus, Aristotle, self-organization, complexity, development

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1. The Concept of Nature after Laplace

The development of physics-chemistry over the last 30 years—followed in its footsteps by a more recent revolution in biology—has radically changed the worldview handed down by Newton (Prigogine & Stengers 1979).

A probabilistic representation has recently challenged the idea that nature may be predictable and exhaustively described through deterministic laws. This new view includes the "arrow of time" between its variables and tries to explain how, far from equilibrium, non-linear dynamic processes originate new emerging structures and, eventually, new order's form.

Indeed, the deterministic approach cannot explain a multitude of phenomena accumulated over the centuries. The amount of "unexpected" and "contradictory" results have led to a radical critique of the dominant paradigm, limiting the validity of Newtonian physics within a well-specified level of observation and narrow areas of phenomena where processes can "reasonably" be considered linear processes (or transformed into linear processes, i.e. "linearized"). There is no doubt that classical science cannot solve problems involving complex systems. This holds true even when only well-defined deterministic forces are at play in the system (e.g. the Three-Body Problem addressed by Poincaré). However, it becomes blatant in areas characterized by

even greater complexity, like embryonic development, or in the genesis of multi-factorial diseases, such as cancer. This aspect deserves to be deepened. Indeed, embryonic development is a well-ordered phenomenon (despite teratogenesis is always a possibility), where many non-linear processes intertwine. The paradox lies on the fact that a complex, non-linear ensemble of dynamical processes—which are dramatically affected even by very small fluctuations in the environmental conditions—almost invariably leads to a foreseeable, well determined, yet non-deterministic outcome. Classical physics and a positivistic approach are unable to accommodate such a bewildering issue, especially when addressing it (as it often happens) in terms of "control" and "cause and effect."

Since Francis Bacon, science has shown a marked (though not exhaustive) tendency to identify the "understanding of nature" with the "control of nature". Without a doubt, the framework of natural processes within models of deterministic and predictable rules, has laid the basis for such a control. Possibly, the confusion arises when the "mechanistic" and the "system" explanations mix: understanding a "molecular mechanism" does not imply that we can capture the "logic" behind an organism (Koutroufinis 2017, pp. 31–37; Koutroufinis 2020, pp. 261–266). Certainly, nature does not care about our models and our attempts to make it predictable. Even linear processes are far from equilibrium. They are subject to unforeseeable developments and affordable only in terms of *probabilities*.

The physics of the past centuries has evolved. It now recognizes that nature is neither "simple" nor able to be explained through a few equations entangled within a "theory of everything." Complexity is an intrinsic feature of nature and requires new methodological and analytical tools.

Newtonian physics posits that the structure of dissipative structures (i.e. open thermodynamics systems) grow disorganized while evolving over time as the system's entropy increases. Thus, a temperature gradient in an isolated system will inevitably efface any difference and lead to equilibrium. The thermodynamics of equilibrium teaches that the process "naturally" tends toward disorganization, evolving into a growing and irreversible disorder. In reality, the vast majority of phenomena does not happen in isolated systems and takes place in conditions that are far from equilibrium. New structures arise precisely from these situations. Rather than leading to a chaotic state, dissipative processes thus originate new forms of order. The equations describing complex systems involve multiple solutions. It is, therefore, impossible to predict the solution that the system will choose. This mechanism underlies the hidden creative power of nature. As Ilya Prigogine pointed out, "as soon as a system departs from equilibrium, automatically, whatever the initial conditions are, complexity appears [...] the non-equilibrium is the source of complexity" (Prigogine & Benkirane 2002, p. 44).

Within equilibrium boundaries, matter is "blind", repetitive, and always equal to itself. Matter far from equilibrium faces a wide variety of situations. It travels through a succession of bifurcations that mark the "history" of the system from a given point: the breaking of symmetry. From such a moment, the system can "sense" the time's flow. We can then recognize "a before" and "an after." Nature can be grasped only as a process, a long narrative, during which it creates and destroys, inventing new solutions. The unpredictable cannot be excluded from the intelligibility of *physis* (Stewart 1989).

The *Age of Enlightenment* prioritized the "being" in opposition to the "development," therefore, binding rationality in the (narrow) realm of determinism and certainty. However, it is increasingly clear that the "becoming" rather than the "being" is essential from an ontological perspective. In other words, there can be no scientific understanding beyond the "history" of a system.

It is remarkable to consider how this modern scientific vision of the world overlaps with the ancient Greek worldview and, more generally, the traditional concept of nature.

2. Heraclitus' aphorism

For Heraclitus, "*physis kryptesthai philei*", namely: "Nature loves [tends] to hide." Somehow, this is the sense that, especially since the Renaissance, had become uncritically dominant until P. Hadot reworded it in such a convincing and very different reading (Hadot 2004). According to the Greek view, at once, "*Physis*" denotes both "nature" as the "essence" of any entity, and its accomplishment, i.e. its development. The embryo offers a meaningful example: it is the "essence"

of the becoming organism and, at the same time, the process leading to it. Furthermore, in alchemy, the egg is a symbol of wholeness, the seed from which the world develops. The egg symbolizes the periodic renewal of nature and signifies how life is born from death: this assumption explains why an egg represents the "secret meaning" of Easter (Chevalier & Gheerbrant 1986). Notwithstanding, this cannot be totally perceived out of the time in which it becomes *self-organized*. Time must be considered akin to a key-dynamic parameter, and it drives the system toward "unexpected" issues. Moreover, identity can only be recognized as an outcome rather than a starting point.

According to the widely known interpretation in reference to the previous statement, "nature loves to hide" and, as Einstein pointed out, "nature hides her secret because of her essential loftiness, but not by means of ruse" ("*Die Natur verbirgt ihr Geheimnis durch die Erhabenheit ihres Wesens, aber nicht durch List*," as quoted by Pais 1982). This is the mainstream meaning, especially since the end of the Renaissance.

Heraclitus himself provided some useful tracks to better identify the hidden meaning of an aphorism, which was otherwise destined to multiple interpretations. He outlined, "*physis* is the process of mixing things that unite and divide." Hadot showed that even more well-based interpretations may be proposed, such as: "nature is what gives birth and kills" and "nature is what makes things appear and disappear." These must be considered with the following Heraclitean statements: "form tends to disappear" and "what is born tends to die." In other words, there is no *physis* outside of time. Sophocles rightly argued:

> The vast, countless time first draws [phuei] things that were not apparent and then buries [kryptetai] things that had appeared (Sophocles, Ajax, vv. 646 ff).

Time in Newtonian physics is an inert support of reversible processes whose "arrow of time" is irrelevant. This is not the time referred to by Sophocles. On the contrary, traditional thoughts on nature conceived time as a fundamental property in shaping natural things. "Everything mixes within the game of the *aion* [the time]" wrote Lucian of Samosata in his *Philospher for sale* (No. 14).

By considering the meaning of this sentence, how can one not think of the complexity of biological pathways of growth, differentiation, and apoptosis? These lead to life through the unfolding of new forms and cyclical phases of programmed death.

Claude Bernard, the father of physiology and forerunner of Systems Biology (Noble 2007) had grasped this paradoxical character when stating:

> There are two types of seemingly opposed life phenomena: the first tend to organic renewal and are somehow hidden; the second are committed to destroy the organic structures (….) These are usually described as the phenomena of life, so that what is named life is essentially death. (Bernard 1872, pp. 327–328, n. 219)

Bernard uses a biological language, but it is easy to see how the process of *emergence* of complexity, as described by Prigogine, shines through his perspective. Like on-equilibrium thermodynamics, the traditional conception of nature shifts the focus from the "essence" toward the "transformation." This tries to grasp the meaning of things in their live "becoming," rather than as isolated entities ("the thing itself"), detached from their environment and time. Most significantly, Marcus Aurelius explains with conciseness:

> Acquire a method of contemplating how all things change into one another. Constantly apply to this part [of philosophy], and exercise yourself thoroughly in it. (Aurelius 2008, p. 124)

Similarly, in his *Diseases* (II, 3, 55), Hippocrates considers *physis* to be the whole organism as shaped by its proper overall development. From the fifth century B.C., according to Plato and Aristotle, *physis* is seen as the formation of something that endeavors to realize its true essence. For both of the above-mentioned philosophers, "nature" is fundamentally an inner principle of change that pushes along a path and leads toward a place (a "state"). The agent recognizes such a place as "natural". Here, "natural" means "proper." The driving force that directs along this state is identified with the "aspiration" toward a "form" on which the natural process tends to be modeled. According to Plato, the divine soul drives such a process. The soul shapes the matter as an artist shapes a work of art. For Aristotle, the developmental

process is immanent to matter: "nature" possesses an intrinsic "outcome" ("entelechy"). Ultimately, this allows for recognizing a true identity: nature becomes what it should be, and the final development is a witness to it. Two millennia later, Marsilio Ficino will add that nature is an art that can shape matter, starting from its inner core (Ficino 1965, Book 4, ch. 1, pp. 239–284). Like an artist who "chooses" the forms, nature selects different forms: the "freedom" to select among different configurations ("forms") provides the fundamentals of "diversity". Nowadays, we would be tempted to say that nature, along its developmental path, selects different states ("attractors") where its trajectories converge. Unfortunately, such a statement left an unanswered question: if Aristotle had assumed that such a selection would occur during the initial states or across the entire developmental path.

Understanding "nature" independently from its proper dynamic context, by which nature becomes "itself," is therefore, impossible. Conclusively, Aristotle points out that "the best method [of investigation] should be to observe how things are born and how they grow" (Aristotle 1999, I, 2:1252a 24).

The aphorisms attributed to Heraclitus—"Everything flows" and "No man ever steps in the same river twice"—clarify how the idea of nature in ancient Greece cannot be separated from the dynamic processes that we observe.

In establishing a parallelism between the emerging of complexity and the artist's work, both Plato and Aristotle seem to give up the cornerstone of the future scientific epistemology, i.e. the certainty of measurement. Epicure and his epigones violently criticized Plato's use of myth in explaining nature. They considered such an approach to be incompatible with the need for scientific certainty (Festugière 1946, pp. 102 ff.). Paradoxically, since Dalton, and then with the advent of quantum physics, it has become increasingly evident that "certainty" is possibly a scientific myth, a modern fairy tale without convincing foundation. Indeed, the quest for "certainty" and "accuracy" has little to do with the intelligibility of the world. Most likely, it is rather meant to satisfy a psychological need, a kind of "infantile obsession," as stigmatized with humor by Robert Laughlin:

> Physical scientists [...] tend to see the matter morally. They orient their lives around the assumption that the world is precise and orderly, and its occasional failure to conform to this vision is a misperception brought about by their not having measured sufficiently accurately or thought sufficiently carefully about the result. This sometimes has bittersweet consequences. (Laughlin 2005, p. 12)

Moreover, a negative consequence of this attitude is "that truth and measurement technology are inextricably linked." Therefore, "exactly what you measure [....] and so forth matter more in the end than the underlying concept" (Ibidem, p. 14).

Laughlin depicts disorder as a characteristic feature of the microscopic world, which is intrinsically uncertain and unpredictable. Unpredictability must be distinguished from noise. Microscopic unpredictability, however, turns into order at higher levels, where complex collective behaviors emerge and couple with environmental constraints. Constraints "canalize" the disordered behavior into a few, well-ordered patterns. This means that "determination" is inevitably associated with a reduction in the degrees of freedom actually available for a system (Bizzarri, Giuliani, Minini, Monti, & Cucina 2020). Conversely, as the process is non-linear and many factors are involved in the morphogenetic process, predictability becomes a statistical property. As such, it does not apply to any molecule, but to the whole. No law can deterministically predict the behavior of individuals. However, the social behavior is likely to be predicted with sufficient reliability. The real mystery is how disorder turns into order when the system shifts from the microscopic to the macroscopic level—*ordo ab chao*, in alchemical terms.

3. The idealization of nature during the Renaissance

The research of the past century does not seem to have received any benefits from this *lectio*. Since the Renaissance, nature has been increasingly considered akin to an immutable reality that must be epitomized and thereby recognized as an ideal entity. After removing time as an intrinsic component of the physical world and as a necessary variable in the scientific description of reality, it eventually became possible to justify a radically different approach that paved the way for a scientific framework (exclusively) rooted on reductionism and determinism.

After forgetting Aristotle (his "*damnatio memoriae*" started with Galileo), modern scientific research has focused on the less noble Stoic inheritance.

In Stoics' belief, *physis* means power (God or otherwise), i.e. the causal principle (*causa prima*), which is involved in generating any natural process. The interpretation provided by Stoic philosophers marks the subtle, yet relevant, transition from the study of the phenomenon ("experience") to the recognition of the power (the "cause") that generated it. Having emphasized the "cause"—even in absence of a clear definition of such a concept—the "real process" lost its relevance and its intelligibility was impaired. The description of the process began to get confused with the description of the "entity" (the thing-in-itself), and this representation eventually ended up identifying the "essence" with its (presumed) "primary" causes. This way, natural things and/or processes were re-absorbed into their presumptive causes, missing the true complexity of the natural system.

In modern times, this was done by identifying the cell or, even worse, the overall organism with the genome: eventually and quite arbitrarily, at the least, all possible "causal powers" have been brought back to the DNA.

The identification of "power" with God or some other principle (*élan vital*, DNA, etc.) has encoded the concept of nature among philosophical categories. This has put the "secrets of nature" into the scenario of the philosophical debate. With time, the decryption of these secrets has become the equivalent of revealing the "divine secrets", as Nature itself has ended up replacing God. Conversely, the difficulty in penetrating these secrets has legitimized the less likely version of Heraclitus, i.e. "Nature loves to hide."

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