

EMERGENCE: BETWEEN REDUCTIVE AND NON REDUCTIVE EXPLANATIONS. DOES IT MAKE SENSE?

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Introduction

Because the concept of emergence only makes sense at the light of interaction and the organizational form one set of elements has (a system), its powerful reemergence is related with the study which, in recent years, has been carried out in order to understand the behavior of complex systems.

These systems that show a high sensitivity in the modification of their initial conditions, that operate far from the equilibrium, and that are characterized by their nonlinear relations find that as a result of their organization process, properties arise which cannot be identified in nor explained from the properties of their constituent elements. This is the tight relationship kept between the study of complex systems and the current resurgence of the debate regarding emergence. An increase in the complexity of a system, the neo-emergentists argue (Kauffman, for example, 1993, 1995), implies the potential emergence of properties never imaged before which add a new form of existence in the universe.

Nevertheless this new driving force, from more than 100 years ago, continues the debate taking the core statement of the emergentism trend and its philosophical scope, that is, its capability to explain concrete complex phenomena as, for example, the arising of life, consciousness, intentionality, amongst others, in a non-reductive way. The Emergentists, contrary to their vitalist predecessors, started from a materialist base explanation or from what their more recent intellectual successors have called physical monism (Stephan, 1997, 1999, 2002). Emergentism, in general, tries to explain there are systemic or organizational properties (Stephan, 2002), which are not in any way related with the particular behavior of their constituents, either because even fully understanding the behavior of the primary elements it's impossible to know the results their interactions produce – we call this approach epistemological emergentism or weak emergentism - or because the systemic properties are causally nonreducible to their basic constituents – we call this approach ontological or strong emergentism.

At the core of the emergence discussion is the dispute between a reductive and a nonreductive conception of the universe, or putting it another way, between an ontological monism and an ontology of levels. The debate is established on two fronts; on one hand, between the defenders of a reductive approach and the vindicators of emergentism; and on the other hand, a dispute between the emergentists, those who are committed with a reductive perspective – micro-determinists - and those who argue in favor of a macro-determinism based on the notion of downward causation. That a reductionist raises objections against the reasons and the scope of the emergence program is understandable, that amongst emergentists there is no point of agreement raises, at the least, suspicions regarding the validity of what they are trying to elucidate.

The literature surrounding the emergence concept abounds with opposing, diametrically opposite arguments, in which a similar example serves to support, at least two different points of view. In order to give support to this statement, two examples from Biology will be taken. Both examples refer to the arising of emergent properties. The works are: *Emergence And Its Place In Nature: A Case Study Of Biochemical Networks*, by Boogerd et al. (2005), and *Downward Causation at the Core of Living Organization*, by Moreno and Umerez (2000). In both cases, taking a similar problem as a point of departure, the result is the formulation of divergent conclusions. The next step is to identify their fundamental assumptions and with that try to understand their differences.

I. Emergence and Its Place in Nature

Boogerd et al. (2005:131), affirms that ‘the philosophical debate is largely inspired by metaphysical concerns’. In this way, argue the authors, ‘metaphysical conceptions of emergence have metaphysical goals (2005: 131)’. From this point of view, metaphysical emergence does not have any value for the natural sciences and there is no place for it in its scope of investigation. For the notion of emergent properties to have, add the authors, any positive role to play in a scientific setting, it must be understood differently. ‘It must be compatible with the thought that scientific explanations are mechanistic explanations (2005: 132)’. Putting it another way, emergence and reduction are not only compatible, but in order to offer a convincing and complete explanation of complex systems existing in nature, both approaches are necessary.

The authors use the work of Broad – for them the most important representative of British emergentism in the first quarter of the last century - to propose an ontologically valid and empirically useful emergentism.

Boogerd et al. (2005) in his work *Emergence And Its Place In Nature: A Case Study Of Biochemical Networks* argues:

“We will show that there is a strong form of emergence in cell biology. Beginning with C.D. Broad’s classic discussion of emergence, we distinguish two conditions sufficient for emergence. Emergence in biology must be compatible with the thought that all explanations of systemic properties are mechanistic explanations and with their sufficiency. Explanations of systemic properties are always in terms of the properties of the parts within the system. Nonetheless, systemic properties can still be emergent. If the properties of the components within the system cannot be predicted, even in principle, from the behavior of the system’s parts within simpler wholes then there also will be systemic properties which cannot be predicted, even in principle, on basis of the behavior of these parts. We show in an explicit case study drawn from molecular cell physiology that biochemical networks display this kind of emergence, even though they deploy only mechanistic explanations. This illustrates emergence and its place in nature [2005: 131].”

First of all, Boogerd et al. (2005) based on the work of Broad (1925) identifies two independent conditions for the emergence of properties, the first, called vertical, establishes that a systemic property is emergent if it is not mechanically explainable, even in principle, from the properties of its’ parts, its relationship within the entire system, the relevant laws of nature and the composition principles.

In other words, what the vertical perspective establishes is the idea of unanalyzability or non-functionality of the emergent properties in a complex system. It does not matter if we know, in extreme detail, the properties of the constituent elements, the relevant laws of nature and the composition principles, it is not possible, even in principle, to deduce what kind of emergent property the system will have. This is the idea of emergence that appears in most metaphysical discussions, particularly in discussions about qualia.

The second is the horizontal condition: A systemic property is emergent in this sense if the properties of the parts within the system cannot be deduced from their properties in isolation or in other wholes, even in principle. The properties of, say, part A in the context of system R (A, B, C) would be emergent in this sense if they were not deducible from the properties of A, B, and C in isolation or in other systems.

Fulfilling the vertical condition, argues Boogerd et al. (2005), means there would be a failure of mechanistic explanation. The properties (and behaviors) of the system would then be inexplicable in terms of the properties (and behaviors) of the parts as they function in the system. Fulfilling the horizontal condition means the properties (and behaviors) of the parts within the whole cannot be predicted from their properties (and behaviors) in other systems. In either case the systemic properties will be emergent. The last condition, the horizontal, is explored in the case study about biochemical networks set out by Boogerd et al. (2005).

The biochemical networks Boogerd et al. (2005) set out exhibit organizational properties, ones not manifested at the level of the parts, but which result from the interactions among the parts. Consequently, they should be explained in terms of component properties, which depend both on the properties of the parts and on the state of the entire system. Although the organizational properties encountered in biochemistry will always be vertically reducible, there are some cases of non-deducibility if the deduction base is restricted appropriately. Thus, it is possible to present cases of emergence from a horizontal perspective, meaning, a reductive perspective. In other words, what the horizontal perspective affirms is that although we take elements participating in a complex system showing emergent properties and we analyze these elements in simpler systems and, finally, we identify their properties with extreme detail –in this case is when it is applied a reductive analysis-, is not possible foretell the properties this elements will exhibit at the moment of interacting within the system of greater complexity.

The Vertical Condition, argues Boogerd et al. (2005), maintains an emergence notion of metaphysical character that sets metaphysical investigation objectives, for this reason this kind of orientation does not have a place in the natural sciences. On the other hand, as Boogerd et al. (2005) expresses, if an emergence concept is useful for the natural sciences it is because of its compatibility with explanations of mechanical character. The horizontal condition makes this compatibility possible.

In the case study Boogerd et al. (2005) explained, from a functional point of view, how chemical reactions are carried out within the cell. A cell is a semi-open metabolic system. They are open insofar as they allow a free exchange of some chemicals and heat with the environment; however, the exchange of other substances is limited because they have a boundary (a membrane) separating them from their environment. They are systems that selectively interact with their environment by way of mass and

energy (heat and work) exchange. The mass exchange is selective. Only certain chemical compounds and ions can enter or exit the cell. The exchange is often active. It is coupled to a chemical reaction that dissipates free energy. As long as such systems are driven by an external free energy source, they will display what is known as non-equilibrium behavior. The cell as a biochemical network shows systemic properties, e.g. being robust to internal and external fluctuations, showing memory, displaying adaptive behavior. These systemic properties do not in general manifest themselves at the level of the parts but arise out of the interactions among the parts. They are therefore organizational properties. Organizational properties, therefore, are likely to be explained in terms of the dynamics of these interactions.

The molecular biosciences teach us that all the action in biological cells is at the level of (macro) molecules: biological cells are physicochemical systems composed of interacting low-molecular weight molecules (metabolites, e.g., lactate, pyruvate), macromolecules (enzymes, protein complexes, DNA, mRNA) and larger structures thereof, all compartmentalized by semi-permeable lipid-containing membranes. Such systems can be looked upon as huge supra-processes composed of networks of interacting micro-processes.

Boogerd et al. (2005) argue that one way to investigate the effects of these (macro)molecules is by making *in silico* reconstructions of biological cells, or of subsystems, on the basis of the (macro)molecular properties. Such models incorporate experimentally determined *in vitro* properties of (macro)molecules and, relying on that knowledge, reconstruct the behavior of cells. Not all properties of enzymes are necessary for predicting cell behavior. For emergence, the only properties that matter are those that refer to the interactions between the enzymes and the other (macro)molecular (sub)system constituents. This approach shows, using a mathematical model, how the sequences of chemical reactions are carried out in a biochemical network composed of 6 metabolites where 5 consecutive reversible reactions are developed, each one catalyzed by one enzyme. The result of these reactions is the transformation of different substrates in different products. These chain reactions (pathways) are important for the homeostasis, a central property of the biochemical networks. The resultant products of these reactions could be utilized by the cell to be used immediately as metabolic products or to set off other chain reactions.

Boogerd et al. (2005) describe in detail how these chain reactions are carried out from the component properties of the enzymes. They are called “components” because they are determined in part by the relational properties of the components and in part by the state of the entire system. A component property of the enzymes depends on the concentration of the metabolites which communicate in the reactions and the relational properties of these enzymes. An explanation of these chain reactions based on the utilization of the component properties of the system is compatible with a mechanistic explanation of the subsystem in question.

Nevertheless we have the most complete knowledge about components analyzed from simpler systems than the real biochemical systems where they develop naturally; it makes the behavior of these components non-deducible in more complex systems. Using this approach, Boogerd et al. (2005) set out that emergence in Cell Biology is ontologically valid and epistemologically useful, since the horizontal condition

proposed by them is fulfilled and furthermore is compatible with a mechanical-reductive explanation model.

II. Downward Causation in the Heart of Living Organizations

Moreno y Umerez (2000), argue that biological systems cannot be explained only in terms of physical laws, but that their organization also depends on the action of informational records which control the construction of the organism's phenotypes. This information is shaped by natural selection through a collective and historical process. By controlling the lower level of molecular interactions, information acts as a kind of explicit formal cause which restructures matter according to a given pattern. As the construction of informational patterns is an open process, essentially independent of the dynamics of their material support, information exhibits compositional capacity which, besides allowing open-ended evolution, constitutes the main difference between formal and physical causation.

Before discussing the proposal of Moreno and Umerez (2000) it is pertinent to express certain considerations. From a general perspective, a systemic property is emergent when it is nonreducible to the properties of its constituent elements, and it is nonreducible because this property, which belongs to a micro-level, can causally inflict changes in the micro-structure of the system from which the property has emerged. It is known as *downward causation* and is the core component of a nonreductive approach regarding the concept of emergence. It can be said that an emergent property is real and not a mere epiphenomena when it has causal powers. Downward causation thesis can not be eluded if we want to concede an ontological status to these emergent properties.

Moreno and Umerez (2000) are intellectually committed with a nonreductive perspective regarding the notion of emergent properties in biological systems. They establish as a reference framework the assertion made by Campbell (1974, 1990) about downward causation:

'Where natural selection operates through life and death at a higher level of organization, the laws of the higher level selective system determine in part the distribution of lower level events and substances. Description of an intermediate-level phenomenon is not completed by describing its possibility and implementation in lower level terms. Its presence, prevalence, or distribution (all needed for the complete explanation of biological phenomena) will often require reference to laws at a higher level of organization as well. [...] all processes at the lower levels of a hierarchy are restrained by, and act in conformity to, the laws of the higher levels [1990: 4]'

The notion of downward causation drives us to conceive a universe constituted of different organizational levels, ontologically real; a hierarchical universe, ascertain Moreno y Umerez. In a biological system some components will not be able to be partitioned into disjointed sets. Most of the complex biological molecules are not found in other organized components that are not living organisms, and it is easy to test how quickly proteins decay out of the cell. When we try to understand why such components exist within cells, we find that a complex web of chemical interactions continuously generates, maintains and replaces them. Accordingly, biological components appear

integrated in a complex organization. On the other hand, all of these molecular components do not belong to the same (unique) level, but they are organized hierarchically.

Moreno y Umeréz (2000) propose a wider and plural vision regarding what causality is, in which prevails the materialistic principle, and overcome the principle of explanatory exclusivity, i.e. multiple causes, acting jointly, can produce a unique phenomena. They affirm biological systems cannot be explained unless we take into account, in addition to physical causality, internally generated constraints. Biological organisms generate and result from a certain kind of boundary condition which selectively constrains those dynamical processes which constitute their identity. This type of causal action is “formal” in the sense that it infuses forms, i.e., it materially restructures matter according to a form. Moreno and Umeréz (2000) give a different meaning to the notion of formal causality utilized in the Aristotelian philosophy. In Aristotle, both formal and material causes are intrinsic, whereas efficient and final ones are extrinsic. From Moreno and Umeréz (2000)’s view of formal cause, being efficient and being intrinsic do not exclude each other. In a sense, formal cause is intrinsic inasmuch as it is inherently generated in the very system which becomes an autonomous complex system.

A formal cause acts materially in the sense that formal causality implies the requirement of complex and specific aggregates of matter and specific and controlled flows of energy. And this restructuring of matter is not an implicit process, but the consequence of a given pattern (whose domain of possible structures is autonomous from dynamical considerations) which brings forth and stabilizes possible—but improbable—complex organizations of matter (i.e. proteins, cells, pluricellular organizations, etc.). The basic type of formal causation in biological systems is genetic information, which consists in a complementary and recursive interaction between certain records (which are the result of previous processes of organization that shape some conservative molecular components) and a set of components in the individual systems that are restructured depending on the causal activity of such records

Accordingly, formal causation is a quite different kind of causality than physical causality. Physical (or “material”) causality lies on the intrinsic activity of matter, whose processes occurs in intrinsic time and energy, and do not require underlying levels of organization. On the contrary, formal causality needs underlying levels of material organization (enormous amount of systems and time) and consists in explicit re-arrangements of matter (in fact, it is an autonomous over-determination of matter in formal terms) and, at the causal level, processes occur at arbitrary times and costs of energy. Hence, the idea of formal causality advocated here differs from physical causality in its matter re-arranging and non-intrinsic character. It is therefore important to emphasize that these causal explanations of a type beyond the mechanical efficient are as legitimate as this one.

In biological terms the relationship between the level of molecular interactions in a cell and the global level of the cell as a whole, can not be fully understood unless we consider it embedded in a collective and historical dimension. The organization of the cell is a highly complex web of chemical reactions. In this organization many classes of components take part, but the extreme precision of this organization relies on the fact that practically all of the biological reactions are controlled by one type of molecule:

enzymatic proteins. If we inquire about the “agent” that produces a given protein (in Aristotelian terms, the efficient cause of this particular protein), the answer would be that the material causes are the amino acids. Concretely, the synthesis of any protein is a direct consequence of the action of tRNAs and peptidyltransferases protein molecules, both involved in the formation of the string of amino acids. Therefore (in Aristotelian terms) amino acids would be considered to be the material cause of the proteins. As Aristotle himself admitted, these different causes may act together.

But proteins are highly specific and complex. This complexity is manifested in their three-dimensional structure, which results from the folding of a specific one-dimensional string of about one hundred small molecules (amino acids). As the proteins are constituted of 20 different aminoacids, and the average length of a protein is about one hundred, there is an incredibly high number of possible proteins (about 20^{100}). Given that in the cellular organization enzymatic functions are highly specific, one fundamental problem is to determine which are the causal mechanisms for explaining the synthesis of every specific protein in a given cell. The answer to this question at an individual cell level is that the specific sequence of amino acids that constitute the proteins of this particular organism, are ultimately related to the specific sequence of the nucleotides of DNA molecules. DNA (and RNA) acts, then, as an "in-formational" template for the synthesis of proteins, because such templates contain the necessary instructions for guiding or regulating the production of proteins.

Hence, in Aristotelian terms, DNA molecules are the formal cause of proteins in biological cells, because their specific sequence of nucleotides conveys the "idea" or "form" of the latter. In fact, the causal role that DNA plays in the synthesis of proteins is, in addition, in-formative in an explicit sense because it is possible to establish explicit mappings between the sequence of DNA and the primary structure of those proteins whose construction is driven by it.

On the other hand, as Moreno and Umerez (2000) specify, a codifier is necessary which joins the nucleotides sequence to the amino acid sequence. This translation process requires a complex number of steps in which some of the same proteins are involved. To sum up, the components that build a system as a “whole” are generated at the same time through a network of interactions from the entire system. To consider the complete chain as a result of an essential level made by the simplest components which their own properties define their interactions, would be partial. The reason for this is that many of these components may only exist as a consequence of the recursive maintenance of the entire network. Examples of models that explain these kinds of systems are those presented by Kauffman (1991): the autocatalytic co-joined model and Fontana (1992): Algorithmic Chemistry. What these models present is the appearance of functional or operationally closed systems, which are necessary in order to understand the origin of biological systems. But, it is another condition, the genetic information which makes speaking appropriately about the appearance of new types of chance relationships possible: the formal causality through records. Thus, what it allows to assume a double chance action in the biological systems – an ascending or mechanic and another descending – is the conjunction of a circular causality with different levels of organization; one of these is constituted by informative components.

Moreno and Umerez (2000) support that the biological organization is more than mere networks of recursive individual reactions. One of its main characteristics is to evolve

by natural selection. The DNA represents the material connection between a collective and historical dimension and the individual organization. The specific patterns that a given DNA molecule possesses have been formed through selective mechanisms which require a collective spatial and a temporary dimension. Due to this fact, the informative role of the DNA in the cellular organization is qualitatively different from the functional activity of all the rest of the cell components. A living organization requires a meta-network where the individual networks constitute a structure of synchronic (competition) and diachronic (character transmission through reproduction) relationships. For this reason, neither the auto-organization nor the generated information through natural selection, are enough themselves to explain the living organization; its action as a whole is necessary.

The information shows compositional capacities due to the construction of information patterns is an open process. This compositional capacity, besides allowing an open and endless evolution process, it constitutes the main difference between formal and physical causality. In functional terms, the chance action of the information permits on one hand, the auto-maintenance process in the first living systems had been solid and on the other hand, an increase in its complexity. The records, formed by a collective and autonomous process, materially realign material subsets of structures by means of which highly organized systems, with major complexity levels than previous systems, are generated.

In these terms, Moreno and Umerez (2000) support that the descending causality, in biological systems, has at least two significances with respect to the living organization:

- 1) On the level of each particular organism, the informative components (DNA molecules) restrict the chemical reactions of a minor level which constitute the cell.
- 2) Considering life as a collective and historical phenomenon, individuals are the result of this collectively and historically generated information.

The authors conclude that the biological system can not be explained unless it is considered that its organization generates and at the same time, is the result of, its internal limit conditions. Such limit conditions, autonomously generated from natural selection, selectively restrict the dynamic process of organisms and thus, connect the physical and chemical laws. This process in biology is usually described in a language on which DNA molecules play a opportunistic role. Due to the fact that biology can identify the material structures involved in these processes and can understand each of their steps, many biologists tend to consider that such descriptions are a successful explanation of the living organization in physical terms. Finally, Moreno y Umerez support that the descending causality appears when meta-networks of extremely complex and interconnected recursive reactions emerge in nature. It is not a surprise to understand that this strange co-joined group of auto-descriptor molecular systems requires something more than standard physical explanations.

III. Emergence: Between reductive and non-reductive explanations

The mechanistic perspective

After presenting on one hand the works of Boogerd et al. (2005), and on the other hand the Works of Moreno and Umerez (2000), it is time to analyze both points of view with respect to the notion of emergence. In the first instance, the point at which both postures

diverge will be presented and in a second instance, the author's particular evaluation in the current work will be shown.

Three elements deserve special attention in the work of Boogerd et al. (2005): his notion of the cell, the type of operating causality in the biochemical networks of the cell and the type of reductionism that supposes his approach.

According to them, one cell is a metabolic semi-open system which selectively exchanges some chemical substances, mass, heat and work (energy) with the environment and that in this complex framework of interactions it presents systematic properties such as: the stability before internal or external fluctuations, organizational memory and the deployment of an adaptive behavior. All of them are properties which do not show themselves at the level of individual cell components. The cell is a unit of autonomous, auto-sustainable processing and it can auto-replicate itself. It is a thermodynamic machinery far from the equilibrium, this means, using the Prigogine language, a dissipative structure.

“A biological system, which metabolizes and reproduces, must effectively exchange energy and mass with the environment; therefore, it functions as an open system. On the other hand, the maintenance of life and growth depend on an infinite number of chemical reactions and transport phenomena, which their control implies the intervention of non-linear factors (activation, inhibition, direct auto-catalization, etc.) Finally, the energy contribution is generally made under unstable conditions because the reaction products are expelled from the living system or sent to other places of the cell so they can perform other functions. In brief: the functioning of the biological systems seems to accomplish the necessary conditions so the dissipative structures can appear.” [1997: 316].

The cell, from the point of view of Boogerd et al. (2005), is a system that can be decomposed into subsets of minor complexity in order to analyze the behavior of its constituent elements and to understand the processes that are made in the biochemical networks. This means, to understand, for example, how the synthesis of proteins, the replication process of DNA or the transformation of substrates in products through the chemical reactions catalyzed by enzymes, are made. Above all, the cell is a functional unity. From this functionalist point of view, if we ask ourselves what is that which causes the regulation process called homeostasis in the biochemical networks, we would respond that it is a chain of events that may begin from a change of temperature or pressure at a level of the organism and that it translates itself into feedback processes which involve a cellular machinery. But, another way to respond is focusing the answer on the chemical control that is made in the cells. When we speak about the chemical control, we speak about the activity that receivers and messengers (hormones) perform; the receivers are glycoproteins which join to specific messengers. This connection produces the events that lead to an answer from the cell. The combination of the receivers with the messengers produces a change in the same receivers, this event is called receivers activation. This can lead to changes in the permeability or the electrical state of the cell membrane, in the cell metabolism, in the secretory activity of the cell, in the proliferation or differentiation of the cell or in its contractive activity. Chain reactions (pathways) of transduction signals are the name for the mechanisms by which the activation of a receiver leads to a final response of a cell. These chain reactions are

those that Boogerd et al. (2005) describes in detail in his work. These chain reactions stop when the concentration of the first messenger diminishes due to its metabolism and diffusion. The receivers are chemically altered, diminishing their affinity with the first Messenger (hormone) or are removed when the receiver-messenger complex is carried to the inside of the cell by endocytosis.

In this functionalistic description, on the one hand, the notion of efficient causality plays a preponderant role. Efficient causality, in this sense, refers to the principles of production, creation or modification that happen in the constituent elements of the cell. On the other hand, material causality is that on which certain transformations operate, in this case, the cellular elements. In the causal explanation of the systemic properties, provided by Boogerd et al. (2005), which claims to describe the function of every element in order to, finally, describe the function of the entire system. This is a mechanistic approach.

But, what is a mechanism? A mechanism is a structure performing a function in virtue of its components parts, component operations, and their organization. The orchestrated functioning of the mechanism is responsible for one or more phenomena (Bechtel & Abrahamsen, 2005). To say that a causal relationship is bottom-up or top-down is to say that things at one level are causally related to things at another level. The term 'level' plays many roles in science (Bechtel, 2006). There are levels of abstraction, being, causation, description, explanation, function, and generality, to name a few, and these are not the same. For each, there is a different sense in which a cause can be said to be at the top (or bottom) and a different sense in which its influence is propagated downward (or upward).

Mechanisms are entities and activities organized such that they exhibit a phenomenon. Scientists discover lower levels by decomposing the behavior of a mechanism into the behaviors of its component parts, decomposing the behaviors of the parts into the behaviors of their parts, and so on. Because mechanisms are organized collections of components and their activities, no component can be larger than the mechanism as a whole, and so levels of mechanisms are ordered by size. For analogous reasons, higher-level behaviors act over longer time-periods than lower-level activities.

Most fundamentally, levels of mechanisms are a species of compositional, or part-whole, relationships. In contemporary debates about reduction and inter-level causation, it is common for authors to talk about 'levels of aggregation,' 'levels of organization,' 'levels of complexity,' and 'mereological levels.' Such descriptions also apply to levels of mechanisms. Higher levels of mechanisms are aggregated (i.e., built up from) or composed from parts that are organized into more complex spatial, temporal, and causal relationships.

This compositional argument is what Boogerd et al. (2005) developed with their essay. It is a reductive argument because it is structured in terms of a mechanistic explanation which, at the same time, is useful for natural science and, in addition, takes into account the organizational dimension of living systems. The compositional argument set the limit for any kind of reductive approach and the limits are the very interacting elements being analyzed by an observer, an observer who outlines the framework of reference; it cannot be otherwise.

This kind of functional analysis is similar to what Mayr (1997) called proximate causes analysis in Biology. As Mayr (1997) clearly described, the functional biologist (the observer) is vitally concerned with the operation and interaction of structural elements, from molecules, to organs and up to whole individuals. His ever-repeated question is "How?" How does something operate? How does it function? The functional anatomist who studies an articulation shares this method and approach with the molecular biologist who studies the function of a DNA molecule in the transfer of genetic information. The functional biologist attempts to isolate the particular component he studies, and in any given study he usually deals with a single individual, a single organ, a single cell, or a single part of a cell. He attempts to eliminate, or control, all variables, and he repeats his experiments under constant or varying conditions until he believes he has clarified the function of the element he studies. Proximate causes is used to answer the question of how. They affect the phenotype, meaning, the morphology and behavior of living systems, and they are, most of the time, mechanics. Proximate causes occur here and now, in a specific phase of the cell cycle and experimentation helps to determine these causal relations. A useful account of emergence in terms of a mechanistic framework is what Boogerd et al. (2005) has done for the natural sciences in an outstanding way.

The Antireductive Perspective

It is important to establish the importance that the concepts of cell information and downward causation have in the works of Moreno and Umerez (2000). Contrary to Boogerd et al. (2005), Moreno and Umerez (2000) define a cell not only as a physicochemical system composed of interacting low-molecular weight molecules (metabolites, e.g., lactate, pyruvate), macromolecules (enzymes, protein complexes, DNA, mRNA) and larger structures thereof, all compartmentalized by semipermeable lipid-containing membranes; a cell, in addition, is the historical and collective dimension of a living organization.

Evolving organizations possess components able to act as records which transfer a set of patterns generated in a collective frame to the individual cells. These patterns are, in turn, autonomously interpreted as specifications or instructions by every individual cell. Once expressed, selective pressures discard many of these embodied patterns. The transmission of these historically generated patterns requires a kind of molecule suitable for (self)replication, storage and transmission of patterns, along with the capability to permit —and transmit— some local changes without altering its remaining functions. DNA is the most suitable kind of biomolecule which establishes a causal link between historical-collective processes and individual organizations.

As it was mentioned, DNA represents the material connection between the collective/historical dimension and the individual organization. The specific pattern that a given DNA molecule possesses (whatever its causal effects might be in the cell that expresses it) has been shaped through selective mechanisms that require a spatial and temporal collective dimension. This is why the informational role of DNA in the cellular organization is qualitatively different from the functional activity of all the other components of the cell.

There is a "bootstrapping" type of process between the setting up of the individuals and the collective network where ultimately the information is generated, because the interpretation of this information occurs in each individual organism and constitutes it. This long-term collectively generated sequence of specifications is what, at the individual level, acts as in-formation, constraining the underlying dynamics of the chemical processes in every organism in a top-down way.

As information lies in non-dynamical and relatively stable material structures, whose changes are independent of rate and energy (at the individual organizational level), the informational domain is only contingently related to the domain of the dynamic organization where it is expressed. Then, information shows compositional capacity because the construction of informational patterns is an open process. This compositional capacity, in addition to allowing open-ended evolution, constitutes the main difference between formal (informational) and physical causation. In functional terms, the causal action of information allows, on the one hand, the robustness of the processes of self maintenance in early living systems and, on the other hand, the increase of their complexity. The informational components (records), shaped through a collective and historical process, materially rearrange material subsets of structures so that highly organized systems, with levels of complexity higher than previous systems, are generated.

In causal terms, Moreno and Umerez (2000) state, the basic type of formal causation in biological systems is genetic information, which consists of a complementary and recursive interaction between certain records (which are the result of previous processes of organization that shape some conservative molecular components) and a set of components in the individual systems that are restructured depending on the causal activity of such records. Accordingly, formal causation is a quite different kind of causality than physical causality. Physical (or "material") causality lies on the intrinsic activity of matter, whose processes occurs in intrinsic time and energy, and does not require underlying levels of organization. On the contrary, formal causality needs underlying levels of material organization (enormous amounts of systems and time) and consists in explicit re-arrangements of matter (in fact, it is an autonomous over-determination of matter in formal terms) and, at the causal level, processes occur at arbitrary times and costs of energy. Hence, the idea of formal causality advocated by Moreno and Umerez (2000) differs from physical causality in its matter re-arranging and non-intrinsic character.

It is therefore important, Moreno and Umerez (2000) explain:

“[...] to emphasize that causal explanations of a kind beyond the mechanical efficient are as legitimate as this one, insofar as materially and scientifically sound connections are provided. In this sense there seems to be no reason to accept an a priori contradiction between emergence and causality, unless we had good reasons to prefer a narrower conception of causality which we certainly find difficult to come with when dealing with the complex objects of study on which science is focusing nowadays (not only in biology but in general in non-linear physics, not to mention psychological or sociological domains)” [2000:103].

Coming back again to Mayr (1997)'s work, what Moreno and Umerez (2000) are talking about is evolutionary biology. The evolutionary biologist differs in his method and in the problems in which he is interested. His basic question is "Why?" "Why"

means "How come?" but it may also mean the finalistic "What for?" When the evolutionist asks "Why?" he or she always has in mind the historical "How come?" Every organism, as an individual and as a member of a species, is the product of a long history, a history which indeed dates back more than 3,000 million years. Everything is time-bound and space-bound. The animal or plant or micro-organism he is working with is but a link in an evolutionary chain of changing forms, none of which has any permanent validity." There is hardly any structure or function in an organism that can be fully understood unless it is studied against this historical background. And it is on this historical background where the reductive arguments lose its useful explaining power. A cell as a historical unit and specifically the DNA as an informational unit, in terms of a formal causality, permit the re-arranging of matter of a bio-chemical network in a downward way.

The Debate: between reductive and nonreductive explanations.

The concept of a cell as a functional unit against the perspective of the cell as an historical unit; efficient and material causality against causal plurality, with special emphasis on formal causality; a mechanistic approach (micro-determinist) against an organicist approach (macro-determinist); the defense of an ontological emergentism from the dissertation of non - deducibility, against the defense of an ontological emergentism based on the dissertation of irreducibility. In short, these are the most notable differences between the works of Boogerd et al. (2005) and Moreno and Umerez (2000), works that, from these opposing perspectives, try to positively argue the validity of the assertion of the existence of emergent properties in the universe.

The conclusions of the present essay are:

- a) If one tries to give consistency to the emergence notion in its strongest (ontological) sense, one has to do so from the defense of the irreducibility thesis and, consequently, of downward causation, both components of a macro-determinist position. Another option is that of sustaining an emergentism based on non-deterministic principles, which will not be explored in the present essay.
- b) If the correct way to raise an ontological emergentism is to do so with the study of irreducibility and downward causation, the work of Boogerd et al. (2005) did not obtain the objective, but the work of Moreno and Umerez (2000) did.
- c) Emergent properties may or may not exist (ontologically), but what is argued in the current work is that the most useful way of defining it is in terms of the irreducibility thesis and downward causation. Ontological micro-determinist emergentism is an absurdity

As a continuation the following arguments are presented:

Broad's work *The Mind and its Place in Nature* is the basis for the Boogerd et al. (2005) essay. In his outstanding work, Broad focuses the emergence concept explanation on the thesis of nondeducibility. Stephan (1992, 39), taking this proposal into account, articulated a definition of emergence on the basis of nondeducibility as follow:

- A system property P (of system S) is called emergent_{absolute} if
- a) there is a law P_L which holds: for all x when x has the microstructure $[C_1, \dots, C_n; O]$ then x has property P.

b) for all microstructures $[y_1, \dots, y_n; w]$ of system S: if there is law P_{L^*} which holds: for all x when x has a microstructure $[y_1, \dots, y_n; w]$ then x has property P, there is no theory T and there are no laws concerning the y_1, \dots, y_n in isolation or in other microstructures, even together with compositional principles, from which could be P_{L^*} deduced. [Stephan, 1992: 39]

The problem with this approach is its emphasis on laws and the nondeducibility of laws from a theory T, specifically fundamental laws, but this is an epistemological concern, not an ontological one. As Schroder (1998) mentioned, a property is emergent as long as either we do not have the right theories about the properties of the parts or we have the right theories but not the computational power to deal with the increasing complexity as we move from H-atoms to economies. Additionally, in Biology there are no laws. If there are not any laws, there is no scope for ontological emergence in Broad's characterization of this concept and, furthermore, there is no scope for reduction at all.

The absence of laws in biology reflects some fundamental and ineliminable facts about the biological realm and the scientific study of that realm. To begin with, individuation of types in biology is almost always via a causal role, and in particular via a function. For instance, to call something a wing, or a fin, or a gene is to identify it in terms of its function. But biological functions are naturally-selected effects. And natural selection for adaptations –i.e. environmentally appropriate effects- is blind to differences in physical structure that have the same or roughly similar effects.

Following Rosenberg (2001), it is the nature of any mechanism that selects for effects that it cannot discriminate between differing structures with identical effects. And functional equivalence combined with structural difference will always increase as physical combinations become larger and more physically differentiated from one another. Moreover, perfect functional equivalence is not necessary. Mere functional similarity will do. Since selection for function is blind to differences in structure, there will be no laws in any science which, like biology, individuates kinds by selected effects, that is, by functions. A law in functional biology will have to link a functional kind either with another functional kind, for example, “all butterfly wings have eyespots” or a structural kind, “all eyespots are composed of proteins”. But neither of these statements can be a strict law, because of the blindness of natural selection (which forms functional kinds) to structure (which will therefore heterogeneously realize functional kinds).

The upshot is not simply that there are no laws; *ergo* neither reductionism nor antireductionism about laws is tenable in biology. The entire character of biology as a discipline reflects the considerations which make laws impossible. Functional kinds have etiologies that reflect natural selection operating on local conditions, and natural selection is constantly changing local conditions. This makes biology an essentially historical discipline.

Beyond the bare theory of natural selection itself, the rest of biology is a set of subdisciplines historically conditioned by the operation of natural selection on local circumstances during the history of the Earth. The functional individuation of biological kinds reflects the vagaries and vicissitudes of natural selection, since biological kinds are the result of selection over variation in order to solve design problems set by the environment. Possible solutions to the same problem are multiple and one biological

system's solution sets a competing biological system's next design problem. Therefore, each system's environment varies over time in a way that makes all putative biological "generalizations" about these systems historically limited descriptions of local patterns. Any subdiscipline of biology--from paleontology to developmental biology, to population biology, to physiology or molecular biology can uncover, at best, historically conditioned patterns, owing to the fact that a) its kind vocabulary picks out items generated by an historical process, and b) its "generalizations" will always be overtaken by evolutionary events. Some of these "generalizations" will describe long-term and wide spread historical patterns, such as the ubiquity of nucleic acid as the hereditary material; others will be local and transitory.

But if the thesis of nondeducibility does not explain what emergence is in Biology, then the next step is to analyze if irreducibility thesis can do it. The intuition of emergence is that of novel causal powers coming into being at specific levels of ontology (Bickhard, 2000). If causal powers do emerge, then, within the framework of any reasonable naturalism, any causal consequences of those higher level emergent powers will themselves involve constituent levels of matter, or at least constituent levels of organizations of quantum processes. That is, any consequences of emergent causality will affect lower levels, constituent levels, of pattern and organization as well as the level at which the emergence occurs. More concisely, causal emergence implies downward causation. Since interesting emergence involves causal emergence, and causal emergence implies downward causation, downward causation becomes a strong criterion for genuine causal emergence and, more generally, for interesting emergence. If a notion of emergence is tenable it is because irreducibility thesis is at the core of the concept. If an emergent property is not causally effective in the universe then it does not have any causal powers at all.

The work of Moreno and Umerez (2000) follows a nonreductive approach. They establish the operation of a formal causality independent of a material causality. This formal causality, informational causality, basically is responsible for the organization of the system. This kind of causality operates in a downward direction. Moreno and Umerez (2000) explain it as follow:

"[...] information shows compositional capacity because the construction of informational patterns is an open process, essentially independent of the dynamics of their material support. This compositional capacity, in addition to allow open-ended evolution, constitutes the main difference between formal (informational) and physical causation. In functional terms, the causal action of information allows, on the one hand, the robustness of the processes of self maintenance in the early living systems and, on the other, the increase of their complexity. The informational components (records), shaped through a collective and historical process, materially rearrange material subsets of structures so that highly organized systems, with levels of complexity higher than previous systems, are generated.

Accordingly, this idea of formal causation is functionally similar to the one expressed by Campbell [...], when he defended the idea of Downward Causation as (the action of) the laws of the higher level selectively determining in part the "presence, prevalence, or distribution" of lower level events and substances. However, this top-down action (downward causation) has at least two complementary meanings in the living organization:

- 1) at the level of each particular organism, the informational components (DNA molecules) constrain the lower level chemical reactions that constitute the cell.
- 2) considering life as a collective and historical phenomenon, the individuals are the result of this collectively generated historical information.

At its turn, the shaping of this information is only possible as a consequence of a selective process, consisting in a functional evaluation of the new forms at the level of the phenotypes. Ultimately, the selection process that shapes the information results from the viability or reproductive capacities of the phenotypes” [2000:115].

The strong concept of downward causation is typically explained in terms of material or physical causality, but this is not the case with Moreno’s and Umerez’s (2000) proposal. They appeal for a weaker version of downward causation, in fact, a medium downward causation. Using the work of Emmeche et al. (2000), the kind of downward causation expressed in the essay by Moreno and Umerez (2000) can be described as follows:

“The distinctive feature of medium DC in contrast to strong DC is that it does not allow higher level phenomena to have a direct influence on lower level laws.

Medium downward causation can be defined as follows: an entity on a higher level comes into being through a realization of one amongst several possible states on the lower level –with the previous states of the higher level as the factor of selection. This idea can be made more precise with the aid of an interpretation of the concept of “boundary condition.”

In relation to level theories, boundary conditions are conceived as the conditions which select and delimit various types of the system’s several possible developments. The realization of the system implies that one of these typical developments is selected, and the set of initial conditions yielding the type of possibility chosen are thus a certain type of boundary condition which has been called *constraining conditions*. They only exist in complex multi-level phenomena on a level higher than the focal level, and are the conditions by which entities on a high level constrain the activity on the lower focal level.

On this basis, *medium downward causation* can be reformulated as follows: *higher level entities are constraining conditions for the emergent activity of lower levels*” [Emmeche et al., 2000: 19-26].

Moreno and Umerez (2000) avoid the stronger concept of downward causation and the logical implications that it carries. Instead, they focus their attention on the potential that information has to explain the process of organization in a biological system and how the system as a whole is organized by itself. These patterns of organization are ontological levels of existence, as real as their material constituents.

If using the downward causation notion as the last word and unquestionable argument in favor of emergence and the thesis of nonreducibility is the most adequate alternative, or not, is something that cannot be solved yet. But what is defended in this work is the following: If we want to make sense of the emergence concept, this must add new light to the problem we are elucidating, and it is necessary to accurately establish what that problem is. Emergence notion arises as a theoretical alternative against the reductionistic and mechanical explanations regarding the phenomenon of life. Finally if life can be explained in terms of a mechanistic approach it is no longer necessary to talk about emergence. It will be argued in historical terms.

The concept of emergence was, according to C. Lloyd Morgan (1923), coined by G. H. Lewes in his *Problems of Life and Mind* in 1875. Morgan specifies that similar concepts are to be found in the theories of J. S. Mill and the psychologist W. Wundt.

It is no pure accident that the concept was in frequent use at the beginning of the 20th century. In most of the more recent discussions on the concept of emergence, it is opposed to those of reductionism, determinism and/or mechanistic materialism. But before the concept of emergence was coined, reductionism and mechanism were most often discussed in connection with another concept. This discussion partner was vitalism.

Historically conceived, when vitalism was discarded as an unusable concept, a new concept was coined, preserving some of the vitalistic viewpoints; this concept was emergence. The concept of emergence consists of those reasonable aspects of vitalism which are worth maintaining. The classical vitalist doctrines from the 18th century insist upon the idea that all life phenomena are animated by immaterial life spirits. These life spirits determine the various life phenomena, but are in themselves unexplainable and undescrivable from a physical point of view. In opposition to this, the reductionist position (in the 18th century) insists upon a large part, if not all, of life phenomena being reducible to physics and chemistry.

The difference between vitalism and reductionism was continuously transformed. After a number of scientific discoveries at the beginning of the 19th century the vitalists did not give up, but they gradually limited their viewpoints to a narrower field. Reductionism now claimed, on the other hand, that every phenomenon in the whole world, including the highest psychological ones, were reducible to physics and chemistry.

Relating these differences between vitalism and reductionism to the concept of emergence, the concept is obviously primarily vitalistic – but it also transforms vitalism, or at least restricts it in a very important aspect. Emergence is first of all defined as “the creation of new properties”. It is very important to distinguish between the vitalists and the emergentists: the vitalist’s creative forces were relevant only in organic substances, not in inorganic matter. Emergence hence is a creation of new properties regardless of the substance involved.

There is one central problem which Morgan does not specify in his definition of emergence – the question of levels. The question of levels is always more or less implicitly discussed, and its explicit discussion is one of the modern aspects of the concept. But levels were also discussed in the 19th century, especially in relation to evolution. The vitalistic ideas are generally discussed as if they only applied to the biological theory of evolution. However, in the 19th century the theory of evolution was a much larger field than it became after neo-Darwinism – as is evident in the general historicism of the epoch covering most scientific works except those of physics and chemistry.

The thought of the system builders is another historical fact which is not very often related to the development of vitalism and theories of emergence. But these system builders’ discussions are very important, and they are one of the main reasons that the concept of emergence was “devitalized”, that is, deprived of an immaterial causal agent.

Among the main system builders in the 19th century were Auguste Comte (1798–1857), Herbert Spencer (1820–1903), Friedrich Engels (1820–1895), Ernst Haeckel (1834–1919), and Charles S. Peirce (1839–1914). The name “system builders” refers to the fact that they all created theories which analyze the relationship between a scientific description of the total world and the different scientific disciplines – two systems were related, the system of sciences and the system of the objects of the different sciences (in total = the world).

The emergence concept merely denotes the creation of new entities (properties) which cannot be derived from preceding conditions. And this is precisely what the great potentiality of the concept is. Emergence is, among other things, the concept which relates levels to each other – or to be more precise, the concept which denotes the very passage between them. Contrary to what Boogerd et al. (2005) say, emergence does not in itself solve anything, but it poses the problem in a general way, making it visible at the border of every specialized branch of science.

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