**Sciences as systems**

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**Abstract**

This paper opens by distinguishing between the multiple concepts of system and the philosophical idea of system. It then goes on to discuss the differences between systems and other proximate ideas, such as whole, set, aggregate and structure. Subsequently, it proposes a definition of system, and then lays out three classifications of systems. When elaborating a general definition of system, the main challenge is finding a general criterion as to characterize both technical systems built by men (for instance, machines), and scientific systems independent of human subjects (for instance, the solar system). The criterion proposed in the text solves this difficulty. Lastly, from the tenets of Gustavo Bueno’s hyperrealist philosophy of categorial closure, I put forward the consideration of the sciences as systems.

**1. System as a concept and as an idea**

Like many other words admitting a wide range of uses, the word "system" frequently refers to the concepts specific to certain sciences or techniques, and may also be used to designate a philosophical idea. To show this, take two other such words admitting varied uses: “matter” and “time”. Both concepts are very precisely defined in the field of Newtonian and relativistic physics. The physical definition of matter, though, is quite different from the concept of matter as used in technical, architectural, sculptural, pictorial or musical contexts. In the same vein, there is a concept of geological time different from physical, thermodynamic, psychological or historical time. Even further, matter and time are also philosophical ideas: the idea of time as an a priori form of external sensitivity in Kant, the idea of time in Aristotle, in Augustine, in Heidegger or in Bergson, as linked to the idea of duration; the idea of matter is present in Gassendi’s, La Mettrie’s, Feuerbach’s and Marx’s philosophical systems.

In this paper, I understand the differences and relationships between science, techniques and philosophies as follows. Techniques and sciences are first-degree knowledge dealing directly with certain areas or regions of the world; philosophies, however, are second-degree knowledge involving the prior existence of a comprehensive body of first-grade knowledge (practical, technical, scientific) whose coordination and composition is not always easy and may even become problematic (Bueno 1995). In what follows, I use the word "concept" in reference to regional fields in science, the arts, techniques and technologies and the word "idea" in reference to parts of philosophical theories. In making this distinction in terms, I hold that a philosophical activity is not a science.

Accordingly, the word "system" may refer to a set of more or less precise concepts originating in regions of reality as diverse as thermodynamics, geometry, logic, mathematics, biology, computer science, law, mechanics, economics, cultural anthropology, engineering, psychology, sociology, meteorology and political or military strategy, to name but a few. Further examples of the regional use of the word “system” include, inter alia, the systems of a biological organism (nervous, respiratory, digestive, immune, etc.), ecological systems, the mind as a computational system, the system of five regular polyhedra, Boole’s logical system, the metric system, the system of linear equations, thermodynamic systems, crystal systems, the tonal system, notation systems, the solar system, the international stock exchange system, the economic system, communication systems, the functional systems of a plane or ship, social systems, political systems, the electoral system, the tax system, legal systems, computational systems, operative systems, expert systems, kinship systems, meteorological frontal systems and engineering systems.

In studying systems, certain approaches have sought to be interdisciplinary or transdisciplinary. "General systems theory", first advanced by the biologist L. von Bertalanffy and inspired by the neo-positivist belief in the unity of science, studies systems in general, regardless of their specific content, so as to discover the general patterns and principles in any system and the mathematical tools used to describe such patterns and principles properly. Bertalanffy’s project implies that “certain principles apply to systems in general, irrespective of the nature of the systems and the entities concerned […] Thus, concepts such as wholeness and sum, mechanization, centralization, hierarchical order, stationary and steady states, equifinality, etc., are found in different fields of natural science, as well as in psychology and sociology” (Bertalanffy 1971, pp. 86-7). Bertalanffy's general systems theory includes certain issues that, from an epistemological standpoint, are highly heterogeneous: on the one hand, it makes use of philosophical theories on the general idea of system, while also taking in certain positive developments, taken particularly from logic, mathematics and cybernetics, regarding the formal structures supposedly present in all systems. Finally, Bertalanffy speaks of the "applications" of the general theory, which are but certain specific systems (often scientific or technological) within a particular region of reality.

This paper aims to characterize the philosophical idea of system, to classify systems based on the determinants of this idea, and to understand sciences as systems.

**2. Whole, set, aggregate and structure**

The noun "whole" designates the idea of "totality", a general idea that serves to differentiate the integrity of a particular region of reality from its environment. The idea of whole is always understood correlatively to the idea of part, which is defined as a portion of the whole. Broken down, the parts of a whole can be determinants, constituents and integrals. In a square, the characteristics of its being quadrilateral, parallelogram, rectangle and equilateral are its determinations (determinant "parts"); the sides and the vertices of the square are its constituent parts (components); and the two isosceles triangles whose hypotenuse is the diagonal of the square are its integral parts (pieces) which together give rise to the whole.

Wholes can be configurational, processual or both at once. Examples of exclusively configurational wholes are found in geometry (triangle, polyhedron, torus), since time is irrelevant to geometric construction. Examples of processual wholes are found in thermodynamics, biology (organisms, for instance) and techniques and technologies (machines, for instance). Sequences and series are examples of processual wholes. Processual wholes usually have a configurational counterpart.

Sets are a special type of whole consisting of elements that share a certain common characteristic. In set theory, there are operations, such as union and intersection, and relationships, such as disjunction. To determine whether an element belongs to one set or another, such element need only fulfil the characteristic defining that set, and there is no need for reference to the parts of that element. A set is defined by the relationship of belonging and need not be endowed with a special internal structure. Sets are a type of wholes, although there are other types of wholes that are not sets since their integral parts do not share a common feature.

An aggregate is a type of whole that lacks a precise structure. The parts may be homogeneous. For example, in mathematics, “aggregate” is often synonymous with “sum”, and a sum assumes the homogeneity of the addends. The same is true in the economic concepts of aggregate supply and demand. In other cases, the parts are heterogeneous: in geology, a mineral aggregate can result in a rock or a conglomerate.

A structure is also a kind of totality whose parts are arranged and related in a certain way. A building or a machine is a structure whose parts are disposed in certain given. The same applies to the structure of a work of art, a narrative, a song or an argument. Structures, as other types of wholes, can be configurational (the structure of a building) and processual (the structure of a sonata). When the relationships between the parts do not play a significant role in defining the totality, it is likely that the whole is not a structure, as seen in the aforementioned sets and aggregates. The use of the idea of ​​structure when referring to a whole lays stress on the importance of the parts’ arrangement and relationships, although the relationships between the parts of a given structure are not dependent on the structure of these parts themselves. This latter characteristic can be seen in algebraic structures (group, ring, field, lattice, vector space). Types of structures include meshes, networks, frames, lattices, webs and plexuses. As a methodology, structuralism promotes the study of certain wholes (in linguistics, cultural anthropology, art, etc.) in an attempt to analyze them as structures.

In the most varied disciplines, systems are defined as complex sets delimited by borders and composed of parts that interact with each other. However, these definitions, which are often deemed appropriate, are of no use when attempting to distinguish systems from structures. In the next section, I look further into the minimum determinants of systems as distinct from structures.

**3. The determinants of any system**

A system is undoubtedly a type of totality; as such, it has boundaries separating it from the environment and consists of parts. Systems share these two features with the other wholes discussed in the foregoing section (sets, aggregates and structures). Taking into account the characteristics shared by the regional concepts of system Bertalanffy, in his general systems theory, proposed the following definition: “A system can be defined as a set of elements standing in interrelations” (Bertalanffy 1971, p. 55). Other later and renowned definitions require a “set of entities” and “relationships among them” as components of systems (Van Gigch 1991, p. 30; Klir 1991, p. 5; Langefors 1995, p. 55). Nevertheless, those definitions fail to differentiate systems from structures, since the latter also entail a compound whole comprising a set of more or less interrelated parts.

Skyttner proposed a definition that involves interacting units while requiring the existence of an “integrated whole intended to perform some function” (Skyttner1996, p. 35). Other definitions contend that in every system the behavior of each element should be influenced by other elements (Ackoff 1981, p. 5; Jones 1982; Flood and Carson 1993). It is debatable whether such requirements exclude structures since structures are integrated wholes performing functions, and structures can include interrelated element behaviors, such as the structure of a building, a novel or a movie. Moreover, such requirements exclude numerous indubitable systems, such as the solar system, the periodic system of chemical elements, biological classification systems and geological systems, since these systems are not designed by anyone to perform a function, and their parts are not agents displaying behaviors. Backlund has clearly reported this exclusion (Backlund 2000, p. 447). Nevertheless, Backlund’s definition, which disregards the interaction between the elements of the system, is too inclusive, since many structures also fulfill his requirement (Backlund 2000, p. 448).

In this paper, I will contend that the parts of a system (which, following Bueno, I will call the “bases”) are not simple elements but are themselves complex wholes composed of other parts which are essential to understanding how the systemic arrangement works (Bueno 2000). Looking at the periodic system of chemical elements, the system bases are the simple elements of the periodic table, and the systemic arrangement of the table, with its periods (rows) and groups (columns), is constructed from certain components of the system bases, such as the atomic number, the electron configuration and the chemical properties of each element. Were the system bases (the simple chemical elements) not analyzed in relation to those components, there would be no periodic system, even if it remained a set or an aggregate of elements, defined by the relationships of belonging or analogy. Systems, therefore, have at least two mereological levels: the first level constitutes the system bases (in this case, the chemical elements) and, the second are the parts of those bases, which are themselves also complex wholes with determinant parts (metal, alkaline, oxidant), constituent parts (protons, electrons) and integrant parts (cortex, nucleus). Hence, according to Bueno:

1) Every system is a whole composed of parts (the system bases) which are themselves complex wholes with their own parts.

2) Arrangement into a system does no take place directly among the bases, but rather through the parts of those bases. The interaction between the parts of the bases is responsible for global systemic arrangement.

Thus, the essential difference between systems and other types of wholes (particularly, structures) lies in the way systemic arrangement takes place. As already stated, arrangement is not a mere classification of the system bases according to certain more or less pertinent features, nor is it a mere listing of the relationships between them. Systemic arrangement implies that the interrelations between the system bases are given through the parts of those bases. In the aforementioned case of the periodic system, the relationships between the different chemical elements in the table are given through certain parts of those elements (atomic number, electron configuration, chemical properties), and only through them does systemic arrangement take place. The requirement of an “interaction between the parts of the system”, which is present in certain definitions of system (Miller 1995, p. 17; Skyttner 1996, p. 35), is but a consequence of that mereological structure, where changes in one of the bases may affect the rest of the bases and even the whole system. From this perspective, the so-called "black box systems", in which only the inputs and outputs of the black box are taken into account and their internal structure and operating principles are unknown, are "alleged or suspected" systems more than actual systems since the systemic arrangement between their bases remains in the dark. Mario Iván Tarride has argued on the necessity of opening the black box to know its internal structure and functions (Tarride 2006).

A system is an integrated whole in which certain changes occurring in some of its parts affect other parts and the system as a whole. For this reason, when proposing a definition of system, the mechanisms coordinating the parts or bases of the system, and unifying and governing the systemic whole, must be taken into account. Accordingly, a complete understanding of a system requires supplementing the analytical path from the whole to its parts (the analysis of the mereological structure) with the synthetic approach showing the mechanisms of systematization.

When confronting the task of understanding the process of systematization, the main challenge is proposing a general criterion which probes to be effective in characterizing both technical (and technological) systems, built by men, for instance, machines, and systems independent of human subjects such as the scientific systems, for instance, the above quoted periodic system of chemical elements. The former are anthropic systems, since they cannot be understood without a reference to humans. Conversely, scientific systems are ananthropic: the solar system, the periodic system of chemical elements, or the geological systems are “natural” systems existing long before humanity appeared. Their truth does not depend on their utility.

The solar system is constituted as a scientific theorem with Kepler's laws and Newton's principles. The bases of the system are the sun, the planets and the satellites, and the parts of those bases are their own determinants: mass, distance to the sun, speed, acceleration, kinetic energy, apparent trajectory, etc. Kepler's laws coordinate the bases. The first two laws, set out in the *Astronomia Nova*, establish that the elliptical orbits of the planets share one of the foci where the sun is located (first law), and that their orbital velocities obey the well-known law of the areas (second law). The third law, formulated ten years later in the *Harmonices Mundi*, coordinates among themselves the orbital periods that keep a constant proportion with the semimajor axis of their orbits. Newton, in the *Principia*, added more elements to this system with the mechanical interpretation of the forces, masses and accelerations of the bodies. Although classical mechanics is built by humans, everyone admits that the solar system has no purpose, and is a scientific truth, regardless of its practical uselessness. The ananthropic nature of its truth makes it, once proven, become part of what we consider the ontological reality of the world (Bueno 2013).

To understand the internal relationship between the laws and principles of sciences and the purposive goals of techniques and technologies I will hark back to an idea from Aristotle who, in *Eudemian Ethics*, established that goals in the productive sciences (techniques) play the same role as principles in the theoretical sciences (Aristotle’s paradigm of these sciences is geometry):

[…] as in the theoretical sciences, the hypotheses are the starting-points, so in the productive sciences, the end is the starting-point and hypotheses. Given that this thing needs to be healthy, if that is to come about, such-and-such must be the case, as in the other spheres [geometry], if the angles of the triangle are equal to two right angles, then so and so must be the case. (Aristotle, *Eudemian Ethics*, 1227b 28-33).

Following Aristotle’s lead, I contend that objectives and practical purposes organize any given technical system, such as a simple machine (a lever) or a procedural system, such as an army in combat, a legal system or a system of government. The same is true for technologies: the goal of transporting loads by air from one place to another is the organizer of the aircraft as a system of integrated parts. In such case, the various sciences (aerodynamics, chemistry, thermodynamics, electronics, etc.) and techniques involved are put to the service of that goal. The same can be said for the goal of healing the sick in relation to the technologies and sciences involved in the practice of medicine. In those cases, there is a purposive goal linked to the human subjects using those techniques or technologies.

In natural and formal sciences, systems (coordinate systems, the system of equations, the solar system, the *systema naturae*, the systems of an organism, geological, thermodynamic, ecological, systems, etc.) lack a purposive goal linked to a subject. The existence of a God-engineer is not a scientific hypothesis and all the scientific theorems involved in those systems would continue being truth regardless of their usefulness. In those systems, the laws and principles of the related sciences are responsible for coordinating the bases. Laws and principles lend unity to the system. The principles of chemistry (the principles of conservation, constant proportions and multiple proportions) ensure the unity of the periodic system and the relationships between their bases (the chemical elements). Kepler's famous three laws and Newton’s principles do the same in the solar system. The laws of biology (evolution, cell theory, chromosome theory) play that role in relation to biological systems. Furthermore, as I will discuss in sections six and seven, any given science can be considered to be a system, the bases of which are its theorems coordinated by the scientific principles.

To summarize, let me outline the determinants of any system:

(1) A system is a whole (configurational or processual) in which there are always at least two mereological levels: first, the system bases, and second, the bases parts since the bases are themselves also complex wholes with their own parts;

(2) In a system, systemic arrangement between the bases takes place through the parts thereof.

(3) In technical and technological systems, those parts are coordinated as a result of the unity generated by the purposive goals, whereas in scientific systems (and in any given science taken as a system), coordination occurs through the scientific laws (and principles). Theoretical laws and principles and practical goals are the “systematizers”, i.e. the mechanisms governing the coordination of the system’s bases.

Consequently, the complexity of the two mereological levels and the way coordination between the bases of the system takes place (through goals or scientific laws and principles) are the distinctive features of systems as compared to sets, aggregates and structures.

Accordingly, every system can be described as structure, but not all structures are systems. A system implies the aforementioned two mereological levels. Furthermore, the interrelation between the bases of the system arises through the parts of those bases due to the existence of certain goals or scientific laws or principles. Nevertheless, there are many structures, either configurational or processual, that do not meet these requirements, for instance the architectural structures (vaulted, framed, suspended, lintelled), the musical structures (sonata, concerto, fugue), the narrative structures (tale, novel, drama, epos). In all those structures, the demiurge assembles the parts without the need for the relations between these parts to be determined by the relationships between their subparts, which allows a wide discretion in the composition.

**4. The classification of systems**

4.1 External versus internal classifications

The classification of systems I will put forward below is not merely an empirical inventory or laundry list. Classifying triangles by color or material is extrinsic to geometry, whereas classifying triangles by relative length of side (equilateral, isosceles, scalene) or by angles (obtuse, acute, and right) is intrinsic to geometry. When seeking to establish an internal classification, identifying the core constitutive parts of the structures being classified, as occurs in triangles classified by side or angle, is the key. Only once the minimal constitutive parts of a given structure have been established can a certain degree of completeness in the classification then be possible.

Let me quickly touch on two examples of external classifications. As relevant as it is to physics and thermodynamics, the classification of systems into three types -open, closed and isolated- cannot be deemed applicable to other systemic contexts, as it can be used referring to sets and other wholes other than systems. Bailey’s classification between conceptual, concrete and abstract systems is grounded on a controversial epistemological distinction (concepts, things and abstractions) that is not internally connected to the architecture of a system (Bailey 1994).

In what follows I will put forward three classifications of systems, which are internal to the main determinants of any system, as stated above in section three. Relatedly, an evaluation of the potency of the proposed classifications may serve to corroborate the appropriateness of the foregoing determinants of systems.

4.2 Systems of relations and systems of operations (procedures)

The idea of system has two moments, which I will call *objectual* and *subjectual*. In the objectual moment, a system is primarily a part of reality existing independently from the human subject, even if the subject has contributed to its construction. The solar system, the periodic system of chemical elements, the nervous system, the immune system and the like may serve as examples. Technical and technological systems are often also systems in their objectual moment, and examples are provided by automatic machines, computer operating systems, electrical systems, and the financial system, among others. The objectual moment emphasizes the relations between objects without regard to human subjects and their operations.

On the other hand, the idea of system has a subjectual, operative moment, under which "system" refers to a methodology or procedure followed to perform a task or achieve a particular purpose. The lists of procedures followed by aircraft pilots may serve as illustrations: these are repertoires of operations that must be performed in a certain way and in a given order. Of course, this procedural moment is closely related to the objectual system or systems the aircraft pilots are handling. The same could be said of legal, political, electoral, military, health and communications systems. In many contexts, the need to act in a "systematic" fashion means that one must follow a given procedure, a system of operations, so as to achieve comprehensive control over the corresponding objectual, relational system.

4.3 Processual systems and configurational systems

Since a system is a special type of whole, the distinction between processual totalities and configurational totalities also applies to systems. The system of the five regular polyhedra, the coordinate system, the system of linear equations, the Hamiltonian system, Mendeleev and Meyer’s periodic system and Linnaeus' fixist *systema naturae* are examples of exclusively configurational systems. In those systems, one cannot speak of the system’s "functioning", except obliquely. For their part, processual systems develop in time, without prejudice to any possible dynamic stability (homeostasis, homeoresis, enantiostasis). Thus, for example, many mechanical, biological, geological, meteorological, kineto-chemical, technical and technological systems are processual. Of course, configurational features are never entirely absent in processual systems and, although there are examples of pure configurational systems (taken from the formal sciences or from more or less conventional synchronous perspective of the natural sciences), there are no processual systems that lack a configurational counterpart.

4.4 The classification of systems based on the mechanisms coordinating their parts

As already stated in the third section, a system requires a whole and its corresponding parts (the system bases) that are, in turn, complex wholes, and these bases must to be coordinated in some way through their parts. As above stated, coordination between bases is possible as a result of purposive goals in techniques and technologies, and of laws and principles in the sciences.

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| Table 1  Modulations of the idea of finality | | | | |
| Type of finality | Configurational  finality  Teleomorphism | Processual finality  Teleocliny | | |
| Non-purposive  finality  (no demiurge)  Sciences | animal mimicry  anatomy of sexual reproductive organs | mitosis  speciation  self-organizing chemical system  Hayek’s catallaxy | homeostasis  homeoresis  enantiostasis  allostasis  dynamic equilibrium | apoptosis  extinction  corruption dissipation  disgregation |
| Purposive  finality  (demiurge)  Techniques  Technologies | adjusting parts and forms of a technical or technological artifact | evolutionary computation  making of a technical or technological artifact | steam engine governor  servomechanisms of self-steering aircraft | traps  weapon system  political parties promoting secession |
| Type of process | (not applicable) | Constitutive | Conservative | Consumptive |

An analysis of the various modulations of the idea of finality may help us understanding the internal link between technical, technological, and scientific systems. Taking cues from Gustavo Bueno’s theory, Table I shows the most significant modulations of the idea of finality (Bueno 1992). At the head of the rows, I distinguish non-purposive finality, which is characteristic of the strict sciences, from purposive finality, which is characteristic of techniques and technologies. Purposive finality occurs when the process or form considered is determined by a planning intelligence who foresees the goal: a purposive aim directs the course and/or arrangement of parts, as occurs in the design of a machine. Non-purposive teleology implies that the directive principle of the finalistic process or form is a result: in biology, finality is seen as a consequence of genetic changes and natural selection. Attempting to explain organic teleology by means of the intelligent design of a constructing subject goes against the principles of biology and is deemed anthropomorphic and metaphysical. In the same critical vein, the ideas of emergence, autopoiesis and self-organization would have to be thoroughly revised by taking into account the environmental determinants acting on supposedly emergent, self-made and self-organized systems and how those environmental determinants change over time (cfr. Alexander 1920; Varela and Maturana 1980; Capra 1996). Albeit in a different setting, notable in this connection is the significant role played by environmental determinants in the cognitive development of organisms as advocated from an enactivist and constructivist perspective (Vygotsky 1978; Glasersfeld 1989).

At the head of columns, I differentiate between teleomorphism and teleocliny. Teleomorphism, or configurational teleology, occurs when a given form (for instance, the way a predator’s mouth and teeth are arranged) is understood in relation to a given aim (chasing, chewing). Animal mimicries to protect against enemies serve as an example. Max Scheler coined the term “teleocliny”, or processual teleology, in reference to certain processes developing in time whose parts or phases are arranged so as to reach a goal (Scheler [1928] 1969, p. 13): mitosis serves as an illustration of a teleoclinic process.

In turn, teleocliny is subdivided into three types, based on the results of the process under examination: constitution, conservation or consumption. Examples of constitutive teleocliny are mitosis, speciation and “evolutionary” computation. Conservative teleology occurs in most processes of homeostasis, homeoresis, enantiostasis, thermoregulation, pH, osmotic pressure, and salt concentration maintenance, etc. Consumptive teleology includes apoptosis, extinction, death, corruption and bombs, to cite but a few.

Based on this theory of the modulations of finality, it is possible a better understanding of the Aristotelian idea that the principles and laws of theoretical disciplines and the purposive goals of practical activities play an equivalent role. As mentioned, the principles and laws of scientific systems and the goals of technical and technological systems establish the coordination between the bases, and give the system its sui generis unity. In techniques and technologies, purposive aims organize the system: the goal of providing location information organizes and coordinates the Global Positioning System (GPS) and the objective of landing an aircraft in low visibility organizes and coordinates the Instrumental Landing System (ILS). In scientific systems, laws are responsible for system organization: Newton’s principles laws govern the solar system as the laws of Liebig, Mitscherlich and Shelford regulate ecological systems.

**5. The role of goals in technical and technological systems**

The artifacts that are the products of techniques and technologies (buildings, tools, machines, instruments) are complex wholes composed of parts. Such parts may also themselves be complex wholes and in turn be analyzed in parts. The unity of a technical or technological device is given by the purposive aim pursued, which coordinates those two (or more) mereological levels resulting in a more or less complex system. Thus, we speak of a computer system, a weapons system, a machine as a system (notably steam engines as a model of the thermodynamic system), a railway system, an instrumental landing system (ILS), an anti-lock braking system (ABS), a global positioning system (GPS), etc. Systems engineering involves analyzing the traits common to the design of all manner of technical and technological systems. Mario Iván Tarride has argued about the teleological operationality as to define those systems (Tarride 2006).

Techniques and technologies do not always give rise to artifacts or products, but rather look to achieve certain results. The healthcare system seeks to turn the sick in healthy individuals, military systems (such as the five-ring system in Warden 1995) serve to win wars, electoral systems seek political representation, the international stock exchange system seeks to facilitate certain types of businesses and capital movements. Judicial, tax, banking, correctional and educational systems also pursue other purposes in human praxis. In such cases, purposive goals also act as coordinators of the various mereological levels and the parts of each system. In this context, Checkland`s development of soft systems methodology (SSM) has proven to be of great interest (Checkland 1994). Human languages of words belong under technical systems, while the scientific comparative study of those languages (linguistics) is a science endowed with theorems and principles (*salva veritate*).

When analyzing a particular work of art, it is common to refer to its structure (the pictorial, sculptural, architectural, theatrical or musical structure), although the idea of ​​system is not used in this context. In the substantive arts, there are no principles (though there may be rules) as there are in the sciences, nor are there purposive aims as there are in techniques and technologies. As such, the arts lack one of the features I have deemed as necessary determinants of any system: laws and principles (science) or goals (techniques and technologies). Substantive arts, to the extent that they deviate from the prose of common life, embody a kind of "finality without end", to put it in Kant’s words: they are autotelic, since they have the goal in themselves (Kant [1790] 2007, §10-17). The substantive works of art are not useful, but they are offered to the subjects to be explored. Accordingly, works of substantive art are not systems, although they may be endowed with a certain structure (since structures can be constructed in the absence of principles and goals). The proposed criterion for characterizing systems is, then, indirectly proved by the fact that we do not use the idea of system to refer to individual substantive works of art.

Another, different issue is the existence of a “system of the arts” thus named to designate a philosophical classification of all the existing arts, assuming they comprise a system with common principles. In this case, the idea of system is being used to designate this general classification of a philosophical nature, even though each separate substantive work of art is not considered to be a system.

Moreover, the idea of system may appear in certain cases associated with the arts, such as when speaking about the tonal system in music. This is because many arts involve the existence of related techniques and sciences, which may include systems. However, once more, the individual substantive work of art (a sonata or concerto), albeit structured, is not a system.

**6. The role of scientific laws in the systematization of theorems**

As stated above, scientific laws act as systematizers of scientific theorems, coordinating their parts through their subparts. As shown in proposition 47 of the first book of Euclid's *Elements*, the Pythagorean theorem is a system whose bases are the right triangle and the squares built on its sides. These bases consist of parts (segments, vertices, angles, areas, rectangles, triangles) such that, in constructing the theorem, we make multiple adjustments among those parts either through contiguity (between lines, squares, triangles, rectangles, etc.) or isological identity (between lines, angles, areas, etc.). Although we change the size of the sides and the acute angles, the system of identities is conserved, and all the subjective, phenomenal aspects of the operations are neutralized. Although the theorem has a human genesis (with technical antecedents in the work of masons, harpedonapts and architects), it is constituted as a non-purposive geometric theorem since, as demonstrated, it is true regardless of its practical usefulness.

In the Kepler-Newton theorem, the bases of the solar system are the sun, planets and satellites, and the determinant parts of those bases are their mass, distance to the sun, speed, acceleration, kinetic energy, apparent trajectory, etc. Kepler's and Newton’s laws coordinate the bases through their determinant parts, stating certain relationships between their velocities, distances, times and trajectories.

In the periodic system of chemical elements, the bases are the simple elements, and the determinant parts of those bases are their atomic numbers, mass, electron configuration, number of electrons, oxidation states, etc. Mendeleiev’s and Lothar Meyer’s laws of periodicity coordinate the elements through their determinant parts, stating certain relationships between them. For instance, elements in the same column (groups) share certain determinants properties and parts, such as atomic valence; elements in the same row (periods) have a similar mass.

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| Table 2  Scientific theorems as systems | | | |
| System | Bases of the system | Parts of the bases | Systematizers |
| Pythagorean theorem | Triangles, squares, rectangles | Sides, angles, areas, vertices | h2 = c2 +c2 |
| Solar system | Sun, planets, satellites | Angles, times, positions, trajectories  Mass, velocities, accelerations, forces | Kepler / Newton laws |
| Periodic system of chemical elements | Chemical simple elements | Atomic number, mass, electron configuration, number of electrons, oxidation states | Mendeleiev’s and Lothar Meyer’s laws of periodicity |

**7. The role of principles in the systematization of a given science**

Furthermore, I argue that any strict science is itself a system and assume that the theorems of a science are the complex bases of this system, while the principles are responsible for coordinating that multiplicity of theorems.

In fact, in the field of a science, all theorems must therefore share the same principles. For example, as regards classical physics, all physical theorems relating to the different types of movements, accelerations, shocks, energy transformations, etc. must adhere to the three well-known principles of mechanics: the principle of inertia, the principle that states the proportionality between force and acceleration with mass as a constant and the principle of action and reaction. Once integrated in the universal gravitation of Newtonian mechanics, the sun and the planets in Kepler’s laws follow the three Newtonian principles, which coordinate Kepler’s solar system theorem with Galileo’s theorems about falling bodies, inclined planes and projectiles since all these theorems share these principles in their internal constituent parts. This Newtonian coordination of theorems through their parts has been traditionally understood as the unification of celestial and terrestrial mechanics and marks the constitution of the unified field of classical physics. Those Newtonian principles are the formulation of certain identities necessary for the fields of science to unite as scientific systems.

As regards 19th century classical chemistry, all theorems about chemical reactions (oxidation, reduction, distillation, dissolution, etc.) leading to the analysis of chemical compounds in their simple elements share the principles of Dalton, Proust and Lomonósov-Lavoisier, which coordinate the theorems governing each type of chemical reaction, just as Newton's famous three principles coordinate the theorems of classical mechanics.

In terms of Euclid’s *Elements*, there are multiple theorems (the theorem of the diametrical triangle, Thales' theorem, the Pythagorean theorem and so many others) that have their own parts (lines, curves, angles, parallels, areas, etc.). At the very beginning of the *Elements*, Euclid states certain principles (common notions, axioms and postulates) coordinating those theorems through their parts, such as the famous fifth postulate of the parallels. In his demonstrations of the theorems, Euclid is appealing to those common notions, axioms and postulates in specific places of each theorem, in such a way that the theorems coordinate with each other.

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| --- | --- | --- | --- |
| Table 3  Sciences as systems | | | |
| System | Bases of the system | Parts of the bases | Systematizers |
| Classical Physics | Terrestrial and celestial mechanical theorems | Sun, moon, planets, falling bodies, projectiles, etc. | Three Newtonian principles |
| Classical chemistry | Theorems governing different chemical reactions | Chemical elements and compounds | Dalton’s, Proust’s and Lavoisier’s principles |
| Euclid’s geometry | The various theorems of the *Elements* | Circles, squares, rectangles, circumferences, polygons | Euclid’s axioms and postulates |

Contrary to popular belief, the scientific principles function is less the "foundation" of a science and more the "coordination" between the various theorems of a given scientific field. The necessity of the coordination of the theorems of a given science under the same principles arises when it reaches certain degree of maturity and has managed to build a set of theorems. Scientific systems are eminently human when considering their etiology, as who conducts the science are humans, using symbolic systems, apparatus, technical systems, and the like. At any rate, laws and principles of the sciences, as they are independent of the subjects, as they are objective, do not depend on human purposes, and the existence of a purposive God-engineer cannot be deemed a scientific explanation.

One might think that sciences are also purposive activities aimed at explaining certain regions of reality. However, the purpose of scientific researchers is paradoxical since they built certain systems (theorems and principles) not depending on the subject's goals, being anantropic, existing even once the subject disappears.

Purposive practical goals, scientific laws, and scientific principles coordinate the bases of the respective systems and act as true "systematizers", as the mechanisms directing systemic arrangement. Table 4 summarizes the differences between technical and technological systems, scientific systems, and science taken as a system. In each case, the type of systematizer involved is specified, and examples are provided of systems with their systematizers.

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| --- | --- | --- | --- |
| Table 4  Systematizers: mechanisms directing systemic arrangement | | | |
|  | Systematizer type | Examples of system | Examples of systematizer |
| Techniques and technologies | purposive goal | GPS (global positioning system)  ILS (instrumental landing system) | providing location information  landing without visibility |
| Scientific systems | scientific law | solar system  periodic system of chemical elements | Kepler’s laws  **Mendeleiev’s and Lothar Meyer’s laws of periodicity** |
| Sciences as systems | scientific principle | classical chemistry  classical mechanics | Dalton’s, Proust’s, Lomonósov-Lavoisier’s principles  Newton’s three principles |

**8. The sciences as ontological categories: hyperreality and categorial closure**

The philosophy of science I take as reference in this paper is Gustavo Bueno’s idea of categorial closure (Bueno 2013). According to Bueno, in the theorems and principles of the strict sciences, human operations are completely eliminated or neutralized and, consequently, the constructed theorems and principles are structurally ananthropic. Once set out, a theorem like Kepler’s or Newton’s about the circulation of bodies in the solar system becomes a universal, objective scientific truth independent of the human subject, one that refers to a real ananthropic system in a certain closed field of phenomena. Long before there were men or living beings on Earth, the planets had been rotating for eons in accordance with Kepler's laws and Newton's principles, and they will continue to revolve according to those laws and principles, even in the event that humanity disappears. This is not an issue depending on humans and their a priori forms of knowledge (were such a thing to exist). The theorems of the strict sciences are anantropic and impose themselves on the human subject.

In this regard, certain readers may admit that while the solar system is a “real system out there” (independent of human thought), the system of chemical elements and biological classification systems are just “bodies of knowledge”, and may accuse me of failing to distinguish between what exists in nature and the theories that people make about it. Countering those claims, I will defend that, from the tenets of the theory of categorial closure, the system of chemical elements or the biological classification system are as real and independent of humans as the solar system. Materialism denies the idea that science is a mere representation of reality; on the contrary, in many ontological regions, reality itself is included in scientific truths and theorems. At this juncture, materialism posits the existence of a sort of “hyperreality” accounting not only for what directly strikes our senses (which defines the epistemological viewpoint focusing on perceptions, appearances, phenomena, etc.), but also for everything that operates, exists and causally determines other things, even if not directly perceived, such as electromagnetic waves, atomic structures, geometric relations and evolutionary processes. The most characteristic function of science, then, is not explaining what exists in nature or constructing models to explain natural phenomena, but rather constituting certain regions of hyperreality.

As stated above, sciences are objective systems of theorems coordinated by ananthropic scientific principles. This is grounded on the theory of categorial closure’s assertion that strict sciences give rise to ontological categories, which inform us about the ontological structure of reality, while still allowing that sciences are human-made historical institutions. The question then becomes one of determining how is it possible to come to ontological categories not dependent on the forms of human knowledge (Kant) or on the structure of the human language of words (Husserl, Ryle), but rather on reality itself. The theory of categorial closure considers this possible since the principles of the strict sciences are also objective and ananthropic. The principles coordinating the system of a strict science, such as the famous three principles of classical mechanics, are also independent of the human subject: the principle of inertia and the principle of the principle of action and reaction are ananthropic since they do not depend on the human subject. The same occurs with the principles of thermodynamics, classical chemistry, geology and biology. Bueno interprets this fact as a clear indication (the only one that can be taken as objective and universal) of the very structure of reality and the ananthropic ontological structure of the world.

Bueno's idea of ​​categorial closure has the advantage of giving a clear and intelligible explanation of the reasons why the categories of reality are precisely those indicated by the existence of strict sciences: they are the results of the history of the sciences (which are universal and constitute reality), a history determining which sciences exist independently of human subjects, for humans cannot make a strict science anywhere they so desire. Thus, the system of a given science informs us about the world’s organization based on the results of all the transformations taking place in it. The existence of a field of a science does not depend on specifically human exteroceptors or on the structure of the thousands of existing word-based languages; rather, it is ananthropic, objective and independent of the human subjects and, accordingly, it provides us invaluable, unique information about the structure of reality itself.

At any rate, it should also be explicitly acknowledged that sciences are not perfect, coherent bodies. Their relative dynamic stability depends on their operational closure (which implies a wide range of operations with objects) and on the fact that their scientific principles ensure ananthropic coordination of their multiple theorems. There are always relatively anomalous regions in the sciences in progress: the system exhibits a certain degree of operational and relational closure but it is not completely closed since such closure would mean that the corresponding science would be finished and perfect. However, the sciences in progress are "infected" and not perfect totalities. Deductive logical reasoning is linear and, as such, when a link in the chain breaks, the deduction collapses. The real sciences do not work that way: the field of science is rather like a network of connections and identities with multiple nodes supporting a certain degree of rupture or anomaly, since the "efforts" are distributed throughout the network and the system’s unity can coexist with holes or faults in certain regions.

So far, I have been referring to strict sciences since human and ethological sciences pose special problems. In these sciences, it is not difficult to find certain theorems in the form of empirical laws: the Weber-Fechner law and the laws of operant conditioning in psychology, the law of diminishing returns, Petty’s law, the iron law of wages in economy, Brugmann’s law or the palatal law in linguistics, among others. Problems arise when it comes to coordinating the theorems of a field by means of general principles, as a plethora of differing principles are proposed by different schools, and no agreement or unanimity about principles is reached. Such conflicts can be seen in psychology, with behaviorism pitted against cognitivism or psychoanalysis, in economics, with monetarism against Keynesianism or post-Keynesianism and in linguistics, with structuralism against transformational grammar. As an aside, this is one reason why the epistemological status of the human sciences poses special problems.

To end this section, I will add some brief remarks concerning the impossibility of a single system of sciences since a unique system of sciences would imply the existence of certain principles shared by all sciences. Materialism acting in this paper implies the defense of ontological and methodological pluralism in line with certain philosophers of the Stanford School (Dupré 1993 and 1996, Galison and Stump 1996, Cartwright 1999).

Peter B. Checkland has vindicated the so called “system paradigm” in order to tackle real-world unstructured problems, as opposed to the defined problems of scientific laboratories (Checkland 1976). In my view, those real-world problems are practical issues directed by aims and purposes and, consequently, may be understood as a variety of technical and technological problems (including issues of social technology).

**Conclusion**

From an ontological point of view, a system is a whole composed of parts that we have called “bases of the system”. The bases, in turn, are complex wholes composed of parts. In this paper, I have argued that, in the systems, unlike what happens in other wholes (aggregates, sets, structures), the bases are related to each other through their parts. To date, there was no criterion to unify man-made, anthropic systems (such as technical and technological systems), and non-purposive systems (such as those described by the natural and formal sciences). In the text, I have proposed a criterion to understand the similarities and differences between those two types of systems: In technical and technological systems, their bases are coordinated as a result of the unity generated by the purposive goals, whereas in scientific systems, coordination occurs through the scientific laws. Scientific laws and practical goals are the “systematizers”, i.e. the mechanisms governing the coordination of the system’s bases. The fundamentals of this criterion, and the unity of the idea of system, lie on the two modulations of the idea of finality: purposive, anthropic finality is typical of techniques and technologies ruled by practical objectives, while non-purposive finality is at work in the scientific systems.

Furthermore, making use of this idea of system, and following the tenets of categorial closure theory, I have argued that a well-formed, strict science (such as physics, chemistry or mathematics) is an ananthropic system whose bases are its theorems that are coordinated by its specific principles.

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