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LOGIC AND THE LAWS OF THERMODYNAMICS

LA LÓGICA Y LAS LEYES DE LA TERMODINÁMICA

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Abstract: The paper illustrates the possibility of relating the fundamental laws of logical thinking with the basic principles to thermodynamics. According to this hypothesis, the idea of a "transcendental realm" that hosts the a priori categories of understanding is no longer needed, because human logic can be regarded as the result of a process of fine-tuning in our mind's ability to perceive of patterns of identity and change in nature.

Key words: A priori categories, thermodynamics, logic, identity, difference.

Resumen: El artículo ilustra la posibilidad de establecer una relación entre las leyes fundamentales del pensamiento lógico y los principios básicos de la termodinámica. Según esta hipótesis, la idea de un "ámbito trascendental" que albergue las categorías a priori del entendimiento resulta innecesaria, porque la lógica humana puede comprenderse como el fruto de un proceso de refinamiento paulatino en la capacidad de la mente para percibir patrones de identidad y cambio en la naturaleza.

Palabras clave: Categorías a priori, termodinámica, lógica, identidad, diferencia.

One of Immanuel Kant's most conspicuous claims points to the existence of *a priori* concepts in the human mind. A deep philosophical question is involved in his attempt at integrating rationalism and empiricism by showing that our understanding is endowed with a series of categories that have been mysteriously transmitted from one generation to another: is it possible to pro-

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ve that there are *a priori* categories inside the human spirit? In case it is, what is their scope and what are their limits?

The importance of Kant's transcendental deduction has been outlined by several authors.[2] In fact, over the last decades there has been a renewed interest in Kant's transcendental argument.[3] In light of contemporary literature, it is clear that studying this dimension of Kant's epistemology is essential for grasping the nature of his entire philosophical project.[4] However, even the advocators of Kant's approach, like Henry Allison, admit that his transcendental deduction of categories is one of the most disputed elements of his theory of knowledge.[5]

In the section called "transcendental analytics" of his *Critique of Pure Reason*, Kant states that the goal of his research resides in decomposing the totality of our *a*[6] *priori* knowledge into the elements of pure knowledge that are present in our understanding. Reading the works of David Hume had helped him awake from his long dogmatic dream: the belief that the traditional concepts of Metaphysics were capable of broadening our knowledge of the empirical world. Hume's critique made him realize that these notions are mere instruments of understanding, whose use does not lead us into any reliable result unless it is conjugated with the data drawn from experience. Purely speculative Metaphysics builds a prison of concepts; it cannot follow the path of rigorous and convincing science. The only valid and testable knowledge stems from the study of empirical reality, although Kant, still strongly attached to the ideal of a science blessed with the power to reach the levels of universality and certitude that empirical reality cannot offer, thinks that the human mind possesses a set of innate categories. When rightly articulated with the information extracted from physical reality (Van Cleve argues that Kant's transcendental deduction manifests the intrinsic necessity of applying the

2. Cf. Förster, E. (ed.): *Kant's Transcendental Deductions*. Stanford: Stanford University Press, 1989.

3. Cf. Bossart, W.H.: "Kant's Transcendental Deduction" in *Kant-Studien* 68, 1977, pp. 383-403; Ameriks, K.: "Kant's transcendental deduction as a regressive argument" in *Kant-Studien* 69, 1978, pp. 273-287.

4. Cf. Stepanenko, P.: *Categorías y Autoconciencia en Kant. Antecedentes y Objetivos de la Deducción Trascendental de las Categorías*. Mexico City: UNAM, 2000; Strawson, P.F.: *The Bound of Sense. An Essay on Kant's Critique of Pure Reason*. London: Methuen, 1973.

5. Cf. Allison, H.: *Kant's Transcendental Idealism: An Interpretation and Defense*. New Haven: Yale University Press, 2004, p. 134.

6. Cf. Kant, I.: *Critique of Pure Reason*. Cambridge: Cambridge University Press, 1998, 201ss.

categories to experience)[7], these notions establish the foundation for the possibility of any science worthy of such a name, at least in Kant's terms.

We know that the Sun has risen today, but how can we be sure that the light of dawn will also appear tomorrow? Through induction, through the accumulation of experiences, we can only achieve moral certitude based upon custom. Induction is therefore incapable of dissipating the skeptical phantoms conjured by Hume. Kant is looking for absolute certainty, and in this passionate search of universal validity induction is ostensibly unable to satisfy his high aspirations. The quest for pure concepts inserted in the human mind, virginal ideas that remain unpolluted by the arbitrariness and mutability of the sensible world, is so narrowly connected with his ideals of universality and certitude that it is sometimes difficult to discover whether Kant bases his analysis upon the objective investigation on the nature of the human mind or whether he is moved by a profound (yet ungrounded) emotional adherence to these epistemological values. In any case, his transcendental analytics will try to systematically elucidate these elementary concepts, capable of covering the totality of pure understanding.

In his *Metaphysics* (book V, chapter 7), Aristotle had elaborated a list of categories or basic modes of attribution, but Kant considers his casting too vague and imprecise, the fruit of an exercise of trial and error rather than the result of a methodological inquiry. In his opinion, it must be possible to discover the set of basic categories inherent to any human understanding, the "software" with which our minds are endowed since the beginning and whose concepts integrate a unitary whole. These categories emerge as the operating rules into whose realm any possible object of the human experience is subsumed: they underlie all forms of judgment. As operators of understanding, categories generate judgments and they also imply a judgment about reality.

One of the presuppositions of Kant's argument is the following: if it exists, this catalog of categories must be coherent and systematic, as pieces harmonized into a congruent mosaic. Let us agree on this audacious presupposition (increasingly dubious as we experience how volatile and incoherent the judgments of man can be, even the most elementary ones, even those reminiscent of the solidity of logic), for we shall show that the principal problem with Kant's attempt lies in the rigidity of his system, regarded by him as a self-subsisting unity. In case of being feasible, this option would simply curtail the possibilities of real human progress: our mind could not escape from a set of inexorable categories bounded to its

7. Cf. Van Cleve, J.: *Problems from Kant*. Oxford, Oxford University Press, 1999; for a discussion, cf. Gomes, A.: "Is Kant's transcendental deduction of the categories fit for purpose?" in *Kantian Review* 15/2, 2010, pp. 118-137.

understanding. No force could rescue us from this obscure prison of innate categories promulgated by nature through arcane decrees, and the evidence that the human being can conceive of spheres of reality and thought unimaginable for our ancestors would seem a Parmenidean illusion.

Kant's strategy to unveil the hard core of these *a priori* concepts that sustain universality and certitude in knowledge departs from studying the modes of judgment. A judgment is a "representation of a representation of an object"[8]: a function that ordains different representations on the basis of a common representation. When I judge something, I link a subject to a predicate. However, how is it possible to ascertain that we have obtained *all* the representations from an exhaustive analysis of the modes of judgment? How can we know that all these hypothetical categories are actually elementary, instead of stemming from a combination of more basic forms of judgment? The distillation of Kant's effort to identify the fundamental categories of the human mind leads us to twelve concepts: three categories of quantity (unity, plurality, totality); three categories of quality (reality, negation, limitation); three categories of relation (inherence and subsistence, causality and dependence, community); three categories of modality (possibility-impossibility, existence-inexistence, necessity-contingency).

However, there is a clear asymmetry between categories. In fact, there is a hierarchy of categories which is not highlighted by Kant. Three of the fundamental categories cannot be reduced into any other one: being, possibility, non-being. The whole realm of thought falls into a basic duality (being and non-being) and the sphere of possibilities as the infinite set of intermediary degrees between being and non-being. The other categories, any other concept that we feel tempted to regard as an elementary notion, is hierarchically subordinated to the spectrum which, from being to non-being, comprehends the realm of the possible. This idea resonates in Parmenides' identification of true knowledge with the concept of being, although he did not pay sufficient attention to the vast chain of intermediary degrees between being and non-being that are also susceptible to knowledge.

Hence, the primary opposition between being and non-being constitutes the fundamental category of the human mind. The other categories investigated by Kant emanate from this distinction through various combinations, as we shall show. His transcendental deduction is therefore essentially mistaken, for it does not contemplate the hierarchy of categories in an appropriate way.

If the human mind uses some basic rules of operation, there must be a cognitive advantage in elucidating them. However, the scope of this "re-

8. Kant, I.: *Critique of Pure Reason*. Cambridge: Cambridge University Press, 1998, 205.

search program" innately attached to the human mind can only be offered by the empirical world itself. The only plausible source from which this set of basic categories could have stemmed is the interaction of man (or any of our ancestors) with nature. Thus, it must empirical instead of pure -as Kant sought-. If we sometimes tend to consider it an immutable set of categories, it is because such a powerful bias towards rigidity obeys the limitations of our worldly experience: the deeper and greater my experience of the world is, the less rigid the fundamental concepts of my faculty of thinking will appear. In the dawn of our rationality, when our knowledge of the overwhelming complexity of the world was still precarious, extremely rigid categories filtered our imagination of the real and the possible. As our experience of the world was expanded and improved, this scheme became broadened (normally in an unconscious, non-reflective way), and the elementary concepts of mind adopted larger degrees of ductility. But the selecting factor resides in the world. Through science, our theoretical imagination has been multiplied exponentially, so that today we are capable of contemplating notions that centuries ago would have challenged even the most luminous intellects. Of course, some irreducible categories persist, from whose influx not even the most courageous and visionary minds can detach themselves: being and non-being. But this fatality does not correspond to any restriction imposed by the human spirit. Rather, it evokes the ineluctable structure of the world: we cannot change the very being of the world; we are therefore compelled to use some basic categories from whose shadow we could only escape in the improbable –not to say impossible- case of a radical subversion of the world and its fundamental laws.

The primary categories that can be derived from our experience of the world are subject to progressive refinements. Nothing prohibits their ramification into more sophisticated modes of judgment, in accordance with the realm of reality to which they are applied. However, their pillars are as solid and unassailable as the structure of the universe and the inviolability of its fundamental laws. Essentially, we can summarize these laws (whose succinct expression can be found in the laws of Thermodynamics) into two great groups:

a) The first is about the identity of the objects in the world. Experience, even in its most rudimentary manifestations, informs us that in reality many bodies remain identical to themselves. The conscience of identity of one object with itself was founded upon the evidence offered by our interaction with the world. No matter how distressing and inexplicable some changes could be, the overall aggregate of our experiences

pointed to one fact: a significant part of the world conserves its structure and powers. The metaphysical notion of "substance" reminds us of an important intuition: within the totality of worldly phenomena, an important fraction of its elements preserves its identity and resists any attempt of relevant modification. The thermodynamic correlate of the idea of identity (the permanence of an object in its own ontological realm) can be found in the law of conservation of energy.[9] In thermodynamics, it is useful to express this principle as implying that the change in the internal energy of the system U must be equal to the heat added to the system minus the work done by the system ($\Delta U = Q - W$). However, this result points to a more general and profound law of nature, namely the symmetry between energy and time as two canonically conjugated variables whose product yields units of action: the total energy of an isolated system remains constant.

b) In the laws of Thermodynamics we find a magisterial synthesis of the great theoretical and technological developments of 19th century energy physics. Nevertheless, this science is incapable of explaining a vast array of material phenomena if its reasoning is based solely on the law of conservation of energy. Soon, it became patent that an additional law was needed to understand how thermodynamic systems work. This second law included a mysterious quantity, baptized as "entropy" by Rudolf Clausius. Its variation between states A and B is defined in terms of the quantity of heat and the temperature of a system.[10] Theoretical progress in Thermodynamics and

9. A technical definition of the first principle of Thermodynamics can be put as follows: "The work needed to change an adiabatic system from one specified state to another specified state is the same however the work is done" (Atkins, P.W.: *Physical Chemistry*. Oxford, Oxford University Press, 1994, p. 61). The second law could be expressed in this way: <<The entropy of an isolated system increases in the course of spontaneous change>>. The third law of Thermodynamics states that it is impossible to reach absolute zero in a finite number of steps. Sometimes a "zero principle" of Thermodynamics is added, according to which <<if two systems are in thermal equilibrium with a third one, they are all in thermal equilibrium>>. See Atkins, P.W.: *Four Laws That Drive the Universe*. Oxford, Oxford University Press, 2007.

10. Although thermodynamic entropy (either in the classical sense given to it by Clausius -based on the macroscopic properties on the system-, the statistical and micro-level description unveiled by Boltzmann or the quantum treatment proposed by Von Neumann) is not strictly equivalent to Shannon's information entropy, both concepts can be connected through the axiomatic approach to thermodynamics suggested by Lieb and Yngvason, as shown by Weilenmann, M. – Kraemer, L. – Faist, P. – Renner, R.: "Axiomatic relation between thermodynamic and information-theoretic entropies" in *Physical Review Letters* 117/26, 2016.

statistical physics contributed to the interpretation of entropy as a measure of the degree of disorder inside a system. The work of Ludwig Boltzmann[11] played a central role in the consolidation of this idea. In fact, the inexorable increase of this magnitude inspired a deep and illuminating analogy with the concept of time. Sir Arthur Eddington[12] referred to the second law in terms of the "arrow of time," inasmuch as it imposes asymmetry, irreversibility between an event and its consequences: if entropy necessarily increases in any spontaneous change, the universe travels in an inexorable direction and time is real; the future symbolizes the point towards which the law of entropy irrevocably leads any present physical system. If disorder could spontaneously decrease, a system could return to its past form without encountering the inflexible limits that drive it into the nebulous future. But the idea of time, the notion of change between antecedents and consequences, also suggests the concept of *difference*. If the first law pointed to the category of *identity*, understood as permanence of an object within its own realm (at least as permanence of significant parts of its structure), the second principle of Thermodynamics is intimately linked to the idea of difference: the limit between one state and another, capable of breaking the apparent and rigid unity expressed by the notion of "permanence." If that which is identical to itself changes, it therefore establishes a difference with respect to itself, adopting new manifestations: "it negates itself." The idea of difference cannot be separated from the concept of negation. In its basic logical form, it points to "non-being" (just as the idea of identity refers to "being").

The explanatory power of these fundamental laws of nature covers the majority of our relevant experiences. If our model is correct, they underlie the two primary categories used by our mind in its exploration of the world: being (identity, permanence, affirmation) and non-being (difference, change, negation). Of course, a huge and potentially infinite specter

11. If a system is in thermodynamic equilibrium, the probability of occupying a state i with energy E is proportional to a function of the kind e^((-E)/kT)/Z, where k is Boltzmann's constant, T stands for the temperature of the system and Z represents the partition function.

12. Cf. Eddington, A.: *The Nature of the Physical World*. Cambridge, Cambridge University Press, 1928.

of relations is associated with this duality: the realm of the possible. Hence, it does not consist of a unity as rigid as Parmenides had imagined in his famous poem, because the ideas of "being" and "non-being," of identity and difference, admit countless conjugations, leading into a much larger elenchus of potential judgments. However, the basic categories are comprised in three fundamental ideas: being, non-being, possibility (regarded as the set of variable degrees of relation between being and non-being). The remaining categories proposed by Kant emerge as ramifications of these three initial concepts and cannot be placed on the same epistemological level.

From being, possibility, and non-being and through the right combinations, we can unveil the other Kantian categories. The categories included by Kant in the realm of "quantity" are entirely reducible to our three primary categories. The notions of unity, plurality, and totality refer to the degrees of relation that can exist between being, possibility, and non-being: being considered in itself (or non-being) is necessarily unitary; if we contemplate the degrees of possibility between being and non-being, we open the window for ontological plurality; if we assume all the potential degrees between being and non-being, we suggest totality. Concerning the categories of quality, there is an immediate connection with being, possibility, and non-being (the real, its negation, and the gradual limitations or differences that can be recognized between both of them; limit is the obvious expression of difference). The categories of modality coincide with our three fundamental notions (impossibility is the conjunction of "non-being" and "possibility;" necessity is a property of the identity of being with itself and the non-identity of non-being with itself; contingency is profoundly linked to the variable degrees of possibility that can divide being and non-being). Regarding the categories of relation examined by Kant, the ideas of inherence, causality, and community arise from the conjugation of identity and difference: because time exists and reality is subject to change, its elements establish interactions and lose the impassibility that would define a static and closed universe (eternal, non-temporal, and incorruptible).

The thesis that our internal capacity of perception is fine-tuned through its interaction with the external world provides a very useful tool to escape from the objection of circularity that can be posed against any theory of innate ideas (or its analogous expression as *a priori* categories). It was Arnauld who, while discussing the principal tenets of Descartes' *Meditations*, realized that the acceptance of innate ideas succumbed to the objection of circularity:[13] if we admit that the human mind is endowed with a set of ideas

13. Cf. Manrique, J. F.: "La lengua universal de Leibniz" en *Saga-Revista de Estudiantes de Filosofía* 8/16, 2007, p. 116.

that have not been induced from the world, we must identify the cause of their presence in our intellect; only a being in possession of the attributes of perfection and goodness –God- can assure that these innate ideas will not deceive us in our interaction with the external world; however, and in order to prove the existence of God, those who support innatism must depart from the innate idea of God and follow the ontological argument, but at this point we reach a *petitio principii*, because we cannot know whether it is God who has placed the idea of himself in our mind before having proved his existence. Nevertheless, if the internal disposition of our understanding (Leibniz's *ipse intellectus*) simply grants us a virtually empty set able to formalize any input (a structure rather than a specific content), even the innate dimensions of this perceptive apparatus will be susceptible to a gradual fine-tuning elicited by the demands of the external world. Hence, it will be possible to obtain an increasing degree of certitude in our conviction that, in spite of filtering our perception of the world through innate structures, their flexibility always overcomes their rigidity.[14] Here we can contemplate the explanatory advantage of any mechanism based upon the duality between variation and selection, whose reciprocity avoids circularity, as it does not consecrate any of the two poles but defines each of them in its mutuality and complementarity with the other.

Kant is opposed to inducing the fundamental categories of the mind from experience. Given that he does not want to run the risk of depriving them from universality and necessity -features that the material world can never bestow-, he prefers to satisfy the demanding petitions of a rationalistic intellect. However, we can find a series of arguments that prevent us from this stubborn reluctance to sustain the fundamental categories of understanding upon the structure of the world.

First of all, Kant himself would have to admit that not all categories are invested with universality and necessity, for what shall we say about the category of "contingency"? Is it necessary? Of course, our author puts this category inextricably paired to the idea of necessity, but the very concept of contingency excludes the features of necessity and universality. Regarding plurality, shall we say that it is necessary for plurality to exist in the world? How do we know that the world could not subsist as a monotonous and immutable unity, with no cleavages between causes and effects, with no division between substances and accidents, with no disharmony between agents and patients? Kant concedes that the human mind empirically associates objects by virtue of affinities. Following him, the categories that nurture the operations of our mind could entail the

14. I have dealt with this problem in "Truth in an Evolutionary Perspective" in *Scientia et Fides 2*/1, 2014, pp. 203-220.

recognition of patterns inferred from the structure of nature, organized in more or less compact domains whose disposition suggests increasing or decreasing degrees of affinity.

Necessity is a category intimately connected with the idea of permanence, of identity (the logical form of an analytic propositions is: "A is A;" this proposition is necessarily true and it can never succumb to contingency), but it does not exhaust the sphere of intelligibility offered by the remaining categories. If we accept the logical legitimacy of change and difference, we must admit the autonomy of the contingent realm, of that which instead of being closed over its own identity assumes new structures, often unforeseeable. Therefore, and in order to become intelligible, not every judgment needs to be reduced into the categories of necessity and universality.

The demand of necessity, upon which Kant constantly insists in his *Critique of Pure Reason*, can stem from two sources: psychological imperatives or knowledge of the fine structure of reality. In the first case, my longing for necessity and my will to find it beyond any evidence is subjective and arbitrary; it is due to causes that are alien to the purity of logical reasoning which Kant has fervently exalted. I want to contemplate necessary connections, radiations of the immutable, because I may feel tormented by the evanescence of my own life, my own happiness, my own hopes and desires. As I fear death and the abrupt ending of all the venturous experiences that I have lived, it is outside me where I look for that permanence that I cannot find in my own being. Distressed by the inconstancy and volubility of many of my thoughts, wills, and efforts, overwhelmed by the deep insecurity that the threatening mysteries of life produce in my spirit, I shed all my anguish into the world and I try to detect in nature signs of the irrevocable permanence which is absent in my mind.

In the second case, the search of necessity is not rooted in the abysses of human psychology but in the understanding of the world. Here we can therefore say that our longing for necessity is utterly justified: it emanates from the discovery of patterns of behavior that describe the most relevant features of the universe. If I know the structure of the world and I am capable of understanding how its parts are imbricated and how some elements are repercussive upon others, then I can predict rules of behavior closely adjusted to reality. It is true that nothing can guarantee, in apodictic terms, that an object released from my hand will always fall on the floor, because there is a disturbing but unlikely chance: at some point, this body may behave in a different, unforeseen way. But if I penetrate the structure of the universe and I unveil its physical laws, I will realize that there is a profound reason why the body falls on the surface of the Earth. Newton called it "gravity," although he could not solve the problem of *actio in distans*: how a body, as massive as it can be, can attract another body if

they are spatially separated. It was Einstein who, through a profound and fascinating study of the structure of space-time, understood that gravity is the effect of the curvature that massive objects exert upon space. And in a set of equations, admirable for their beauty and synthetic power, he summarized this intuition in terms of the relationship between the curvature tensor and the stress-energy tensor. With knowledge, uncertainty before the future disappears: if I know the fine structure of the universe, my predictive power asymptotically approaches the limit of perfection that would bless a divine intellect.

There is, of course, a quantum uncertainty that forbids the complete determination of the destiny of the universe. But the world could be locally non-deterministic and globally deterministic. Also, we have discovered this limit to our predictive knowledge after a deep and rigorous research into the structure of the world. This inquiry has permitted us to elucidate a fundamental uncertainty and express it into a set of equations which in some way "circumscribe" it (or, as paradoxical as it may sound, they determine this uncertainty). And contrary to the constraints imposed by Heisenberg's principle, the chaotic behavior shown by some systems that are extremely sensitive to small alterations in their initial conditions does not involve a fundamental uncertainty; therefore, it does not close (at least in such a clamorous and sometimes saddening manner) the gates of our understanding of nature.

Our knowledge of the world still lies in darkness. In every branch of science new questions emerge, and it is possible that the power of our intellect will never solve all mysteries. However, as we gain a more comprehensive understanding of the universe and its astonishing sophistications, shall we not feel legitimate to say that we have elucidated the patterns of behavior prevailing in the world, so that uncertainty before the future does not distress us any longer? Untamed questions will always exist and will constantly increase our thirst of wisdom, the horizon of our curiosity, because the world is potentially infinite, and a finite intelligence can never extinguish the unceasingly new light that the universe offers under the form of unknown intellectual challenges.

The "transcendental" realm, the hypothetical sphere that contains the conditions of possibility of understanding, simply reflects the degree of development of our conscience of the world and our own beings. It can be perfected through the feedback given by the world itself; it has happened in the past and it can occur in the future. Kant's rigid scheme of categories confines understanding to a timeless prison, obstructing any fruitful dialogue with evolutionary biology. It raises a wall, colossal but futile, between epistemology and biology, condemning philosophical inquiry to a sterile conflict with the natural sciences. Of course, we can excuse the

egregious philosopher from Königsberg for having supported this understanding of the human mind, because a fundamental truth about the human species and nature (evolution) was still unknown. But nowadays we are capable of deciphering the intimate language of the biological kingdom, and the discoveries about our evolution from non-human ancestors whose intellectual faculties were inferior to ours grant us invaluable light on our origin.

Overwhelming evidence suggests that mind has evolved from less complex stages into the levels crowned at the present time. Nothing can be gained from opposing this fact. To take refuge in the lacunae that still cover some aspects of the theory of evolution will only delay the advent of the inevitable: an evolutionary understanding of the genesis of our most remarkable mental abilities. It is unfeasible to think that the set of elementary categories used by the human brain[15] in its exploration of the world has been born once and forever, in an unknown moment of the past and through enigmatic causes, because science draws a very different and plausible picture (the gradual development of more sophisticated categories out of more elementary notions; evolution may still be working). Hence, any philosophy that is melancholically attached to epistemological dualism and eager to build a celestial temple for human intelligence, a sacred citadel that protects it against any kind of empirical serfdom, is condemned to capitulate sooner or later.

Logic, in short, is the mental replication of the world. Perhaps not so metaphorically, it may be said that logic is the assimilated world; it is mental thermodynamics, because it sticks to the operational rules that govern the universe, whose foundations appeal to the basic principles of thermodynamics (the transformations of energy). Nature provides the norm for the basic categories of our logic. The universe constitutes its own law, but the human mind needs to split both spheres and distinguish between the elements and the operative rules that deal with them.

15. Although still a broad speculation, it is not implausible to think that the human brain is endowed with some neurobiological structures in charge of recognizing the fundamental logical patterns that we have outlined in the previous paragraphs (in essence, identity, difference, and possibility). Neuroscientists have gathered evidence of the existence of "place cells" that activated in tasks relating to spatial orientation (see O'Keefe, J.: "A review of the hippocampal space cells" in *Progress in Neurobiology* 13/4, 1979, pp. 419-439). Would it be too bold to suggest the presence of "logical cells", activated when we use these primary logical categories?

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