

**WALKING THROUGH THE CANTOR'S PARADISE AND ESCHER'S  
GARDEN: EPISTEMOLOGICAL REFLECTIONS ON THE MATHEMATICAL  
INFINITE (II)**

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**Abstracts**

Infinity is not an easy concept. A number of difficulties that people cope with when dealing with problems related to infinity include its abstract nature, understanding infinity as an ongoing never ending process, understanding infinity as a set of an infinite number of elements and appreciating well-known paradoxes. Infinity can be understood in several ways with often incompatible meanings, and involve value judgments or assumptions that are neither explicit nor desired. To usher in its definition, we distinguish several aspects, teleological, artistic (Escher), and some definitive, some potential, and others actual. This paper also deals with some still unresolved aspects of the concept of infinity.

**Keywords:** axiomatic formal system, infinity, metaphysics, paradoxes, set theory, transfinite regions

*Thus, after Cantor, there can be no argument about the central place of the infinite in mathematics... Yet despite all the evidence, many modern mathematicians persist in denying the objectivity of infinity. (Woods, 2003, p 358).*

**1. INTRODUCTION: ART AND INFINITY**

We might describe an artist not so much as a creator of novel content but rather as an imitator that expands and deepens the contents of experience so that the imitation is never accurate, but rather highlights a nuance that changes the direction of our thinking.

The function of the artist is not, therefore, to create something from nothing, but precisely to imitate (*mimesis*), to create an appearance from a model, change the forms of the appearance of things, clothe them, give them a new skin, and change their meaning. Plato was aware of this and in his tenth book of the *Republic* expels the artists from the city, because they can mimic everything that is in the world, can create new appearances, give new meanings to things, and so give new meaning to the world as if it were a game. Plato sees the danger of artists in his idea of creating a harmonious and well-ordered Republic, as artists would be responsible not only for destroying all harmony, but also undermining and disrupting the order of things. Under this logic the function of the artist is defined as a turning point, a new organization of the elements, and the result is affected by exactly how the elements are accommodated. As Martinez (2000) has suggested, the order of factors alters the product.

Further, we should not think that artists only come within the categories of art, but should think of artists within a broader framework, i.e., we find them in physics, mathematics, economics, biology, philosophy, etc. Artists then are those making a readjustment of the elements to deepen our understanding of them, to the extent that each new accommodation is a new nuance that allows us to imagine and understand in a different way our concepts and our problems. Hence the importance of art, the very meaning of which is to delve into our concepts and ideas, to open possible doors in the world. The enterprise of art must then be that branch of human knowledge that is responsible, not to create knowledge, but by experiment and aesthetic exercise, to develop the contents of our own knowledge through representation. We recognize an artist, when the meaning of our conceptual frameworks and content is changed; and when, in representing the world, the meaning of the world itself is extended.

By definition, art does not need to be guided by certainties. Certainly this is not so in contemporary art. Better still, art is not defined today by cognitive effort. Rather, art is a multilevel and hybrid representation of an encounter. Science itself for almost a century has relied on the existence of uncertainty and made it one of the strands with which to weave the fabric of the complexity of the universe. However, the need for certainty assails us at times, usually causing insomnia and stealing peace of conscience and of spirit. We need to learn in everyday life some wisdom. For life then becomes more pleasant, and more possible.

Well, we live in an era in which science and reality itself are increasingly counterintuitive and complex. This is also the case in art in general. Art is particularly complicated today, in that the boundary between science, arts, technologies, tools and languages has become increasingly blurred. Indeed, contemporary science (as indeed most of our culture) is characterized by the fact that natural perception plays only a minor role in seeing understanding or explaining many phenomena in today's world. Concepts such as solidarity, genome and proteome, peace, research, quantum entanglement, the Higgs particle, photosynthesis, consciousness or mind, information processing and many others have become part of our daily reality. More fundamental concepts like health, and love, understanding, and fairness - these are more difficult to see. These constructs we conceive and we imagine. But we do not see them with (pleonasm) physical eyes. And yes, some of these phenomena include the idea of the infinite.

## **2. THE ESCHER'S GARDEN**

*"For me it remains an open question whether [this work] pertains to the realm of mathematics or to that of art." — M.C. Escher*

In working on this section we have consulted the works of Ernst (1994) and Escher (2000). In 1959, in an article, Escher expressed what motivated him to represent the idea of infinity: *"as long as there have been men [...] upon this globe [...] we have held firmly to the notion of [...] all of which must continue to be everlasting in time and infinite in space"* (Weiting, 2010, p.27)

Regular partition of any surface does not demonstrate the idea of infinity, but suggests it. If the surface were infinitely large - impossible in our everyday reality - endless partitions are needed to cover it in its entirety. But there are other ways to artistically represent infinity. Escher made several attempts to represent it, originally influenced by previous work on partitions of a plane. The idea is simple. This is a drawing of figures that fit together filling the plane that slowly increase or decrease in size to give the impression that there are an infinite number of them (Figure 1).



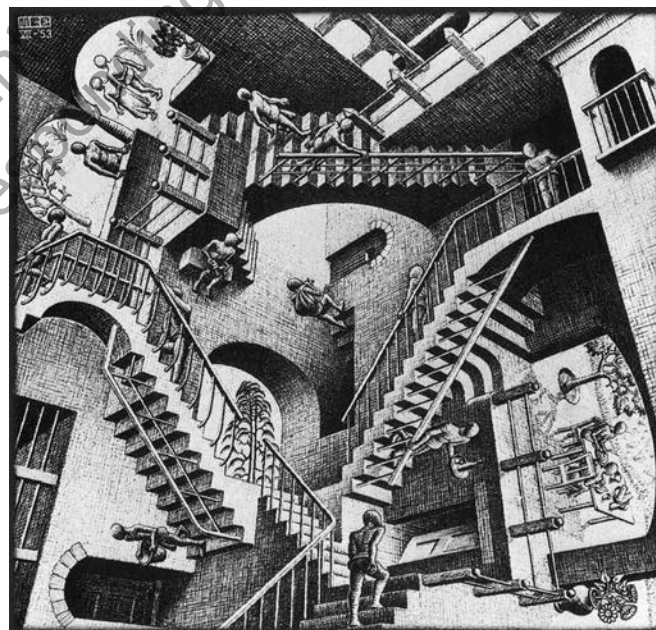
**Figure 1: Escher: Woodcut II, strip 3.**

But it is not just an impression, since we have a method, used by Escher, to fit an infinite number of figures in a finite space. Simply take objects whose areas follow the rule:  $1/2, 1/4, 1/8, 1/16, \dots$  and so on. If we add all the areas we have the expression:  $1/2$

$+ 1/4 + 1/8 + 1/16 + \dots = 1$ , which is a convergent series with sum unity. With this method we can draw an infinite number of figures in a finite area.

As [Hollingdale \(1999\)](#) pointed out, just like Nietzsche's provocation regarding the delimitation of music under the conditions of space and time, a similar phenomenon could arise in the work of Escher, because he also changes the whole idea of the work, understood as a demarcated production in space and time, to give a new meaning to confined space, as its nature goes beyond the limits imposed on it. A picture, a painting, a drawing, each has a frame that encloses and, in a sense defines it.

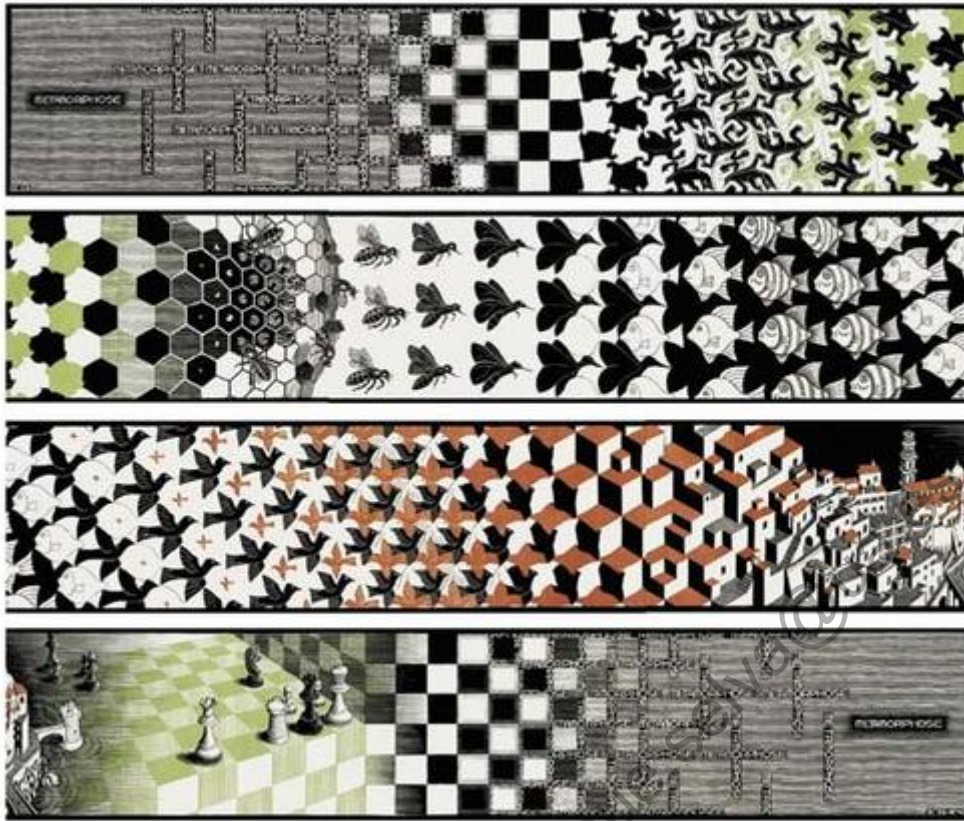
What draws our attention in the case of Escher's work, is that many of his drawings are inserted within a limited space, and propose just the opposite. In other words, Escher deepens the condition of infinity within the very edges of the drawing. There is more we can say about seeing perspectives that seem to have no beginning or end. The stairs is certainly the most famous, as one goes along the stairs not sure exactly where it begins and where it ends (Figure 2).



## Figure 2: Relativity.

Paradoxical one can walk an infinite number of times in the picture and get nowhere. While space is limited, it does not mean that the road runs out; on the contrary, we can travel indefinitely and infinitely in the picture, even though it has limits. That is Escher's triumph: playing with infinity in a finite space. The infinite is not defined in quantitative terms or even in terms of magnitude or size. Space is called infinite precisely to the extent that it is huge and unmanageable, so we tend to think that the infinite is linked with large magnitudes. However, Escher shows us the opposite: infinity is not a matter of size, it is a matter of dislocation that will take everything out of place and not give any place in return. Infinity, then, cannot be measured, since there is no point of reference from which to measure, without a beginning or end, and so infinity is defined precisely by not being defined. Current mathematicians who have studied the drawings, lithographs and xylographs, may see how Escher has fundamentally challenged their notion of infinity and by imitating the ways that the world offers, he has deepened the paradoxes of this concept, leaving us with a new opening for rethinking what infinity is and what it represents.

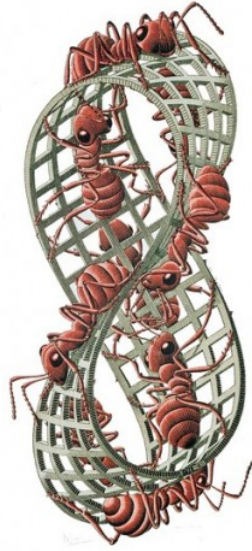
Metamorphosis II (1939), is perhaps one of his most famous works, with merging insects, lizards, fish, birds, horses, boats and buildings (Figure 3).



**Figure 3: Metamorphosis II.**

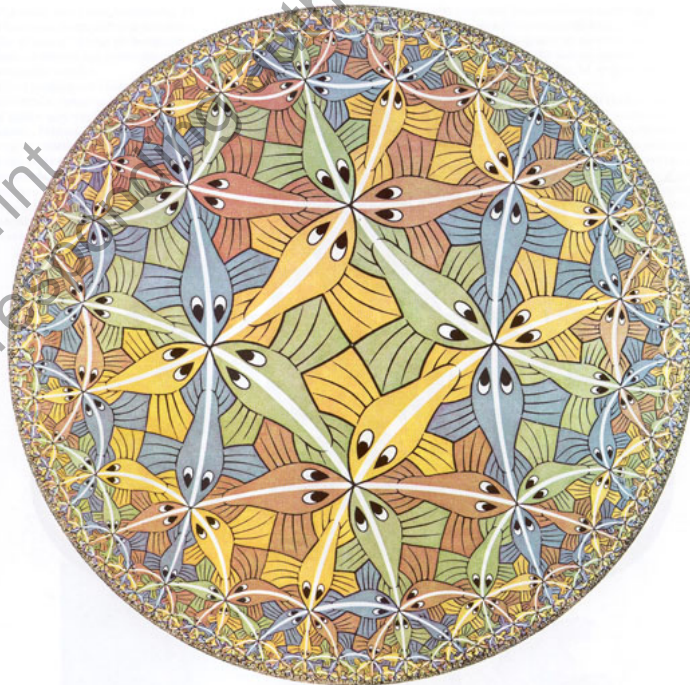
The work, which has a length of four meters, ends as it begins, closing a circle looking at infinity.

In other representations concerning infinity, Escher made more complex works such as *Möbius Strip I* (1961) and *Möbius Strip II* (1963) (Figure 4). In this last work he resorts, again, to animal figures like ants traversing the ribbon, without beginning or end, again indicating the infinite.



**Figure 4: Möbius Strip II**

One of the most interesting pictures of Escher: *Circular Boundary III* (Figure 5).



**Figure 5: Circular Boundary III.** In this case, the real dimension of the work is of great interest, because we admire how Escher suggests infinity in a confined space .



The continuum of fish and the uncertainty of the drawing as it approaches the limit point to the idea of an infinite path, but it is an illusory construction, which is not real. The line where the fish swim is bounded between two points. They are those of its intersection with the boundary circle. Its dimension is finite and can be covered from one extreme to another in a finite time interval. The road around the edge of the circle is not infinite, but can be divided infinite times, and this process cannot be represented nor constructed; it is symbolized by the vagueness of the drawing at the edges. Fish cannot get across the road because they decrease in size as they approach it. The movement and transformation of the fish will be infinite. They will swim forever, but in a limited way. We find a similarity here with the famous paradox concerning the race of Achilles and the tortoise. Escher's drawing being considered as the racetrack where they swim, or are still swimming? Achilles and the tortoise, do not have an infinite space, it is an illusion. Escher has drawn a subdivision process that tends to infinity, and therefore cannot be built entirely, leaving only a suggested continuation. Dreams within dreams are a progression, like the trajectories of the fish in the Escher drawing. They are all, ultimately, material representations of a mathematical progression that tends to infinity. Also in all cases there is an instant in which the progression is interrupted. And when the progression is interrupted, the illusion vanishes. Because the real author of an infinite space is time. It is the real architect. The key to an infinite space is that it is always under construction. It is never finished.

### **3. THE GREAT CORRUPTOR: HEGELIAN CONSIDERATIONS**

Infinity has been called "*the great corrupter of mathematics*", whatever it touches becomes poisonous and slippery. It is like a public enemy, who for 2,500 years mathematicians have not known quite what to make of it or how to treat it.

Comments made about Hegel in relation to modern science often relate to his writings on infinity. In his *Science of Logic* (Hegel, 1989), infinity is just another way of naming the absolute, which is the subject of philosophy, as he saw philosophy as nothing more than an attempt to access infinity: infinity can be seen as a new definition of the absolute. For this reason, we believe that the core of Hegel's critique of maths is in relation to infinity. Note that Hegel makes a distinction between two types of infinities: the spurious infinite and the true or good infinity (Wallace, 2005). We might describe the first spurious way of looking at infinity as consisting of an infinite series across time: something changes, and changes repeatedly and so on to infinity. This implies an infinite series looked at from an external point of view, and infinity itself is implied and separate from the finite. The second way of looking at infinity is to look at it dynamically where the infinite and the finite are instances of the infinite. Any finite thing is an identity that is a negation of what it stands out from. As finite things change, one thing changes into another (denial of the original think) and so is reflected in the other and can be examined from this other point of view (back to itself or negation of negation). So as Hegel discusses in his comments on Transition in relation to Infinity (Hegel 1989, Ch. 2) a new self-identity, which is a negation of a negation, is an affirmation of being and so another aspect of the finite. That is, in this example of the true infinite, the finite is only a necessary outward manifestation of an infinite interior, such manifestation which from one point of view is observed, then is overcome and assumed in the transformation. Bad or spurious infinity is expressed only as beyond the

finite, while the good infinite is expressed internally where the finite is an instance of the infinite.

From the above, consider which of the two infinities applies in studying mathematics. We have no doubt that number is the instrument which science uses. For Hegel, the only number is 1; the rest of the numbers are undetermined and will be deduced from the familiar arithmetic operations, the main two are addition and subtraction. Thus, the sum is nothing but a collection counting units, while subtraction is the opposite of this process. Hegel says that “...numbers can, in general, be produced in two ways, either rby aggregation, or by separation of an aggregate already given;..”(Hegel, 1989 p. 206). By way of composition we have operations like addition, multiplication and raising to powers (e.g.,  $2^2 = 4$ ); and inversely we have operations of subtraction, division and forming square roots. The purpose of these arithmetic operations is to show what a number is, but this demonstration is only external to numbers because there is no “within them”, no inner movement in a number that goes from one to another. There is no internal connection between numbers in arithmetical operations. The connection is external and the number is irrelevant. This irrelevance of numbers to the operation is shown by the fact that the connection between them is given only outwardly: arithmetic operations are carried out with the help of a “representation ...illustrated sensuously, and the operation b which number is generated is a process of counting on the fingers, dots, and so on” (Hegel, 1989, p. 206). It is clear from this expression that here mathematics deals with the spurious or bad infinite.

However, take note that elsewhere in his *Logic*, Hegel acknowledges that there is a mathematical infinity approaching the concept of the true infinite: this is the infinite that is expressed in rational numbers. Hegel says that “*in a philosophical respect the*

*mathematical infinite is important because underlying it, in fact, is the notion of the genuine infinite...*” (Hegel, 1989 p. 241). Let's see how this happens with the rational numbers by referring to Hegel's example. Take the rational number  $\frac{2}{7}$  that, although not a whole number, is a finite number, but its peculiarity is that it is not an immediate number but is mediated by two numbers: 2 and 7, which are presented only as examples of rational numbers. Here, the numbers “they directly count no longer simply as 2 and 7 but only according to the specific relationship in which they stand to each other. In their place, therefore, we can just as well put 4 and 14, or 6 and 21, and so on to infinity.” (Hegel, 1989 p. 245) That is,  $\frac{2}{7}$  also can be expressed as  $\frac{4}{14}$  or as  $\frac{6}{21}$ : all these numbers express the same quantity. As rational numbers, these numbers (2 and 7, 4 and 14, 6 and 21, etc.) are no longer seen as mere numbers, but are also designed now qualitatively, that is, in relation to each other. They have, therefore, according to this aspect, infinity in them, while not only they are no longer precisely themselves but are defined in their quantitative determination (relationship), as a qualitative determination that exists in itself, i.e., their value is in the relationship. An infinite variety of other numbers can take their place, so that the value of the ratio does not change, due to the determination of the relation. In other words, the rational numbers are identical internally, while externally being different. Further, the external number is simply the manifestation of an implied value giving  $\frac{1}{4}$  or  $\frac{2}{8}$ : the externality is here obscured. Here we have the infinite inwardly, not outwardly; infinity is intensive and qualitative, not extensive and quantitative. Even so, because mathematical infinity expresses better true infinity than classical metaphysics, because the infinity of classical metaphysics is a separate infinity of the real or God. While mathematical infinity, as seen in rational numbers is an infinity present in its finite manifestations, but never exhausted.

#### 4. SOME PHENOMENOLOGICAL REFLECTIONS ON THE CONCEPT OF INFINITY

A long tradition in Western philosophy approached truth in terms of relationships between beings, or in terms of relationships with being. And the task in this tradition was to account for knowledge, using models of identity in which the tension generated by the relationship is tempered by comprehension. But it has been a project built against the backdrop of a *beyond*, which precisely this relational character was responsible for emphasizing. Therefore, the task of thinking was an *in-finite* task without end; but, in turn, this showed that the model of reduction and adequacy of immanence has never been carried out at all. If so, why not say that the history of philosophy has been nothing but the effort to explain transcendence? The phenomenon pointed to in the theme of phenomenology - *to the things themselves* - is just that: a manifestation or revelation of what a “thing” is in its being in itself.

In general, a physical image and a negative significance (Aristotle saying infinity was only potential and not actual) have become the handiest means of referring to the Infinite. There is a tendency for people to take cognitive shortcuts in thinking, so it is not surprising that the Infinite has been treated this way in Western thought with a tradition of being determined to give a reason for everything. The ontological context of western philosophy, with its theological moments and reflections on the Supreme Being, shows the relevance of a concept of the Infinite with an essentially polyhedral character (Mondolfo, 1971). From the time of the Presocratics, the Infinite has been associated with notions such as the indeterminate (the *apeiron* of Anaximander), the *indefinite* (Pythagoreans), and *eternal recurrence* (Heraclitus), all aspects of classic reflection on the nature of the Infinite.

In Plato and Aristotle (Drozdek, 2008; Guthrie, 1975) this polysemy of the term infinite is resolved emphasizing its negativity. So the Infinite, instead of meaning fullness, positivity and reality, connotes incompleteness, non-being and therefore evil. So for example, Plato speaks of the unity or the One, linking the notion of infinity to eternity to discuss the participation of perishable things in imperishable and eternal ideas. Here infinity is the indefinite multiplicity of every one thing. It is therefore the limitlessness of this indefinite multiplicity which explains the negative meaning, this being the characteristic of *what becomes*. The unlimited multiple results point to being imperfect, while the One is perfect and limited.

Aristotle's comments are, if anything, stronger. The infinite, is declared as non-being; Moreover, it is denied physical actuality, leaving it only as potential; either as infinite potential, as shown in division (e.g., an infinitely divisible line), or as an infinite potential in addition, as shown in numerical series. In both cases it is a mathematical infinite. Only when speaking of the first cause, can one speak of infinity as a cause, but this also denies the infinite in respect to magnitude.

Interestingly this negative theming of the Infinite, which ends with the classical period of Greek philosophy, opens the door to the Infinite becoming a matter for philosophy. Said positively, the Infinite can now be treated and comprehended; enough to make a new reading of the two qualities – things ending at infinity and things going on indefinitely to infinity - denoting the imperfect aspect that could not be actual, which by definition excludes unfinished and undefined appearance. The issue is whether that actual infinity as a presence, which is the subject of ontology, exhausts the meaning of all possibilities. Does thought end in knowledge as knowledge of concepts, or does it refer to intelligibility, by whose light, captures the thought. Neo-Platonism and Plotinus inaugurate this positive dimension of the Infinite (Graham and Kantor, 2009), as

aspiration and a return to the One, from whom emanates intelligence and knowledge. So, emanation as possibility of diversity, from the One, is possible because from the One, comes the definite and infinite, ensuring the *distinct*. So to think this is to think other than the One, the multiple. But nothing and no one can alter this aspiration, this upward path of thought to the One as being in itself.

The notion of positive Infinity or actual infinity in God, explains well the two levels of reality: the creator and the created; and reveals, in turn, that only God is infinitely infinite, and the rest is only relative. Metaphysical transcendence which emphasizes this idea of the Infinite, assures God in the plane of being, but also introduces a tension, in so far as that other beings regard the background of the Infinite which is, in turn, God. This explains the scholastic study of the various ways of speaking of *infinitum* or *infinitas* and the tendency, ever increasing, to consider the infinite *in fieri* of created reality as infinite in act, because logic and mathematics could consider the possible reality of it.

The step that gave Nicholas of Cusa, determined to resolve this tension from the very idea of the Infinite, is the consideration of the world as infinite or, at least, physically undefined, the image given by the Galilean revolution. Thus, this difficult cohabitation emerged out of two infinities - God and the Universe, which does away with the Greek idea of a closed whole, finite and well-ordered in favor of an indefinite universe, even an infinite Cosmos having its own laws. These lines of thought go through Descartes, Spinoza, Newton and Leibniz, culminating in the step from *finitism* to infinitism in modern times; a step that is present in what has been called "*the pathos of the infinite*" that will be so crucial in the anthropological turn of philosophy.

Certainty as an assurance of truth, central in the wisdom of philosophy, and the investigation of valid criteria was highlighted at two culturally and *anthropologically*

*significant turning* points: the moment of the *cogito* and the age of reason. For both, there is an emphasis on subjectivity to ensure accuracy, but while in the *cogito* the criterion is overwhelmingly personal, reason assumes the burden of proof to the point of becoming absolute reason. Reason is self-sufficient to take account of everything. That is why it is not surprising that if the classical model of thought of the Infinite emphasized transcendence, Heidegger's (1996) model of modern and contemporary philosophy is that of immanence; a model in which the requirements of the absolute and beyond are absorbed in the transcendental structures in which reason is expanded and reflexive, and is identified following the same scheme: reduction of the *Other* to the *Same*. (Levinas, 1991; Rose and Skempton, 2010) The basic idea to perform this task is simply to understand the origin of thinking and subjectivity as self-position; a subjectivity that has a monopoly on the word because it is self-consciousness. That power of the Self to speak to him or herself, is the source of any reduction of the Other and explains better than anything the legitimacy of violence and all political versions of totalitarianism, which find their philosophical justification here. But the question is: can it still be sustained, after Freud and Nietzsche, that this Self has in his or her hands the keys to self-interpretation? Do not we not lose the subject in the thickets of the subconscious, caught in the meshes of the system?

The Romantic Movement had already created a stifling atmosphere in conceiving thinking exclusively in terms of reason. But now, it seemed natural to postulate an open-end version of the Infinite – in the heady almost unbreathable atmosphere emphasizing Self.

Husserl realized this. The alternative, however, is a new twist to the Greek model of philosophy, namely the task of expunging obstacles to reach the pure vision and revelation of being, ensuring maximum knowledge: the final goal, knowledge of all and



the Whole, infinite knowledge. But then, where is this quasi *natural* disposition of thinking in an *open way*? In Husserl (1960), the recurrence to open thinking is resolved in the infinite openness of the intentionality of consciousness, able to interpret all transcendence, all otherness. Not that the outside does not exist, the determining factor is that it makes no sense, unless it can be known. Therefore, the intent, which is the path to account for all through the presence of all, testifies to the reality of what is given as data. In other words, if the perceived coincides and runs in perception, and *noesis* in the *noema*. We need to remember, that consciousness has dark corners to which the Self does not have easy access.

Moreover, the designed model of evidence, as a movement of knowledge, would it not be required for surveillance of the Self as *a living presence of the Self for himself*, ensuring a transcendent Self in the immanent? If so, this would overcome a model of identity and presence as a model of knowledge.

The crisis of consciousness is that until now, by intentionality such consciousness believed it had the power to name the object. It had not noticed that the very condition of object required the ability to manifest, as a condition of its free essence, to postulate a primordial *outside* that cannot be reduced. This is a break with the immanence of consciousness, but the model of transcendence of infinity is resolved in the light that surrounds and reveals everything. And what manifests or reveals itself is not only what is in its being itself, which summarizes the eternity and infinity of an immanent Being, whose light is uncovered the being as the entity that is (*Da-sein*), but a sort of consecration or *ek-stasis*. This latent characteristic of transcendence in philosophy was because the model that prevailed in the explicitness of it was a religious model, against which always thought was stamped as knowledge. Hence the predominance of negative terms to express it, except when it was recognized to inhabit another world or

reinterpreted from the self. The thought is not confined to the thinkable, because beyond the thinkable is *what makes us think*; and this remains as an unthinkable thought of the thinkable. This is the task of a future paper, which requires a different beginning from Greek philosophy. But it's a new beginning with being, modeled on transcendence in immanence or immanent transcendence.

## 5. CONCLUSIONS

Infinity: A temptation of human thought? A term which refers to a mystery that consoles us? A category requiring scientific explanation? Is it a scientifically definable concept? Is it a philosophically definable concept, evident in its existence, and concretely unattainable? Is it a reason for the unity of mathematics? Is it an anarchic concept of a mathematical anarchist? Is it an ideal to be achieved or an unattainable utopia?

Robinson (1965, p. 230) summarized the status of the established contradiction between Cantor's conception and the formal axioms of set theory as follows: the foundations of mathematical formalism constitute two principles:

*1) Infinite totalities do not exist in any sense of the word (i.e., either really or ideally). More precisely, any mention, or purported mention of infinite totalities is, literally, meaningless.*

*2) Nevertheless, we should continue the business of Mathematics "as usual", i.e., we should act as if infinite totalities really existed.*

Zeno's paradoxes are the appropriate response found in modern mathematics, but are we finishing the war between the infinite and the intellect of man? Or will the eternal last?

Infinitely? Perhaps intuition is manipulated by the languages of Philosophy and Science? Does experience always provides concepts that can be clearly represented in formalist terms? Is our knowledge is limited by formalisms? Do Intuitionism, Constructivism, formalism and axiomatization obey external laws or knowledge? Or as Einstein says: "*I know only two things that are infinite, the universe and human stupidity, and I'm not so sure about the former.*"

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