René Thom's topological theory of meaning and semiotics

A teoria topológica da significação de René Thom e semiótica

Arthur Araujo*
aart037@gmail.com

Abstract: This paper represents a second step of my research on the work of the French mathematician René Thom. I primarily focus on two papers by Thom's theory of the sign: *From icon to symbol* (*De l'icône au symbole*), 1973 and *Space and Signs* (*L'espace et les signes*), 1980b. In this paper, exploring Thom's topological conception of meaning, I expound on his idea that all forms of semiosis (as meaning processes) develop a spatial form. It is from his working on the reconstruction of global forms in topology that Thom sets his semiotic program. In particular, as I will show, Thom converts Charles S. Peirce's triadic classification of signs (icons, indexes and symbols) into a space-vector interpretation. Advancing my study of René Thom's work (Araujo, 2022), I explore his topological theory of meaning according to which semiosis can be understood as a topological space. In parallel with his work on morphodynamics in biology, Thom redefines the dynamics of sign, object and interpretant (according to their mutual interconnections) that topologically configure the very space of semiosis.

Keywords: Meaning. René Thom. Semiotics. Topology.

Resumo: *Este artigo representa uma segunda etapa da minha pesquisa sobre o trabalho do matemático francês René Thom. Foco principalmente em dois artigos da teoria dos signos de Thom: Do ícone ao símbolo (De l'icône au symbole), 1973 e O Espaço e os signos (L'espace et les signes), 1980b. Neste artigo, explorando a concepção topológica de significação de Thom, exponho sua ideia de que todas as formas de semiose (como processos de significado) desenvolvem uma forma espacial. É a partir do seu trabalho na reconstrução de formas globais na topologia que Thom define seu programa semiótico. Em particular, como mostrarei, Thom converte a classificação triádica de signos de Charles S. Peirce (ícones, índices e símbolos) em uma interpretação espaço-vetorial. Avançando meu estudo sobre a obra de René Thom (Araujo, 2022), exploro sua teoria topológica da significação segundo a qual a semiose pode ser entendida como um espaço topológico. Paralelamente ao seu trabalho sobre morfodinâmica em biologia, Thom redefine a dinâmica do signo, do objeto e do interpretante (segundo suas interconexões mútuas) que configuram topologicamente o próprio espaço da semiose.*

Palavras-chave: *René Thom. Semiótica. Significação. Topologia.*

Toute ma métaphysique sous-jacente, c'est d'essayer de transformer le conceptuel en géométrique, la logique en dynamique

(René Thom, from a letter to Claire Lejeune, February 20, 1980a).

1 Introduction

As a first step, my research on the work of the French mathematician René Thom has already produced results with the publication of my paper

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* Universidade Federal do Espírito Santo.

(Araújo, 2022). From the academic collaboration and partnership with Professor Robert Innis, in this second step of my research, this paper will primarily focus on two papers by René Thom's theory of the sign: *From icon to symbol* (*De l'icône au symbole*) (1973) and *Space and Signs* (*L'espace et les signes*) (1980b).[1] For Thom, in particular, Peirce's triadic classification (icons, indexes and symbols) can be directly linked to a vector representation. Many philosophers, semioticians and biosemioticians have been amplifying Thom's intuitions: Petitot-Cocorda (1985), Sebeok (2001), Merrell (2003), Favareau (2010), Wildgen and Brandt (2010), Bundgaard and Stjernfelt (2010), Wildgen (2015; 2020a; 2020b).[2] In 2023, we celebrated the centenary anniversary of René Thom's birth.[3]

Why is topology of interest to semiotics? Answering this question was René Thom's greatest challenge throughout his intellectual life. As observed by Wolfgang Wildgen (2020a), epistemologically speaking, Thom is a Platonic mathematician and strives to trace a correlate of topological structures in the reality of phenomena. Like Aristotle, moreover, Thom is a philosopher of form, and topology is the accurate language for describing the spaces of forms. In other words, Thom is interested in the space of forms rather than forms in space. In this sense, attentive to morphodynamic investigations in biology, Thom is interested in the space of forms as indicating the deployment of the boundaries between organism and environment (or the organism's Umwelt) according to a dynamic of spatial transformations. In *Topological Models in Biology*, incidentally, Thom (1969, p. 313) says: "There appears to be a striking analogy between this fundamental problem of theoretical Biology and the main problem considered by the mathematical theory of Topology, which is to reconstruct a global form, a topological space, out of all its local properties". It is in particular by working on the reconstruction of global forms (understood topologically) that Thom sets his semiotic program.

Contrary to the quantitative dogma in the contemporary science, Thom believed that since we create theories independently from a material substrate, we are free to consider space as devoid of any matter. According to him, this space concerns biology and linguistics as it represents qualitative discontinuities on a certain continuous background. By discontinuity, René Thom means "catastrophe" and it is around this notion that he builds up his relationship with semiotics as a space of qualitative transformations. In parallel with his theory of catastrophe, introduced in *Structural Stability and Morphogenesis* (1973/1975), René Thom's idea is that the sign is a discontinuous form emerging from a material *continuum*. Assuming that this process consists of a non-linear trajectory, Thom employs topology as the accurate language for interpreting the catastrophic matrix of the sign. In *Space and Signs* (1980b), for instance, Thom makes this interpretation explicit, relating C. S. Peirce's triadic classification (icons, indexes and symbols) to a space-vector.

Needless to say, we will have difficulty in understanding Thom's theory of meaning apart from biology. For Thom, in fact, extending Uexküll's theory of meaning is to recognize that "it is obviously in biology – the science closest to man – that we could expect to see the notion of meaning reappear" (Thom, 1974, p. 194, my translation). Using the language of spatial forms (or topology), Thom approaches the problem of the origin and succession of forms from an original intuition: all forms of life – including linguistic forms – incorporate spatial forms. Thom's intuition relating topology and language can be summed up in his own words: "meaning is always tied to the attribution of a spatial place" (Thom, 1983,

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1   I translated *De l'icône au symbole* into Portuguese as a part of my research on René Thom's relation with Semiotics developed in collaboration with Professor Robert Innis, at the Department of World Languages and Cultures, University of Massachusetts, Lowell, between September and November 2023. The translation is in this issue of Cognitio (Thom, 2024).

2   On Thomas Sebeok's personal edition of René Thom's *Structural Stability and Morphogenesis*, we can read the following handwritten dedication: "*Au Professor Sebeok, en témoignage de sa merveille comprehension. Bloomington, le 11 October 1979*".

3   On the occasion of the centenary of the mathematician René Thom's birth in 2023, Fields Medal 1958, l'*Académie des sciences* et l'*Institut des hautes études scientifiques* (France) paid tribute to him. Etienne Ghys, also a mathematician, looks back on the intellectual heritage of this extraordinary geometer, in his "white letter" to "World" (Le Monde, September 27, 2023). For a remarkable review of René Thom's work celebrating his centenary of birth, see Wolfgang Wildgen (2023): *René Thom's contribution to linguistics and his semiophysics applied to art and music. A retrospective on behalf of the centenary of his birth*; and also, Isabel Marcos & Clément Morier (2023): *Centenaire de René Thom* (1923-2023)*: hommage sémiotique et morphodynamique*.

p. 294). In this research, exploring the topological conception of meaning, I expound on Thom's idea that all forms of semiosis (as meaning processes) develop a spatial form. Although it is hardly reasonable to assert that semiosis is a ubiquitous process in the universe, few doubt that even the humblest life forms are able to perform meaning processes in space (and time).

Referring to *From icon to symbol* (1973) and *Space and Signs* (1980b), in particular, this paper will focus on Thom's topological theory of meaning. Although these essays seem to have little value among researchers in Thom's work, they reveal an unrivaled innovation in semiotic studies. According to Thom's interpretation of Peirce's triadic classification (icons, indexes and symbols), semiosis can directly be associated to a vector-structure as indicating a topological form.[4] In the essay *Space and Signs* (*L'espace et le signes*), incidentally, Thom advances a topological representation of semiosis (as related to a vector-space) in which time is also counted as variable. In addition to topology, Thom was interested in dynamics. For him, mathematics is above all a method for obtaining realistic representations of space and dynamic processes in time. Thom extends this combination of topology and dynamics to morphogenesis in both biology and semiotics.

Here, continuing my study of René Thom's work (Araujo, 2022), I continue exploring his topological theory of meaning according to which semiosis (as meaning process) can be understood as topological space. In the development of this paper, I first consider Thom's Phase 1: Catastrophe Theory *in Structural Stability and Morphogenesis* (1972/1975) and his early intuitions on topology and language (all forms of life – including linguistic forms – incorporate spatial forms). Secondly, I center on *From icon to symbol* (1973) and *Space and Signs* (1980b) as representing Thom's Phase 2 and his intuitions on topology and semiotics: the vector representation of semiosis.

I end this paper foregrounding that in an original way, René Thom converts semiosis (as a meaning process) into a space of dynamic transformations. In parallel with his work on morphodynamics in biology (in which he develops a topological representation of the deployment of the boundaries between organism and environment), Thom redefines the dynamics and the edges of sign, object and interpretant from their mutual interconnections that topologically configure the space of semiosis.

2 Phase 1: catastrophe theory ([1972] 1975): first intuitions on topology and language (all forms of life – including linguistic and non-linguistic forms – incorporate spatial forms)

The first phase of René Thom's intellectual journey, that put mathematical and philosophical concerns in synergy, began in the mid-1960s and resulted in his *Structural Stability and Morphogenesis* (1972/1975). In this work, particularly, Chapter 8: *Biology and Topology*, Thom presents an ambitious program to apply mathematical theory to morphogenesis in biology. In *Topological Models in Biology* (1969), Thom had previously noted that the problem of morphogenesis in biology finds an analogy in topology when we try to reconstruct a global form (or topological space) from local properties. By "form", Thom means structures that take up some part of space and last for a certain period of time.

> One of the central problems posed to the human mind is the problem of the succession of forms. Whatever the ultimate nature of reality (assuming that expression has any meaning), it is undeniable that our universe is not chaos; we discern that there are beings, objects, things that we designate by words. These beings or things are forms, structures endowed with a certain stability; they occupy a certain portion of space and last for a certain period of time. (Thom, [1972] 1977, p. 1, my translation).

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4   In a very interesting article, Jérôme Havenel (2010) returns to Peirce's forays into topology as applied to his conception of the nature of space, time and logic. In this paper, however, nothing is mentioned regarding the relation between topology and Peirce's semiotics.

For Thom, ontologically speaking, there are no "things". What has been metaphysically taken to be "thing" means "form" and the description of forms opens the perspective of considering all forms of life (including linguistic forms) as endowed with some degree stability and taking up some part of space. According to him, in particular, this space concerns biology and linguistics as it represents qualitative discontinuities on a continuous background. By discontinuity, René Thom means "catastrophe" as a space of qualitative transformations. For him, the theory of catastrophes is essentially an overt attention to the qualitative discontinuities of the world or forms: "what we usually call a form is always, in final analysis, a qualitative discontinuity on a certain continuous background (Thom, 1993, p. 35, my translation).

Developed throughout his *Structural Stability and Morphogenesis*, Thom presents a mathematical model (based on the differential topology and the theory of singularities) aiming to advance the description of catastrophes as an abrupt or sudden change of states that gives rise to a successive unfolding of singular forms. In order to develop a general theory of forms, Thom (1972/1975, p. 8) insists that it starts from the ontological independence of form in relation to a material substrate. Contrary to the quantitative dogma in the contemporary science, Thom believed that since we create theories independently from a material substrate, we are free to consider space as devoid of any matter. In his view, additionally, the study of morphogenesis (as being the creation of form in itself) should confront the fundamental problem in biology: that is, how do (new) forms emerge in the world and change. By change of form, in particular, Thom means "catastrophe" as the process resulting from an unstable, discontinuous, and unstoppable phenomenon passing from one stable state to another.[5] In this sense, Thom had an insight that the different phases in the process of embryological development (from a frog to the fertilized egg) could be described mathematically as the successive unfolding of singular forms (Bundgaard; Stjernfelt, 2010, p. 43). Thom begins his foray into biology from the study of topological forms which will be extended to linguistics and then to semiotics.

For Thom, even though there is a dynamic resulting from unstable, discontinuous, and unstoppable phenomena, catastrophe is not a chaotic process since structural stability can be observed as resulting from an unfolding of singularities. If a structure preserves its form resisting deformation or collapses under the action of external pressures (earthquakes, wind, snow, and environmental factors, etc.), it is structurally stable. As I will describe further, an exemplary case of structural stability is performed by the behavior of coral reefs. Considering an ontological background, I think, the notion of structural stability brings René Thom closer to a process-ontology such as that of Whitehead in *Process and Reality*. Instead of being made up of 'things', reality consists of a dynamic of forms endowed with some degree of structural stability: forms taking up a part of space and lasting for a certain time.

By making reference to structural stability as to both forms in space and processes in time, Thom was able to understand the precise determinations of the forms in which stability can occur (Østergaard, 2010, p. 38). Within the framework of Thom's ontology, the notion of structural stability built a conceptual bridge uniting topology and semiotics. This is the most important lesson that can be learned from René Thom's *Structural Stability and Morphogenesis*: all forms of life – including linguistic and non-linguistic forms – incorporate spatial forms as expressing structural stability. But, given that the phenomenal world is situated in space and time, mathematical and semiotic investigations should be limited to experience in four dimensions.

In *Structural Stability and Morphogenesis*, Thom confronts the issue of explaining that a catastrophic jump results in a discontinuity and that "nothing disturbs a mathematician more than discontinuity" (Thom, 1972/1975 p. 9). Considering the ontological background of a process-ontology (such as that

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5 "Thom calls the points whereat a continuous process 'jumps' into discontinuity, and in so doing is reconfigured into a newly continuous state, catastrophe points, after the Greek word καταστροφη – a term used to designate that point in the ongoing development of events (e.g., a drama), whereat a 'sudden turn' initiates a consequential new trajectory. Such continuity-breaking and trajectory-changing events are critical to the development of any kind of form" (Favereau, 2010, p. 339).

of Whitehead), the category of the *continuum* is a basic aspect, and this is not different for Thom. By addressing the issue of discontinuity in catastrophic phenomena, it is interesting to note that Thom endeavors to develop a description of the world from the perspective of the *continuum* (Østergaard, 2010, p. 36). Confronted by the tension between the catastrophic constraint of discontinuity and the ontological imperative of the *continuum*, Thom (1972/1975, p. 10) claims that all the basic intuitive ideas of morphogenesis can be found Heraclitus' philosophical assumption that conflict is the source of all things as well as being the matrix of every form. To develop his theory of catastrophe and to model different forms of structural stability in biology (and in semiotics), Thom interprets Heraclitus' philosophical assumption of conflict based on a geometric and dynamic framework. In order to illustrate Thom's interpretation of the Heraclitan conflict, allow me to recall the structure of coral reefs as an exemplary case of a morphodynamic process relating material *continuum* and structural stability.[6] Coral reefs are also an interesting case of morphodynamic processes insofar as they are on the boundary between the non-living and the living.

The behavior of coral reefs exhibits the development of forms that, on one hand, incorporate a complex of environmental variables within a continuously slow dynamic and, on the other hand, represent catastrophic changes. Emerging from a material *continuum*, the behavior of each coral reef unfolds from a singular form that is endowed with some degree of structural stability: forms taking up a part of space and lasting for a certain time. In parallel with Thom (1972/1975, p. 102) that "even the conversion of matter into energy can be considered as a catastrophe", I understand that the behavior of coral reefs represents the morphodynamic conversion of a material *continuum* into topologically semiotic forms.

Considering the phenomenological character of the behavior of coral reefs, insofar as it represents the surface discontinuities grounded in a physical *continuum*, we can recognize in Thom's theory of catastrophe a semiotic aspect: the stability of surface phenomenology functions as a sign to the underlying complex process (Østergaard, 2010, p. 37). That is, to the extent that the boundaries of coral reefs vary relative to environmental pressures, their structures represent topologically the fusion of meaning and space: in each coral reef, we observe a topological structure-built in semiotic relation with its environmental space. Using Umberto Eco's terms (1975, p. 21) in parallel with René Thom's conception of catastrophe, the coral reefs built-structures represent the morphodynamical transformation of a (*continuum*) physicochemical (non-semiotic) world into a (semiotic) world of singular forms. In this sense, recapitulating Peirce's conception of a dynamic interpretant as being either emotional, energetic, or logical (CP: 5.475-476, 1907), it is fair to say that the coral reef is a form of energetic interpretant: it represents the physical effort of transforming the continuous flow of energy and matter from the environment into a meaningful built-structure.

Applied to understanding the topological determinations in which structural stability can occur, Thom's catastrophe theory suggests an interpretation of the semiotic contexts whereby all forms of semiosis – including linguistic and non-linguistic forms – incorporate spatial forms. Considering Thom's catastrophe theory as a reference to the structural stability regarding both forms in space and processes in time (such as in the case of the structure of coral reefs), implies the assumption that semiosis would be restricted to the natural world. The idea is rather that the semiotic incorporation of forms (in space and time) also includes cultural contexts such as "painting, sculpture, music, dance, architecture, film, ritual practices, spontaneous gesture, theater performance, and so on" (Johnson, 2017, p. 12). In all these contexts, people are spatially experiencing a semiotic process resulting from catastrophe dynamics: while a sensorimotor *continuum* involves the bodily apparatus, a spontaneous and phenomenal form takes place in the space of experience and shapes its topology. Keeping close to gestalt psychology in *L'Espace and les signes* (*Space and signs*), the form taking place in and shaping the experience from

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6   In a previous publication (Araujo, 2022), I worked on the behavior of coral reefs in connection with René Thom's reading of Uexüll's theory of meaning.

sensory matter is what René Thom (1980b, p. 200, my translation) will call "sensory pregnancy": "this discontinuity is placed in a content of sensory forms presenting a certain order [and] any disruption of this order will be felt as sensory pregnancy". Similarly to the non-linguistic semiotic contexts, if someone experiences small changes in writing (like a b*u*g and a b*a*g, for example), even in this case (Orden, 2002, p. 1), emerging from a catastrophe dynamic, we observe a spontaneous and phenomenal form taking place in the space of experience and shaping a singular topology.

Considering the notion of "spontaneity" in the semiotically non-linguistic and linguistic contexts within René Thom's catastrophe theory framework, the door is open to address the questions of creativity, novelty, and freedom: in other words, the possibility of grasping in what conditions spontaneity takes place in the world as opposition to determinism. By "spontaneity", one must understand "the rejection of both the mechanistic and teleological doctrines of inevitable predestination [as] a real force in nature which corresponds to Peirce's Tychism" (Vehkavaara, 2007, p. 264). The idea of an element of unpredictable spontaneity is not supposed to be thought of as being in nature only (as indicating the increasing complexity), but it should also be considered in aesthetic and ethical contexts. In contexts where spontaneity takes place, we find meaning processes (or semiosis); conversely, in contexts devoid of spontaneity, semiosis cannot arise.

Following this line of thinking, I believe, we should consider that René Thom's catastrophe theory assumes the need of a "threshold" in which the living emerges from the non-living. For Thom (1972/1975, p. 143), in fact, "the phenomenon of threshold stabilization is one of the typical features of biological morphogenesis; singularities that should never have appeared […] appear in a stable way". Anticipated by Umberto Eco in the 1970s, incidentally, the notion of the threshold has been an important conceptual tool for semioticians and biosemioticians when considering that semiosis is a co-extensive process with life (Sebeok, 2001; Hoffmeyer, 2010 Kull *et al.*, 2011; Higuera and Kull, 2017; Araujo, 2020; 2022).

In parallel with threshold stabilization in biology as noted by René Thom, it is fair to assume that since creativity, novelty and freedom do not seem to be pre-determined in the world and appear abruptly in stable ways, they represent forms of spontaneity in space and time – forms of spontaneity that stand for the threshold between the non-living and living domains. If we consider René Thom's notion of threshold stabilization, it represents not only an original approach to morphogenesis in biology, but also the intuition in topology and language according to which all forms of life incorporate a spatial form.

3   Phase 2: Thom's intuitions on topology and semiotics: the vector representation of semiosis

In this part of the paper, I will focus primarily on two papers by René Thom: *De l'icône au symbole* (From icon to symbol) (1973) and *L'espace et les signes* (Space and signs) (1980b). Although these two papers are little known, in a very original way, they represent Thom's intuitions on the topological interpretation of semiosis and, in particular, on the vector representation of Peirce's triadic classification (icons, indexes and symbols). Why vector representation? Because this seems to be the best representation of semiosis as a non-linear process. In addition, considering Thom's topological interpretation of semiosis, incidentally, we discover a conception of meaning that goes beyond the traditional concepts of extension, denotation, reference, correspondence, or representation. For Thom (1983, p. 294), in fact, meaning is a reference to space: "meaning is always tied to the attribution of a place of spatial nature". The idea is that by incorporating a vector form (i.e., a relational form), meaning represents the spatio-temporal localization of semiosis in non-linguistic and linguistic contexts . In fact, according to Thom's intuitions on semiotics and topology, since meaning incorporates a vector form, it cannot be regarded exclusively from a linguistic perspective. Parallel to Wittgenstein's Philosophical Investigations (108), according to which "we are talking about the spatial and temporal phenomenon of language, not about

some non-spatial, non-temporal phantasm", René Thom reaffirms the topological nature of meaning as a phenomenon taking place in space (and time).

3.1 From icon to symbol: outline of a theory of symbolism (*De l'icône au symbole: Esquisse d'une théorie du symbolisme*,1983)

In this paper, Thom refers to Peirce's second trichotomy (icons, indexes and symbols) based on a (bio) semiotic construction which exposes the transition between man and animal. But, at the same time, Thom (1983, p. 261) recognizes that symbolic activity is also manifest in elementary mechanisms such as, for instance, inanimate matter. In my view, this is a controversial point. According to the biosemioticians descending from Jakob von Uexküll's theory of meaning, semiosis is not ubiquitous in the world. For many biosemioticians, in fact, since semiosis overlaps life and forms of life, it does not seem to figure in inanimate matter. This is an interesting aspect because René Thom begins his topological interpretation of Peirce's triadic classification (icons, indexes and symbols) from the molecular level and the replication of DNA. At this level, certainly, a form of symbolism is evidenced that does not seem to correspond to the behavior of inanimate matter. At this symbolic level, in fact, there is a point of inflection (for many biosemioticians, the threshold zone) below which we find no semiosis. Considering René Thom's topological interpretation of Peirce's of icons, indexes and symbols and, in particular, his analysis of the genesis of the image in the replication of DNA, there seems to be little doubt that he (Thom, 1983, p. 262) was not aware of a point of inflection (or threshold) in nature.

According to Thom (1983, p. 263), compared to the photographic process in which the image (the icon) becomes a memory of the model, DNA replication also stands for this type of dynamic isomorphism, i.e., the representation of a certain spatiotemporal translation from the parenting material into a new genetic structure. Borrowing Hoffmeyer's words in parallel with Peirce's terminology, this process can be described as "interpretation" and I suppose this is how it incorporates the form of an energetic interpretant. Returning to Thom's topological framework, it is important to keep in mind that the notion of morphogenesis foregrounds his strategy of dealing with the issue of forms as emerging and dynamically taking place in space and time. Admitting that DNA replication incorporates the form of an energetic interpretant, we can associate this form with a space-time vector and therefore grant a morphogenetic basis of explanation to this specific semiosis.

In addition, if we consider that DNA replication incorporates a semiotic process of interpretation, this process can be described as a topological structure in which forms take place in space and in a certain period of time. For Thom, the recognition of these topological structures is an important move for understanding in which conditions qualitative transformations occur in the phenomenal world (i.e., the world of processes in space-time). Following Poincaré's steps, it is no coincidence that Thom finds in topology a mathematical tool that can be applied to understanding the qualitative dynamics of the phenomenal world as an alternative to the quantitative methods in science: "The topological is essentially qualitative, not quantitative. So, in the field of mathematics, we have structures which are interesting, and which are not quantitative" (Thom, 1993, p. 79, my translation).

For instance, considering the perceptual experience, Thom understands that perception consists of extracting a form or a structure from the matter in which it is implemented as a qualitative transformation. In this sense, when Thom speaks of qualitative transformations in the phenomenal world, he refers to the process of extracting forms. If so, the lesson that can be taken from Thom's topological interpretation of the Peircean icon is that it is an extracted form, and time also counts as a variable in its formation: "the formation of the image from a model appears as a manifestation of the universal dynamic having irreversible character" (Thom, 1983, p. 264, my translation).

In the field of non-equilibrium thermodynamics in Physics, by irreversibility, one means a one-way direction of time, or asymmetry. For Thom, not only the formation of the image supposes time

as a variable, but it is essentially an irreversible process. In this sense, more than a trivial similarity between object and sign or even an instantaneous representation of the present, images (icons) engender spatiotemporal translations by incorporating specific topological forms in a large variety of contexts (such as DNA replication, for instance). For Thom (1983, p. 64), moreover, the iconic processes instantiate "the Heraclitan notion of the irreversible flow of time" in the sense that an image regenerates the meaning each time it is interpreted, as for instance, a descendant regenerates the meaning of the parent.

In the essay *From icon to symbol*, Thom not only advances a theory of symbolism based on a topological framework, but, above all, gives a dynamic interpretation to the Peircean icon going beyond the graphic representations relating images and objects. This basic form of symbolism finds a parallel with Whitehead's theory of perception (1927, p. 3): "if we are tired, [we] pass straight from the perception of the coloured shape to the enjoyment of the chair". According to Whitehead, this situation instantiates an interesting point in relation to the very notion of object: regardless of colors, shapes, and so on, the object "chair" is in relation to all sorts of purposes for a chair and no matter if it is in relation to men or puppy dogs' purposes (Whitehead, 1927/1978, p. 4). Here, drawing a parallel between Thom's topological framework and Whitehead's theory of perception, we find an argument for expanding the boundaries of symbolism beyond human language. Compared to the image of a chair intended for men or puppy dogs, this expansion of symbolism can include instances of creativity (see Kling, 2017, p. 125).

Considering the situation described by Whitehead within Thom's topological framework, the image "chair" is not derived from a representation of colors, shapes, and so on; instead it results from the regeneration of meaning whenever these sensory aspects are spatiotemporally interpreted: that is, the image "chair" (or object in Whitehead's terminology) has nothing to do with a relation of similarity, but it is actually the translation of environmental contingencies that results in specific topological forms in space and time (men, puppy dogs, so on). In a latter phase during which Thom will deepen a topological theory of meaning, he will seek to describe the origin and development of these spatio-temporal forms in his theory of salience-pregnancy.

Continuing his interpretation of Peirce's second trichotomy, René Thom considers how indexes acquire significant relevance in leading the object; that is, relevance understood as biological relevance. Moreover, differently from images or icons in which the semiotic dynamic does not appear to be temporally manifest, indexes have the virtue of engendering a spatiotemporal form leading to the object. For Thom (1983, p. 267-268), for instance, if the pair a, α corresponds respectively to a being and an index: 1) the index has no value or symbolic function in itself; 2) the relation linking the a, α is a form of intelligence which is obviously settled on a semiotic bedrock. In order to develop these two points, Thom presents two examples.

In the first example, (a) is a gazelle; and (b) is a tiger. Assuming the perspective of b, the catastrophe a → b represents a biological relevance and the index α may be the tracks of the gazelle on the ground. But, if we assume the reversal of the catastrophe a → b, obviously, the vector direction will be altered and so the index α may be the tracks of the tiger on the ground. In the second example, Thom considers: (a) is a drink, α is a bottle of wine, and (b) is an inveterate drinker. In this situation, no matter if the bottle is full or empty, it has value for the drinker. In comparison with Pavlov's experiment, if the bottle is empty, a false index (α') will equally take place in the catastrophe a → b. For Thom, nevertheless, the occurrence of a false index does not mean that the index of animal is typically inferior to man. Drawing a parallel between Humean empiricism and modern elementary particle physics, Thom (1983, p. 268) argues that it is practically impossible to dissociate causality and spatio-temporal contiguity: that is to say, 1) no index has value in itself; 2) every index is associated to a specific vector space. Taking these two points into account, it is fair to say that René Thom reaffirms not only that indexical processes may represent distinctive forms of intelligence, but also the matrix of symbolism and the (bio)semiotic transition between man and animal. In the final part of *From Icon to Symbol*, not by chance, Thom addresses the theme of symbolism.

As the last part of his topological interpretation of Peirce's second trichotomy, René Thom broadens the (bio)semiotic construction of a theory of symbolism by investigating the transition between man and animal. Here, even shortly, Ernst Cassirer's *The Philosophy of Symbolic Forms* must be considered in parallel with Thom's (bio)semiotic of a theory of symbolism. In the chapter "The Universal Function of the Sign: The Problem of Meaning", because human beings interpose systems of signs relating to the world in all of its richness and diversity, Cassirer argues that they should be understood most fundamentally as symbolic animals. According to him, beside and above the world of perception, human beings freely produce their own world of symbols as the basis of the process of language formation which goes beyond the simple phenomena of individual consciousness (Cassirer, 1957/1980, p. 88-89). Even admitting for a parallel with Cassirer's *Philosophy of Symbolic Forms*, it seems to me that the most important and original aspect of Thom's (bio)semiotic theory of symbolism is his idea of relating localization and meaning.

In parallel with Cassirer's description of the process of language formation going beyond the simple phenomena of individual consciousness, René Thom considers the description of the spatio-temporal processes in the environment that differentiates human psychism from that of animals. For Thom, differently from animal's automatism in relation to environmental contingencies, human being's psychism has evolved in a distinctive direction (Thom, 1983, p. 274-275): 1) the symbolic activity and the appearance of language have freed human beings from the sensorial enthrallment of things by giving names to them; 2) freed from this enthrallment, most important, the ego has been able to support the spatial representation of the bodies; and, as a consequence, 3) things have had their representation located in Euclidean space.

From this (bio)semiotic picture representing the emergence of symbolism in man, René Thom explores the view that all forms of meaning – including symbolic forms – depend on a geometric or topological study of space. In other words, he makes explicit his intuitions in topology and semiotics according to which any sign can be represented in a vector-structure as indicating a spatio-temporal form. In the essay *Space and Signs* [L'espace et le signes], Thoms advances these intuitions insofar as he systematically develops a topological representation of semiosis (as related to a vector-space) in which time is also counted as variable.

3.2 Space and Signs (*L'espace et les signes*, 1980b)

In the essay Space and Signs which exposes exemplarily Thom's intuitions on topology and language, associating a space-time vector with signs, he develops an understanding of meaning as having a continuous mode. Drawing a parallel with topology, Thom considers continuity as a central category for dealing with the issue of meaning. In this sense, if we consider the association of a space-time vector with the sign, we must also consider what mode semiosis takes: is it a continuous or discontinuous mode of meaning? Given that it is difficult to propose a precise definition of "boundary" according to the language of modern topology (Papadopoulos, 2019, p. 12), we face the same difficulties in relation to semiosis' mode as well as the boundaries of sign, object and interpretant. However, considering René Thom's paper *Aristotle as a topologist* (Aristote topologue) (1999), we can assume an understanding of semiosis as based on a continuous mode and as topological space in which the boundaries of sign, object and interpretant are defined. Taking into account this topological picture of semiosis, what precisely does René Thom mean by a "place" ?

According to him (Thom, 1999, p. 41), we do not find in Aristotle's work the word "topos". For him, nevertheless, the Stagirite had original topological intuitions regarding the notion of "*topos*" or "place". Working on Aristotle's writings, in particular, Thom (1999, p. 41) discusses the relation between "*topos*" and "*eschata*" which means "limits" or "extreme boundaries": that is, the idea that a place (*topos*) has

an "*eschata*" as a reference to a boundary. By using the term "*eschata*", in particular, Thom strives to make precise a definition of "boundary" that is consistent with the language of modern topology which means more than the understanding that the boundary defines the object. In Thom's own words (1999, p. 41, my translation): "we must now explain the structure of the eschata in a place, which a priori presents a surprising duplication: the double crown of the 'eschata' [as] the zone of the extremities [that corresponds to] the notion of 'edge' or 'border'".

In parallel with his interpretation of Aristotle's use of "*eschata*", René Thom (1999, p. 42) finds in Stokes' formula the requirement for considering the notion of a minimal limit applied to the topological definition of boundary: "the edge of the enveloped body and the edge of the enveloping body are together, [and] we could geometrically identify these two edges" (my translation). For him, speaking topologically, the "*eschata*" (i.e., object's limits or extreme boundary) translates the notion of minimal limit and therefore represents the structure of a double ring relating the edge of the enveloped body and the edge of the enveloping body. For Thom, indeed, the edge has a topological meaning: "There is something like an edge. A common source: the *continuum*. For me, it is [...] the topological *continuum*, underlying both the qualitative and the quantitative" (Thom, 1993, p. 80).

According to Thom's view, moreover, since topology does not concern quantitative representations, we can consider the qualitative deformation of the forms that are really interesting: "How is a sphere different from a ball? It is not really quantitative. How is the circle different from a disk? It is not a question of quantity, it is a question of quality" (Thom, 1993, p. 78, my translation).

For Thom, this way of regarding the qualitative transformations is not only consistent with the modern topology, but also it is in convergence with the study of the use of space by living beings in contemporary ethology. For instance, since the work of Jakob von Uexküll, the study of the organisms' Umwelt has contributed to understanding the way in which they use space as a qualitative reference to their environments.

Considering the examples of qualitative deformations of forms (like a sphere into a ball), it is fair to say that the reference of organisms to their environment can be translated by the notion of "*eschata*" as Thom uses it: that is, meaning the edge of the enveloped body and the edge of the enveloping body, "*eschata*" stands for the structure of a double ring that expresses the spatial integrity of the organism's edges as a place (or topos) in continuous deformation. Given that this double ring could be geometrically represented (as indicating that the edge of the enveloped body and the edge of the enveloping body are spatially together), Thom (1999, p. 46, my translation) resumes Stokes' formula as a fundamental axiom of modern topology: "the relation of the edge of an edge is empty".

Tracing a parallel between this axiom and Thom's interpretation of the Aristotelian notion of eschata, one can say that the emptiness of boundaries refers to an essential ambiguity regarding the very topological notion of place (as well as an essential ambiguity regarding the edges between organism and environment). To bring to mind a more expressive picture of this ambiguity, let's consider the Borromean rings:

Figure 1: the Borromean rings' structure. Speaking topologically, each ring and its respective place exist only in reference to a dynamic of interconnections – none of them exists in isolation.
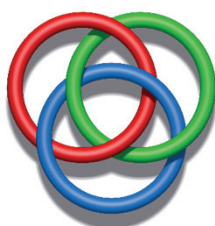

Illustration: Rini, 2014

Assuming René Thom's topological description of the relations between edge and place, I understand that semiosis an be represented on a similar basis: associating semiosis to a topological space, the edges and places of sign, object and interpretant are defined by their mutual interconnections since in isolation they are empty of reference. In the dynamics of the Borromean rings' depicted above, we can respectively associate each ring and its respective place to the interconnection of sign, object and interpretant. In René Thom's essay *Space and Signs* (which offers a topological interpretation of Peirce's second trichotomy), we find this intuition on vector-space as representing the structure of semiosis. In this paper, particularly, Thom (1980b, p. 193, my translation) draws attention to the fact that human symbolic activity lies essentially in the operation of reference (*renvoi*): "the signifier refers to the signified, the *signum* to the *signatum*". He suggests that this reference may be interpreted as a three-dimensional Euclidean localization in which the sign is associated to a space-time vector.

Figure 2: Vector S of an index
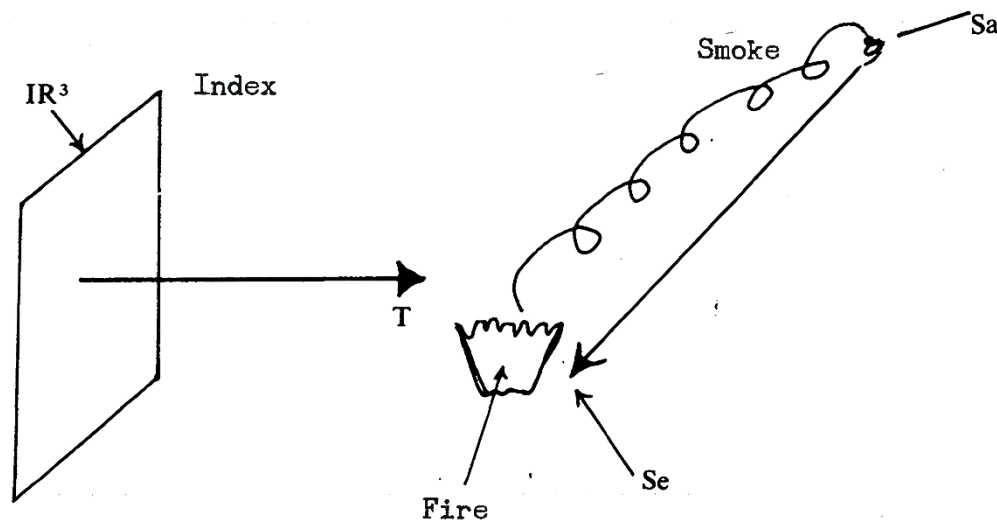
Reference: Thom (1980b, p. 194)

In this interpretation, we find not only the use of a topological vocabulary applied to semiosis, but also, as Thom's original turn of thought, time is counted as a variable. By interpreting Peirce's second triadic classification of signs, Thom connects index, icon, and symbol to dynamic transformations of forms over time. In this sense, contrary to the pre-eminence of synchronic analysis, he relates semiosis (as a meaning process) to a dynamic ("more geometrico") point of view generalized in the field of topology (Wildgen, 2017, p. 8). For Thom, that means to assume the spatial and temporal aspects as being primarily preconditions of analysis. It is not surprising that in the most orthodox linguistic and semiotic circles, René Thom's radical turn of thought was not well received.

In addition to topology, Thom was interested in dynamics. For him, above all, "mathematics is a method to obtain realistic representations of space and dynamic processes" (Østergaard, 2010, p. 35). It is in this framework integrating topology and dynamics that Thom interprets Peirce's triadic classification of icon, index, and symbol: each of these signs can be associated to a space-vector which is considered in relation to time as reference to present (icon), past (index) and future (symbol). The originality of René Thom's morphodynamic semiotics is that while Peirce applies the topological concepts to all forms of continuity, i.e., the nature of space, time, and logic (Havenel, 2010), he assumes topology as language of spatial forms in his modeling of semiosis. For Thom (1980b, p. 194), in particular, if we accept Peirce's view that "the essence of the symbol is being in the future (*esse in futuro*)", the symbols can be understood arising out of a temporal reversal. To illustrate this temporal reversal, Thom takes up the experiment of Pavlov's dog.

Figure 3: Vector S of a symbol (points to the future)
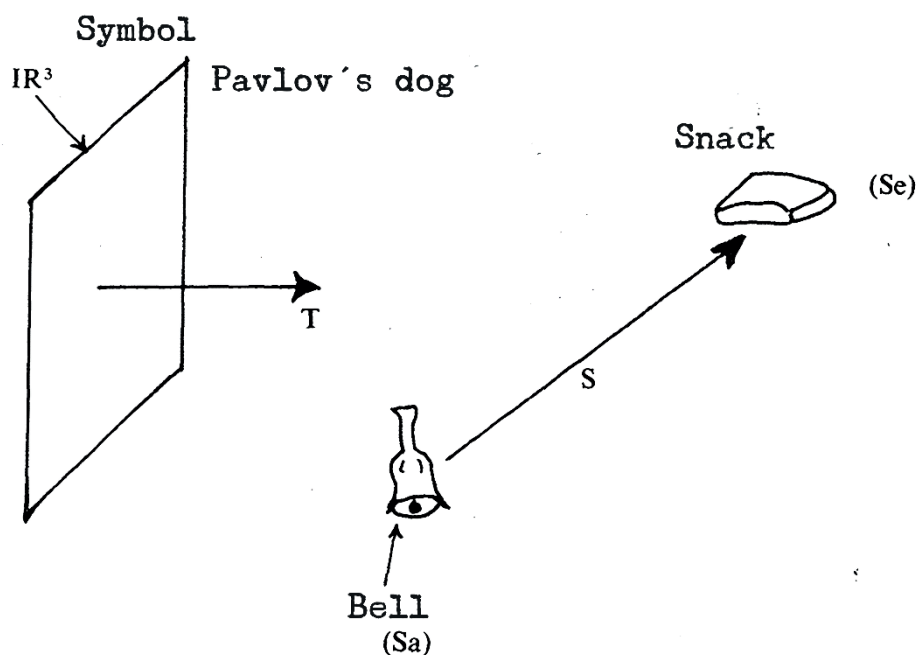
Reference: Thom (1980b, p. 195)

Assuming that the ring of the doorbell is the sign (in Pavlov's experiment), Thom argues "the 'meaning' [...] can be identified with the totality of reactions that it arouses in the interpretant subject" (Thom, 1980b, p. 199, my translation). Even in the absence of the originally inducing form (meat), the dog salivates and so the ring of the doorbell acquires a symbolic value: "the meat leads to total satisfaction, while the doorbell alone, after an anticipatory pleasure, leads to frustration by absence of an expected reaction" (Thom, 1980b, p. 199, my translation). For him, since the meaning of the ring of the doorbell (as a sign) is subject to a temporal reversal, he concludes that every sign is in principle polysemous: on the one hand, the ring of the doorbell acquires a positive value as a sign of pleasure; the other hand, it acquires a negative value as a sign of frustration.

In parallel with the studies of contemporary ethology, Thom considers that semiosis (understood as a meaning process) takes place as a part of the regulation of a living being's behavior. According to his line of thinking, nevertheless, the difference between non-human and human semiotics on which we can speculate is that while the former is characterized by a low polysemy, the latter consists of free representations, long and branched chains of symbolic use.

4 Final remarks

To end this paper, very shortly, it is important to understand that much more than being an interpretation of Peirce's second triadic classification of signs, René Thom's essay *Space and Signs* deepens his topological theory of meaning. Anchored in a mathematical and dynamic framework, Thom converts semiosis (as a meaning process) into spatial form. In parallel with his work on morphodynamics in biology (in which Thom develops a topological representation of the deployment of the boundaries between organism and environment), he redefines the dynamics of semiosis: that is to say, the edges and the places of sign, object and interpretant are topologically interpreted from their mutual interconnections that configure the spatial form of semiosis. The idea that all forms of semiosis (as meaning processes) incorporate a topological space sums up Thom's (bio)semiotics. Although it is hardly reasonable to

assert that semiosis is a ubiquitous process across the universe, it is undeniable that the humblest forms of life are capable of carrying out meaning processes that develop in space (and in time).

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