

Organic Semiosis and Peircean Semiosis

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Abstract The discovery of the genetic code has shown that the origin of life has also been the origin of semiosis, and the discovery of many other organic codes has indicated that organic semiosis has been the sole form of semiosis present on Earth in the first three thousand million years of evolution. With the origin of animals and the evolution of the brain, however, a new type of semiosis came into existence, a semiosis that is based on interpretation and is commonly referred to as *interpretive*, or *Peircean* semiosis. This suggests that there are two distinct types of semiosis in Nature, one based on coding and one based on interpretation, and all the experimental evidence that we have does support this conclusion. Both in principle and in practice, therefore, there is no conflict between organic semiosis and Peircean semiosis, and yet they have been the object of a fierce controversy because it has been claimed that semiosis is always based on interpretation, even at the cellular level. Such a claim has recently been repropounded in a number of papers and it has become necessary therefore to reexamine it in the light of the proposed arguments.

Keywords Organic codes · Interpretation · Peirce · Origin of mind · First-person experiences · Macroevolution

Introduction

Biosemiotics is based on the idea that semiosis (the production of signs) is such an essential component of life that one cannot exist without the other (the principle that “*life and semiosis are coextensive*”).

But what is semiosis? On this point, unfortunately, biosemiotics is split into two opposite camps that represent its two historical starting points. The synthesis of biology and semiotics that today we call ‘biosemiotics’ was developed in fact in

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two fields that lie at the opposite ends of academia. The first origin took place in molecular biology as a result of the discovery of the genetic code (the name “molecular biosemiotics” was coined by Marcel Florkin (1974) precisely to designate the study of semiosis at the molecular level). The second origin of biosemiotics took place in the humanities and was masterminded by Thomas Sebeok in two distinct stages. In 1963, Sebeok extended semiosis from human culture to all animals and founded the new research field of “zoosemiotics” (Sebeok 1963). More than 20 years later, he explicitly made a second extension from animals to all living creatures and called it “biosemiotics” (Anderson et al. 1984; Sebeok and Umiker-Sebeok 1992; Sebeok 2001).

It is these two “birthplaces” of biosemiotics that have nurtured the two different concepts of semiosis that still divide the field into opposite camps.

In biology, the existence of a real genetic code is proof enough that semiosis exists at the molecular level, and this implies that *organic semiosis is defined by coding*.

In the humanities, the dominant view is the Peircean concept that semiosis is always an interpretive process, and this implies that *Peircean semiosis is defined by interpretation*.

We have therefore two types of semiosis, one based on coding and one based on interpretation, and each of them represents phenomena that undoubtedly exist in Nature. There is ample evidence that animals are capable of interpreting the world, and this clearly means that *Peircean* (or *interpretive*) *semiosis* is a reality. But it is also evident that the rules of the genetic code do not depend on interpretation because they have been the same in all living creatures and in all environments ever since the origin of life.

The logical conclusion is that the two types of semiosis are both present in Nature and represent two distinct evolutionary developments. Organic semiosis appeared at the origin of life with the genetic code and was responsible for the origin of many other organic codes in the three thousand million years of cellular evolution. Interpretive semiosis came much later and evolved exclusively in animals because only nervous systems can produce it (Barbieri 2011).

This common sense conclusion, however, is precisely what the supporters of the Peircean concept of semiosis do not accept, on the ground that there must have been *continuity* in evolution (what Peirce called *synechism*). If there is mind, interpretation and semiosis in nervous systems, they claim, it is because there have been forms of mind, interpretation and semiosis in all previous systems, including free-living cells and the precursors of the first cells. This takes us all the way to Peirce’s cosmological conclusion that mind is everywhere, that “the universe is perfused with signs”, that in the beginning there was ‘pure firstness’ in the form of ‘pure feeling’ or ‘pure quality’.

A Tribute to Peirce

Charles Sanders Peirce (1839–1914) was an American polymath, educated in chemistry, who gave lasting contributions in philosophy, logic and semiotics. In philosophy he was the founder of ‘pragmatism’ (or ‘pragmaticism’ as he called it), and in logic he was the first who went beyond Aristotle by adding the new category of ‘abduction’ to the classical Aristotelian categories of ‘induction’ and ‘deduction’

(abduction is an ‘extrapolation from limited data’, an operation by which a result is reached by “jumping to conclusions”). But his greatest contribution was in semiotics, the *doctrine of signs*, a field that he virtually rescued from oblivion after the long neglect imposed by the Cartesian cut between mind and matter (Favareau 2007).

Signs have been traditionally defined as “something that stands for something else”, and since antiquity have been divided into two great classes called *symbols* and *symptoms*. Augustine (389ad) called them *signa data* and *signa naturalia*, a distinction that continues to these days under the terms of *conventional signs* and *natural signs*. The conventional signs (or symbols) are those where there is no *physical* relationship between signs and objects and a link between them can only be established by arbitrary rules, i.e. by conventions. Names, for example, are signs (because they ‘stand for’ the named entities) and are conventional signs because they are not determined by the characteristics of the named entities. In the same way, there is no necessary connection between symbols and the entities that they stand for (between a flag and a country, for example).

In natural signs, by contrast, a physical link is always present between signs and objects. Typical examples are the *symptoms* that doctors use to diagnose illnesses (spots on the skin, a fever, a swollen area, etc.), as well as a variety of *cues* (smoke as sign of fire, odours as signs of food, footprints as signs of organisms, etc.). In all these cases there is a physical relationship between the visible signs and the invisible entities that they point to, and yet the relationship is *underdetermined*, so much so that it takes a process of learning and an act of interpretation to establish it. The diagnosis of an illness from symptoms, for example, is always an interpretive exercise, and even simple associations, such as those between clouds and rain, depend upon processes of learning and memory.

All this suggests that semiosis is based on interpretation in natural signs and on codes in conventional signs, as Aristotle, Augustine and Thomas Aquinas had indicated. On this point, however, Peirce broke with tradition, argued that conventions too are interpretive processes and concluded that semiosis always requires interpretation. According to Peirce, in other words, the agent of semiosis is necessarily an *interpreter*, and this is why Thomas Sebeok (2001) declared that “...there can be no semiosis without interpretability” (p.68).

This conclusion was expressed in formal terms in the treatise *Semiotik/Semiotics* edited by Posner et al. (1997), where semiosis has been defined in the following way: “The necessary and sufficient condition for something to be a semiosis is that A interprets B as representing C, where A is the interpretant, B is an object and C is the meaning that A assigns to B” (p.4).

Modern semiotics, in short, is firmly based on the foundation laid down by Peirce, and it is no exaggeration to say that Peirce’s contribution is comparable to Aristotle’s. But even Aristotle made mistakes, and his teaching has often been turned into fundamentalism. Today we have the same problem with Peirce. The best way to honour him is showing that some of his ideas are still perfectly valid and extremely useful, whereas others can be safely abandoned, including his grand vision of a universe perfused with signs.

The alternative is the idea that mind had an origin, that interpretation had an origin, that consciousness and first-person experiences did have origins, so let us see how they could have come into existence.

Evolving the Brain

The organs of animals are not enlarged versions of the cell organelles, but there is nonetheless a parallel between them because there are similar molecular mechanisms at the two levels of organization. The same basic proteins, for example, are expressed in the muscles of an animal and in the contracting region of a cell, so it is likely that the evolving animals took advantage of the mechanisms invented by the ancestral protozoa.

This makes sense from an evolutionary point of view, and suggests that the first animals already had the potential of expressing an internal division of labour. Some of their cells, for example, could preferentially express the genes of locomotion, thus becoming the precursors of the future motor organs. Other cells could preferentially express the genes of signal transduction and become the precursors of the future sense organs. A third type of cells could establish a link between them and prefigure in this way the future *nervous system* because this system is, by definition, a bridge between sense organs and motor organs.

The nervous system is made of three types of neurons: (1) the *sensory neurons* transmit the electrical signals produced by the sense organs, (2) the *motor neurons* deliver electrical signals to the motor organs (muscles and glands), and (3) the *intermediate neurons* provide a bridge between them. In some cases the sensory neurons are directly connected to the motor neurons, thus forming a *reflex arch*, a system that provides a quick stimulus-response reaction known as a *reflex*. Intermediate neurons, therefore, can be dispensed with, and a few animals do manage without them. It is a fact, however, that most animals do have intermediate neurons, and what we observe in evolution is that brains increased their size primarily by increasing the number of their intermediate neurons. The evolution of the brain, in other words, has largely been the evolution of the ‘intermediate brain’.

The first nervous systems were probably little more than a collection of reflex arches, and it is likely that the first intermediate neurons came into being as a physical extension of those arches. Their proliferation was favoured simply because they provided a useful *trait-de-union* between sensory neurons and motor neurons. Once in existence, however, they could start exploring other possibilities.

Their first contribution was probably the development of a multi-gated reflex-arch system. The behaviour of an animal must take into account a variety of clues from the environment, and to this purpose it is useful that a motor organ receives signals from many sense organs and that a sense organ delivers signals to many motor organs. This inevitably requires multi-gated connections between sensory inputs and motor outputs, and that probably explains why intermediate neurons had such a great evolutionary success.

In addition to transmitting electrical signals, however, the intermediate neurons could do something else. They could start *processing* the signals, and that opened up a whole new world of possibilities. In practice, the processing evolved in two great directions and produced two very different outcomes. One was the formation of neural networks that give origin to feedback systems and provide a sort of ‘automatic pilot’ for any given physiological function. The other was the generation of feelings and instincts.

The first processing was totally unconscious and was carried out by a component of the intermediate brain that can be referred to as the *cybernetic brain*. The second

processing was adopted by another major component of the intermediate brain that can be referred to as the *instinctive brain*. The intermediate brain, in short, evolved from a primitive reflex-arch system and developed two distinct types of neural processing, one completely unconscious and the second controlled by instincts. But why *two* types of processing? Why develop feelings and instincts if a cybernetic brain can work perfectly well without them?

Feelings and Instincts

A cybernetic brain can control all physiological functions and can cope with the vagaries of the environment, so there does not seem to be any need to evolve also feelings and instincts. We should not forget, however, that a cybernetic brain is an intermediary between sense organs and motor organs, and can work only if there is a *continuous* chains of reactions between inputs and outputs. This means that all the operations of a cybernetic brain form an unbroken sequence, and the initial input is inevitably a signal from the outside world. An animal with a fully cybernetic brain, in other words, is virtually a puppet in the hands of the environment. An instinctive brain, instead, is a system where the orders to act come *from within* the system, not from without. An animal with an instinctive brain takes decisions on the basis of its own instincts, of its own internal rules, and has therefore a certain autonomy from the environment. But does such autonomy have an evolutionary advantage?

In circumstances when there is no food and no sexual partner in the immediate surroundings, a cybernetic animal would simply stop eating and mating, whereas an instinctive animal would embark in a long journey of exploration well beyond its visible surroundings and even in the absence of positive external signals. An internal drive to act, irrespective of the circumstances, in short, can have a survival role, and that is probably why most animals evolved both a cybernetic brain and an instinctive brain.

It must be underlined, however, that an instinctive brain is not a system that can simply be ‘added’ to a cybernetic brain. An instinctive brain acts on the basis of internal drives, and that means that it has the ability to send its own orders to the motor organs, i.e., to generate its own electrical signals. That in turn means that the signals delivered to the motor organs do not come all from the sense organs.

The evolution of the instinctive brain, in brief, required a major change in brain circuitry. The bridge between sense organs and motor organs provided by the cybernetic brain had to be *interrupted*, and the gap was filled by a new bridge made of feelings and instincts. The instinctive brain did not simply *add* feelings to a pre-existing system. It physically broke the continuity of the cybernetic bridge and introduced a new bridge in between. As a result, the intermediate brain, acquired an entirely new control system, a new intermediary between sense organs and motor organs, and this intermediary—the instinctive brain—was capable of taking autonomous decisions based on internal drives. But how could that happen? How could physiological processes give origin to the subjective experiences that we call feelings and instincts? How could the brain produce the mind?

A similar problem exists in the origin of life: how could matter produce life if there is a fundamental difference between them? How can something give origin to

something fundamentally different from itself? Many have decided that no such difference can exist, and therefore that “*life is chemistry*”, a conclusion that goes in parallel with the idea that “*mind is brain*”. But a logical solution does exist.

Any biological system that makes objects according to the rules of a code is generating biological artifacts, and a world of artifacts is fundamentally different from the world whence it came (Barbieri 2003). A manufacturing system based on the genetic code could generate molecules that cannot be formed spontaneously, thus bringing absolute novelties into existence. In a similar way, a brain manufacturing system based on a neural code could generate absolute novelties that cannot be formed spontaneously such as feelings and instincts. This is the *code theory of mind*, the idea that there was a *neural code* at the origin of mind as there was a genetic code at the origin of life (Barbieri 2006, 2010).

The Neural Code

In the origin of life, the key event was the appearance of *proteins*, and the genetic code played a crucial part in it precisely because it was instrumental to protein synthesis. In the origin of mind, the key event was the appearance of *feelings*, and our hypothesis is that a neural code was as instrumental to the production of feelings as the genetic code was to the production of proteins. The parallel, therefore, is between feelings and proteins, and this immediately tells us that there are both similarities and differences between the two cases.

Proteins are *space-objects*, in the sense that they act in virtue of their three-dimensional organization in space, whereas feelings are *time-objects* because they are ‘processes’, entities that consist of flowing sequences of states. The same is true for their components. Proteins are assembled from smaller space-objects like amino acids, and feeling are assembled from lower level brain processes such as neuron firings and chemical signalling.

The idea of a deep parallel between life and mind leads in this way to a parallel between proteins and feelings, and in particular between genetic code and neural code. But does a neural code exist? This term is used fairly often in the scientific literature and stands for the unknown mechanism by which the signals from sense organs are transformed into feelings and sensations. But such a mechanism could well be different from animal to animal, whereas the origin of mind requires a universal mechanism. Can we really say that a (nearly) universal neural code exists in all animals as a (nearly) universal genetic code exist in all cells?

Let us consider, for example the transformation of mechanical stimuli into tactile sensations. Rats have mechano-receptors on the tip of their whiskers while we have them on the tip of our fingers, and there is no doubt that our tactile exploration of the world is different from theirs; but does that mean that we use a different neural code? The evidence is that the physiological processes that transform the mechanical stimuli into tactile sensations are the same in all animals, and this does suggest that there is a universal mechanism at work (Nicolelis and Ribeiro 2006). As a matter of fact, the evidence in question comes from animals with three germ layers (the triploblasts), but they represent the vast majority of all animal taxa, so let us concentrate our attention

on them. How can we generalize the experimental data and conclude that virtually all triploblastic animals have the same neural code?

We do know that the starting point of all neural processing is the electrical signals produced by sense organs, but we also know that the sense organs arise from the basic histological tissues of the body, and that these tissues (epithelial, connective, muscular and nervous tissues) are the same in all triploblastic animals. All signals that are sent to the brain, in other words, come from organs produced by a limited number of universal tissues, and that does make it plausible that they represent a limited number of universal inputs. But do we also have a limited number of universal outputs?

The neural correlates of the sense organs (feelings and perceptions) can be recognized by the *actions* that they produce, and there is ample evidence that all triploblastic animals have the same basic *instincts*. They all have the imperative to *survive* and to *reproduce*. They all seem to experience hunger and thirst, fear and aggression, and they are all capable of reacting to stimuli such as light, sound and smells. The neural correlates of the basic histological tissues, in short, are associated with the basic animal instincts and these appear to be virtually the same in all triploblastic animals.

What we observe, in conclusion, is a universal set of basic histological tissues on one side, a universal set of basic animal instincts on the other side, and a set of neural transformation processes in between. The most parsimonious explanation is that the neural processes in between are also a universal set of operations. And since there is no necessary physical link between sense organs and feelings, we can conclude that the bridge between them can only be the result of a virtually universal *neural code*.

The ‘First-person’ Experiences

Feelings, sensations, emotions and instincts are often referred to as ‘first-person’ experiences because they are experienced directly, without intermediaries. They make us feel that we know our body, that we are in charge of its movements, that we are conscious beings and that we live a ‘personal’ life. Above all, they are quintessentially private internal states, and this makes it impossible to share them with other people.

The goal of science is to produce testable models of what exists in nature, and first-person experiences are undoubtedly part of nature, so we should be able to make models of them. Models, of course, are not reality (“the map is not the territory”), but they are ideas of reality and what really matters is that these ideas can be tested and improved. In our case, the problem is to build a model that makes us understand, at least in principle, how first-person experiences can be produced.

Let us take, for example, the case in which a toe is injured. We know that electrical pulses are immediately sent to the central nervous system and that the intermediate brain processes them and delivers orders to the motor organs that spring the body into action. Here we have two distinct players: an observer system (the intermediate brain) and an observed part (the injured toe). It is the observer that gets the information and transforms it into the feeling of pain, but then something extraordinary happens. We do not feel the pain in the intermediate brain, where the feeling is created, but in the toe, where the injury took place. Observer and observed have become one, and it is

precisely this collapse into a single feeling unity that generates a ‘first-person’ experience.

Something similar takes place when we receive signals from the environment, for example when we look at an outside object. In this case, an image is formed on the retina and electrical signals are sent to the intermediate brain. Again, there is a separation between observer (the brain) and observed (the retina). What we see, however, is not an image on the retina, where the visual information is actually produced. The intermediate brain and the retina collapse into a single processing unity and what we see is an image in the outside world. This is again a first-person experience, and again it is generated by a physiological process that short-circuits the physical separation between sense organs and intermediate brain.

What we call ‘first-person’ experiences, in brief, is nothing elementary, undifferentiated and indivisible. The exact opposite is true. They are the result of complex neural processes where many highly differentiated cells act in concert and create a physiological short-circuit between observer and observed.

This implies, in particular, that first-person experiences cannot exist in cells. Like feelings and instincts they could evolve only in multicellular systems and their origin was a true macroevolution, an absolute novelty in the history of life.

The Origin of Interpretation

The instinctive brain delivers orders to the motor organs, and is the directive centre of an animal, the basis of its ability to survive and reproduce. The cybernetic brain is essentially a servomechanism, and it is precisely this function that explains its enormous expansion and development in evolution. The instinctive brain has changed very little in the history of life, and the major developments took place precisely in the cybernetic tools that animals evolved to provide the instinctive brain with increasingly sophisticated servomechanisms.

The neural networks are probably the most powerful of such tools. Their ability to create feedback loops allows them to produce a goal-directed behaviour in a system, but they also have other outstanding properties. In artificial systems, for example, it has been shown that neural networks can provide the means of *learning* and *memory* (Kohonen 1984), and it is likely that they have similar properties in living systems.

Memories allow a system to compare a phenomenon with previous records of similar phenomena, and it is from such comparisons that a system can ‘learn’ from experience. Memories are clearly a prerequisite for learning, but what does learning achieve? What is the point of storing mental representations and comparing them? So far, the best answer to this problem is probably the idea that memories and learning allows animals to *interpret* the world. Interpretation, on the other hand, is a form of semiosis, because it is based on signs and meaning—but is it a *new* form of semiosis?

Neural networks have the ability to form memories, and a set of memories provides a model of the world that is continuously updated. Such a model, on the other hand, is necessarily formed by a limited number of memories, whereas the real world offers an infinite number of possibilities. Clearly, a model based on memories can never be perfect, but it has been shown that neural networks can in part overcome this restriction by interpolating between discreet memories (Kohonen 1984). In a

way, they are able to ‘jump-to-conclusions’, so to speak, from a limited number of experiences, and in most cases their ‘guesses’ turn out to be good enough for survival purposes.

This ‘extrapolation from limited data’ is an operation that is not reducible to the classical Aristotelian categories of ‘induction’ and ‘deduction’, and for this reason Charles Peirce called it ‘abduction’. It is a new logical category, and the ability to interpret the world appears to be based precisely on that logic. We realize in this way that interpretation is truly a new form of semiosis because it is not based on coding but on abduction. What is interpreted, furthermore, is not the world but *representations* of the world, and only multicellular systems can build them.

Single cells decode the signals from the environment but do not have the physical means to build internal representations of them and therefore cannot interpret them. They are sensitive to light, but do not ‘see’; they react to sounds but do not ‘hear’; they detect hormones but do not ‘smell’ and do not ‘taste’ them. It takes many cells which have undertaken specific processes of differentiation to allow a system to see, hear, smell and taste, so it is only multicellular creatures that have these experiences.

The evolution from single cells to animals was a true macroevolution because it created absolute novelties such as feelings and instincts. Later on, another macroevolution gave some animals the ability to *interpret* the world, and we can actually prove that that ability evolved in stages. Some animals (like snakes) stop chasing prey when it disappears from sight, whereas others (like mammals) deduce that the prey has temporarily been hidden by an obstacle and continue to chase it. Some can even learn to follow the footprints of a prey, which reveals a still higher degree of abstraction.

The ability to ‘interpret’ the world, in short, was a genuine novelty in evolution. It had an origin and created a new type of semiosis that can be referred to as *interpretive* semiosis, or, with equivalent names, as *abductive* or *Peircean* semiosis.

What Does it Take to Produce Interpretation?

It is worth recalling, at this point, the story of the old lady at a conference who claimed that the Earth is standing on the back of a giant Turtle. “But what is the giant turtle standing on?” asked the speaker, “on a second giant turtle, sir”, replied the old lady. “But what is the second...”, “it’s no good, sir”, said the old lady, “it’s turtles all the way down”. This is the traditional version of the story, but there is another, more subtle, way of delivering that message. The old lady could have said “I don’t really know what the Earth is standing on, sir, but whatever it is I call it ‘turtles’—names are just labels, aren’t they?—and that’s why I can say that “it’s turtles all the way down”.

This trick of solving problems by name-giving is precisely what has been employed in our field to claim that the cell is capable of interpretation, or, in the spirit of the turtle story, that “it’s interpretation all the way down”. Such is the conclusion of two recent papers that have applied the *terminology* of Peircean semiosis to the description of some molecular biology processes. The first paper is “What Does It Take to Produce Interpretation?” by Brier and Joslyn (2013). The second is “Anticipatory Functions, Digital-Analog forms and Biosemiotics” by Arnellos et al. (2012).

In the first paper, Brier and Joslyn present the problem in this way: "...we established that semiotics requires codes. The question is whether codes, in turn, require interpretation and interpreters." To show that this is the case, Brier and Joslyn distinguish between 'code-making' and 'code-following' (i.e., between coding and decoding), and ask the question "... what can 'interpretation' mean, if it is not code following?". Their answer is that code-following is indeed a form of interpretation "...we can identify interpretation in general as any process which encounters a sign and takes it for its meaning in virtue of some code. Moreover, interpretation in this sense of code-following requires a mechanism to physically detect the sign and manifest the corresponding meaning. And in seeking to merely identify this mechanism, it is natural to call that no less than an 'interpreter'. Thus *a ribosome is an interpreter*. And the right amino acid is its interpretation of some codon."

Here we are then. Molecular biology has shown that the cell performs operations of coding and decoding by means of enzymes, adaptors and ribosomes, and by giving them suitable names we can immediately say that the cell is a quintessentially interpretive system. All we need is to say that decoding is 'interpretation', that adaptors are 'interpretants' and that the ribosome is an 'interpreter'. The answer to the question in the title "What Does It Take to Produce Interpretation?" is straightforward: all it takes is the right choice of words.

The same conclusion is obtained in the paper by Arnellos et al. (2012) with a description of signal transduction in Peircean terms.

...Through signal transduction, living systems are capable of internalizing a cue to a certain aspect of the environment, by producing intracellular signs in response to an extracellular sign. *Receptors* play a central role in this processes ... in Peircean terms one should consider how the processes described above instantiate a triadic relation in which, a receptor, *which acts as a local interpreting system*, recognizes a sign (the extracellular signal, an antigen), which refers to an object in the world (a dynamical object, say, a pathogen) through a feature semiotically available in its representation (the molecular form of the antigen, as an immediate object that indicates the pathogen, as a dynamical object). *Receptors act as interpreting systems* by coupling to transducers, catalytic molecules that trigger the production of another sign inside the cell in response to the extracellular sign. This subsequent sign is the interpretant of a first triadic relation, and it takes the role of a sign for a subsequent triadic relation, allowing signaling to proceed.

Again, coding and decoding operations are classified as interpretive processes and the inevitable conclusion is that the cell is constantly engaged in interpretation. Problem-solving by name-giving, q.e.d.

Why All this Fuss About Names?

Names and words are tools that we employ for countless purposes and we are quite used to give them multiple meanings, according to circumstances, so what is all this fuss about them? What is wrong in saying that decoding can be called interpretation?

Why should we not generalize the concept of interpretation, and say, for example, that “*the ribosome is an interpreter*” or that “*receptors are interpreting systems*”?

In principle we can use words as we please, of course, but there is a caveat. If we generalize the concept of interpretation in order to include coding and decoding, nothing prevents us from generalizing it even further. Edwina Taborsky (1999, 2006), for example, has done precisely that, and has proposed that any function $f(x)=y$ is an act of interpretation where the function ‘ f ’ interprets ‘ x ’ as representing ‘ y ’. In this way, any physical law expressed by a function like $f(x)=y$ would be a process of interpretation and therefore an act of semiosis.

This would imply that semiosis exists everywhere in the Universe—a view known as *pansemiosis* or *physiosemsiosis*—but it would also imply a deep re-interpretation of the notion of ‘function’ and of the concept of physical laws. This point is important because Peirce himself maintained that the laws of physics are not immutable rules, but *habits* that nature acquired in the course of time, and embraced the view that semiosis is everywhere: “... the entire universe—not merely the universe of existents, but the universe which we are all accustomed to refer to as ‘the truth’—all this universe is perfused with signs, if it is not composed exclusively of signs.” (Peirce 1906).

The extension of the term ‘interpretation’, in other words, is not done in the name of a greater liberty of expression. It is done to convey the message that “it’s interpretation all the way down”, that “it’s mind all the way down”, that we have consciousness because there is a little bit of consciousness in every atom of the universe. This is the ancient doctrine of *hylozoism*, the view that ‘matter is pregnant with life’, that ‘matter is exhausted mind’, that ‘mind is everywhere’.

In such a cosmology there are no ‘origins’, only the unfolding of pre-existing potentialities. There was no origin of life and no origin of mind because life and mind have always been there. There has been no origin of interpretation, no origin of semiosis, no origin of consciousness and so on. Which is a comfortable way out, after all. We no longer have to struggle with origins. We can sit back and relax at the sweet thought that “it’s turtles all the way down”.

The Hermeneutic Cell

The idea that the cell is living by coding and decoding, not by interpretation, has been criticized many times by Anton Markoš and his colleagues (Markoš and Cvrčková 2002; Markoš and Švorcová 2009; Markoš and Faltýnek 2011) and recently it has been the object of a renewed attack (Markoš and Cvrčková 2012). Markoš insists that cells are interpretive organisms, but his theoretical framework is hermeneutical (in the sense of Heidegger 1950) rather than Peircean, and his model can be referred to as ‘the hermeneutic cell’. It is a model where “*cells are able to make wise decisions and act upon them*”

In order to illustrate this point, Markoš compares two games, chess and ice-hockey. The cells based on coding and decoding are like chess players that behave according to a fixed set of rules, whereas the hermeneutic cells are like ice-hockey players, “... who create the game *within* the given limits. They are not pushed and pulled by external forces, they themselves govern—or better, “negotiate”—the

dynamic of the match. Each of them enforces his fitness upon the given world, they take risk, they recognize the meaning of their doings—and the output is by far not the result of decoding.” (Markoš and Cvrčková 2012).

The problem with this view is not only that there is not a shred of evidence in its favour but that all the experimental data that we have tell us a completely different story.

- [1] Bacteria are cells whose behaviour is fully accounted for by coding and decoding, as proved, for example, by the fact that they are commonly employed for the industrial production of proteins that they have never encountered before (Danchin 2009). It has been found, furthermore, that bacteria have not changed much in the history of life, as illustrated by the fact that modern stromatolites built by cyanobacteria are virtually identical to the 3.4 billion and to the 1.8 billion year old stromatolites that have been found in the fossil record (Schopf 1999; Knoll 2003). The extraordinary thing is that it was precisely by continuously adapting to the environment while conserving a fixed set of organic codes that bacteria have literally transformed the Earth and have turned it into the blue oxygenated planet that has supported all the other forms of life.
- [2] In contrast with bacteria, the eukarya did become increasingly more complex in the history of life, but this is well accounted for by the development of new organic codes. With the terminology of game playing, the bacteria are chess-players whereas the eukarya are chess players + bridge players + rugby players + ice-hockey players ...and so on. While the bacteria have adopted a streamlining strategy, the eukarya have maintained the ability of the ancestral systems to explore the coding space, and it was this code-creating ability that took them all the way up to multicellular life. Cells are indeed game players, but all it takes to play games is codes, and organic codes are all we need to account for cell behaviour and cell evolution.
- [3] Free-living single cells have a context-dependent behaviour, but that does not mean that they are capable of interpretation. A context-dependent behaviour means a context-dependent expression of genes, and this is obtained by linking the expression of genes to signal transduction, i.e., by integrating the genetic code with a signal transduction code. It takes only two context-free codes, in short, to produce a context-dependent behaviour, and there is no need to assume anything more complicated than that, especially for the cells that appeared at the beginning of the history of life.

It is absolutely true that there are organisms “...that make wise decisions and act upon them, ... that take risks and recognize the meaning of their doings”—in short, that have a hermeneutic behaviour. But those organisms are animals, not cells, and the origin of animals was a true macroevolution, followed by the origin of mind and by the origin of hermeneutics. The idea to give cells the status of ‘honorary animals’ saves us a lot of trouble because it makes origins disappear, but that is not what biology is about.

The Novelty of Organic Semiosis

According to the classical doctrine of semiosis developed by Aristotle, Augustine and Aquinas, signs are divided into two great categories—conventional signs and natural

signs—and this for two different reasons. One is because they derive either from nature (*signa ex natura*) or from culture (*signa ex cultura*). The other is because they are either symbols (*signa symbolica*) or symptoms (*signa symptomatica*). If we explicitly mention both these characteristics, signs are defined in the following way:

- [1] the conventional signs are *signa symbolica ex cultura*, and
- [2] the natural signs are *signa symptomatica ex natura*.

The discovery of the genetic code came as a bolt from the blue precisely because it revealed the existence of a *third* category of signs that all great thinkers of the past had not been able to predict: the existence of symbols that come from nature, not from culture. In addition to the two classical categories, therefore, we now have a third one:

- [3] the organic signs are *signa symbolica ex natura*.

This is the immense novelty of the genetic code. It brought to light a third type of semiosis that exists in the organic world and for this has been called *organic semiosis*, or *code semiosis*. In order to accept this conclusion, however, we need to *prove* that organic semiosis is real semiosis, i.e., that organic signs and organic meanings do exist at the molecular level.

The signs and meanings that we are familiar with are those produced by our mind (or brain), and what is crucial about them is that they are *mind (or brain)-dependent entities*. A mental sign is never an *intrinsic* property of a mental object. It is something that the mind can give and the mind can take away. More generally, the links that are established between signs and objects are totally dependent upon the *agent* of coding, i.e., upon the *codemaker* of a system. What really defines signs and meanings, in other words, is that they are *codemaker-dependent entities*.

We know that proteins are made by a ribonucleoprotein apparatus that is the physical seat of the genetic code and represents therefore the *codemaker* of the cell. This tells us that every cell does have a genetic code and a codemaker, but what about signs and meanings? Genes and proteins appear to have only ‘objective’ chemical properties, not the ‘codemaker-dependent’ properties that *define* signs and meanings. A messenger RNA, for example, appears to be a unique and objective sequence of molecules, but let us take a closer look.

A messenger RNA is certainly a unique and objective chain of *nucleotides* but in no way is it a unique sequence of *codons* because different codemakers could scan it in different ways. If the nucleotides were scanned two-by-two, for example, the sequence of codons would be totally different. The same chain of nucleotides, in other words, can give origin to many sequences of codons, and it is always the codemaker that determines the sequence and actually *defines* the codons. A linear sequence of codons, in short, does not exist without a codemaker and outside a codemaking process. It is totally dependent on codemaking and is therefore a *code-maker-dependent entity*, which is precisely what a sign is (Barbieri 2008). In the same way, the linear sequence of amino acids that is produced by the translation apparatus is also a codemaker-dependent entity, because only a codemaker can produce it, and different codemakers would arrange the amino acids in different ways, which shows that the sequence of a protein is only one of the many possible ‘meanings’ that could be given to a string of nucleotides (Barbieri 2008).

The sequence of a gene and the sequence of a protein, in conclusion, are not objective properties of those molecules. They are codemaker-dependent entities made of organic molecules and are therefore organic signs and organic meanings. All we need to keep in mind is that *signs and meanings are mental entities when the codemaker is the mind, but they are organic entities when the codemaker is an organic system* (Barbieri 2003). We conclude that the cell contains all essential components of semiosis (signs, meanings, code and codemaker) and that organic semiosis (*signa symbolica ex natura*) is a fundamental component of life.

The Principle of Continuity

There is a diffuse tendency, today, to assimilate the organic codes to cultural codes despite the fact that they are separated by more than 3 billion years of evolution. The genetic code, for example, is often compared to the Morse code because both of them consist of mappings between two domains. And yet they could not be more different. For one thing, the Morse code is perfectly *reversible*, or *invertible* (it transforms the letters of the alphabet into dots and dashes and vice versa), whereas the genetic code is absolutely *irreversible*, or *non-invertible* (it goes from genes to proteins and absolutely *not* vice versa. The reverse transformation is not just avoided, it is physically impossible). A second outstanding difference is that the messages in Morse are perfectly equivalent to those in the alphabet, whereas in the organic codes they are not. Genes are not at all equivalent to proteins and the two types of molecules represent totally different worlds. A third difference is that the Morse code is imposed by an outside operator, whereas the rules of the genetic code come *from within*, from an internal codemaker, which implies that they are subject to continuous mutations and must be *actively* conserved in every cell and in every generation.

The fact remains, however, that the Peircean concept of semiosis is widely regarded as a *logical necessity*, a framework that describes all possible types of signs and must therefore be applicable *a priori* to all semiotic systems. In reality, this generalization is valid only if we accept the *principle of continuity* proposed by Peirce.

It is an experimental fact that animals are capable of interpretation, but it is the principle of continuity that allows us to extend this faculty to all previous organisms. It is that principle that makes it legitimate to use the same terminology at all levels, and say, for example, that “the ribosome is an interpreter”, that “receptors are interpreting systems”, that “cells are able to make wise decisions and act upon them”.

As a matter of fact, things are not that straightforward because the principle of continuity works both ways: it is equally legitimate to say that “it’s mind all the way down” as to claim that “it’s chemistry all the way up”. In both cases it is the principle of continuity that gives us the solution, and people seem unable to cope without it. How could it be otherwise? How could something give origin to something fundamentally different? How could matter produce life if there was a discontinuity between them?

The principle of continuity is often taken as a logical necessity, and yet an alternative does exist. It is the principle that there are real discontinuities in Nature because organic codes bring genuine novelties into existence. There is nothing absurd

in the idea that many types of molecules appeared spontaneously on the primitive Earth and that some of them had the ability to stick other molecules together by chemical bonds. They were the first molecular machines and started producing molecular artifacts—objects that cannot be formed spontaneously and represent an entirely new world, a real discontinuity in Nature.

The origin of the first cells was a genuine novelty and it was the genetic code that made it possible. The origin of mind was an historical fact and there was a neural code behind it. Human culture did have a beginning and it was a language code that brought it into existence.

The difference between Peircean semiosis and organic semiosis, in conclusion, is real and fundamental because it is the difference that exists between continuity and discontinuity. It is high time therefore that we recognize that both of them exist in Nature, and that the synthesis of biology and semiotics in biosemiotics has precisely the purpose to find out how both of them created the one world we live in.

The Problems of Biosemiotics

The genetic code was only the first of a long series of organic codes that have appeared in the history of life (Barbieri 2003), and this raises at least three formidable problems.

[1] Origin and conservation of the organic codes.

Before the origin of the genetic code, the ancestral ribonucleoprotein system, or *ribotype*, was still in the process of evolving its coding rules and was therefore a *code exploring system*. After the origin of the genetic code, however, the situation changed dramatically. No other change in the coding rules was tolerated and the cell became a *code conservation system*. Another part of the ribotype, however, maintained the potential to evolve other coding rules and behaved as a new code exploring system. The ancestral *Eukarya*, for example, had a *code conservation part* for the genetic code, but also a *code exploring part* for the splicing code. This tells us that the ancestral cells had to solve two distinct problems. The first was a *code conservation problem*: in a situation where all cell components were subject to continuous mutations, how did the cells manage to conserve their organic codes for billions of years? The second was a *code exploring problem*: how did some cells manage to maintain the potential to explore the coding space and to give origin to new organic codes? These issues are important because they account for the two most crucial events that took place in evolution. The ability to create coding rules accounts for the origin of the genetic code and of all other codes that followed. The ability of the cell to conserve its own codes accounts for the fact that the organic codes are the great invariants of life, the entities that must be conserved while everything else is changing.

[2] The role of the organic codes in evolution.

The genetic code was a precondition for the origin of the first cells, the signal transduction codes divided the first cells into three primary kingdoms, the splicing codes were essential to the origin of the nucleus, the histone code provided the

working rules of chromatin, and the cytoskeleton codes allowed the eukarya to perform the internal movements of mitosis and meiosis (Barbieri 2003). All great events of macroevolution, in short, are associated with the appearance of new organic codes, and this gives us a new description and a completely new understanding of the history of life.

[3] The transition to higher forms of semiosis.

The organic codes provided the sole form of semiosis that existed on Earth in the first three thousand million years of evolution, but eventually two higher types of semiosis did appear. First came the *interpretive semiosis* that evolved in nervous systems (*signa symptomatica ex natura*), and then the *cultural semiosis* that made us human (*signa symbolica ex cultura*). The organic codes, in other words, do not explain *everything*, far from it. They just account for the coding processes of the organic world. They code for objects that cannot be formed spontaneously and which have unpredictable properties. They are the quintessential instruments of creativity in life, and the higher their number the greater is the creative potential of a system. But they account only for the generative rules of life, not for the flesh and blood of history.

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