Leonardo Chiatti[1]

Elementary particles as signs

Abstract

C.S. Peirce's semiotic approach admits the possibility of natural signic systems. This article explores the possible connection between the concept of elementary particle and the irreducible relations of Peircean semiotics. The potentialities and the limitations of a semiotic vision of elementary physical processes are addressed.

1. Introduction

This article attempts a possible answer to a simple but unconventional question: do elementary particles form a set of signs in the sense of C.S. Peirce logic of relatives and semiotics? According to this latter, the concept of sign is appliable even to natural systems. Now, the physical world consists - in a relational perspective- of events (the so called interaction vertices) where some elementary particles are annihilated and new sets of particles are created.

So, let us define an elementary particle (lepton, meson or baryon) as a connection between two interaction vertices where it is created and successively annihilated. We recall here that only leptons seem really elementary, while mesons and baryons contain two and three quarks respectively. We leave gauge bosons a part, because they can be considered as operators exchanging leptons or quarks in a given vertex.

Speculatively, we can identify this connection as a N-adic relation in the sense of Peirce logic of relatives. It seems natural to regard adic relations as leptons, diadic relations as mesons and triadic relations as baryons. The N index, representing the number of relatives involved in relationship, thus becomes the number of subcomponents (N=1 for leptons, N=2 for mesons and N=3 for baryons).

This relation between subcomponents belonging to the same particle, however, does not consist of their mere mechanical interaction, in conformity with the bottom-up causation scheme dominating the current physics. Instead, it has to be identified with their self-duality which, according to the bootstrap axiom, permits their co-emergence from a vacuum (creation) and their common disappearance in a vacuum (annihilation) in the context of that particular event which is the interaction vertex.

How we have demonstrated elsewhere [Chiatti 2012] the bootstrap axiom necessarily involves triadic relations (represented in so called “bootstrap graphs”) which cannot in any way be reduced in collections of dyadic or adic relations, except for the identification of two or three relatives respectively. Therefore, the self-duality is essentially triadic and cannot be broken in simpler relations. In other words, it is a genuine triadic relation in the originary Peircean sense; even more, the Peircean rotation of Interpretant, Object and Representamen is nothing else that an informal statement of bootstrap hypothesis. We meet here a substantial difference respect to linguistic semiotics, where several approaches supporting the possibility of breaking of triadic relations in smaller dyadic relations have been presented along past decades [see Paolucci 2008 for a critical discussion of these approaches].

As pointed out by Paolucci 2008 the nature of Peirce relation is essentially topological. We have

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therefore a topological language which makes possible the reintroduction of a sort of top-down causation, in addition to the ordinary bottom-up causation (from subcomponents to particles) widely used in standard model. The re-appearance of the Aristotlean *causa formalis* solve several riddles which plague the standard theory; for example, it makes quark confinement and the same systematics of particles more understandable. These possibilities arise due to the accomodation of global constraints and local dynamics in a same topological picture. We remark, to contrast, that local dynamics is structured according to a predicate-subject scheme (in physics language, interaction and interacting objects) and therefore it assumes a sort of independence of interacting objects respect to their interaction. An approach taking into consideration local dynamics alone not permits to understand, for example, why quarks exist only when they are tied together in some specific configurations, and instead other configurations or isolated quarks do not exist.
We examined the poietic self-creation process (so-called "bootstrap") of minimal clusters of physical properties (the "elementary particles") in an earlier work [Chiatti 2012]. We described the correspondence between these clusters and special finite geometries, classified as type I and type II graphs.
In this article we present a transformation that naturally converts these graphs into graphs of the N-adic relations (N = 1,2,3) of Peircean semiotics, also known as Rhemata. Rhemata derived from type I and II bootstrap graphs can be naturally unified; thus a graphic sign (which we call "glyph") is associated with each physical elementary particle (lepton, meson or baryon). A glyph may be interpreted as the scheme of a symmetry breaking cascade which yields a particular kind of particle starting from the same undifferentiated and unnamed original state (the Void). Conversely, it can also be interpreted as a series of restored symmetries which reverts a specific particle to the original and archaic Void.
There are two dichotomous variables relating to the identification of elementary fermions (quarks and leptons) that are not defined by glyph topology: one of these defines whether the fermion is a particle or antiparticle and the other determines the sign of its weak isospin. Elementary fermions are created as pairs of opposite values of these two variables, from gauge quanta of electroweak interaction. The existence of gluons "confined" in hadrons is theoretically possible as well. The systematics of fundamental interactions (except gravity) is thus univocally defined.
According to Beil and Ketner 2004, 2006, Feynman diagrams where elementary fermions exchange a boson are interpreted as relations of mutual signification of those fermions. However, this signification process applies exclusively to the dichotomous variables mentioned above.
This set of results shows that although Peircean semiotics provide formal tools that are useful for understanding elementary particles (worthy of further investigation), the nature of the latter does not seem to be captured in a "horizontal" paradigm of mutual signification. The underlying structure is that of a poietic process correlating the Void and particles according to a generative order. This refers to the pre-Socratic doctrine of the Cosmic Fire, and suggests a modern form of hylozoism.
This paper is structured as follows. Bootstrap graphs are introduced in Section 2 and their conversion to N-adic relations (N = 1,2,3) is illustrated. Glyphs are introduced and their meaning is analysed in Section 3. The Conclusions provide a philosophical evaluation of the results.

2. Bootstrap graphs

Consider a quantum system associated with the ket:

$$|\psi\rangle = |\psi_1\rangle + |\psi_2\rangle, \qquad \langle\psi_1|\psi_2\rangle = 0$$

which is subject to the discontinuous variation (quantum leap) $|\psi\rangle \rightarrow |\psi_1\rangle$ at a given instant in time. Whatever the agent causing the jump, its mode of action is completely described in fully formal terms, such as the action of the projector $|\psi_1\rangle\langle\psi_1|$ on the ket. And yet, the agent cannot be "mechanical" by nature (such that its action is a necessary consequence of external constraints) as it is capable of making a choice between two possible projectors that implement the jump: $|\psi_1><\psi_1|$ e $|\psi_2><\psi_2|$. It is a well known fact that this choice is free and essentially unpredictable within the limits of ket statistics. Quantum discontinuity requires us to acknowledge Nature's creativity and spontaneity at least at the level of its elementary constituents [Peirce's *tychism* (Zuccaro 2014)].

The next question after the initial trauma is as follows: is the creation and annihilation of particles, observed daily in our research equipments or in cosmic rays, essentially characterized by this spontaneity? In other words, can this spontaneity be partially captured in a sufficiently powerful formal description to justify the systematics of the observed particles and their interactions?

We tried to develop such an approach in a previous paper [Chiatti 2012]. Without going into details, suffice it to say that we identified a correspondence between particle systematics and some forms generated by the poietic process of their manifestation [which we call "bootstrap" in honour of a prior historic attempt in this direction (Chew 1979)]. These forms are represented by three graphs that take on a different meaning depending on whether they refer to the poiesis of elementary fermions (quarks and leptons) or complete physical particles (leptons, mesons, baryons). In the first case, the graphs are called type I, in the second case, type II. Topologically, the graphs of the two classes are the same and only their interpretation changes.

Fig. 1 displays the three "bootstrap graphs" α, β and γ; their interpretations as graphs of type I (column 2) and type II (column 3) in terms of the currently accepted systematics of elementary particles are reported in Table 1.

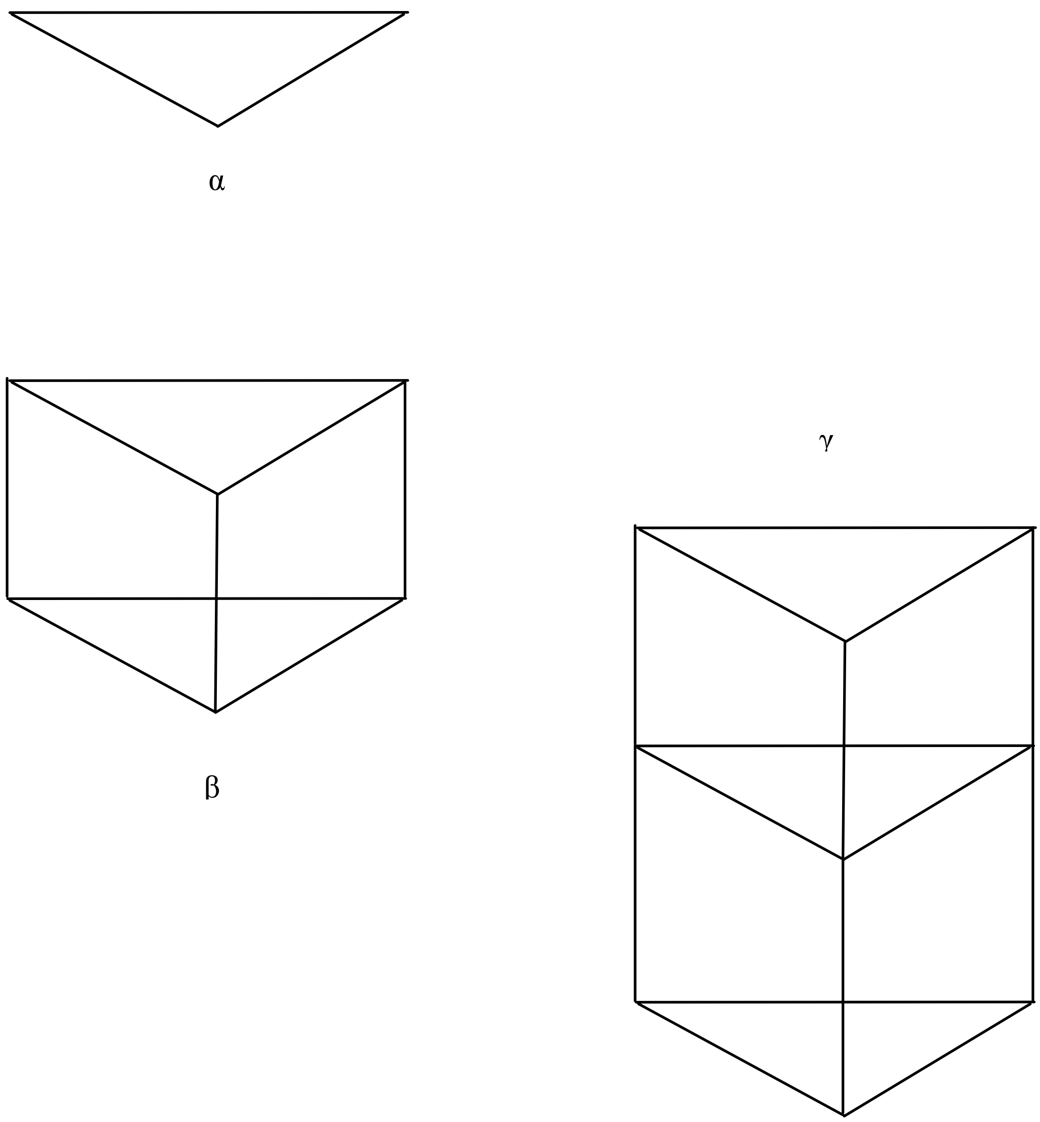

Fig.1; Bootstrap graphs

Bootstrap graphs have one, two or three horizontal "planes" consisting of triangles. The vertices of each triangle are then joined by vertical "towers".

Type I graphs correspond to fundamental fermions (quarks and leptons) of three distinct generations. These are not physical particles observable in free space, except for leptons. We merely state here that each tower can be in one of two states and the complex of these states defines the flavour of the particle and, in the case of quarks, the colour, whereas the number of planes determines its generation. Type I graphs do not distinguish between particles and antiparticles; e.g. both electrons and positrons are associated with the same graph (α).

Type II graphs correspond to combinations of elementary fermions which are physically observable particles: leptons, mesons and baryons.

Table 1. Interpretation of bootstrap graphs		
graph	**Type I**	**Type II**
α	First generation basic fermions (e,u,d,ν_1) and their antiparticles	Leptons Antileptons
β	Second generation basic fermions (μ,c,s,ν_2) and their antiparticles	Mesons
γ	Third generation basic fermions (τ,t,b,ν_3) and their antiparticles	Baryons Antibaryons

The vertices of the same tower are the elementary fermions constituting the physical particle: one for a lepton, two for a meson, and three for a baryon respectively. The vertices of a triangle are the colour (anticolour) states of a single elementary constituent fermion (antifermion). The total colour is always white. All colour states of the physical particle are present simultaneously in the graph.

Now we want to describe a particular geometric transformation of the three graphs α, β and γ. The first step of the transformation is to collapse the three towers of each graph into a single tower, identifying the vertices of the same triangle. The result is shown in Fig.2. In type I graphs the identification of the vertices of the same triangle means that the towers are no longer distinct by their state. It loses any information on colour and flavour of the elementary fermion; the only information remains on the generation of membership, represented by the number of the planes and then of survived vertices.

In type II graphs, different colour/anticolour internal states are no longer distinct; the outcome is the loss of distinction between particle and antiparticle.

Step two consists of applying to each surviving vertex the extreme of an open line (Fig. 3). In step three, the remaining vertices are collapsed, i.e. identified. The result is displayed in Fig.4.

The effect of this identification is that the information on the number of original planes is moved from the vertices (which disappear) to the open lines. In the case of type I graphs this means that the number of open lines determines the generation of the elementary fermion. In the case of type II graphs on the other hand, the number of open lines instead represents the type of physical particle: lepton, meson, baryon.

The three graphs α, β and γ transformed thus represent respectively the monad, the dyad and the triad of Peirce's semiotics, i.e. the three fundamental N-adic relations with N = 1,2,3. We now consider their meaning.

A proposition regarding a single object such as "the glove is white" provides an example of a monadic relation. This relationship can be generalized by generalizing the object and thereby obtaining "... is white". In the diagram of Figure 4 the general subject "..." is represented through the open line (*loose end* in Peirce's terminology), while the predicate "is white" is represented by the point.

Let us pass to the dyadic relation. Consider any proposition regarding two objects, such as "Mary is the sister of John". Generalizing objects, we get the abstract relationship "... is the sister of ...". In the diagram of Figure 4 the two undefined objects "..." are indicated by the two loose ends, while the brotherhood relationship is represented by the point.

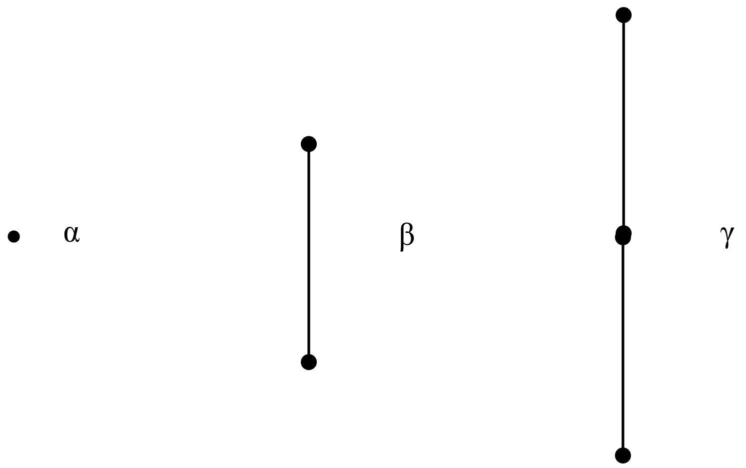

Fig.2; Bootstrap graphs after the collapse of towers

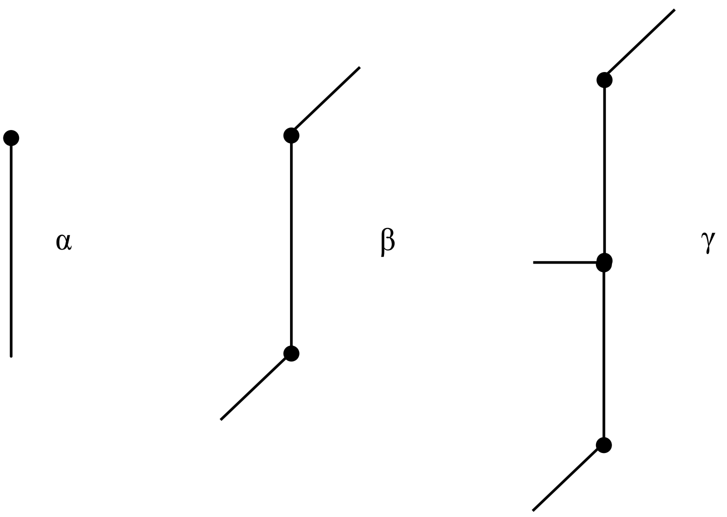

Fig.3; Bootstrap graphs after the collapse of towers and the application of external lines departing from vertices

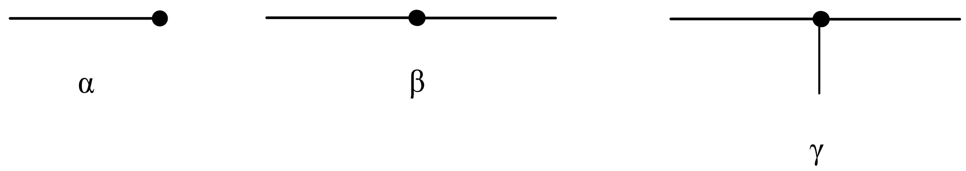

Fig.4; The same of Fig.2, after the collapse of vertices. Monadic, dyadic and triadic graphs of Peirce's theory are derived.

We now consider the triadic relationship. Consider a statement regarding three objects, such as "Mary gave the book to John". The generalized form of this proposition is "... gave the ... to ... ". Again, the three undefined objects are represented by the three lines in the diagram of Figure 4, while the relation manifested in giving the book is represented by the point.
The interpretation of transformed bootstrap graphs in terms of Peircean diagrams (*Rhemata*) is quite clear: the loose ends represent the original triangles, and the point is the self-duality relationship between them. In metaphorical terms, we could say that the point includes the power of spontaneity, which structures itself in the relation expressed by the diagram. The point is part of the diagram and yet it transcends it; we return to this important feature below.
Two Rhemata can be combined (*bonded* in Peirce's terminology) joining two of their loose ends, and then identifying the points. It can thus be shown that combining a monad and a dyad yields a monad; two dyads yield a dyad, a monad and a triad yield a dyad, and so on.
There are two important principles regarding Rhemata, established by Peirce and more rigorously substantiated recently (Herzberger 1981,Ketner 1986, Burch 1991), which are relevant here.

Reduction Principle: no genuine triadic relation can be reduced to collections composed only of dyadic relations. Conversely, there is no collection of dyadic relations which will be sufficient to construct a genuine triadic relation.

Completeness Principle: All genuine relations of greater complexity than three (tetrads and above) can be constructed from triadic relations only.

The structure of the self-duality relation between triangles, represented by the points of our Rhemata, makes the reduction principle self-evident. As a particular consequence related to type II graphs, this principle does not allow baryons to be decomposed into mesons, or to build baryons from mesons. This impossibility is clearly expressed by the conservation of the baryon number in particle physics, which to this day turns out to be a valid law without exception.
In the specific case of our Rhemata, self-duality does not allow graphs of higher order than three, thus the principle of completeness is not applicable in our context even though it is valid. We will, however, refer to it in the next Section, when we face the problem of interactions.

3.Glyphs

Representation by means of monads, dyads and triads has an advantage over bootstrap graphs, because it allows the unification of type I and II graphs. Recall that in Rhemata derived from type II graphs each loose end is a triangle of the original graph. On the other hand, the vertices of this triangle are the different colour states of the same fundamental fermion, which is represented by a type I graph. We can thus tie the loose ends of a type II Rhemata with the vertices of type I Rhemata of their corresponding fundamental fermions. The result is a graphic symbol specific to each elementary physical particle (lepton, meson, baryon). We call this symbol "glyph". Fig.5 shows the glyphs of some elementary particles.

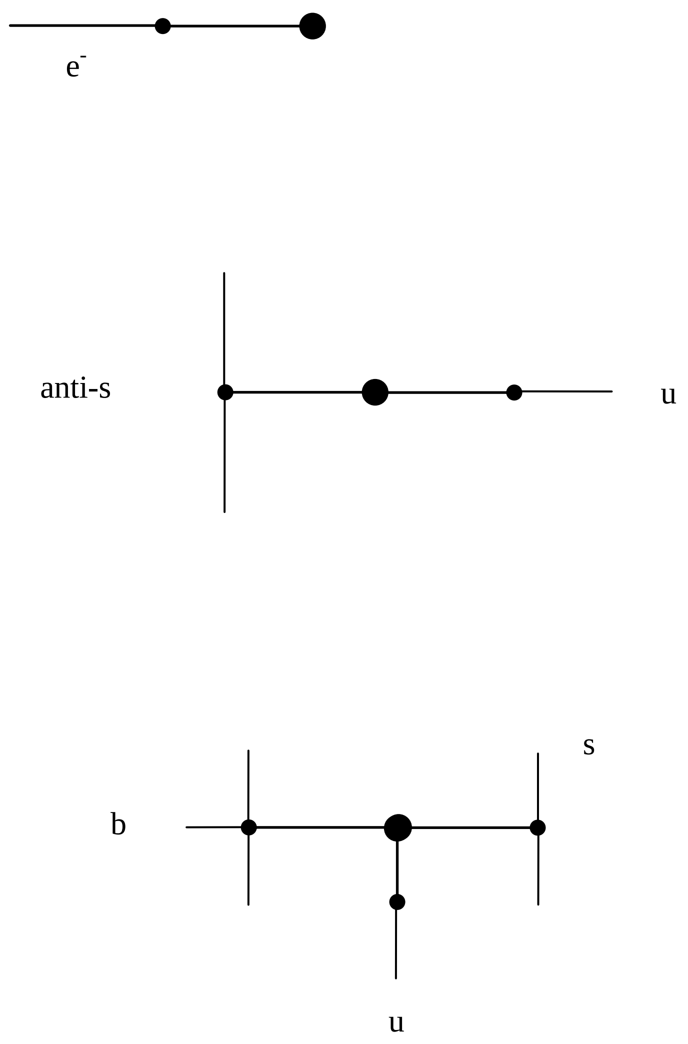

Fig.5; Glyphs of electron, meson $u\bar{s}$ and baryon usb.

For clarity, the vertices of the original type II Rhemata are represented by large circles, while the vertices of additional type I Rhemata are represented by smaller circles. Clearly, every glyph has a single "big" vertex and may contain one or more "small" vertices. The symbol of the corresponding fundamental fermion is indicated next to the latter. This symbol contains information that is not contained in the topology of the glyph, because it was suppressed during the identification of the vertices of the bootstrap graphs. This information is related to two dichotomous variables: the weak isospin sign of the relevant elementary fermion and the answer to the issue of whether it is a particle or an antiparticle. All the remaining information is represented in the topology of the glyph.
The vertices of a glyph have the same meaning that they had in the original Rhemata: they represent the power of creation (*poiesis*). The relationship between the largest vertex and minor vertices within a glyph is defined by the fact that the former creates the latter, which in turn create the loose ends that define the generation of the associated elementary fermion.
A glyph can be interpreted thus, going from the big vertex towards peripheral points, like a cascade of breaking symmetries. An undifferentiated original Void (the big vertex) is fragmented into a number of branches; following one means having determined whether we are referring to a lepton - in which case the branch is the only one to get out of the big vertex - or a quark within a hadron. By following the branch, we reach a small vertex which branches off into one, two or three open lines; that fermion's generation is determined thus. We now specify the weak isospin of the fermion and whether it is a fermion or antifermion; the topology of the glyph does not specify this additional information, which is expressed by the fermion's symbol. Thus, the glyph is the map of successive differentiations/specifications (breaking symmetries) which lead to a specific elementary particle as a finished product from the original Void.
The glyph can also be read in reverse order, proceeding from any peripheral point towards the large vertex at the centre. It then becomes a map of a series of removed distinctions (restored symmetries) which lead back to the original Void from which the specific particle under consideration emerged.
Clearly, the only information not contained in the topology of the glyph relates to opposites (positive weak isospin, negative weak isospin) and (fermion, antifermion). It is interesting to note that gauge bosons of electroweak interaction create exactly these pairs of opposites, as seen in the Feynman diagrams shown in Fig. 6. All the systematics of electroweak elementary couplings can be obtained by crossing these diagrams, as shown in Figure 7.
In fact, any information regarding the colour of the quarks belonging to a hadron has been removed in the generation of the glyphs. Colour is also generated in colour/anticolour pairs from the specific gauge bosons known as gluons. Thus gauge interactions provide information (dichotomous for electroweak interactions, trichotomous for colours) which is not specified in the topology of the glyph. Beil and Ketner give an interpretation of elementary interaction vertices in terms of Peirce's semiotics (Beil and Ketner 2004,2006) based on this approach.
According to this interpretation, an elementary vertex as shown in Figure 7 (please note that Feynman diagrams of couplings between elementary fermions and gauge bosons are all ternary) is a process of signification. During this process an Object (an incoming electron in Fig.7) is associated with a Representamen (outgoing electron) by an Interpretant (the photon). Beil and Ketner's proposal is characterised by the fact that the non-topological information required for the specification of a fermion is given by the Interpretamen in a signification process where gauge bosons appear as the Interpretant. The completeness principle then ensures that all complex interactions (Feynman diagrams of order greater than one) are represented as bonding of "elementary" significations. This statement is known to apply in the context of quantum field theory. Indeed, any Feynman graph of any order can be obtained by combining elementary ternary graphs like the one shown in Figure 7.

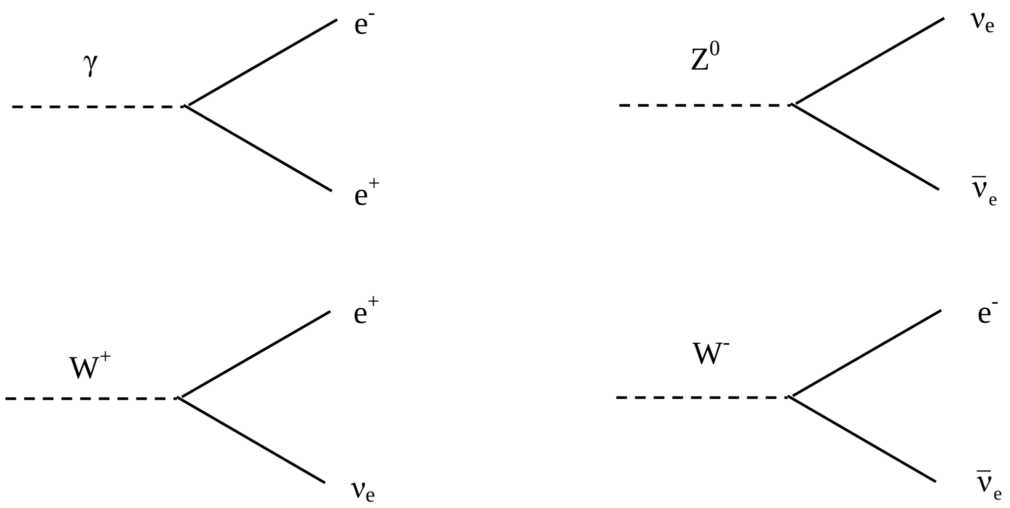

Fig.6; Examples of creation of particle-antiparticle pairs (top) and of pairs of particles having opposite values of weak isospin (down). The time is directed from the left to the right.

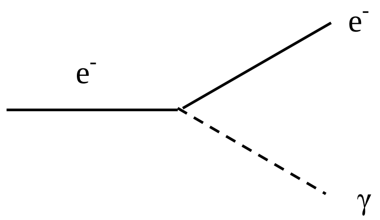

Fig.7; Example of crossed coupling. The time goes from left to right.

It is interesting to note that in this description, the spatiotemporal order emerges simultaneously with the ordinary diachronic causality associated with the interactions. Indeed, the glyph is clearly the graphical representation of the creation (going from the big vertex towards peripheral points) or the annihilation (going in the opposite direction) operator of the field associated with the particle. The big vertex, taken individually, is out of space, time and causality; it is the same for all glyphs in the sense that all the particles emerge from the same vertex and return to it. The appearance (disappearance) of an outgoing line from the big vertex refers to the creation (annihilation) of a field quantum at a given instant in time. The temporal order appears at this point.

We reach a small vertex along the line which represents the appearance (disappearance) of an elementary fermion with its full complement of spatial coordinates referring to that moment. A

lepton has one set of these coordinates, a meson has two, a baryon has three[2]. The spatial order emerges at this point and at this point the nature of the spatialised object (quark or lepton) is specified based on the interactions it takes part in, in the newly emerging spatiotemporal order, i.e. diachronic causality emerges at this point, everting in spacetime the properties (colour, weak isospin, particle *versus* antiparticle) already defined in the process of formative causation.
Beil and Ketner 2006 associate the interactions to the action of projectors, i.e. they actually refer to real interactions, i.e. "quantum leaps" like the one described at the beginning of Section 2. Elementary particles are thus the links of a network whose nodes are quantum leaps. This network, i.e. the physical world, is thus the representation fragmented in space-time of a single, timeless and spaceless Archè from which the particles emerge and to which they return. It is a particularly radical representation of Peirce's (Beil and Ketner 2006, Zuccaro 2014) *synechism* which refers in some way to the classical inheritance.

Conclusions

The principal results of previous sestions can be summarized as follows:
1) In an interaction vertex, particles are created from the Void or annihilated in it. A similar process of radical creation/annihilation not happens in macroscopic world of everyday life.
2) A certain particle is created or annihilated as a whole; therefore, its subcomponents (if any) appear or disappear together. The appearance (disappearance) of one of them is not an effect of the appearance (disappearance) of the others. Therefore, the usual scheme of bottom-up causality not works here. Instead, a sort of formative causation exists with a clear top-down structure (from the Void to subcomponents or reverse).
3) The possible configurations of subcomponents are determined by a genuine triadic relation of mutual co-creation of subcomponents, the so called self-duality relation. Therefore this relation places severe constraints to the systematics of elementary particles.
4) Peircean logic of relatives permits a topological description of these facts, which can not be captured by the usual logic based on the subject-predicate structure.
5) Elementary interaction vertex itself represents a triadic relation which can be interpreted as a “sign”. The information involved makes explicit the type of particle.
6) At the microscopic level, the mutual co-creation referred in 3) supports Peirce’s *tychism*, while the connection to Void can be considered as a possible basis for his *synechism*.
Based on the results in this paper, we conclude that particle physics undoubtedly presents some important aspects of a semiotic nature. In particular, the identification of gauge interactions between elementary fermions with Peircean signification processes proposed in the pioneering work by Beil and Ketner seems correct. However, in our opinion, the results presented do not imply that the essence of the physical world is determined in a diachronic and "horizontal" process of mutual signification of elementary processes. The problem lies in the fact that mutual signification is performed by gauge bosons exchanged from elementary fermions and only relates to specific features of the latter (weak isospin sign and particle *versus* antiparticle nature). The remaining information is made explicit in structures such as glyphs which, as schemes of action of the creative power of a primordial Void, are evidently archetypal by nature. Moreover, the same dichotomous variables defined by signification provide information *present* in the original bootstrap graphs which has merely been concealed in the transition to Rhemata and then to glyphs.
The mutual signification of elementary processes should therefore be considered in the broader context of poiesis, as its phase or step. The semiotic approach does not resume known issues of quantum field theory in a language more appropriate to the prevailing fashion of "complexity"; it makes the "vertical" origin of the elementary constituents of matter explicit. Thus, a glyph provides

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[2] This suggests the existence of a distinctive fundamental length of elementary particles, which constitutes an upper limit of the distances of the elementary fermions associated with the same glyph. From an experimental point of view, this length should be of the order of 10^{-13} cm.

descriptive but also generative order associated with the process of manifestation *in* or de-manifestation *from* the physical world. The glyph is exactly the pattern of this synchronic, vertical process connecting that which is manifest to that which is unmanifested.
Thus, signification does not exhaust the process of existence, but is a part of it. It is a part of the incessant, inextinguishable Cosmic Fire, which constitutes its essence and inner Life, in its most complex and evolute forms as well as in the tiniest granules of matter.

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