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BIOSEMIOTICS, EVOLUTION, AND PEIRCEAN GENERALIZATION

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ABSTRACT

Current philosophy tends to restrict the term generalization to the intellectual domain of concepts and theories. Peirce, on the contrary, viewed logical generalization as just an analogue of a concrete generalization that takes place in nature. The acquisition and transformation of habits, which are generalizing tendencies, propels the unfolding of cosmic, biological, cultural and technological novelties. I attempt to extend this idea by observing that conceptual generalizations preserve as limit cases the conceptions they generalize (e.g., as the real numbers include the integers). I propose that evolutionary novelties analogously preserve aspects of the structures from which they evolved, and show that there are striking analogies and parallels between conceptual generalization and other forms of evolution. This leads to the hypothesis that all other instances of evolution (biological, cultural, technological, etc.) are special cases of concrete generalization.

INTRODUCTION

In the tradition of analytic philosophy the term "generalization" is confined to the sphere of logical or intellectual operations (as in the generalization of concepts or theories) and barred from the realm of concrete physical and biological phenomena. For Peirce, on the contrary, logical and conceptual generalizations are simply the analogical counterpart within the mind and within semiotic activity in general, of the concrete process of generalization that continuously transpires in the physical world. He sometimes referred to this process as "the law of mind." The driving agency of concrete generalization is the growth, acquisition and transformation of *habits*. Habits are generalizing tendencies and a generalization of habit, *the habit of taking habits*, propels evolutionary changes through a continual emergence of novelties (cosmic, biological, cultural, technological, etc.).

A distinctive characteristic of major conceptual generalizations is the fact that generalized concepts or theories preserve in a certain sense the original concepts or theories as limit cases (or degenerate forms), in the sense in which we say that, e.g., relativity theory contains Newtonian physics as a special case, or that projective geometry subsumes Euclidean metric geometry as a special case. Analogously, concrete

generalizations emerging as evolutionary novelties appear to retain, in that sense, some of the most general aspects of the structures from which they evolved. [1]

In this paper I attempt to show how Peirce's sketchy and unfinished characterization of evolutionary processes may be expanded and made more precise through the incorporation of twentieth century scientific discoveries and ideas that were not available or foreseeable during his lifetime. I will also try to show how this extended conception opens new vistas on the relationships between biosemiotics and evolutionary biology.

THE GENERALIZATION OF "GENERALIZATION"

The reality of generality and the growth of generality through the action of generalizing are among the most central of Peirce's ideas. These conceptions evolved as strands in the temporal unfolding of his thought and became themselves, in a sense, generalized. A generalization of the very idea of generalization may seem at the outset a paradoxical notion, but we have some grounds for thinking that Peirce had entertained such an idea. In the midst of a polemical review of Pearson's *Grammar of Science*, he contended that

> […] everything that we can in any way take cognizance of is purely mental. This is a truth, because every object of thought is either a percept or a **generalization**, that is, an inference from percepts. I am conscious that my meaning here is but vaguely expressed, because **I use the word "generalization" in a generalized sense**. Unfortunately, I cannot explain myself without tedious developments of exact logic into which I cannot here enter [emphasis added]. (CP 8.153, 1901).

There are different varieties of conceptual generalization. In many cases generalizing consists in showing that an idea in a given context can be thought of as a special (less general) case of a more general idea within a larger encompassing field. The separate notions of mass and energy of traditional physics, for example, became special cases of a generalized notion (mass-energy) as a consequence of their equivalence within the wider framework of the special theory of relativity. Similarly in mathematics algebraic functions and transcendental functions merged as special cases of analytic functions.

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[1] Major conceptual generalizations involve more elementary forms of generalization, such as abductive steps, that do not display the existence of a limit case. Peirce's characterization of such elementary cases can be gleaned from the following examples: "Generalization in its strict sense means the discovery, by reflection upon a number of cases, of a general description applicable to them all. This is the kind of thought movement which I have elsewhere called formal hypothesis, or reasoning from definition to definitum." (CP 2.422, 1893, footnote); he identified generalization with the capacity "to see that what seems at first a snarl of intricate circumstances is but a fragment of a harmonious and comprehensible whole" (MS 252, n.d.; quoted by Campos 2009). On the role of imagination in Peirce's views on conceptual creativity see the insightful accounts of Barrena 2009 and Campos 2009).

Peirce's contention that generalization is operative in nature's evolutionary process, taken together with the fact that human intellectual activities are an evolutionary continuation of those processes, leads to the realization that conceptual generalization is either a special case of concrete generalization or perhaps a special case of a wider, third kind of generalization that subsumes both the concrete and the conceptual kinds. It is intriguing to contemplate the possibility that Peirce's unconcluded search for a maximal form of generality through the idea of continuity was aimed at grasping this third, all-inclusive variety.

Peirce considers conceptual generalization as a process embedded in mental action and the formation of habits, where generalization is the "law of mind:"

> The one primary and fundamental law of mental action consists in a tendency to generalization. Feeling tends to spread; connections between feelings awaken feelings; neighboring feelings become assimilated; ideas are apt to reproduce themselves. These are so many formulations of the one law of the growth of mind. When a disturbance of feeling takes place, we have a consciousness of gain, the gain of experience; and a new disturbance will be apt to assimilate itself to the one that preceded it. Feelings, by being excited, become more easily excited, especially in the ways in which they have previously been excited. **The consciousness of such a habit constitutes a general conception** [emphasis added] (CP 6.21, 1891).

The habits associated with general conceptions in the mind are for Peirce the mental counterpart of **concrete habits** operating in nature. Concrete habits act in two different capacities: they are both the source of the causal constraints that govern the course of physical events and also the driving generalizing tendency propelling cosmic and biological evolution (see e.g., Fernández 2014b). I term this habit-driven evolution "concrete generalization."

The most basic common attribute of conceptual and concrete evolution appears to be the **generation of novelty**, but there are several other commonalities to be discussed later on. For the time being I will leave aside the relations between conceptual and concrete generalization to return to them at a later section. I will first develop these ideas through separate examinations of conceptual and concrete generalization in the next two sections, to be followed by a third section concerning their similarities, differences and mutual relations.

CONCEPTUAL GENERALIZATION

Thinking brings forward a concatenation of signs conforming to the strictures of logic in lesser or greater extent. Each sign, in carrying out the mediated determination of the interpretant by the object, is a potential generalization of its immediate object. Signs combine in such manner that this proto-generalization grows into larger and expanding generalizations in the formations of concepts, propositions and arguments. Scientific theories, in particular, contain arguments directed to the explanation of phenomena and to second-order explanations of those explanations.

For instance, Galileo gave an explanation of why objects fall with constant acceleration. Newton later gave an explanation of why objects approximately follow Galileo's law, and at the same time explained why planets move according to Kepler's laws and why a growing multitude of other phenomena happen as they regularly do. We say that Newton's theory is a generalization of Galileo's theory. It is more general not only in that explains many more things but also in that it retains Galileo's theory as a special, restricted approximation. The latter gives correct predictions only when the distance of fall is short and we can thus ignore the change in the acceleration of gravity between higher and lower points. Generalized theories, in comparison to their predecessors, are applicable to wider ranges of phenomena and serve to unify previous unrelated theories under a single inferential umbrella. Key concepts of the generalized theory also become generalized in the process.

Of course, the growth of theories in the natural sciences is not simply a matter of conceptual generalization. Theories evolve in dialectical interplay with experimental praxis, which has the double task of testing hypotheses and of gathering information about the world. Through the continuous invention of new instruments (microscopes, telescopes, particle accelerators, DNA sequencing technologies, etc.) the scope of human experience and thus the range of phenomena open to scrutiny, research and manipulation, are incessantly expanding. New instruments make possible new theories and new theories open new possibilities for the invention of artifacts, including scientific instruments. In important respects the evolution of these artifacts resembles the evolution of organisms (see Fernández 2014a).

The concept of theoretical generalization evolved considerably during the twentieth century under the influence of new discoveries in logic, mathematics and natural science. Peirce or his contemporaries could not have anticipated most of them. We can cite for instance Gödel's incompletability theorems, quantum physics, the expansion of the universe, the genetic codes, stellar nucleosynthesis, the standard model of particle physics, symbiogenesis, among others.

In one important case the **process of generalization itself** became internalized within physics as a powerful heuristic instrument, through Bohr's introduction of the *correspondence principle*.[2] At the early stages of the development of quantum mechanics researchers were often confronted with empirical findings not explainable, and often not even intelligible, in light of the received notions (those of "classical physics"). What was needed was a guide for transforming and extending the old conceptions into notions capable of explaining and making understandable the new revelations. The correspondence principle fulfilled that role. It prescribed generalizing the classical laws and concepts into new hypotheses capable of making predictions in asymptotic agreement with those of the old ones at scales (large orbits, high energies, etc.) at which

[2] Max Jammer famously observed: "There was rarely in the history of physics a comprehensive theory which owed so much to one principle as quantum mechanics owed to Bohr's correspondence principle." (Jammer 1966, p. 118). For connections between Bohr's ideas and Peirce's see Fernández 1993, Maleeh and Amani 2013.

the classical notions gave approximately correct predictions. Bohr considered this principle as an internal feature of quantum physics, and he often described quantum theory as a "rational generalization" of classical physics.[3]

CONCRETE GENERALIZATION

Peirce did not use the expression "concrete generalization," but at times alluded to this idea as "objective generalization:"

> …[in cosmic evolution a] habit of acquiring habits began to be established, and a habit of strengthening the habit of acquiring habits, and a habit of strengthening that habit, and so on ad infinitum. The acquiring [of] a habit is nothing but an **objective generalization** taking place in time [Emphasis added]. (NEM IV: 140, no date).

He uses "objective generalization" on at least one other occasion, but in this second instance he expresses dissatisfaction with using the term "objective":

> The acquiring [of] a habit is nothing but an objective generalization taking place in time. It is the fundamental logical law in course of realization. When I call it objective, I do not mean to say that there really is any difference between the objective and the subjective, except that the subjective is less developed and as yet less generalized. It is only a false word which I insert because after all we cannot make ourselves understood if we merely say what we mean. (Peirce, MS 942, 1898).

I believe the term "concrete," in its contrast to "abstract," renders the intended meaning clear and free from the metaphysical baggage that burdens the term "objective."

Peirce's conception of habit is closely associated with those of generalization and growth:

> [...] all things have a tendency to take habits. For atoms and their parts, molecules and groups of molecules, and in short every conceivable real object, there is a greater probability of acting as on a former like occasion than otherwise. This tendency itself constitutes a regularity, and is continually on the increase. In looking back into the past we are looking toward periods when it was a less and less decided tendency. But its own essential nature is to grow. It is a generalizing tendency; it causes actions in the future to follow some generalization of past actions; and this tendency is itself something capable of similar generalizations; and thus, it is self-generative. (CP1.409, 1890, from "A guess at the riddle," also in EP1: 277).

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[3] A penetrating account of Bohr's conception of 'rational generalization' is given in Bokulich & Bokulich 2005. The correspondence principle itself became in turn generalized. In a remarkable and influential paper by Heinz Post, "Correspondence, invariance and heuristics: in praise of conservative induction," the generalized correspondence principle is characterized in these terms: "The most important heuristic restriction is the General Correspondence Principle. Roughly speaking, this is the requirement that any acceptable new theory L should account for the success of its predecessor S by 'degenerating' into that theory under those conditions under which S has been well confirmed by tests." (Post 1971, p. 228). See also Radder 1991.

Peirce sketched in necessarily vague terms the process of cosmic evolution. The generalizing drive of the habit of taking habits impels the emergence of novelty and variety through the breaking of old habits and the acquisition of new ones. After a full century of wondrous scientific discoveries we are now much better equipped for the task of putting flesh on this bare bones account of evolution as generalization. To some extent this is already happening in physical cosmology (see e.g. Fernandez 2014b). I believe biosemiotics, a rising discipline of Peircean inspiration, could be instrumental in filling the details of this sketch for the stages of biological evolution. The creation of novelty in the evolution of organisms goes through an ascending succession of transitions and diversifications that seem to be always accompanied by a concomitant creation of expanded semiotic powers and capabilities (see e.g. Fernández 2014a, 2014c). The interplay of energetic and semiotic actions defines every stage in the course of life processes at all temporal and spatial scales.

The following operations and processes appear at all levels in the course of biological evolution:

> **Generation of novelty** (emergence of unprecedented properties, functions or structures); **Replication** (novelties emerge at a point in time and later propagate in space through the generation of multiple copies); **Synthetical (compositional) novelty** (radically new types result from novel combinations of old-established parts or properties); **Divergence** (evolutionary trajectories in time undergo bifurcations at the emergence of new types); **Convergence** (the same evolutionary innovations reappear at different times through a process not traceable to common ancestry); **Exaptation** (former novelties are co-opted to fulfill new functions).

It is quite remarkable that all of these features are similarly manifest across different forms of concrete generalization (e.g., evolution of organisms and of technical artifacts) and also in conceptual evolution (for a variety of examples see Fernández 2014a). This naturally leads to the hypothesis that generalization and evolution are two sides of the same phenomenon and conform to the same laws.

SIGNS AND ORGANISMS

Although diverse kinds of generalization share the notable commonalities enumerated above, they also exhibit striking differences. The most important for the subject at hand is that of the nature of replication in living systems as compared to that at work in other types of evolution (of linguistic signs, musical instruments, literary genres, etc.). This difference can be best understood in light of the Peircean distinction between types and tokens.

In ordinary signs, such as the letters on this page, a general type (e.g., the letter *a* as a type or legisign) can only exist as embodied in individual concrete replicas (a token of that letter as an ink mark, a sinsign). These signs are easily transferred from one embodiment to another. For instance, I can read aloud this text and give a new habitation to the signs, which now become incarnated into a dynamical sequence of sound

vibrations. The relative independence of sign replicas from the nature of their supporting media facilitates sign replication and propagation, which is ordinarily performed by purely mechanical or physical means (printing, telephony, recordings, etc.).

In pronounced contrast, individual organisms generate replicas of themselves by that extremely complex sequence of interacting energetic and semiotic actions that we term biological reproduction. This process is based on the replication of internal genetic records (transcription, translation, etc.), and proceeds through protracted transformations of the entire medium in which a biological type (taxon) is embodied. It ends in the splitting of the supporting medium into separate working replicas of the same type.

Peirce thought of signs, and especially of symbols, as proto-organisms, endowed with many of the qualities of life (see e.g. Nöth 2014). From the perspective advanced here organisms are highly generalized instances of semiotic processes, while ordinary signs and their actions (semiosis) are basic constituents of organisms and their associations. Biological evolution is thus envisioned here as an instance of concrete semiotic generalization. It progresses through the embodiment of emerging types (taxa) into increasingly complex supporting media, capable of self-organization and of biological reproduction. The outcomes of reproduction are culled by natural selection and further constrained by the obstacles, challenges and opportunities encountered in the environment. [4]

BIOSEMIOTICS AND THE FUTURE OF PEIRCEAN GENERALIZATION

Biosemiotics proposes an integration of physical and semiotic causation in biology's explanatory accounts of the dynamics of life and its evolution. Many biologists are still unreceptive to this view and their reluctance seems due, at least in part, to seldom-articulated philosophical tenets. One clear case is the exceedingly narrow view of evolution countenanced by neo-Darwinism, the orthodox stance through most of the last century, and still prevalent. In this perspective organisms evolve through an aimless, blind process of selection out of samples of randomly generated genetic variation. Organisms are seen as passive participants in the course of evolution, stumbling into novel and more complex forms thorough the agency of sheer chance and the culling of natural selection. This view, in turn, is rooted in an old-entrenched conception of nature that deprives it of all **inner spontaneity**. In contrast, evolution as concrete generalization bestows onto nature a spontaneous drive towards the creation of that novelty and variety that so much enthralls us when we pause to contemplate its manifold bounties.

In recent decades difficulties in accommodating new discoveries have led to a growing

[4] Peirce distinguished three forms of biological and conceptual evolution: tychastic (evolution by fortuitous variation), ananchastic (evolution by mechanical necessity), and agapastic (evolution by creative love). He considered the first two to be degenerate cases of agapastic evolution. There are interesting connections between these notions, the ideas advanced here, and present attempts at expanding or modifying the traditional, neo-Darwinian views. Nonetheless, we must forgo considering these issues within the limited bounds of this paper.

dissatisfaction with the received views on biological evolution, and have generated many attempts at expanding or radically modifying them (see e.g., Lane et al. 2013, Noble 2011, Jablonka and Lamb 2014, Pigliucci 2009, Shapiro 2011, Woese & Goldenfeld 2009, Aerts et al. 2012, Bejan & Lorente 2010). Although quite promising, with few exceptions these new developments do not advance a generalized conception of evolution applicable beyond disciplinary boundaries. The Peirce-inspired view of evolution as concrete generalization, on the other hand, does definitely advance such a generalized conception and may offer a new perspective capable of restituting spontaneity to nature and of naturally assimilating semiotic notions into the conceptual fabric of biology.

Returning to the theme of conceptual generalization, it is in the realm of mathematical creation in the last hundred years since Peirce's death that we encounter the most outstanding progress in the creation of new forms of generalization and their applications. The discussion of these developments (metamathematics, non-standard analysis, category and topos theory, algebraic geometry, and many others) is beyond the scope of this paper. Mathematical ideas were an unending source of inspiration for Peirce and the new mathematical discoveries will no doubt continue to inspire those who want to proceed along his path, advancing towards the attainment of the monumental synthesis he left unfinished.

As regards this latter point I would like to draw attention to a remarkable and promising undertaking in the work of Fernando Zalamea and Giovanni Maddalena, individually and in collaboration (see e.g., Maddalena 2012, Zalamea 2012, 2013, Maddalena & Zalamea 2012). These authors are developing, modifying and extending Peirce's synechism, his conception of the continuum as a maximal form of generality transcending any aggregation of individuals and any measuring process. For this task they draw resources from seldom exploited philosophical insights inherent in the investigations of such extraordinary twentieth century mathematicians as Gödel, Grothendieck, Atiyah, Connes and Kontsevich, among several others. Their project reaches a novel conception of syntheticity aimed at redressing the prevailing imbalance in favor of analytical methods —a disparity that they acutely discern in much of last century's philosophical thought. These authors' ideas offer a deeply informed and original proposal connecting synechism to all forms of creativity in connection with Peirce's ideas about ethics and esthetics.

Creativity, as the generation of novelty, is also the unceasing outcome of cosmic, biological and cultural evolution. The conception of evolution as concrete generalization that is advanced here may at some point converge with the new synthesis that Maddalena and Zalamea are forging.

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