Progress in Biophysics and Molecular Biology 119 (2015) 469–480

Contents lists available at ScienceDirect

Progress in Biophysics and Molecular Biology

journal homepage: www.elsevier.com/locate/pbiomolbio

How the living is in the world: An inquiry into the informational choreographies of life

Pedro C. Marijuán*, Jorge Navarro, Raquel del Moral**

Bioinformation and Systems Biology Group, Aragon Institute of Health Sciences (IACS) – Foundation IIS Aragón, Av. San Juan Bosco 13, Zaragoza 50009, Spain

ARTICLE INFO

Article history:
Available online 11 July 2015

Keywords:
Communication
Information flow
Phenomenology
Life cycle
Self-production
Informational formula

ABSTRACT

Understanding the nature of life has always been a fundamental objective of human knowledge. It is no wonder that biology, as the science of life, together with physics, has traditionally been the discipline that has generated the deepest philosophical and social repercussions. In our time, the major achievements in bioinformatics, systems biology, and *"omic"* fields (genomics, proteomics, metabolomics, etc.) have not only spurred a new biotechnological and biomedical 'postindustrial revolution', but they have also disclosed an intriguing molecular panorama of biological organization that invites us to reinterpret central themes of philosophy in the light of the new knowledge. Essential tenets of phenomenology may take an intriguing new turn when contemplated from these new biological perspectives: Does the living cell instantiate a unique biomolecular way of being in the world? How is life self-produced in continuous communication with the surrounding world? How can the incessant flows of mass, energy and information inherent of *embodiment* be coherently harnessed across billions of cellular individuals?

In this paper, based on the latest developments in cellular signaling, we will discuss the dynamic intertwining between self-production and communication that characterizes life at the prokaryotic, eukaryotic, organismic, and social levels of organization. An in-depth analysis of the particular transcriptional responses of a bacterium (*Escherichia coli K-12* strain), taking as a model system, will follow. It is the creation, transmission and reception of signals which, in all instances, provides guidance and orientation to the inner self-production activities of the living agent and connects it with the world. Transitions to new levels of organization are marked by the emergence of new forms of communication, embedded in the correspondingly augmented life-cycles of the more complex entities. As will be argued here, the ascending complexity of life is always information-based and recapitulates level after level, a successful "informational formula" for being in the world. The phenomenological basis for the naturalization of cognition has moved from the biological to a new scientific arena: informational. The philosophical notion of being-in-the-world (*Dasein*; Heidegger) is shown to be completely compatible with the latest advances in biology and information science.

1. Introduction: information and life

Throughout history, the phenomenon of life has fascinated philosophers, scientists, and thinkers of all kinds. In order to provide adequate responses to questions about the mysteriousness of life, the source of heredity, and the nature of human consciousness on the one hand, and the optimization of agricultural, botanical, and husbandry practices, as well as the demands of social health on the other, an enormous portion of mental energy has always been devoted to increasing the theoretical and practical knowledge of life (Gillispie, 1960). In fact, all philosophical doctrines and scientific worldviews have reserved an essential role for life and human reason, except in the dominant Newtonian framework, rather ironically. We have had to wait until the last two centuries to find expostulations on life couched in truly scientific terms. Solving the problem of "the origins of species", consolidating the evolutionary view, and approaching the "gene particles" of heredity were absolute prerequisites for the advancement of a genuinely scientific discourse in biology (Reid, 1985). Afterwards, the relationship of

* Corresponding author.
** Corresponding author.
E-mail addresses: pcmarijuan.iacs@aragon.es (P.C. Marijuán), rdelmoral.iacs@aragon.es (R. del Moral).

http://dx.doi.org/10.1016/j.pbiomolbio.2015.07.002
0079-6107/

this 'fortified' biology with philosophy and the rest of disciplines and with the general fabric of social thought became deeper, more intense, and more controversial. During the crucial period of the "second scientific revolution", at the end of 19th century and first decades of 20th century, the new biology was caught in all sorts of philosophical and political debates, the object of heterogeneous catchwords and doctrines: *progress, competition, selectionism, racism, eugenics, hygienism, naturalism* … However there was little productive discussion of a possible interrelationship between biology and the nascent phenomenology.

Following Reid's narrative (1985) one could distinguish, though rather arbitrarily, the following main currents of biological thought at the time: (neo) Darwinism, physico-chemical positivism, vitalism, and holism. These currents were expressed more or less strongly in the different branches of biology: genetics and population biology, physiology, embryology, psychology–neuroscience, and ecology. From our perspective, the most interesting ideas came from a group of 'holistic' authors, disciplinarily not easily classifiable, who focus the integration of processes within the organism: Joseph Needham ("Order and Life", 1936), Jan Smuts ("Holism and Evolution", 1927), D'Arcy Thompson ("On Growth and Form", 1917), Samuel Alexander ("Moral Order and Progress", 1899), as well as Lloyd Morgan, Claude Bernard, Walter Cannon, Thomas Huxley, etc. However, neither the content of their work nor the personal influence of these authors provided firm ground for accompanying the new philosophical elaborations. Mainstream phenomenologists and semioticians remained blocked within their mostly anthropocentric positions—with important exceptions, e.g. Merleau-Ponty (1945). But they nevertheless contributed to inspire a new generation of integrative physiologists, ethologists, and systemic thinkers.

One philosopher well attuned to the phenomenological and biological reflections of that time was the Spanish thinker José Ortega y Gasset. He was widely read mostly through his internationally acclaimed book "The Rebellion of the Masses" (1930). Curiously, given his criticisms to Husserl's program based on language and logic (Husserl, 1911, 1970 trans.), phenomenologists considered him a stubborn existentialist, but existentialists disregarded his claims on both rationalism and vitalism and considered him a phenomenologist. An excellent analysis of the complex interaction between Ortega's *perspectivism* and Husserl's phenomenology is provided by Rodríguez Huescar (1994). Ortega, with neuroscientist Santiago Ramón y Cajal ("Textura del Sistema Nervioso del Hombre y los Vertebrados", 1899-1904), was a towering figure in Spanish intellectual life. A generation of philosophers, scientists, artists, and intellectuals of the Spanish culture (in those decades experimenting what has been known as a *'silver age'*) avidly followed Ortega's work, in particular, the painter Pablo Picasso and the poet Antonio Machado. This peculiar 'existentialist-phenomenological' track inspired wonderful paintings and poems from which an intense sentiment of life transpires, unfolding a passionate intellectual reflection. In painting, never had the deconstruction of symbolic elements conflated with unstructured human expressions under global generative processes of choral symmetries and symmetry-breakings had achieved such categorical representation of human tragedy—"The Guernica" (Leyton, 1992). In poetry, a few astonishing lines from one of Machado's poems will provide us a vivid metaphor about the meaningfulness of life … for a bacterium. Unfortunately, an in-depth analysis of that 'silver age' is outside the scope of the present essay. During brief periods, far less than a generation, some cultures get in touch with universal values of life, and these flashes of insight may be useful for us to give a human dimension to the abstracts findings of science.

The history of science, like that of humanity itself, is full of the improbable, of the unexpected, of the revolutionary. It happened in the science of the post-World War II generation: the sweeping revolution of *molecular biology* pushed the old, traditional physicochemical reductionism to a fascinating new direction, although it had to be re-elaborated under a completely new discourse. During the 1950s and 1960s, there emerged a collective commitment to represent genetic function as an information-storing system, and relentless energies were devoted to rewrite biology as an information science (Kay, 1993). Information technologies and their attendant computational discourse were permeating the wider scientific and cultural circles, loudly resonating in the work of the soon-to-be intellectual leaders of molecular biology: James Watson, Francis Crick, George Gamow, Henry Quastler, Jacques Monod, François Jacob, and Sydney Brenner. As the late historian Kay (2000) put it, this epoch implies the first historical triumph of the reductionist approach to life. It represented the weakening of holism and caused the fatal blow and total disappearance to vitalism. The information metaphor as enshrined by the founding fathers of molecular biology – expression, transcription, code, translation, messengers, transference, signaling, and so on – was giving way to the projection of the biological stuff within the ascending technology of the time, that of the disembodied binary bit.

At the same time, this first wave of revolutionary molecular-biological discoveries was planting the seeds for a series of influential non-reductionist approaches. The turmoil of discovery also put into action alternative ways of thinking that crafted new conceptual constructions: self-replication, self-organization, self-reference, autopoiesis, self-transcendence, autogenesis, autocatakinesis, etc., recapitulating the discoveries of that time from quite different angles. Factually, some fields of theoretical biology, physiology, thermodynamics, natural computation, and ecology were incorporating a plethora of alternative discourses during the last decades of the 20th century (well known authors such as Robert Rosen, Howard Pattee, Michael Conrad, Stuart Kauffman, Erick Jantsch, Humberto Maturana, Luis Varela, James Kay, Scott Kelso, Robert Ulanowicz, etc., to name but a few).

Yet another transforming way of discoveries was arriving. At the turn of the millennium, amazing achievements in bioinformatics, systems biology, the "omic" fields (genomics, proteomics, metabolomics, etc.) and signaling science were spurring a new biotechnological and biomedical scientific/industrial revolution, refocusing biological thought on highly specialized and even more technologically-entrenched grounds.

In the wake of the Human Genome Initiative, developments in automation, the explosive growth of data, and the introduction of information science tools to master these very data have changed the biological playing field forever (Lenoir, 1998). In the futuristic agenda of the revamped discipline there appear a variety of new fields: synthetic biology, high yield sequencing, artificial synthesis of complete microorganisms and chromosomes, personalized medicine, nanobiosensing, artificial cells and artificial organs, ecosystem remediation, and geoengineering. Even the teleportation of organisms is envisioned by the most imaginative leaders (Venter, 2013). As the bioinformatic champions proclaim: "In terms of discipline biology has become an information science; institutionally, it is becoming "Big Science" (Lenoir, 1998). And more sharply: "*biology is an information science*" (Leroy Hood, cited in Smaglik (2000)), or *"the living is digital"* (Hood and Galas, 2003). For Eric Lander: "Biology is undergoing one of the most fundamental revolutions that any science has seen … the whole 20th century can be read, in some sense, as the prelude to this information biology" (Nature advertisement, ©AB Applied Biosystems, 2003).

Needless to say that, as in the previous biomolecular turmoil, alternative ways of thinking are needed to re-examine more attentively the achievements of this new wave of scientific