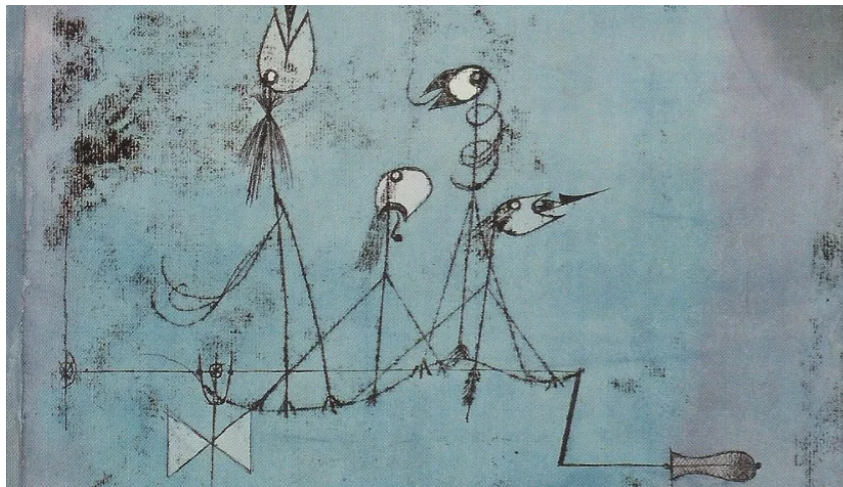


The proletarianization of biological thought

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Die Zwitscher-Maschine (Twittering Machine), Paul Klee, 1922; Image Credit: Wikimedia

PHILOSOPHY

SCIENCE

Unlike the proletarianization of artisans, the proletarianization of biologists did not start by a technique driven simplification of laboratory work, but by the way of theory. This conceptual impoverishment started with the idea that biology could be reduced to chemistry and physics, and that cells and organisms are analogous to machines, including computers. Proletarianization was further achieved by simplified laboratory practices introduced by commercial assay kits producing numerical outputs. As a consequence, scientists concentrated their efforts on generating immense amounts of data. Now, they willingly transfer the task of generating hypotheses to computers and “data scientists”. We posit that this theoretical impoverishment can be corrected using an organicist perspective for the construction of relevant and precise biological theories.

Additional sources of proletarianization are current managerial practices that restrict scientific judgement like the use of bibliometrics to evaluate scientific output and the acceleration of work under pressure to publish massively and rapidly for the sake of personal career advancement. A critical engagement towards theory construction may lead scientists to overcome and eliminate these proletarianizing factors.

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(We dedicate this essay to the memory of our dear friend and colleague, the late philosopher Bernard Stiegler. Bernard was one of the most stimulating thinkers of the 21st century who we encountered in our long peripatetic intellectual journey. His vision of the crisis that humanity is traversing during the Anthropocene, particularly the proletarianization of the human mind induced by computational thinking and digital technology, encouraged us to study the current impoverishment of biological thought. Bernard invited us to discuss this work at an informal meeting of the Internation group held in 2019 and at a public conference entitled “les entretiens du nouveau monde industriel”, at the Centre Pompidou, later that same year.

While adopting a pragmatic attitude, Bernard retained his perennially optimistic view of the human capability to find solutions in a communal contributive way. To that end, he committed himself and engaged others, to the creation of local and international projects. He developed those projects in partnership with members of the community who, guided by ethical principles, engaged in the creation of knowledge, “savoir-faire”, and “savoir vivre”. Taking into consideration the importance of engagement with the world we live in, our essay offers a hands-on solution to a major source of proletarianization of biological thought. This will be achieved through the systematic rethinking of our discipline, critically reviving fundamental concepts and through rigorous theoretical work.

There is an additional problem affecting academic sciences particularly in universities. The sine-qua-non components of universities are professors and students. The current growth of an administrative class of self-appointed ‘leaders’ of a ‘scientific workforce’ interferes with the main functions of the university, namely, acquiring knowledge, teaching and learning. We deeply regret that Bernard is not here to provide insight on and leadership to our quest to overcome this regrettable state of affairs.)

“It would be fruitful for science to gain, from its commerce with philosophy, a certain kind of freedom, which would prevent it from superstitiously treating knowledge as a long-sought revelation and truth as positive dogma. It is thus profitable to look for the elements of a conception of science and even of a method of culture in the history of science, understood as the psychology of the progression by which notions have attained their current content, as the articulation of logical genealogies and—to use an expression of Gaston Bachelard—as a census of ‘epistemological obstacles’ overcome.” (1)

Introduction

Biology is undergoing a crisis; a multiplicity of reports and essays have focused on its symptoms, such as a lack of reproducibility of experimental and epidemiological results, fierce competition for dwindling funds, and the introduction of neoliberal ethics and misguided management practices (2). Other essays suggested that theoretical and conceptual shortcomings are at the root of this situation (3). In this article we posit that the concept of proletarianization illuminates the origins of this crisis.

It was Karl Marx who, in mid-19th century Europe, developed the concept of proletarianization as a process whereby people move from an unemployed or self-employed status to one of employed as wage labor. At that time, industrialization transformed the production process by reducing the final product to an arrangement of its basic components/parts. In factories, individual workers produced one of the many parts rather than the whole, with the consequent de-skilling of those who previously had been true artisans. Marx posited that automatization furthered the process of impoverishment of skills and global “know-how”. Workers no longer needed to creatively use their minds for their labor.

In Marx’s own words: “In no way does the machine appear as the individual worker’s means of labour. Its distinguishing characteristic is not in the least, as with the means of labour, to transmit the worker’s activity to the object; this activity, rather, is posited in such a way that it merely transmits the machine’s work, the machine’s action, on to the raw material -- supervises it and guards against interruptions. Not as with the instrument, which the worker animates and makes into his organ with his skill and strength, and whose handling therefore depends on his virtuosity. Rather, it is the machine which possesses skill and strength in place of the worker, is itself the virtuoso, with a soul of its own in the mechanical laws acting through it; and it consumes coal, oil etc. just as the worker consumes food, to keep up its perpetual motion. The worker’s activity, reduced to a mere abstraction of activity, is determined and regulated on all sides by the movement

of the machinery, and not the opposite. The science which compels the inanimate limbs of the machinery, by their construction, to act purposefully, as an automaton, does not exist in the worker's consciousness, but rather acts upon him through the machine as an alien power, as the power of the machine itself" (4). In summary, proletarianization is the loss of knowledge experienced by workers because it has been transferred into the technological apparatus (i.e., the machines). Therefore, workers do not need this knowledge to perform the tasks required by their new jobs.

At the turn of the current millennium, biologists once more brought technology in to bypass the stasis resulting from the lack of success of reductionism when addressing complex biological phenomena.

More than a century later, the philosopher Bernard Stiegler described three stages in the process of proletarianization, stages that correspond to three stages of capitalism. The first, corresponds to that described by Marx as the proletarianization of know-how in the 19th century, which occurred through the development of industrial mechanization and the implementation of the scientific organization of labor (productivist capitalism). The second, the proletarianization of "savoir-vivre" in the 20th century, which occurred through the development of mass media such as radio, cinema, television (consumerist capitalism). And finally, the third, the proletarianization of design skills in the 21st century, which occurs through the development of digital and algorithmic technologies and of what is called "artificial intelligence" (computational capitalism) (5).

The introduction of the neoliberal ideology in the 1940's contributed to this process of proletarianization in all aspects of society, with clear repercussions in the scientific domain (6). The proletarianization of biological thought has at least two aspects, namely, a political-economic aspect and a scientific one. Although these two aspects are intertwined, we will concentrate mainly on the scientific aspect, only alluding to the political-economic aspect when it directly affects scientific practice.

Proletarianization in biology starts at the theoretical and conceptual core

Historically, proletarianization of workers was a consequence of the introduction of technologies and machines used in the production of consumer goods and its components. This entailed the reduction of a product to its component parts and consequent division of labor. Technically inert objects can be divided in parts and assembled such as is done with chairs, tables, clocks and cars. This partitioning is often referred to as "modularity" when the design is conceived to take advantage of the possibility of recombining the components in multiple configurations. This simplification of the means of production led workers to lose their skills.

Contrary to the proletarianization of artisans, that of biologists did not start by the introduction of new technologies into the praxis, but by the irruption of these technologies into the conceptual and theoretical core of the discipline. There is a reason for this singularity: To start with, unlike inert objects, biological ones, namely, organisms are not modular; not only do the parts depend on the whole but the whole also depends on its parts, all linked by a circular causal regime. These parts are not the result of assemblage, but the result of embryonic development, a process that intertwines the whole organism and its organs. At the end of the 19th century the introduction of stances belonging to the sciences of the inert such as reductionism, the idea that organisms are like machines, and that biology could and should be reduced to physics and chemistry resulted in the study of the parts without much concern about their reciprocal relationship with the whole. Thus, machine-based technology entered directly into the theoretical core of biology, and mechanism became the gold-standard of explanation, while traditional biological concepts and circular causation were tossed aside.



Reconstruction of Leonardo da Vinci's mechanical lion; Image Credit: Thomas Samson, Getty Images

Why do we need theories?

Before addressing the impoverishment of biological thought, it is useful to review some philosophical aspects of scientific theories. Scientists seek knowledge for its own sake, and as a guide to act responsibly when using this knowledge. At the beginning of the Scientific Revolution, scientists thought that they had direct access to their outside world and thus to their objects of study: God's will warranted the intelligibility of nature. Ever since the separation of science and religion, scientists realized that objectivity must be constructed by means of theories. Thus, scientific theories provide intelligibility principles to frame observations, experiments and explanations. Theories determine which are the proper observables and conversely, the choice of observables by scientists represents a major theoretical commitment (Z).

Biological theories

Some of the theories enunciated in the 19th century remain as major pillars of biological thought. These theories have been modified since their inception, but not only, as is generally thought, due to incongruencies between observations and theory. Indeed, the way observations lead to theory modification is neither direct nor simple. As the philosopher Georges Canguilhem stated "Theories never proceed from facts. Theories only proceed from previous theories, often very old ones. Facts are only the route (rarely direct) by which theories proceed from one to another". One does not have to search exhaustively to find that two pillars of contemporary biology, the cell theory and the Darwinian theory of evolution underwent significant changes throughout their long history. Regarding the former, a difficult issue has been the relationship of the whole with the parts, particularly when both the parts (cells) and the whole are considered individuals (which, as is etymologically obvious, cannot be further divided). Regarding evolution, we are in the midst of a crisis, with at least two sides, one defending the gene-centric modern synthesis, the other seeking to introduce development back into evolution, the physiological concept of function and system, as well as various aspects of epigenesis. An important issue that separates these two perspectives is the locus of agency, namely, natural selection for the modern synthesis and organisms for those that favor the extended synthesis.

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While theorizing about evolutionary biology continues, biology lacks a theory of the life cycle of organisms, spanning from fertilization to death. Instead, since the beginning of the 20th century, there has been a progressive degradation of biological thought in the branches of biology addressing the life cycle of organisms. The main problem has been the gradual devaluation of theory that

culminated with transferring the task of posing hypotheses to the analysis of enormous amounts of data (“big data”). Practitioners of this new way of doing research call it “discovery science” (8). Below, we will analyze this process of impoverishment.

The road to the impoverishment of biological thought

During the 18th and 19th centuries biologists made explicit their stance regarding whether biology could be entirely explained by physical principles. In this regard, a group known as *physicalists* thought that biology should be entirely explained by physical principles. The other group known as *vitalists*; thought that to explain biological phenomena, in addition to physical principles, it was necessary to invoke a vital force. To the vitalists, this force was comparable to the force of universal gravitation because both forces were equally mysterious but neither contradicted the physical principles current in the 18th century. As it was for physics, theory was still central to biology.

An early step towards impoverishment was the drastic change in the conceptualization of biological phenomena that took place at the beginning of the 20th century (9). Hitherto, biologists studied multicellular organisms bearing in mind the interdependence of cells and the organisms to which they belong (10). This view was challenged at the beginning of the 20th century by three reductionist research currents. The first was due to the introduction of genetics and evolutionary theory. The philosopher Lenny Moss described this change as a turning point that imposed a choice “... between a theory of life which locates the agency for the acquisition of adapted form in ontogeny...versus a view that expels all manner of adaptive agency from within the organism and relocates it in an external force—or as Daniel Dennett (1995) prefers to say, an algorithm called ‘natural selection’” (11). This enormous change resulted in the almost complete disappearance of agency, normativity and individuation from biological language. In addition, from 1920 to 1950 classical Darwinian selection theory was merged with Mendelian inheritance in the form of population genetics, resulting in the Modern Synthesis (12). This development led to the disappearance of the organism from the entities useful to this updated version of evolutionary theory. These useful entities were Mendelian traits/genes and natural selection. By extension, during the ascent of molecular biology, the organism became just a “readout”. The second was the introduction of cell/tissue culture into experimental biology as an important tool to study cell-based events (13). Finally, the third current was the publication in 1914 of Theodor Boveri’s book on carcinogenesis in which he posited that tumors were due to alterations in the structure of chromatin (considered by then to carry the genetic material) in a normal cell that would eventually become a cancer cell from which a tumor will grow in size and complexity by the accruing of mutated cells (14). Altogether, these three-overlapping cell-based, bottom-up approaches (i.e., genetic determinism, cell culture and the somatic mutation theory of carcinogenesis) lead experimental biologists to adopt a cell-centered interpretative perspective of the living at large that became strengthened and hegemonic to this day.

The role of the molecular biology revolution in the impoverishment of biological thought

The molecular biology revolution introduced the concepts “information”, “program” and “signal”, precise terms borrowed from rigorous mathematical theories, without proper critical consideration of their relevance to biology. In biology, these terms are just dangerous metaphors, even more so as they have been reified as entities residing in specific molecules. The adoption of these mathematical concepts, however metaphorical, have created a turn towards the mathematics of the discrete, i.e., of that which can be counted, to the detriment of the mathematics of continua. This bias is one of the factors that led to simpler explanations and to a bias toward molecular ones. For example, a gene is induced or repressed, a hormone is effective when it interacts with its receptor, an antagonist blocks binding to the receptor, etc. Equally important, molecules became agents (“hormone action”). This oversimplification is equally inimical to physics and biology, because both require the analysis of systems.

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Oversimplification was accompanied by the elimination of traditional and distinctive biological concepts. The very concept of “organism” was no longer a fundamental biological entity; if the “program” actually resided in the genomic DNA, then genes, not organisms, were the unit of

selection.

Another central concept in biology, teleology, that is, explaining something as a function of its goals, was offensive to scientists embracing mechanistic stances (15). In Jacob's own words: "For a long time the biologist has been consorting with teleology as with a woman without whom he can't live, but with whom he doesn't want to be seen in public. To this hidden relationship, the concept of program gives a legal status" (16). Going forward, cells and organisms became passive recipients of a program, which, at its best, played the role of euphemism for teleology, and at its worst, got reified. The logical consequence of this juggling was the hunt for the "mechanisms" and components of such program. The use of program to invoke teleology did not completely make biologists stop thinking teleologically. Thus, the word teleonomy was created, which means the "quality of apparent purposefulness of structure or function in living organisms due to evolutionary adaptation" (17). Teleonomy came to the rescue of the biologist to elude the problems caused by physicalism (organisms as machines and mechanism as explanation) and the shortcomings of the information-program-signal triad.

The introduction of these mathematical concepts became useful in the short term to explain DNA complementarity and the relationship of DNA-RNA-protein; in fact, this represents a strictly Laplacian causal regime which is appropriate for these genuine mathematical concepts and the discrete mathematics of computer programs. However, this interpretation is inadequate to explain the fundamental physico-chemical interactions at the core of this "copying" and "translating" activities that are not at all mediated through 0's and 1's, as in computer codes. These molecular interactions are explained by quantum mechanics, a realm of physics with a structure of determination very different from, even inimical to Laplacian determinism.

The transfer of agential properties to molecules other than genes, such as hormones, also created an image of cells and organisms as the passive results of internal (genes, hormones, etc.) and external (natural selection) agents (18). As a consequence of this phylogenetic turn, biologists concentrated their attention on the cell adhering to mechanistic explanations leaving behind the circular causality that links the organism with its parts. Another consequence of the phylogenetic turn has been the internalization of natural selection as if each cell in the organism were a totally autonomous entity. Currently, this mechanistic and reductionistic stance is being contested both by philosophers and biologists, who are bringing back agency and teleology as *bona fide* biological concepts (this promising development will be addressed later).

In sum, the *program* and *information* metaphors hindered the study of several disciplines, especially physiology and embryology. Regarding physiology, function evokes purpose and thus, teleology, the very idea that these molecular biologists wanted to eradicate. "Function" then acquired an evolutionary interpretation; as stated by the selected effect theories of biological functions, the function of a biological trait is the function that the trait was selected for. Here teleology becomes an etiology. Regarding embryology, the idea of a developmental program excludes the important role of the environment in the determination of phenotypes and in developmental plasticity. Hence, the old discipline that used to be called embryology became developmental biology, but for the most part was just developmental genetics.

An appraisal of the introduction of neoliberal ideas in the practice of scientific research at large, and in biomedicine in particular calls attention to the shift in academia from the freedom to explore one's ideas to a system where funding is the foremost goal and a measure of prestige

Another problem is that the digital bent of information is static and bottom-up; it biases the study of causality towards molecules. It also excludes dynamics and contextual dependencies, which are important determinants of biological causality. The latter are better understood by non-discrete and global perspectives (19). Thus, it is not surprising that the biomedical literature of the last half-century has given molecules, particularly DNA, a privileged role in causation. The reification of "information" "program" and "signal" is exemplified by the way researchers talk about genes containing information and of "signaling" molecules such as hormones that order obedient cells to do something (20). In sum, in less than two centuries, biologists went from thinking that, by God's will, they could have direct access to their objects of study, to realizing that this was not the case. Since then, theories played a central role in the construction of objectivity. Finally, coming back full circle, they settled for the naïve idea that we actually observe reality as it is. In this world view, observations and data are free of theoretical burden. Instead, contemporary philosophy recognizes

the theory-ladenness of empirical results; that is, that even 'raw' data is already theory-imbued (21). As the philosopher Dan Dennett succinctly stated: "There is no such thing as philosophy-free science; there is only science whose philosophical baggage is taken on board without examination" (22).

When history and contingency are forgotten

In the vague theoretical background provided by the metaphorical use of ideas borrowed from the mathematical theories of information, the "becoming" of the organism, a process taking place in four dimensions, is reduced to a program. This view ignores the complexity of multilevel interactions among cells, extracellular components, biomechanics and bioelectricity and reduces development to a play of molecules orchestrated by information emanating from a program. In the absence of a rigorous theoretical framework, hypotheses "float" in a theoretical vacuum. A vague ontology of signal-program-information feeds these hypotheses. When experiments disagree with the assumptions, there is no rejection; experimentalists just claim "complexity" to accept one thing and its opposite. As R. Feynman noted, vague theories are impossible to reject (23); they hinder scientific progress. The consequences of this ontological, epistemological and theoretical impoverishment such as irreproducibility, fraud, etc., are usually attributed solely to sociological causes, which of course, contribute to this situation but are not its only determining factor. The origin of the problem is also the absence of theory and thus of being able to produce appropriate observables.

Research without theory... the myth of big data.

At the turn of the current millennium, biologists once more brought technology in to bypass the stasis resulting from the lack of success of reductionism when addressing complex biological phenomena. Researchers that previously practiced genetic reductionism then proposed a new strategy, a 'postgenomic' research program whereby new techniques of computer-assisted analysis identifies patterns of gene expression, which in turn are used for hypothesis building (24). This move was a capitulation on reductionism: the task of proposing hypotheses was left to computers. This approach generated extraordinary amounts of data but very little biological knowledge. Intriguingly, however it led to well-funded research programs, new careers such as "data scientists", and the arrogance of proclaiming "the end of theory" (25).



The Blind Leading the Blind, Pieter Bruegel the Elder, 1568; Image Credit: Wikimedia

The sequencing of the human genome finalized in 2003 revealed a much lower number of genes than expected. This was not good news for those who thought that there was a direct relationship between genotype and phenotype. Despite the lack of progress in understanding complex phenomena, the NIH website celebrated the 30th anniversary of the unveiling of the genome project in a triumphant mode. Francis Collins, the Director of the National Institutes of Health stated, "The Human Genome Project transformed the way we study our biology and medicine. From accessing a genome sequence at the click of a mouse, performing newborn genome sequencing in an intensive care unit or the group's revolutionary decision to share the data with all, the Project's intentions and goals have spilled into how we do science today" (26). However, the genome project and its spillovers, i.e., genome-wide association studies (GWAS) and precision medicine, have yet to show a modicum of usefulness (27). Even Wikipedia recognizes the lackluster performance of GWAS by stating, "As of 2017, over 3,000 human GWA studies have examined over 1,800 diseases and traits, and thousands of SNP associations have been found.[7] Except in the case of rare genetic diseases, these associations are very weak, but while they may not explain much of the risk, they provide insight into genes and pathways that can be important." (28) Indeed, these big data which now consist of genomics, transcriptomics, proteomics, metabolomics and other profiling techniques is at

the core of another failing promise, that of “precision medicine” (29). Theoretical biologist Eva Jablonka refers to these “disciplines” as “genetic astrology” (30).

Proletarianization by laboratory tools

Before the ascent of molecular biology there was an “artisanal” side to laboratory work in biology. Laboratory personnel made the reagents and sometimes the equipment they needed and used their imagination and ingenuity to make some of the tools and contrivances dictated by their research program. Many universities had a workshop where these prototypes were refined to become more reliable tools. The advent of the molecular biology discipline brought about the use of recombinant enzymes which at the beginning were laboriously prepared in the research laboratories that used them; the preparation of reagents took a significant amount of time. Soon a whole industry developed first providing these reagents, then selling “kits” specifically designed to measure a variety of end points. Using the kits reduced lab work to simple repetitive tasks. Later on, the researcher was replaced by an automatized workstation that handled large number of samples. Because the content of the kits is proprietary, oftentimes it is difficult to assess if they are working properly and if they don't, how to fix them. These kits are veritable black box tools. When there are no available kits for a given test, a rather small number of people, the older ones, have the general skills to develop them. This is how basic skills are lost. Although we have up until now referred to biology in general, conceptual and technical impoverishment is equally evident in the biomedical sciences. From the latter proletarianization enters medical practice.

Proletarianization of Medicine

Although medicine is not a science, it uses science. Like in biology, in medicine, proletarianization happens when students are not exposed to the history, the epistemology, and the theoretical underpinnings of this discipline. Further proletarianization occurs via the systematization of basic knowledge and treatment via what is called “evidence-based practice” in medicine and the use of digital and algorithmic technologies including what is called “artificial intelligence” in diagnostic and prognostic tools. However, physicians do not treat a disease but a patient. To do so, they must have a panoply of medical skills. There is no substitute for taking a good clinical history, asking the right questions and performing a good clinical examination. Clinicians may miss a tumor that is transparent on an MRI if they do not know how to palpate a patient. Practitioners tend to rely too much on algorithms that are supposed to make predictions, or in sophisticated technical tools without knowing their limitations. Relegating diagnosis to tests and algorithms negatively impacts the training of medical doctors, who are less and less cognizant of classical medical skills.

As a consequence of this phylogenetic turn, biologists concentrated their attention on the cell adhering to mechanist explanations leaving behind the circular causality that links the organism with its parts.

Additional factors that contribute to proletarianization of biological sciences and biomedicine

There are political-ideological-societal influences that exacerbate the impoverished scientific stances we discussed above. The application of neoliberal ideology to the management of learning institutions, namely, universities, research institutes and medical schools perpetuate and fix proletarianized thinking through funding strategies and the recruiting professors and young scientists. By being exposed to neoliberal managerial practices during their training, young biologists and physicians become ignorant of their right -and duty- to think freely. They are thus willing to comply with the rules of management, consisting of evaluating productiveness arbitrarily measured by quantitative indicators. The latter cannot assess originality or scientific insight, but only the number of papers in arbitrarily ranked publications and of the number of times these papers are cited.

An appraisal of the introduction of neoliberal ideas in the practice of scientific research at large, and in biomedicine in particular calls attention to the shift in academia from the freedom to explore one's ideas to a system where funding is the foremost goal and a measure of prestige (31). The “market of ideas” has become the arbiter of funding and thus of excellence in science (32). There is a close relationship between this problem and the ethical crisis in biomedical research (fraud, lack of reproducibility, conflict of interest) (33).

Scientists are no longer considered a “thinking elite” but a “scientific workforce”. A close relationship between this problem and the ethical crisis is becoming evident. When the director of the

prestigious French Centre National de la Recherche Scientifique, an institution comparable to the US National Science Foundation, expressed his support for “an ambitious, unequal law—yes, unequal —, a virtuous and Darwinian law, which supports the most productive scientists, teams, laboratories and institutions on an international scale, a law that mobilizes energies” (34), he revealed that he misunderstood Darwin. In his statement *successful* means approved by the establishment or, in neo-liberal language, approved by the market of ideas (35). This statement was severely criticized by prestigious researchers and philosophers (36) in an open letter published in “Le Monde” which collected 12,000 supporting signatures in a couple of weeks. Although the law was finally promulgated, French scientists and philosophers continue to fight these neoliberal absurdities.

Regarding medical practice, a comparable inadequate management style is causing physicians to “burnout” in the US (37); medical doctors are obliged to “process” patients, which translates into treating them like customers. Instead of fixing the problem, the usual institutional attitude is to make doctors more resilient (38). Understandably, physicians work long hours and are “disillusioned by the productivity orientation of administrators and absence of affirmation for the values and relationships that sustain their sense of purpose.” What they need is “enlightened leaders who recognize that medicine is a human endeavor and not an assembly line” (39). The physician’s job now encompasses an increasing number of clerical duties and a significant decrease in the time spent with patients; interns in medicine “now spend 40% of their time at work on the computer and only 12% of their time on direct patient care” (40). In addition to these problems created by “the new economy” (i.e., neoliberal doctrine), there are intrinsic problems related to the same type of proletarianization observed in biology.

Correcting or neutralizing the nefarious effects of neoliberalism at large is a worthy pursuit. Preserving and improving academic freedom and strengthening tenure would improve the work conditions of scientists (41). However, it will not directly provide a solution to the impoverishment of biological thought. For this, it is necessary to address the theoretical problems we identified in the first part of this essay.



Sketch of a Roaring Lion, Leonardo da Vinci; Image Credit: leonardodavinci.net

How to right the wrongs: The return of organicism and of theory

We have explored how diverse currents in Molecular Biology created the misconception of a privileged causal level, preferably that of the gene or that of a molecule, an obsession with “molecular mechanisms”, and the conception of a reified program governing biological entities. This ideology attempts to reduce biology to physics and chemistry while ignoring the need for system analysis, which is central not only to biology but also to physics. This mistake leads to impoverishment by oversimplification and by ignoring the need for precise bases for the construction of objectivity; that is, the construction of a theoretical frame. After the failure of the mechanistic view in its latest incarnation, namely, the organism as a computer, organicists have, as an alternative, developed the conceptual analysis that makes it possible to return to the organism and its classical properties.

Organicism has its philosophical bases in Immanuel Kant and in his vision of the organism. The organicist school emerged between the two World Wars in continental Europe, Great Britain and the US. Their proponents rejected the traditional opposite views of reductionism and vitalism and aimed

to create a third way that circumvented the limitations of both. They considered organisms as organized systems, rather than an aggregate that can be reduced to physics or chemistry. Thus, they believed that biology was an autonomous discipline that needed its own theories (42). Moreover, they made it clear that mechanism was not an adequate type of explanation because in biology explanations address the reciprocal relations between parts and whole in living systems. Thus, alternative ways to explore causality had to be constructed (43).

According to Gilbert and Sarkar, organicism is a materialistic philosophical stance that, contrary to reductionism, considers both bottom-up and top-down causation (44). Others explained emergence without downward causation (45). In both interpretations, new properties that could not have been predicted from the analysis of the lower levels appear at each level of biological organization (46). Also, implicit in this view is the idea that organisms are not just “things” but objects under relentless change. Given the importance of change in both ontogenesis and evolution, some philosophers have considered them as processes rather than things (47).

Organicism has not become hegemonic but was endorsed by distinguished and vocal members such as von Bertalanffy, Woodger, Weiss and others. For von Bertalanffy, “the chief task of biology must be to discover the laws of biological systems to which the ingredient [physicochemical] parts and processes are subordinate” (48). The advent of computer sciences and molecular biology, however, “won the day” for a while during the heady times when the DNA structure and the processes of transcription and translation were being described. Meanwhile, both philosophers and biologists started to realize the shortcomings of the “new biology”.

The mechanist and reductionist views are conducive to proletarianization because they decompose biological processes into mechanisms that would be understood independent of the whole organism. To the contrary, organicism posits that parts may be analyzed only in relation to the whole, that is, the organism in its milieu.

Advances in the understanding of dissipative non-equilibrium physical systems that self-organize gave impetus to those interested in the origin of life (49). Additionally, starting around 1970, a new wave of organicism inspired by the Kantian concept of biological organization (“a thing exists as a natural end if it is cause and effect of itself”) which recognized that Kantian organization is dissimilar from spontaneous self-organization, worked out a new regime of circular causation (50). In this circular organization regime, the parts depend on the whole and vice versa; this organizational regime not only produces and maintains the parts that contribute to the functioning of the whole integrated system, but the integrated system also interacts with its environment to promote the conditions of its own existence.

Organicists have worked out the conceptualization of teleology, agency and normativity in ways that are compatible with scientific notions of causality, for example, the cause should precede the effect (51). As such, these “naturalized” concepts are being re-introduced in biology by the way of theoretical principles a century after having been removed with dire consequences to the development of biology (52).

The above-referred to principles are the bases for the construction of a theory of organisms that explains the organization and behavior of matter in unicellular and multicellular organisms. This theory addresses life cycles from ontogenesis to death. In this regard, we proposed three founding principles for such a theory: 1) the default state of cells, meaning constitutive proliferation with variation and motility, 2) a principle of variation generated at the cellular as well as at the supracellular level during the non-identical iterations of morphogenetic processes, and 3) a principle of organization having its roots in circular causation, further developed by Moreno and Mossio and Montévil (53).

This theory of ontogenesis would complement the theory of evolution that addresses phylogenesis while defining the proper organismal observables. From this perspective, morphogenesis would then be the result of the default state producing both the cells and the extracellular matter making the organism, the principle of variation that generates novelty and plasticity, and the principle of organization, that makes the organism and its parts interdependent while providing robustness and stability. The application of these principles has already shed light over developmental processes such as mammary gland morphogenesis (54), carcinogenesis (morphogenesis gone awry) (55) and physiological processes such as the regulation of glycemia (56).

This video features a goat that was born with paralyzed front legs. The animal soon learned to adopt a biped stance and move around by walking on its hind legs. Its behavior illustrates the ability of organisms to create their own norms with the aim to keep themselves alive.

The recognition of the organism as a fundamental biological concept is a good starting point for the construction of a better theoretical framework to guide research and produce understanding. The mechanistic and reductionist views are conducive to proletarianization because they decompose biological processes into mechanisms that would be understood independent of the whole organism. To the contrary, organicism posits that parts may be analyzed only in relation to the whole, that is, the organism in its milieu. Then, the integration of heterogeneous levels of organization is central, and by its integrative nature, is inimical to proletarianization.

The organism as a fundamental biological concept is far more complex than the mechanisms of molecular biology. Understanding the organism requires practicing critical thinking. Biologists may as well use critical thinking to re-evaluate their own role as thinking entities in the process of doing scientific research and of creating a new understanding. Additionally, organicism invites biologists, from students to practitioners, to stop asking computers and so-called “data scientists” to plug in data to find patterns, so that the oracle of “artificial intelligence” might give an answer regarding the meaning of these data.

At the turn of the current millennium, biologists once more brought technology in to bypass the stasis resulting from the lack of success of reductionism when addressing complex biological phenomena.

This de-proletarianization of biologists by means of rich concepts and theories will improve the discipline while de-proletarianizing those who use biology, like physicians, nurses and public health officials. It should also impact the technical aspect of research. Biologists will cease to be limited by the type of tools and automated instruments available to them. Like before proletarianization, they will invent their own tools, and probably universities will again have machine shops that will build novel tools designed by those that need them to pursue the questions they are trying to answer.

Conclusions

The impoverishment of biological thought led to the abandonment of the idea that science requires a theoretical framework and that vague theories are no substitute for narrowly defined, specific ones. Vague theories cannot be rejected. As a result of this impoverishment, research on organismal biology is being conducted in the absence of a global theory. Instead, its conceptual framework is a loose set of metaphors derived from the mathematical theories of information and by additional operational definitions. This combination of factors resulted in contradictions that hindered progress, and in further proletarianization by delegating theoretical work to computers. Meanwhile, practitioners are collecting huge amounts of data (mis)guided by the notion that computer/data

scientists will find patterns that in turn will lead to solid knowledge. Additionally, the application of physical principles without proper analysis of the differences between biological and physical situations has also contributed to the current crisis. Further degradation of this situation is anticipated by the deleterious managerial practices imposed by neoliberal ideology.

In spite of these dire conditions, the progress made by organicists particularly during the second half of the 20th century and up to the present in the current century is providing a proper scientific conceptualization of the central biological properties that were abandoned during the 20th century, such as teleology, agency and normativity. This conceptual progress demarcating differences between the physics of inanimate and that of living matter provides a sound perspective for the construction of a much-needed theory of organisms (57). This novel perspective led us to enunciate founding principles adequate for framing experiments and conceptual and mathematical modeling both in developmental biology and physiology (58).



Danseuse sur scène, Edgar Degas, 1877; Image Credit: Musée d'Orsay

The efforts of these organicists indicate that we have not reached the end of science as a fruit of creative human activity. The idea that biology is so complex that computers, which are mere creations of the human mind, will fulfill the role of scientists is erroneous. Because neoliberal ideology is based in part on spurious biological ideas pertaining to evolution, a new critical and

rigorous biology could become a powerful tool to reconceptualize our world. Similarly, the impoverished biology of the 20th century contributed to the environmental problems we are facing today and the creation of a regulatory process for environmental chemicals which is based on faulty science. Once formerly proletarianized scientists will again be allowed to fully use their capacities, they will stop thinking that the neoliberal ideology of government and finances is as inexorable as universal gravitation. Moreover, de-proletarianized biologists should play a major role in determining whether computers, robots and artificial intelligence can develop even minimal agency, which is an important aspect of several social debates on governance, civic liberties and transhumanism. In brief, enlightened biologists could provide the elements to promote scientifically sound ways to protect humans and their environment.

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