ISSN 2299-0356

Filozoficzne Aspekty Genezy — **2026, t. 23, nr 1**

Philosophical Aspects of Origin s. 1–6

https://doi.org/10.53763/fag.2026.23.1.257

RECENZJA / BOOK REVIEW

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A Paradigm Shift in Biology?

Philip Ball, **How Life Works: A User's Guide to the New Biology**, University of Chicago Press, Chicago 2023, pp. 552.

Received: April 20, 2026. Accepted: June 6, 2026. Published online: July 14, 2026.

In 2023, Philip Ball published an important book entitled **How Life Works**. Ball is a British physicist and chemist who studied at the University of Oxford and received his doctorate from the University of Bristol. He is internationally recognized as a scientific communicator and columnist for *Chemistry World*. What makes Ball's work especially relevant to our analysis, however, is the fact that for more than twenty years he served as an editor at the prestigious scientific journal Nature. This gives his views particular significance as representative of the evolution of scientific understanding within the international community over recent decades. We may therefore appeal to the testimony of his extensive and detailed treatise as evidence that the ideas it contains reflect a broadly shared outlook among specialists. Ball embodies two of the most representative features of that community. On the one hand, he openly supports the idea of a paradigm shift in our understanding of biology and the phenomenon of life, along the lines developed by Denis Noble and James Shapiro. On the other hand, he explicitly affirms both his evolutionary convictions and his commitment to materialism. To what extent those two positions are ultimately coherent is a matter that inevitably invites reflection.

Ball's book does not focus primarily on evolution. He does not challenge it; he simply takes it as a starting assumption. His subject is life itself — what it is, and how that thing we call life actually works. For that reason, his extensive and rigorous work stands as an evidence of the paradigm shift that has been taking shape over the last two decades and has now become firmly established within a scientific community that Ball knows and represents exceptionally well. Ball presents clearly and without ambiguity, the criticisms that his colleagues direct at the gene-centric model. The metaphors of the genome as a program or as a blueprint for the organism are inadequate; he prefers instead the metaphor of the genome as a musical score that must be interpreted by an orchestra. Yet that orchestra is precisely the living organism itself — hence the paradox that the existence of life can only be explained on the basis of life's own prior existence. If one places the genome of any organism in a tray, Ball tells us, nothing happens. An orchestra is needed for the music contained in the score to become reality, just as a living cell is required for the genome to produce any effect whatsoever.

He also points to the error of the so-called central dogma of biology, a theoretical principle coined by Francis Crick, who perhaps did not fully appreciate the meaning of the word "dogma," Ball remarks: an idea that is not entirely wrong, but which is neither a dogma nor truly central to biology. The fundamental mistake of the Modern Synthesis lies in the prominence granted to protein-coding genes. Completion of the Human Genome Project at the beginning of this century brought the surprise that the human genome contains only around 20,000 genes, whereas, for example, a banana has roughly 36,000. At that point science began to understand the functioning of life somewhat better. The vast — and overwhelmingly predominant — non-coding sequences of the genome turned out to be chiefly responsible for life's processes. Their transcription into RNA sequences proved fundamental in regulating gene expression, while the editing functions of the spliceosome made it possible to "cut and paste" genetic sequences in order to construct different proteins serving profoundly different vital functions. What is striking, then, is that the cell chooses among different operational pathways and determines the most appropriate expression of a given sequence according to the needs of the organism. The directive, therefore, comes "from above": there are hierarchical levels of decision-making beyond the genome itself.

Information does not flow exclusively from the bottom up; the cell is an open informational system. Moreover, Ball states that many proteins synthesized

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within the cell do not possess a perfectly determined three-dimensional form, and this enables them to perform diverse functions by coupling with different kinds of molecules. What we observe is not a perfectly regulated dynamic activity, as though it were the exact execution of a computer program or the automatic operation of a precisely engineered machine. We do not see mathematical order; rather, we see indeterminacy and noise. What biological processes reveal is a kind of apparently chaotic dynamism that is nevertheless exquisitely effective in serving what is best for the organism. It is diffuse, unpredictable, at times vertiginous activity that does not appear to follow a strictly codified orchestration. This biological activity at the molecular level unfolds outside the conscious control of the complex organism; once again, the image of choreography — an astonishing molecular dance — naturally comes to mind.

Ball goes on to explain that it is common to think that the complexity of higher organisms is simply the consequence of the extraordinarily complex networks we detect in biological processes. Many proteins act as transcription factors, switches that turn on or off the possibility of expression in different genes. An astonishing number of components participate in a gigantic regulatory network governing genomic activity. This inevitably gives rise to a question: how is all of this orchestrated so successfully for the benefit of the organism? Remarkably, the system as a whole consistently arrives at reliable decisions — unlike bacteria, much simpler organisms in which decision-making can, by analogy, be assimilated to a digital information-processing system. Here, by contrast, we would speak of "collective" decisions. This diffuse, blurred tangle of complex and collective, almost deliberative decisions becomes an essential characteristic of our molecular biology. And here comes the crucial conclusion: Ball tells us that we simply do not understand how it works. We see that it works, but we do not know how or why.

This lack of understanding leads Ball to reflect on the source of the problem. It is not a matter, he says, of seeking greater complexity to account for molecular dynamics. Rather, we must contemplate a simpler principle of "design" (sic), and for that we must relocate ultimate responsibility for the functioning of the whole away from the organism's lower levels (the genome) and assign it to higher levels of hierarchical organization. The system functions in a way that shows itself to be "designed" (once again), so as to remove the burden of responsibility for its functioning from the genome. It thus becomes clear that genes are not ultimately responsible for our phenotype or our behavior. Genes provide resources for con-

structing the body plan, Ball explains, but there is no body plan in the genome. We must embrace a radical shift in identifying the true causes operative in biology. This is not merely a metaphor: there is a phenomenon of emergent causation that cannot be ignored, and that phenomenon is increasingly present the more complex organisms become.

As we can see, Ball himself — a self-professed materialist — cannot entirely escape the force of the evidence for design, that troubling concept for traditional evolutionists which, together with Shapiro's notion of genetic engineering, makes it difficult to locate formulas of causation for all observed phenomena within the framework of orthodox naturalism. Emergentism, as a form of causation, is one of the traditional explanatory resources: the appearance of an effect without any apparent or specific cause, the attribution of an event to the creative capacity of Nature, to the supposed self-organizing power of matter as the ultimate explanation for the detectable order of the real world.

The British scientist reminds us that the behavior of living beings is not the result of automatic or programmed responses; on the contrary, it is manifested through improvised responses to often unexpected or novel circumstances. It is a genuinely cognitive processing of information perceived from the environment in order to produce the behavior that best serves the organism's ends. This is not merely an analogy. Even at the level of the most elementary unicellular organisms, many scientists regard this as clearly the way life functions. All living cells, Ball tells us, possess cognitive systems. Cognitive faculties, of course, do not imply consciousness. Only higher organisms possess consciousness and a developed nervous system, and only human beings possess rational consciousness. Yet we must not forget that multicellular organisms operate through molecular and cellular dynamics at different hierarchical levels of organization, and that their biological systems — obviously devoid of any form of consciousness — nevertheless behave as fully cognitive systems, reacting to environmental circumstances through effective, timely, and successful decision-making, as we have described.

Another fundamental characteristic of living beings, which Ball draws from what is now the dominant current in science, is the agentive character of life as a constitutive feature of its nature. He devotes an entire chapter — Chapter 9, entitled "Agency: How Life Gets Goals and Purpose" — to this subject. Ball even suggests that this purposive dynamism is not limited exclusively to goals of survival and reproduction, but may extend to other kinds of purposes. Agency, he says, is

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a term that defines the characteristic feature of living beings better than most alternatives, and more accurately than the mere enumeration of traits often listed in attempts to define life—metabolism, reproduction, survival, and so forth. For this reason, Ball argues, we need to develop a theory of agentive behavior and its implications. One of these, of fundamental importance, is what we call free will. Free will, a defining characteristic of the human species, is a manifestation of that form of agentive activity that human beings — endowed with cognitive and sentient faculties, as well as rational consciousness — are capable of exercising. This agentive behavior, applicable to all organisms at every level of complexity, also implies the observable capacity to anticipate and generate predictions about the environment and about the behavior of other organisms. But for this, Ball continues, organisms must possess some form of memory in order to store information about the environment and construct some kind of representation of it. The importance of agency as an inherent property of life and its implications is being studied with increasing intensity within the scientific community.

There is another idea put forward by Ball that deserves comment here. A paradigm concerning life ought to be fruitful from the standpoint of medicine. If we know how life works, that knowledge should lead us to appropriate responses and solutions to the problems posed by disease and biological disorder. Yet the gene-centric paradigm, together with its corollary in neo-Darwinian evolutionary theory, has proved entirely unproductive in this regard. In reality, the notion that a gene produces a phenotypic trait has been widely discredited by research, and we now know that only in a small number of cases is there a direct relationship between a defective gene and a specific disease or malformation. Most disorders are not related to coding sequences in the genome, but to its regulatory regions. This is why many therapeutic approaches to major diseases such as cancer, aimed directly at genetic sections, have produced disappointing results. It has proved more effective to intervene at the level of the immune system, helping the organism itself fight the disease. A paradigm that offers a more accurate vision of life — such as the one Ball presents — based on recognition of the complexity of biological systems and the impossibility of functionally reducing them to physico-chemical causes, should open new avenues for medical research, entirely apart from evolutionary dogmatism.

Ball does not shy away from the profound implications of his reflections on life and the functioning of biological systems and processes. He asks: “What makes

a living thing to be alive?" This is the great enigma that centuries of scientific research and philosophical reflection have failed to resolve. Ball does not reject the suggestion — made by some — that the very existence of life constitutes an irresolvable paradox, as Richard Dawkins himself once suggested. The existence of life is difficult to explain — one might add — at least for anyone irrationally committed to a materialist metaphysics. Ball cites the eminent British physicist Michael Berry, who, when asked what he considered the greatest unresolved problem facing physical research today, replied: "If, as we believe, all matter must be interpreted according to quantum mechanics, then where does the living condition of living matter come from?" Living matter, Berry said, is profoundly different from inert matter, and — once again — "we do not know why." Ball adds that biologists must not forget that one part of the universe — ourselves — has become conscious of itself and of its place in the cosmos, and that what biologists must seek to do is understand and explain that fact. This, he concludes, is the deepest question facing science.

Nor does Ball avoid the inescapable philosophical consequences of the matter. Life, he tells us, is astonishingly teleological, however much that may trouble many biologists. We cannot avoid asking what end is being pursued by the complex and sophisticated biological mechanisms displayed by living beings. The principal challenge of biology is to find models that help us understand concepts such as agency, information, purpose, and meaning in biology. These are not optional additions for enthusiasts of biological reflection, Ball insists; they lie at the authentic heart of life's processes. We cannot answer the question "How does life work?" if we do not understand where life is directed. Ball's great contribution, ultimately, lies in raising the questions that had been obscured by the dominant narrative of the Modern Synthesis. For the answers, we shall have to wait.

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