Social Epistemology

A Journal of Knowledge, Culture and Policy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsep20

The Evolutionary Dimension of Scientific Progress

Alexander Yu Antonovskiy & Raisa Ed Barash

To cite this article: Alexander Yu Antonovskiy & Raisa Ed Barash (2021): The Evolutionary Dimension of Scientific Progress, Social Epistemology, DOI: 10.1080/02691728.2021.2000662

To link to this article: https://doi.org/10.1080/02691728.2021.2000662

Published online: 28 Nov 2021.

SOCIAL EPISTEMOLOGY
https://doi.org/10.1080/02691728.2021.2000662

Routledge
Taylor & Francis Group

ARTICLE

Check for updates

The Evolutionary Dimension of Scientific Progress

Alexander Yu Antonovskiy [a] and Raisa Ed Barash [b]

[a]RAS Institute of Philosophy, Moscow, Russian Federation; [b]Institute of Sociology of Fctas RAS, Moscow, Russian Federation

ABSTRACT

This article considers *problems that the biologically based general theory of evolution is facing today when it is extrapolated to the problem of scientific progress*. It investigates how scientific theories can be interpreted as replacing each other, about what the *external environment* of scientific communication is, what institutions are responsible for the *selection* of the best theories, and the extent to which the autonomous mechanisms of scientific evolution are differentiated, namely, the mechanisms of random variation, natural selection, and inheritance. The authors deploy David Hull's concept of causal individuation and Stephen Gould's concept of semantic individuation, identifying the possibilities of reconciliation and synthesis of these evolutionary approaches.

The authors use 'a complex multidimensional environment of scientific communication', formed by the social, factual, and time dimensions of scientific communication. This concept 'removes' the distinction between local and global optima and, consequently, eliminates the difference between *problem-solving* and *semantic* understandings of scientific progress. It concludes that understanding the *scientist's consciousness* as a 'case-sorting machine' eliminates the apparent inconsistency of the evolutionary metaphor and 'saves the evolutionary analogy', substantiating *the independence of the mechanism of random variations* from *the mechanisms of natural selection* and stabilization of knowledge at the population level.

KEYWORDS
Scientific evolution; science as a communicative system; truth; progress

1. The Paradox of Scientific Progress as a Problem of the Philosophy of Science

In our opinion reconstructing the mechanisms of evolution at work in scientific knowledge, will help us to come closer to solving the *paradox* of scientific progress as it is formulated by Max Weber. On the one hand, science formulates true and objective propositions and only this – in the *factual dimension* of scientific communication – distinguishes its world from value judgments (i.e., ideology, religion, art). On the other hand, 'the lifespan of truths is 10–40 years' (Weber 2017). Thus, any claim to truth (objectivity, validity as distinguishing features and criteria of scientificity) in the *temporal dimension* of science (and hence, any statement about scientific progress) looks unconvincing. This temporal relativism is clearly different from progress in value discourses, where each stage of development (style or work of art), even if not replaced by 'better works', at least retains or even increases its value for centuries.

Thomas Kuhn proposed a solution to the paradox by formulating criteria for better theories to replace each other in the course of scientific progress, which appear as the alternation of stages between 'normal' and 'revolutionary' science. Kuhn's proposed solution was developed later in

CONTACT Alexander Yu Antonovskiy antonovski@hotmail.com RAS Institute of Philosophy, 12/1 Goncharnaya Street, Moscow, 109240, Russian Federation

greater detail by Laudan (1977), who conceptualized progress as a change of paradigms that set models for solutions to certain scientific problems, calling it the 'problem-solving approach to scientific progress' (Bird 2007). However, this attempt at resolution failed because it did not explain how the mechanisms of conversion from normal to revolutionary science work. A further issue with Kuhn's explanation arose, according to Lakatos, because the mechanism of conversion appears in Kuhn's works as an irrational process. In light of this observation, Lakatos proposed a solution of his own by setting up a distinction between 'progressive problem-shifts' and 'degenerating problem-shifts' at the level of research programs. However, this attempt also failed to establish a criterion of progressiveness, because it required the introduction of a time limit on expectations: what today seems to be a degenerative lineage (as demonstrated by the Prout program[1]), may turn out to be a progressive one later.

While Kuhn proceeded from the ability of theories to 'exemplarily' *solve problems* as its criterial property in a comparative perspective, Popper understands progress as a semantically consistent *approach to the truth*.[2] Thus, according to Popper, scientific theories do not need to be 'saved' by adding to them all sorts of ad-hoc modifications to explain anomalies. On the contrary, theories pass the *test of viability* (and in a sense, fertility), where the possibility of falsification acts as a functional analogue to natural selection. In this sense, the very evolution of concepts appeared as a *trial-and-error* process where only the fittest survived. Passing such tests for falsifiability indirectly indicated a certain gradual approximation of the truth (verisimilitude). However, even Popper felt the inconsistency of his evolutionary approach because *repeated* successful tests of a theory led to an inductive conclusion about the *better* fitness of said theory.[3] This 'whiff of induction' was incompatible with Popper's general anti-inductionism. Any concept 'surviving' in competition should not automatically claim priority over any other, since no approach to truth (*verisimilitude*) should depend on such an unreliable means of justification as an *inductive* series of successfully passed tests. After all according to Popper, induction cannot reduce the likelihood of possible falsifications in the future or in any way soften the rigidity of the corresponding logical law *modus tollens*, to which the development of science is allegedly subject.

The fact that 'approaching the truth' implied some – albeit unattainable – ultimate goal of scientific development, indicated that Popper had not completely gotten rid of the 'teleological' understanding of science and the influence of the so-called 'old European semantics', i.e., of the idea that, after the discovery of the final truths, the evolution of knowledge would come to its completion – a state of rest or 'state of perfection' (Luhmann 2017). Our evolutionary terminology denotes this unattainable state as the 'global optimization' of scientific theory.

Stephen Toulmin, in turn and in his own way, applies Darwin's ideas to the analysis of scientific progress from the point of view of the procedure for *substantiating* scientific knowledge. To some extent, he manages to overcome the dangers of inductivism that Popper faced. Toulmin, who professed a descriptive approach to the history of science and generally called for abandoning the understanding of the development of science as the history of logically connected propositions, considers the history of scientific theories through an analogy with the development of an evolving organism (Toulmin 1974).[4] Natural selection, from his point of view, affects many 'conceptual options'. Only the 'fittest' to the 'explanatory pressure' on anomalies survive. The anomalies that appear and require explanation are the very 'natural conditions' of the environment to which the paradigm (or the sum of 'conceptual populations') must adapt. New knowledge, obtained and substantiated in the context of 'explanatory anomalies', serves in this approach as a criterion of scientific progress.

Our brief excursion showed that the evolutionary interpretation of scientific progress, at least, does not contradict any of the three main (problem-oriented, semantic, and epistemic) meanings of scientific progress (Bird, 2007)). Below we will try to develop the evolutionary analogy of science to clarify and specify the concept of scientific progress.

2. Five Problems of an Evolutionary Solution to the Paradox of Scientific Progress

This evolutionary analogy ran into a number of problems that pointed to a mismatch between the evolutionary development of science and the evolutionary development of organic life. First of all, the following issues required a solution:

(1) What processes or instances in science can act as analogues of *genotype* and *phenotype*?
(2) What in scientific knowledge can be compared with an organic *population* as the bearer of the entire set of newly formed properties?
(3) What is the *external environment* to which scientific knowledge adapts?
(4) Is there an analogue of *sexual selection* in scientific cognition, which accelerates and condenses variational diversity?
(5) How can thoughtful, substantiated, and *goal-oriented* scientific variations (hypotheses, explanations, projects, etc.) act as analogues of *random* biological mutations?

What instance in scientific research acts as an analogue of organisms or phenotypes, as 'material incarnations' of genetically given instructions? From the evolutionary point of view, only the 'material incarnations' of theories can directly compete with each other for better adaptation to the 'material' external world and proliferate in case of evolutionary success. This role can be claimed by very heterogeneous entities. There can also be *empirical consequences* of theories (or 'existential hypotheses' 'as science-extending operations' in Harre's sense (Harré 1970, 161)) that manifest as 'material incarnations' of those abstract theorizations. In addition, such 'material realizations' of theories can be theoretical *models* – idealizations of natural processes.[5] Furthermore, as a phenotype one can consider competing *scientific teams*, as well as – having a material (physiological) basis – the *mental processes* that are activated in the minds of scientists upon assimilating or formulating a scientific theory.

No less controversial is the question of the *environment* in which the *external selection* of the best theories is determined through the ability to adapt. This 'external environment', in contrast to a specific adapting system, is extremely difficult to define in all its multidimensionality, complexity, and causal significance. The environment could also include the human experience of observable facts, to which theoretical constructs must 'adapt'. But in this function of the 'external environment as a factor of natural selection', social systems (scientific institutions, education, industry, political regulators of science, etc.) can also act as systemic 'consumers', customers, and 'evaluators' of scientific achievements. Simultaneously, concrete individuals can act as direct 'beneficiaries' of the achievements of scientific progress.

In addition, the problem of the '*local optimum*' (the fifth point of our problem list), which evolutionism faces in its reconstruction of scientific progress, requires a solution. Indeed, unlike organisms that are 'indiscriminate' in their forms of adaptation, theories claim truth as a kind of absolute meaning of their statements or 'global optimum'. Scientists are not satisfied with just correct predictions (in the style of Ptolemaic epicycles) or ad-hoc assumptions that make it possible to adapt a theory to almost any empirical reality in accordance with the Duhem–Quine thesis.[6]

From a critical perspective on the evolutionary approach to science the *pool of variability* of scientific proposals and hypotheses, which is already at the stage of variation, is determined (and, as a consequence, significantly limited) by the requirements of *future selection*, target guidelines, requirements of scientific methodologies, expectations of the scientific community, etc. This significantly limits the heuristic nature of evolutionary theory itself in its application to scientific progress, because it is necessary to abandon the key feature of evolution – the mechanism for generating random variations. Furthermore, the heuristic nature of the evolutionary theory of science calls into question another discrepancy with regard to organic evolution in the field of random generation of 'mutations'. Within the framework of the latter the variability of new formations are intensified in the process of *bisexual reproduction* (the fourth item on our problem list). Are there similar mechanisms for accelerating variability in science?

3. Individuation of Scientific Theory: Semantic and Causal

The aforementioned difficulties, (i.e., the mismatching the general theory of evolution and the evolutionary theory of scientific progress), are reflected in the leading evolutionary approaches to science when the 'individuation of scientific theory' is being considered. To make scientific production distributable over the selected levels of evolution (levels of variations, selection, populations), theories must be individualized in one way or another. Versions of a theory (for example, different versions of Newtonian mechanics or quantum mechanics) obviously differ from their original formulations. The initial versions serve as the source of 'conceptual lineages' (David Hull), that are *individualized* in the course of their evolution into options or concrete realizations. Yet this individuation runs into a paradox.

On the one hand, the formulation of a scientific theory is a *causal* process. Some scientists learn from others and adopt their achievements, formulations, concepts, methods, and scientific goals. This sociohistorical fabric of science shows *continual* properties cannot be torn apart despite all the contradictory theoretical versions these interacting scientists propose. In this case, the theory is individualized in physical space and time as a *causal* process – without any connection with its present or absent *semantic* unity. On the other hand, each theory must contain an internally consistent core (*hardcore* in the sense of Lakatos) and therefore can be invariantly reproduced for decades and centuries. The theory is individualized, in this case, on the basis of its semantic core which is reproduced in all variations.

Given this tension, how can one ensure that the individuation of a theory fixes the complex units of scientific knowledge that are evaluated and replace one another in the course of scientific progress? After all, this requires the combination of the obvious *historically given causal continuity* of theories, where some statements of scientists provoke response statements, with the *logical* or semantic continuity of a scientific theory. Both factors help to fix the *space–time* boundaries of 'individualized theories' as kind of 'things'. But what distinguishes a certain 'instant slice' or a specific version (theory as a token) of a continual, lasting, but in itself identical theory from this theory itself (theory as a type)? Indeed, the replacement of such individualized theories with other more successful theories constitutes the evolutionary process and, in this sense, scientific progress.[7] Without explication of the *criteria of its individuality*, any question about the criterion of the best theory, and therefore about scientific progress, may remain unanswered. Let us consider these ways of individualization in more detail.

4. Causal Progress in the Evolution of Scientific Theory (David Hull)

The evolutionary analogy for scientific progress within 'causal individuation' was conceptually developed by David Hull. In his *Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science* (Hull 1988), evolutionary mechanisms are described in terms of the *replicator, interactor*, and *selection*:

(1) A replicator is an entity that reproduces its invariant structure in successive replications.
(2) Interactor is an entity that, as an integrated whole, interacts with the environment, owing to which replications are differentiated.
(3) Selection is a process in which differentiated extinction or proliferation of interactors, in turn, differentiates the reproduction of the corresponding replicators (Hull 1988, 408–409).

This generalization is specified in relation to organic evolution, in which *genes and their alleles act as replicators*. Regarding scientific evolution, replicators are represented by *concepts, beliefs, research techniques, etc*. In both cases, replicators are units of variation capable of self-copying and are responsible for the first and most hidden mechanism of evolution. On the second 'level' of evolution, there are *interactors*, represented by phenotypes of the organic world. Their analogies in science are individual researchers or groups of scientists as subjects and, at the same time, objects of evolutionary selection. Finally at the third stage, some of the selected properties are stabilized in the form of *populations* in the organic world. In science, their analogs are '*conceptual lineages*'. These lineages can change their semantics, while maintaining temporal continuity. An evolutionary lineage is:

'an entity that changes indefinitely through time either in the same or an altered state as a result of replication. Neither genes nor organisms can function as lineages neither can change indefinitely without becoming individuals numerically different from each other. However, both of them form lineages that can and should develop' (Hull 1989, 106).

The evolutionary process of changing theories is represented by Hull in his concept of *individuation through naming*. This makes it possible to somehow *distinguish* between the invariant 'theory as a type' and its variation 'theory as a token'. This distinction works to separate the phenotypic level of evolution from the population level. On the one hand, a theory has a founder whose name it usually bears, for example, *Darwinism*. This theory is developed by his students and each subsequent version, which often contradicts the original version, is *causally* linked to the previous versions due to one physical contact or another such as, the personal communication of a student or teacher writing and reading. The historical continuity of individualized theories owes its existence precisely to this kind of physical causality and allows for conflicting versions within the same 'conceptual lineage':

'Just as species cannot be treated simultaneously as historical entities and as eternal and immutable natural kinds, neither can concepts. More strongly, if an evolutionary account of conceptual change is going to have any chance of succeeding, the basic units of both evolutionary biology and conceptual evolution must be viewed as the same sort of thing – either as spatiotemporally unrestricted classes or as spatiotemporally connected lineages. In our account, we opt for the second alternative. The things which are evolving as a result of selection, whether species or concepts, must be treated as historical entities' (Hull 1988, 16).

In this context, Charles Darwin's version of evolution and Alfred Wallace's version of evolution constitute a common continuous conceptual lineage of Darwinism, while the independent although conceptually related theory of Patrick Matthew is causally unrelated to Darwinism and therefore does not belong to this conceptual lineage (Hull 1989, 233).

5. The Circular Nature of Hull's Theory and the Difficult Problem of Scientific Progress

Hull's theory, reconstructing the process of selecting theories and in this sense acting as a methodological approach to assessing the best scientific theories, is faced with the paradox of self-justification. Claiming to be true, methodologically significant, viable, and proliferative, it must meet its own criteria. That is, to be a 'best methodology', it must form a 'conceptual lineage' and as such must somehow collide with the external environment, adapt to it, and be selected or rejected on this basis. From our point of view, its success could be explained by its ability to clarify the *difficult problem of scientific progress*, part of which it is destined to become in case of this success. To put it another way, in order to be considered a successful scientific theory, the evolutionary theory of science must explain the success of science as an *evolving system*. It must answer the question of why science has become a powerful and influential enterprise capable of carrying out not only applied but also *basic* research, solving autonomous tasks, and fulfilling autonomously set goals that do not have a direct and obvious connection with profit or utility for adjacent social systems or communities (i.e., for the external environment to which it adapts).

A theory 'adapts well to the environment' if it answers a number of questions: Why does society as an *external environment* of science pay, thereby making a selection, those who satisfy their own curiosity at the expense of the state? Why did the scientific community manage to organize itself in such a way that the competition for selection does not interfere, but on the contrary, maintains internal solidarity based on exclusively *intrascientific* mechanisms? Note that in adjacent communicative systems of this kind such as the economy, natural *integration* through *competition* is not always observed. Thus, the internal mechanisms of free competition in the economy are insufficient for its self-regulation, lead to regular crises, and require *external* restrictive, meaning selective, intervention from the 'agencies of rationality' (Olson 1965). The economy cannot do without *external* rationalization and regulation, the seizure and redistribution of part of the profits, the establishment of antitrust laws, and, therefore, the limitation of economic competition and internal autonomy. The economy still generates internal social conflicts and splits the interests of participants in economic communication.

Meanwhile in science, unlike in the economy, self-regulation and tough competition for limited funding resources and temporary priority in scientific discoveries, complement one another, provide internal integration. Additionally but to a much lesser extent, they require this kind of 'external', for example, political, rationality. Science creates its own 'agencies of rationality' and mechanisms of self-regulation, not by splitting but through uniting the community engaged in scientific work. Science rationalizes itself by creating corporate ethics (such as the scientific ethics of Robert Merton (Merton 1973)), around which the so-called 'scientific self-policing' crystallizes (Baldwin 2015) and is watched over by enthusiasts and volunteers who monitor the observance of scientific ethics.

In our opinion, it is the *evolutionary* understanding of science that explains the fact that the *individualistic* goals of scientists coincide with the goals of science as a *community* or, to use Hull's terminology, *interactor* researchers are interested in recognition from other *interactors*. As if following the theory of rational choice, their individual 'profit' is calculated and depends on whether their contribution to the 'conceptual lineages' is recognized and is in demand on the part of *other* researchers; on whether other scholars will cite them. They depend therefore, on whether the same conceptual lineage or 'theory as a type', the invariant structures they reproduce in their *replications*, will be continued; on whether they will defend this lineage as physically acting interactors – in discussions, at conferences, and at the defense of dissertations for example. In these conditions, the rejection of scientific honesty, forgery, fabrication of results lead to the rupture of causal links, the rupture of continuity, and, as a consequence, conceptual lineages. Hence the interactors themselves do not 'survive' or proliferate, but instead are filtered out by the environment:

' . . . it explains why lying (publishing fabricated research) is so much rarer than stealing (failing to give credit where credit is due). It also explains why misconduct in general is so rare . . . Why do scientists seem to adhere so much more closely to theirs than do members of other professions?' (Hull 1988, 302).

Attention to continuity and ethically normalized reproduction of structures, such as time priority or clarity of citation, is strictly supported and controlled by the interactors themselves, some of whom are recruited into the 'internal scientific police'.

6. An Extensive Interpretation of the Evolution of Science (Michael Ruse)

Hull's concept raises a number of objections. On the one hand, in science the process of generating variations is indistinguishable from their selection and is even focused on it.[8] On the other hand, 'conceptual lineages' in the development of scientific concepts or scientific theories are not at all similar to their biological counterpart or prototype, namely, to a biological species or population. In this sense, different levels or mechanisms of *variation, selection*, and *stabilization* of inherited traits in populations do not appear as deeply differentiated in science as in organic evolution. Scientists' hypotheses and projects seem to be oriented *in advance* of the planned selection in the future and, based on the previously known selection criteria, formulate their own versions. Therefore, the key statement about the evolutionary analogy between science and the organic world is called into question.

This problem is, to a certain extent, solved in a broader version of the evolutionary conceptualization of science. From this point of view, the mechanisms of scientific evolution can, of course, exhibit properties that are inconsistent with organic evolution. But in this case scientific theorization can be interpreted as a kind of *generic* property of sociality and Homo sapiens, who have developed a cognitive ('protoscientific') orientation in the external world, can be viewed as having their own evolutionary advantage in competition with other species. The evolution of Homo sapiens as a species presupposed the crystallization of a number of evolutionarily successful 'protoscientific' 'epigenetic rules' of adaptation to the environment. Importantly, these evolutionarily successful adaptations arose by chance and are *not oriented* towards future selection. For example, we can talk about the discretization of the continuous spectrum into individual colors, which among other things, presumably helped to distinguish ripe from unripe, about innate linguistic structures in the sense of Noam Chomsky, and about the social prohibition on deceiving members of the community, etc.

In this sense, scientific progress is understood as the development of the aforementioned 'epigenetic rules' that ensure human survival. What later appeared as the disposition of scientific rationality, in the form of avoiding contradictions, checking statements, recognizing patterns, and making successful predictions, in essence, is only a later design of the evolutionary adaptive acquisitions of Homo sapiens, but in essence represents the basic conditions of human existence, survival, and distribution as a species. In this sense, the requirement of *scientific truth* could be interpreted as an extension of the evolutionarily successful norm of prohibition on deception, which once integrated primitive communities.

7. Semantic Individuation of Scientific Theory

Strong arguments against Hull's concept have been made within the evolutionary theory of science itself. One example comes from the evolutionary-semantic approach of Stephen Gould, who proceeds from the need to individuate theory as a condition (reconstruction) of scientific progress. From Gould's point of view, a certain theory demonstrates continuity and can be individualized if a certain axiomatic basis is reproduced in its various versions and formulations, meaning the sum of sentences and meanings of the incoming terms that form its conceptual core.

' . . . if I wish to call myself a Darwinian in any just of generally accepted sense of such a claim, I do not qualify merely by documenting my residence within an unbroken lineage of teachers and students who have transmitted a set of changing ideas organized around a common core [. . .]. I must also understand the content of this label myself' (Gould 2002, 9).[9]

In *The Structure of Evolutionary Theory* Gould argues 'from the absurd' that the Hull-style historicization of theory leads to a paradox. The new version of the theory may conflict with the previous one, even though the theory itself is recognized as identical to the earlier theory. This is how the paradox of the evolutionary philosophy of science arises.

How can we connect the obvious physical-causal continuity or the unity of 'conceptual lineages' and the 'logical dimension' of the unity of scientific theory? After all, together they help to clearly fix the boundaries of 'individualized theories' replacing one another in the course of scientific progress. Or in another formulation: how can one distinguish a certain 'instant slice' or a specific version, a token, of a continual but identical theory from this invariantly reproducible theory itself as a type? After all, if changes and negations of previous versions occur *within* a theory as a type, the level differences between types and versions of the same type become indistinct.

8. Criticism of the Evolutionary Concepts of D. Hull and S. Gould

First Improvement: The Evolutionary Dimensions of Scientific Communication are Equal

We will try to reconcile the concepts of Hull and Gould by applying Niklas Luhmann's theorization of the three-dimensional space of scientific communication. The space is formed by three equal *factual, social, and temporal* dimensions or horizons. According to Luhmann science as a social system, or conceptual lineage, in Hull's terminology, consists of interconnected communications (Luhmann 1991). Communications claiming to be scientific, for example scientific publications and other scientific messages, are either accepted as systemic elements or are rejected as not belonging to the system. Belonging or non-belonging is determined by whether or not the elements receive the appropriate values with each horizon or dimension. For example, a system is successfully reproduced if:

(1) there is at least minimal *agreement* among scientists, if a scientific statement (= a request for communication) receives values corresponding to one or another convention in the broadest sense, including the rules of conduct in the scientific community, correct citation, registration, structural requirements for scientific articles, etc. (*social* dimension)

(2) communications are differentiated and structured around relevant topics or problems of scientific communication (*factual* dimension)

(3) there are expectations in the *prospects* of some theory, expectations that the project will lead to a scientific discovery in some foreseeable future; or if the theory was good at predicting past and future events (temporal dimension),[10] even in the case when there is no confidence in the *substantive* truth of scientific proposals[11]).

In this system-communicative context, it becomes obvious that Gould's ideas give priority to the *factual* horizon of scientific communication. Hull's idea, on the contrary, appeals to the *social* dimension, in which the continuity of communication between scientists and scientific groups defines the spatiotemporal boundaries ('birth and destruction') of a theory in a literal sense as a 'physical thing'. Each of them actually proceeds from the fact that only a certain (either social or factual) dimension individualizes (= reifies) a scientific theory in the sense indicated above.

We assume that the complex dialectic of the dimensions of scientific communication can be reconstructed, proceeding from the fact that all the designated dimensions are fundamentally equal,[12] although in different eras and in different social conditions, in specific disciplines, and at different stages of the development of science, one or another dimension may dominate. For example in Soviet science, the social dimension obviously dominated, determining the relevance of certain topics[13] as well as the temporary prioritization of certain projects and research areas.

Second Improvement: From 'Natural Selection' to Evolutionary Mechanisms: Variation, Selection, and Stabilization

Another possible improvement in Hull's and Gould's concepts would be to reinterpret their understanding of 'population'. They see a scientific analogue of a biological population in 'conceptual lineages' (i.e., theories as types). Theories as types seem to be composed of their 'individual tokens'. Say, Newtonian mechanics as a conceptual lineage 'includes' its versions, interpretations, or tokens (for example, Ernst Mach's model, dispensing with absolute space, time, and motion, or Henrik Lorentz's model with his corrections of Newtonian mechanics at high speeds). Likewise, quantum mechanics can appear as such a social analogue of a biological population and include, as von Neumann showed, *equivalent* tokens in the form of Heisenberg's matrix mechanics and Schrödinger's wave mechanics.

It is precisely the 'conceptual lineages' as *populations* that act as genuine subjects of external selection in Hull and Gould, although Hull admits that selection can be carried out at other levels of evolution as well. Still this point of view, according to which a theory as a type that is reproduced as tokens acts as an analogue of a population in science, looks like a certain deviation from a biologically based general theory of evolution. According to the latter, the subjects of natural selection are not populations but phenotypes (organisms) that *physically* collide with the external environment.

But scientific theories themselves, no matter types or tokens, are not directly *physically* tested for their empirical validity in the broadest sense. This happens indirectly and in a variety of ways: through experiments and observations; through the approval of experts, scientific councils, or editorial boards; and through grant support or 'purchase' of a scientific product by industry or government regulator. It is not theories that 'meet external reality' and are ultimately selected by some breeder arbiter independent of science itself. Or, to put it another way, the selection of theories is not a direct result of their physical contact with reality or the external environment.

In our opinion, this *gap* between theory and the external environment in its function as an external breeder does not contradict Hull's key idea that scientific 'conceptual lineages' receive individuation precisely as analogs of a population and that they can be reified in space-time as some kind of temporal duration of 'individual things'. In our opinion, this discrepancy between the understanding of organic and scientific evolution can be avoided if the 'natural selection' of scientific theories is not limited at a specific (genotypic, phenotypic, or populational) level, where a 'meeting with reality' as an omnipotent breeder or arbiter should take place, but rather is assessed by the scheme of separate evolutionary mechanisms provided by Campbell–Luhmann (Luhmann 1991; Campbell 1960). This transforms the classic distinction between *internal variation* and *external selection*. Variation can have external impulses and selection can be anticipated from within.

The aforementioned *mechanisms of evolution* can be considered as a generalization of biological, social, and scientific evolutions. These mechanisms – at each stage – clarify and concretize the conditions for the acceptance or rejection (selection) of 'messages', including scientific ones, and the problem of breaking with the environment does not arise.

In Niklas Luhmann's scheme of social evolution and also in relation to scientific evolution, three mechanisms correspond to these stages:

(1) Mechanisms for accepting/rejecting communication. Thanks to the linguistic mechanism of negation, the fact that in natural language there is the particle *no*, negation can be applied to any affirmative statement. This provides the function of *maximizing variability*, including in relation to scientific messages;

(2) The mechanisms of selecting communicative messages ensure their action by means of 'symbolically generalized media', which includes power, money, faith, truth, respectively, in political, economic, religious, scientific communication systems; thanks to these mechanisms, the best scientific publications in science, the best proposals in the market, the best political programs, etc. *are selected*;

(3) Mechanisms of stabilizing newly acquired evolutionarily successful traits. At this level, the selected messages or meanings receive their final, universally recognized, internally consistent form. The emergence of a mature, disciplinarily differentiated science as a full-fledged communication system is the level of the population, at which, within separate disciplines, the formation of certain complete, stable forms of knowledge, for example, paradigms, research programs, etc. is possible.

Third Improvement: Theory Continuity Depends on the Observational Position

The third improvement presupposes the rejection of scientific ontologism, which directly follows from the absolutization of the factual dimension of scientific communication. This kind of ontologism proceeds from the presence of a 'conceptual core', consisting of statements describing 'ontologically given' entities (i.e., substrates, processes, physical constants, particles, fields, energy, entropy, etc.), are the naturally given *referents* of theories. It is the spatiotemporal continuity or discreteness of these referents, fundamental entities, or processes of nature that in this case determine the *continuity* and spatiotemporal boundaries of the conceptual lineages describing these entities, as indicated by Gould's approach. This ontologism asserts the priority of the factual dimension of scientific communication. It seems to follow the continual subject of the theory – as the basis of the continuity of the theory itself and the unity of its conceptual core.[14]

However, any statement about any kind of continuity in theory presupposes an *observer* fixing this continuity from his own perspective. The 'conceptual core' as a pivotal formation in each conceptual lineage, which Gould insists must be consistently reproduced, may well be 'preserved' and continue to be reproduced even if the old theory is *rejected* in the transition to a new one. This circumstance is, in a sense, asserted in the Niels Bohr principle of complementarity as it is applied to quantum theory and classical mechanics. Thus, affirming the continuity of the conceptual lineage of geocentrism, an observer can always appeal to the principle of relativity and *equality* of all reference systems depending on the goals and objectives of his calculations or observations. For example, a rocket trajectory or marine navigation can be oriented to the Earth as the center of the frame of reference. In this limited area of application and from this observational perspective, the theory of geocentrism does not deviate but 'continualizes;' it *adapts* to a specific empirical reality and is selected on its basis, which does not contradict the ontological statement that the Sun and the planets revolve around common gravitational centers. In this sense, continuities and discontinuities depend on the observational perspective, objectives, practical needs, open-mindedness, and imagination of the observers.

However, Gould is right that the factual dimension, with all the relative arbitrariness and dependence on the observational position of those who fix the continuity or discontinuity of conceptual lineages based on the properties of the theoretical descriptions' referents, is still an independent dimension of the evolution of scientific theory and scientific progress along with the social and temporal dimensions. Thus, when considering the temporal dimension (i.e., in its ability to predict the future positions of the planets of the solar system) of Copernicus' heliocentric system it does not significantly exceed Ptolemy's geocentrism. In particular, the Copernican system retains the epicycles and deferents of the Ptolemaic model. However, when considered through its factual dimension, Copernicus' system obviously belongs to the 'conceptual lineage' of classical heliocentrism (Kepler's, Newton's, etc.), which does not imply any epicycles or deferents.

9. System-communicative Approach: From the Problem of Reference to Self-reproduction in a Multidimensional External Environment

If the systemic-communicative understanding of evolution is applied to explain the progress of scientific knowledge, we have to significantly change the ways of explaining the development of science. Explanations must move from the 'problem of reference' to the 'problem of reproduction' regarding scientific communication. This requires supplementing the factual dimension of scientific progress with other dimensions of the multidimensional external environment of science.[15]

The previous evolutionary theory of knowledge served as a kind of solution or clarification of the *problem of reference*, as discussed above by Michael Ruse. The correct and adequate (= adapting to reality) fixation of an object is a condition for the selection and survival of the cognitive ability and its carriers – this is what connects the evolutionary useful properties of science and the evolutionary useful cognitive abilities of the organism: 'if the eye did not see something that is really present in reality, it would hardly be able to establish itself as an evolutionary achievement' (Luhmann 2017, 216). If science did not fix real objects, it would not have established itself as an evolutionarily successful social enterprise.

On the contrary, in the systemic-communicative approach to evolution, the analogy with organic evolution appeals to its other property, namely, to the ability to reproduce, to autopoiesis in the context of a *multidimensional* external environment. Systems are busy reducing this complexity by isolating themselves and increasing their own complexity. This allows their reproduction to proceed relatively *independent* from the pressure of the external environment.[16] So the evolutionary advantage of verbalized language is that it made possible the self-referential reproduction of communication, society, practically regardless of the given environment that is discussed or described in communications. In public communication, adequate descriptions of external reality (the function of external reference) are certainly important as well. But this external-referential function of communication becomes vanishingly small in comparison with the self-referential function of communication. 'Cognitive apparatuses', of an organism, a person, or scientific communication, survive not so much due to the achievement of better (= more adaptive and, as a consequence, adequate to reality) *representations* of the external world. They survive[17] (since they are able to successfully *reproduce* themselves in the world better than others. The objective and factual cognition is only one of the conditions of their self-reproduction.

With regard to the evolution of science this means that in the process of cognition knowledge *is selected* on the basis of *past* knowledge, consistent with the multidimensional landscape of the environment. This idea of a complex and 'multidimensional fitness landscape' in relation to the general theory of evolution was elaborated in detail by Sergei Gavrilets (Gavrilets 2004) and partly solved the problem of 'local optimum'. After all, a biological organism on the path of survival and successful reproduction does not have to reach any *maximum* indicators on the scale of adaptability. For its reproduction, it is enough to have some local success that ensures these tasks. Organisms do not optimize structures, or focus on the task of *future* better adaptation. In this sense, variations or mutations in organic evolution are not programmed in any way based on the future targets of this or that organism. In addition, numerous evolutionary changes take place in the organic world that are not directly related to adaptive success and, nevertheless, are fixed in populations. In other words, genetic mutations as a separate evolutionary mechanism within organic evolution are not specially adjusted to the mechanisms of natural selection.

Unlike the evolving organism, authors of publications who write from within the framework of scientific evolution strive to 'adapt' to the external environment, no matter how we understand it, and are not content with the mere achievement of 'local optimization'. Scientists are not satisfied with successful predictions or 'saving the appearance' without 'penetrating into the deep essence of things'. As opponents of the application of a complete evolutionary analogy to science argued, scientific reports, including hypotheses, assumptions, scientific projects, presentations at conferences, are initially focused on achieving the global optimum, preconfigured to take into account the requirements from the external environment (institutions carrying out external selection), as well as other selection factors (requirements of leading journals, expectations of scientific authorities, methodological and theoretical attitudes, requirements on relevance and novelty, up to the expectations of the state regulator or the appetites of technology entrepreneurs who pay for applied research).

Here there is a mismatch between scientific and organic evolution. However, it can be overcome if we introduce the concept of 'multidimensional fitness landscape' in relation to science, as it was developed by Sergei Gavrilets. So while Copernicus' theory preserved epicycles, it 'survived' and 'proliferated' not because it reached a certain 'global optimum' in comparison with Ptolemy's geocentrism. It survived, meaning that it was reproduced relatively independently of the external environment, since it responded to the complexity of the 'multidimensional landscape'. In each dimension 'optimization' received different values that were not always optimal and therefore not always positive for heliocentrism.[18] Heliocentrism in the *factual* dimension of evolution was not more adapted to the conditions of empiricism in comparison to the geocentric system. Still, it was 'promising' in the temporal dimension, demonstrating promising extensions and extending to new data. Each of the competing theories reached a *local optimum* in different evolutionary dimensions of scientific communication. But in relation to the entire *complexity* of the 'fitness landscape', geocentrism did not demonstrate adequate explanatory force in the factual dimension. In particular, it did not explain why the retrograde motion of Jupiter occurs more often than the retrograde motion of Mars. Copernicus's theory also did not reach the global optimum in all the dimensions of scientific communication. However, it covered more data in the factual dimension, and additionally was promising in the temporal dimension.

Therefore, a scientific theory like organic forms, does not reach globally optimal values, but it is reproduced in each dimension of the complex 'fitness environment', which gradually improves its values. Their total assessment is a condition for the subsequent selection of the 'best'. In this sense, the systemic-communicative approach to scientific evolution 'removes' the one-sidedness of Gould's semantic approach, which absolutizes the factual dimension of scientific progress, and the one-sidedness of Hull's approach, which absolutizes the social dimension, the transfer of theories from scientists to other scientists. It is this synthesis that allows us to solve the problem of *limiting the pool of variability* arising from the apparent orientation of scientists towards the global optimum, which, it seemed, characterizes scientific communication in contrast to local *optimization* of organic evolution. From the point of view of adaptation to a multidimensional and complex external environment, the concept of some peak (global or local) value of some evolutionary lineage becomes inapplicable. In conclusion, let us consider how the mechanism of independent variability is specifically implemented in the system-communicative interpretation of the evolution of science.

10. Conclusions: The Consciousness of a Scientist as a 'Case-sorting Machine' and a Solution to the Problem of Limited Variability of Scientific Evolution

The autopoietic process of reproduction of the structures of scientific theories can be specified for each evolutionary level: mechanisms of variability, selection, and stabilization.

The mechanism of variability is related to specific *events of scientific communication*: 'something newly formed (unexpected, deviating) is pronounced, proposed, described, and, possibly, printed, the condition of which is only comprehensibility and *written* fixation' (Luhmann 2017, 215). Variability is forced and accelerated in the course of the process, which Luhmann designated as 'the interpenetration of the *consciousness* of a scientist and scientific *communication*'. This mechanism elegantly solves the problem of 'localizing' the researcher as a thinking and conscious person. Scientists-researchers as interactors and especially the structures of their consciousness carry out direct mental processing of old theories and generation of new ones, and furthermore, are involved in the selection of the best theories. The mental structures themselves are at least in part the products of scientific theories or, more broadly, scientific texts. In this sense, the consciousness or thought resources of researchers turn out to be both products-consequences (phenotypes) and at the same time carriers of 'genetic information'. In this sense, the consciousness of a researcher is a *kind of storage* or *genetic recording* of theoretically significant information, while simultaneously appearing as a phenotypic expression of the same theories that constitutes the external environment which scientific theories must face and adapt to.

In this context of the 'omnipresence' of the scientist's consciousness at all levels of the evolution of scientific knowledge and the resulting conclusion about the nondifferentiation of the three mechanisms or levels of evolution again calls into question the possibility of extrapolating the general theory of evolution to science and scientific progress. Yet, in our opinion, this problem of inconsistency can be eliminated if, following Luhmann, the *consciousness* of a specially trained and professionally socialized scientist is understood as a source of impulses generating random variations, a kind of mutation, for subsequent independent selection at the stage of selection. This function of *generating chances* is ensured by the fact that scientific communication and consciousness have different material bases or 'memories'.

At the first evolutionary level, 'consciousness plays a special role in being *distracted* from external influences at the stage of variation – to a greater extent than in the process of evolutionary selection. < . . . > Consciousness in its own autopoiesis of continuation from thought to thought . . . makes possible . . . leapfrogging associations . . . is capable of nonverbal processing of thoughts or connects vague associations and reflections to verbal mental work. Consciousness senses its thoughts, controls itself, focusing only on – at its own disposal – memory and therefore can intrude into communication in an amazing way. It is a quasi-material prerequisite for communication, and it is an irritating, confusing, leading to disorder potential, which is not capable of transforming the actualizing structures of communication; and yet, it is capable, by irritating, to induce communication to a certain specification' (Luhmann 2017, 220).

The social memory of science, the texts of publications, is meaningfully different from the 'spontaneous, nonverbal, chaotic' *memory of consciousness*. In this sense, at the level of variations in science where consciousness and communication interpenetrate and, in this sense, 'mutually fertilize' each other, a process similar to organic evolution takes place. In organic evolution, variation is intensified and accelerated in the process of bisexual production or sexual selection. Hull himself considered the transition from *individual scientific work* to the work of scientific groups as such an analogy of 'bisexual reproduction' that provides additional variability.[19] We, relying on Luhmann's analysis, attribute this role to the special and spontaneous ability of a researcher's consciousness. Consciousness acts as a kind of 'case-sorting machine' and is specialized in generating chances, which are then supplied to scientific communication. The pool of variations is significantly enriched in the process of *interpenetration* (and at the same time, structural conjugation) of two complexities. The complexity of the consciousness of scientists, the 'well-trained abilities of perception and thinking', is unpredictable for scientific communication and is structurally linked with the complexity of scientific communication, which is partly unpredictable for the consciousness of a scientist (the complexity of scientific texts processed by the scientist).

As a result, scientific communication provokes irritations, which are in no way programmed in a targeted way by science itself: 'the consciousness of a scientist, aimed at scientific communication, functions as a case-sorting machine, which does not even allow many guesses to reach their full awareness, but overwhelms them in their appearance, while it does not notice others and again forgets; it rejects others again, because it is not possible to give them a clear formulation; while it notices others, but does not communicate since it is not possible to create a suitable context for them, for example, a publication. This kind of condensation of presorted chances, for its part, functions without any rational certification, outside of intrascientifically controlled selection, even without any goal-orientedness. It is simply realized in its connection with the evolution of knowledge, and this is why it remains pure variation' (Luhmann 2017, 222).

This understanding of the evolutionarily variative function of a scientist's consciousness solves, in our opinion, the above-mentioned problem of local optimum and the search for a scientific-evolutionary analogy with bisexual production in organic evolution.

Notes

1. Focused on the provision that the atomic weights of chemical elements are multiples of the atomic weight of hydrogen and 'falsified' by the fact of the fractional atomic mass of chlorine (35.5 amu).
2. In this sense, Alexander Bird distinguishes between key meanings and approaches to scientific progress: problem-functional, semantic (getting closer to the truth), and epistemic (getting better-grounded knowledge) (Bird, 2007, 64–89).
3. In general, the thesis about the 'best' adaptation does not stand up to criticism from the point of view of a biologically based general theory of evolution. Note that all adapted biological species either adapt well or have not adapted at all. In this sense, the presence of concepts that provide a comparatively better or worse explanation looks like a kind of anomaly in the context of the general theory of evolution.
4. Long-term large-scale changes in science, as elsewhere, occur not as a result of sudden 'leaps' but owing to the accumulation of small changes, each of which was preserved during the selection process in some local and immediate problem situation.
5. Thus, the simpler ideal-gas model competes with the more complex model of 'virial expansion' of gas for better 'adaptation' to reality, where the 'behavior of gas' in nature can act as such. The former demonstrates a greater explanatory power. The latter is more accurate in predictions, which is its competitive advantage (Cartwright 1983, 57).
6. Perhaps, for the first time such a *strategy of local optimization* of a scientific theory was formulated by A. Osiander in a letter to Copernicus. But still scientists, proposing competing versions or options, not only strive to win by any means, giving a plausible answer, but also claim to be true.

7. Such a confusion of token and type was caused, for example, by van der Waals' extrapolation of kinetic theory to gases with high pressure. Pierre Duhem considered this to be a substitution of one theory for another (i.e., a change of types). N.R. Campbell saw this only as an extended version (as a change of tokens within a type) of kinetic theory.
8. 'The gamete has no clairvoyant capacity to mutate preferentially in directions pre-adapted to the novel ecological demands which the resulting adult organisms are going to encounter at some later time' (Cohen 1973, 47). Meanwhile, in science, concepts, research techniques, methodological rules, etc., are created consciously, meaningfully, and purposefully – with an eye on their subsequent selection as universally recognized by other researchers and relevant to current scientific knowledge.
9. For example, Darwinism itself is represented by a set of judgments that make up its conceptual core reproduced in each version of the theory: (1) if inherited variations arise, (2) if one of the variations is better suited for a certain task than the other, (3) if success in its implementation affects the body's ability to survive and cope with the effects of the external environment, then natural selection produces evolutionary changes (Ghiselin 1969, 65).
10. For the fact that *factual* substantiation of the theory's statements can be carried out relatively independently of its temporal justification, for example, by referring to past or future evidence, see, respectively: (Glymour 1980, 74; Miller 1987, 297–389; Zahar 1973, 103). Thus, the *earlier* zero result of the Michelson–Morley experiment should nevertheless be recognized as '*new*,' (i.e., later, confirming evidence in favor of the later formulated STR), because Einstein did not initially accept this result as a problem-solving (factual) condition for formulating his theory. But the same distinction between *old/new* is not synonymous with the distinction between *socially new* and *socially old knowledge*, i.e., how *unexpected* to the community, contrary to existing conventions, or expected (conventional) the result of the experiment was. All this confirms that this or that evidence can take different (both positive and negative) meanings in the three designated dimensions, support a theory in one dimension, but require its rejection in another dimension.
11. The infamous Titius–Bode rule has long been viewed by many as a scientific law due to this kind of incidental but constantly confirmed, relatively correct, predictions of the distances between the Sun and the newly discovered planets. For a logical interpretation, see (Peirce and Ketner 1992).
12. This does not negate the paradoxes of self-justification: the very content of one or another recognized theory, experimentally confirmed in the laboratories of the world and having acquired the character of collective knowledge, determines the scientific consensus among scientists. But it is precisely this unity of opinion of scientists that is the argument in favor of the truth of this theory.
13. The concept of 'competition' was banished not only from economic theory but even from biology. Conversely, 'collectivity,' 'cooperation,' and 'solidarity' were welcomed as concepts that could be used to describe subjects in a wide variety of disciplines (Todes 1989).
14. A number of approaches, among others, testify in favor of leading role of the factual dimension of the evolution of science. For example, Sellars' idea of the 'identity' of a theoretical model and the subject described in it: gas at low pressure is identical to its model – a cloud of molecules as point masses, which are almost unaffected by intermolecular forces (Sellars 1970, 348). Another argument in favor of the priority of the factual dimension over the social is within the so-called 'propositional' approach to science ('Nonstatement View of Theory' (Suppe 1971)). Different versions of the theory get their status of variants (tokens) of the same type or invariant (as in the above example with quantum theory) precisely due to the presence of this factual conceptual core. The function of the conceptual core is then performed by a *proposition* as a 'state of affairs' determining the truth of different versions of the same theory. The theory as a type in this sense appears as a kind of 'true reality in itself,' 'nonlinguistic essence,' which invariantly manifests itself in different syntactic forms (both in Heisenberg mechanics and in Schrödinger mechanics), which turn out to be only 'replicas, idealizations of physical systems' (Suppe 1971, 222).
15. Wilkins, in turn, refers to the multidimensional 'fitness landscape' of S. Gavrilets as the external environment of science, identifies the empirical, sociological, and psychological dimensions of the complex environment of science (Wilkins 2008). In our opinion, all of them can, without prejudice to the content, be reduced to the indicated factual, social, and temporal horizons.
16. Here, the evolutionary success of precisely *basic* science (science for the sake of science) is explained, as if freed from external coercion on the part of the social environment (industry, state), requiring more and more new, primarily, applied achievements.
17. As the analysis of latent functions by Robert Merton has convincingly shown (Merton 1973).
18. 'Sciences do not typically adopt theories that are less empirically adequate than their predecessors, Copernicus's heliocentrism notwithstanding. But they may adopt a theory that offers some promise in gathering new or more accurate kinds of data even if at the moment of adoption they do not deliver' (Wilkins 2008, 666).
19. However, just as the advent of sexual reproduction introduced a new set of partially conflicting goals into biological evolution, the formation of research groups in science introduced a comparable set of partially conflicting goals into science, as scientists had to cooperate with their conceptual competitors. Hull (2020). *Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science*. Chicago: University of Chicago Press.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The research was carried out with a financial support of the Ministry of Science and Higher Education of the Russian Federation (Project 'New tendencies of the humanities and social sciences development in the context of digitalization and new social problems and threats: interdisciplinary approach', Agreement № Федеральная целевая программа 075-15-2020-798)

Notes on contributor

Alexander Yu Antonovskiy, Leading researcher at the Institute of Philosophy of the Russian Academy of Sciences, Professor of the Faculty of Philosophy at Moscow State University named after M.V. Lomonosov, Department of Social Philosophy and Philosophy of History. Graduated from Moscow State University in Philosophy. Received PhD (Doctor in Philosophy) from the Russian Academy of Sciences in 2016. Implemented several international research projects on the sociology of knowledge and science as a visiting researcher of leading universities: Catholic University of Eichstätt-Ingolstadt (Germany), University of Giessen (Germany), University of Karlsruhe (Germany), University of Bielefeld (Germany), University of Albert Ludwig (Germany), Columbia University, Department of Sociology (USA), University of Eberhard-Karl (Germany). As a Professor of Moscow State University, leads the implementation of scientific projects of the Department of Social Philosophy, Faculty of Philosophy, Moscow State University. Translated into Russian, and adapted classical texts on the sociology of knowledge by F.D.E. Schleiermacher, M. Weber, K. Hübner, N. Elias, N. Luhmann. Author of several books on social philosophy of science: 'Niklas Luhmann: Epistemological Introduction to Theory of Social Systems' (2007, in Russian), 'Socioepistemology' (2011, in Russian), 'Communicative Philosophy of Knowledge' (2015, in Russian), 'Systemically-Communicative Theory: Science and Protest' (2019, in Russian).

https://eng.iphras.ru/antonovskiy.htm

https://philos.msu.ru/node/219

Raisa Ed Barash, Graduated from Moscow State University in Political Science. She received her PhD (Candidate in Political Science) from Moscow State University in 2010. She is currently a Senior Researcher in the Federal Center of Theoretical and Applied Sociology of the Russian Academy of Sciences, Moscow. Participated in several research projects of the Russian Academy of Sciences, devoted to features of mass public attitudes and perceptions in modern society. Interested in the sociology of identity, knowledge and science.

ORCID

Alexander Yu Antonovskiy http://orcid.org/0000-0003-4209-8213
Raisa Ed Barash http://orcid.org/0000-0002-5899-973X

References

Baldwin, M. 2015. ""*Disorderly Publication" Nature and Scientific Self-Policing in the 1980s*." In *Baldwin M. Making "Nature": The History of a Scientific Journal*, 200–227. Chicago: University of Chicago Press. doi:10.7208/chicago/9780226261591.001.0001.

Bird, A. 2007. "What Is Scientific Progress?" *Nous* 41 (1): 64–89. doi:10.1111/j.1468-0068.2007.00638.x.

Campbell, D. 1960. "Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes." *Psychological Review* 67 (6): 380–400. doi:10.1037/h0040373.

Cartwright, N. 1983. *How the Laws of Physics Lie*. Oxford: Oxford University Press.

Cohen, L. J. 1973. "Is the Progress of Science Evolutionary?" *British Journal for the Philosophy of Science* 24 (1): 47. doi:10.1093/bjps/24.1.41.

Gavrilets, S. 2004. *Fitness Landscapes and the Origin of Species*. Monographs in population biology. Vol. 41 vols. Princeton, NJ; Oxford, England: Princeton University Press.

Ghiselin, M. 1969. *The Triumph of the Darwinian Method*. Berkeley: University of California Press.

Glymour, C. 1980. *Theory and Evidence*. Princeton, NJ: Princeton University Press.

Gould, S. J. 2002. *The Structure of Evolutionary Theory*. Cambridge-MA: Belknap Press of Harvard University Press.

Harré, R. 1970. *The Principles of Scientific Thinking*. London: Macmillan.

Hull, D. 2020. Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science. Chicago: University of Chicago Press

Hull, D.L. 1988. *Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science*. Chicago: University of Chicago Press.

Hull, D.L. 1989. *The Metaphysics of Evolution*. Albany: SUNY Press.

Laudan, L. 1977. *Progress and Its Problems*. Berkeley, CA.: University of California Press.

Luhmann, N. 1991. *Wissenschaft der Gesellschaft*. Berlin, Germany: Suhrkamp.

Luhmann, N. 2017 Evolution of Science. *Epistemology & Philosophy of Science* 51 (1): 215–233. doi:10.5840/eps201752240.

Merton, R. K. 1973. "The Normative Structure of Science." In *The Sociology of Science: Theoretical and Empirical Investigations*, edited by Robert K. Merton, 267–278. Chicago: University of Chicago Press.

Miller, R. W. 1987. *Fact and Methods*. Princeton, NJ: Princeton University Press.

Olson, M. 1965. *The Logic of Collective Action: Public Goods and the Theory of Croups*. Cambridge MA: Harvard University Press.

Peirce, Ch, and K. Ketner. 1992. *Reasoning and the Logic of Things: The Cambridge Conferences Lectures of 1898*, 194–196. Cambridge, MA: Harvard University Press.

Sellars, W. 1970. The Language of Theories, in: B. Brody (ed.), Readings in the Philosophy of Science. Englewood Cliffs, 343–53. NJ: Prentice-Hall.

Suppe. 1971. "The Search for Philosophic Understanding of Scientific Theories." In *The Structure of Scientific Theories*, edited by Suppe, 221–260. Urbana, IL.: University of Illinois Press.

Todes, D. 1989. *Darwin without Malthus: The Struggle for Existence in Russian Evolutionary Thought, Monographs on the History and Philosophy of Biology*. New York: Oxford University Press.

Toulmin, Stephen. 1974. *Rationality and Scientific Discovery*, 394–406. Dordrecht: Boston Studies in the Philosophy Of Science.

Weber, M. 2017. *Wissenschaft als Beruf*. Berlin: Matthes & Seitz.

Wilkins, J.S. 2008. "The Adaptive Landscape of Science." *Biological Philosophy* 23 (5): 659–671. doi:10.1007/s10539-008-9125-y.

Zahar, E. 1973. "Why Did Einstein's Programme Supercede Lorentz's?" *British Journal of Philosophy of Science* 24: 96–123 .