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Teleodynamics: A Neo-Naturalistic Conception of Organismic Teleology

Introduction: Philosophy of Biology and Biophilosophy

The Philosophy of Biology is a discipline that was founded in the early 1970s. The best-known representatives of this discipline, which has become especially established in the USA, are theoretical biologists and philosophers.¹ Because of their commitment to the metaphysics of biosciences the philosophers of biology and their adherents make up merely a subset – even if the most efficacious one – within a philosophic tradition that has existed since antiquity and will hereafter be referred to as “biophilosophy.”² There are two reasons why I suggest making this distinction between philosophy of biology and biophilosophy, considering the former as included in the latter: First, in contrast to the philosophers of biology, who, in their reflections about matter and causality, almost never contravene the basic metaphysical frame dictated by today’s mainstream biology, the philosophical presuppositions of the biophilosophers follow very different metaphysical systems. Second, considering biophilosophy to be the metaphysically more broadly conceived field allows us to point to the relevance of works of philosophers like Aristotle and Kant for current biosciences, without characterizing them as “philosophers of biology” since the term “biology” was introduced in the very beginning of the 19th century when this discipline was founded. The borders, however, between both fields are fluid.

Current philosophy of biology seems to be increasingly adopting the former role of theoretical biology, whereas, worldwide, the latter tends to be reducing itself to a technique of computer-aided modeling of biological processes which serves biotechnology and is operated by mathematicians, physicists and computer scientists.

The issue of teleology – which has been intensively discussed since antiquity – is very suitable for demonstrating central natural-philosophical differences between philosophy of biology and non-scientific biophilosophical approaches. But even inside current philosophy of biology there are widely varying understandings of teleology. In this paper I will show how a recently suggested model of pre-cellular organization introduces a new form of teleology which has some consequences for our understanding of biological naturalism.

¹ Among the best-known philosophers of biology are Francisco Ayala, Robert Brandon, Michael Dupré, Peter Godfrey-Smith, Stephen Jay Gould, Paul Griffiths, David Hull, Eva Jablonka, Richard Lewontin, Ernst Mayr, Sandra Mitchell, Susan Oyama, Alexander Rosenberg, Michael Ruse, Elliott Sober, Kim Sterelny and Karola Stotz.

² Some pivotal occidental representatives of this tradition are Aristotle, Theophrastus, Harvey, Leibniz, Kant, Goethe, Carus, Fechner, Darwin, Haeckel, Nietzsche, Bergson, Driesch, Whitehead, Peirce, von Uexküll, Portmann und Jonas.

1. On different approaches to teleology in the philosophy of biology

In the last few decades, several biologists and many philosophers of biology have claimed that organisms may be considered teleological entities. This tendency is often celebrated as the renaissance of teleological thinking – also known as “neo-teleology.” However, when dealing with the issue of teleology in contemporary biology, it has to be stated in advance that it is a very multitudinous and complicated subject that has been tainted with misunderstanding. Usually, it is doubtful whether opponents are arguing over the same thing (Costa 183-188).

Aristotle is the biophilosopher most mentioned by philosophers of biology. The interpretation (and subsequent acceptance or rejection) of central concepts of Aristotelian theory of teleology is a reliable landmark for recognizing the metaphysical foundation of different authors’ understandings of teleology.

It is typical for all philosophers of biology that I am familiar with to reject at least every kind of universal teleology or panteleology. In other words, they reject the Aristotelian, Platonic or Leibnizian reasoning which considers the whole cosmos as a finally aligned totality (Töpfer 36f.; Mahner and Bunge 348). Neo-teleologism is confined to a specific biological variety of teleological reasoning – the “special” (Töpfer 36) or “regional” (Mahner and Bunge 348) teleology which merely refers to single living bodies and not at all to global phenomena like the evolution of the species and much less the cosmos. Special teleology is again subdivided into “inner” and “external” teleology, the former emphasizing the growth of the entire organism, its elements and their functional role, and the latter ascribing “utility for something else” to the organism as a whole (Töpfer 36). Philosophy of biology recognizes only special inner teleology.

In the long history of biophilosophy – from Aristotle via Leibniz to Peirce, Whitehead, and Jonas – a great deal of attention has been paid to special inner teleology; however, it has not been considered as the only kind of natural teleology. In biophilosophy the term “telos” was able to keep its double meaning of both “end” (or rather “end-state”) on the one hand, and “purpose,” “aim” or “goal” on the other, with a remarkable perseverance over more than two millennia. In Aristotelian hylomorphism, the end-state of living processes is something aimed at and purposed. As Hans Jonas has shown, Aristotle made a distinction between the “mere ending and internal »end« of a movement” (203, translation S.K.). So in the first clearly formulated theory of teleology, as presented in the works *Physics* and *On the Soul*, the concepts of aim or goal, end, and purpose denote inseparable aspects of one and the same thing: they designate essential elements of the “*eidos*” (εἶδος), i.e., the form or the biological species to which a single living being belongs. But it is even more important for the understanding of Aristotelian teleology that *these concepts presuppose the existence of a mental agent, i.e., an experiencing and striving subject* – even if it is an unconscious one (see

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section 2). Aristotle's understanding of teleology confirms Mark Bedau's position that one may unproblematically talk of teleology in connection with entities to which one can ascribe values (see section 2), since a subject always strives to attain something valuable.

In neo-teleological approaches to the philosophy of biology the concept of telos is understood as end-directedness, but here "end" means the end-state of a material process which has been achieved by blind deterministic, non-mental factors alone. Embryogenesis, physiological processes, the search for food, achieving a certain geographic position (e.g., in the case of migratory birds) and final acts of behavior (e.g., in the case of mating) are considered to be typical examples of end-directed processes (Mayr 61). According to Aristotle, in contrast, organismic end-directedness is the result of mental factors for which achieving a certain end has an intrinsic value. Thus, from his point of view, achieving an end-state by blind deterministic factors has no value since, in his metaphysics, a mental factor is required to assess the value of something.

A source of major confusion in contemporary debates is due to the fact that it is easy to get the impression that the Aristotelian amalgamation of end and purpose has survived. The relevant literature is teeming with expressions like "purpose" and "aim" or "goal"; less frequently there is talk of "purposiveness." This gives the impression of a close proximity to non-scientific biophilosophy, which often makes proponents of mental teleology euphoric. Obviously the crucial question in order to see through the neo-teleologism is the actual meaning of "purpose" and "aim" in this approach. This question leads us to three milestones in the renaissance of teleology in the 20th century:

1) In 1943 the founders of Cybernetics – Wiener, Rosenbluth and Bigelow – published the article "Behavior, Purpose and Teleology," in which they argued for the rehabilitation of teleology. They used the term "purposeful" to denote an act where "the act or behavior may be interpreted as directed to the attainment of a goal – i.e., to a final condition in which the behaving object reaches a definite correlation in time or in space with respect to another object or event" (18). In this definition the term "purpose" is coextensive with a special understanding of the expression "final condition," which in this context means "end-state." In cybernetics "aim" or "final condition" mean "end-state," that is, the encounter between a behaving object (e.g., a missile) with a certain external object (e.g., a ship) – and this is merely a spatiotemporal event. On the basis of this concept of purpose that excludes every conceivable kind of a first-person perspective – the behaving object does not have an *aim of its own*, as Jonas correctly states (202) – cyberneticists define teleologic behavior as the variety of purposeful behavior which reaches an end-state by means of a mechanism of *negative feedback*:

"We have restricted the connotation of teleological behavior by applying this designation only to purposeful reactions which are controlled by the error of the reaction – i.e., by the difference between the state of the behaving object at any time and the final state interpreted as the purpose. *Teleological behavior thus becomes synonymous with*

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behavior controlled by negative feedback, and gains therefore in precision by a sufficiently restricted connotation.” (Rosenblueth et al. 23-24; italics S.K.)

There is an intrinsic relation between this understanding of teleology and the cybernetic concept of *information*: Wiener thinks of information as something that is used by a “behaving object” which is controlled by a negative feedback for steering it towards a predefined goal. Wiener developed his concept of information almost contemporaneously with Claude Shannon in the 1940s. Both authors use the same formalism and connect information tightly to the concept of statistical entropy. Wiener defines information as “the negative of the quantity usually defined as entropy.” (62, s. also 11) Although Shannon’s concept of an amount of information is defined as an amount of entropy, so that Shannon-information is the arithmetic opposite of Wiener-information, there is an essential similarity between both concepts: Since the operations of cybernetic and information processing automata do not have meaning and value for the automata themselves but always for human beings which determine the “goals” and “purposes” of the devices both concepts of information have only a syntactic aspect and are void of any semantics.

2) Some Neo-Darwinists welcomed the non-metaphysical conception of purpose and telos provided by the cyberneticists. They adopted and further developed cybernetic teleology. Ernst Mayr added that the mechanisms which orientate the negative feedbacks towards an end-state and activate them are programs. Mayr, Jakob and Monod are the best-known proponents of the program metaphor in biology. They consider programs as genetic or behavioral algorithms which were generated in evolution and brought *selective advantages* to their organisms. Normally Neo-Darwinist theoreticians of teleology interpret purpose as *function*. They do not attempt to explain, for example, how the wing of a bird embryo develops step by step by molecular mechanisms, but rather content themselves with stating that wings develop in order to perform a function which in evolution led to a positive selection of all its bearers which were progenitors of the bird embryo in question (Ariew 179; Mayr 75, 61). The “what for” questions and “in order to” replies typical of teleological language were retained; they refer, however, only to natural selection:

“The sense in which what-for questions and their answers are teleological can now be clarified. Put cryptically, we explain A’s existence in terms of A’s function. More fully, A’s existence is explained in terms of effects of past instances of A; but not just any effects: we cite only those effects relevant to the adaptedness of possessors of A” (Brandon 188).

Griffith put in a nutshell this kind of Neo-Darwinist teleological reasoning that arose from the identification of purpose with function: “Where there is (natural) selection there is teleology” (quoted by Töpfer 42; translation S.K.). The Neo-Darwinistic idea of the genetic program or genetic information is based on the concept of information as it is introduced in cybernetics and informatics. This makes it difficult to ascribe to it semantic aspects which, however,

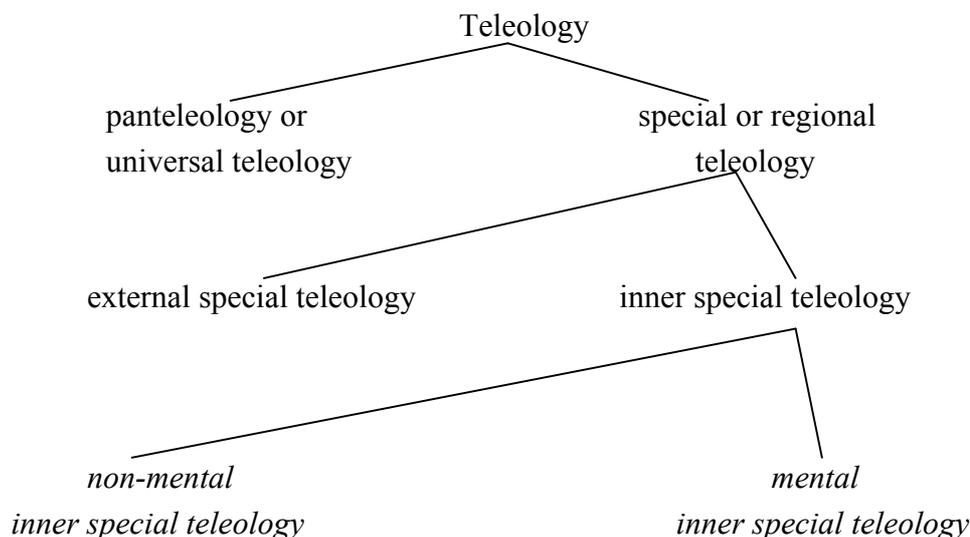
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should be possible, since survival, reproduction or death cannot be conceived of, at least not for animals, without any reference to meaning and value for the organisms themselves.

3) Despite the problematic conception of program the lack of even a simple concept of organism remains the decisive weakness of Neo-Darwinism. While Neo-Darwinistic teleologism only considers single functions, a whole phenotype is selected, that is, a complex structure of *mutual conditioning functions or elements*. Two hundred years ago, Kant already emphasized this most essential aspect of the organism with his concept of “self-organized things” (see below). Because of this weakness of Neo-Darwinism, an organismic turn is currently taking place in the philosophy of biology in which dynamic systems theory (or the theory of self-organization) plays an essential role. The directedness of embryonic and other processes towards a certain end-state or an “aim,” as it is often called, is understood as the outcome of the *self-organized* complex molecular dynamics of organisms. The proponents of this conception integrate cybernetic and Neo-Darwinist ideas into a more sophisticated model of organismic complexity: the organism would be a self-organized dynamic physico-chemical system, the dynamics of which results from an extremely complex structure of interdependent positive and negative feedbacks (Christensen 308f., Rosen 173f., Goodwin) that were successful in natural selection. Dynamic systems theory (and theories of self-organization and complexity) build the theoretical foundation of the third and most recent kind of biological neo-teleologism.

Philosophy of biology gives all three neo-teleological approaches great credit for providing interpretations of “purpose,” “aim” and “telos” without any reference to mental factors. Philosophers of biology sharply differentiate between versions of special internal teleology divested of all psychological or mental connotations and others which assume mental factors. According to philosophers of biology, only *non-mental special internal teleology* comes into question for biology. Thereby they distance themselves from many biophilosophers including Aristotle, as the following diagram shows:



All three approaches serve the creation of a new form of teleologism allowing biology to use teleological language without neglecting scientific metaphysics.

2. Mental teleology in the writings of Aristotle and Kant

The philosopher and scientist Mark Bedau rightly noted that “we are unsure whether teleological notions apply in roughly the same cases as those in which we are unsure whether value notions apply” (272-273). In my opinion this statement is fully applicable to Aristotelian and Kantian considerations of organismic teleology.

The second book of the *Physics* occupies a crucial position in Aristotle’s theory of biological teleology that, from a present-day perspective, can be assigned to special inner teleology. In this text Aristotle makes clear that the concepts “end” and “purpose” – the Greek expression for “purpose” is “ou heneka” (οὐ ἕνεκα) which means “for the sake of which” – are inseparably mutually related. The query is, however, whether the Aristotelian term “purpose” refers to something mental, i.e., an experiencing unity which sets its own aims and strives to attain them. Neo-teleologically minded biologists and philosophers strongly tend to interpret the Aristotelian concept of purpose in a functionalistic manner (Ariew, 173) by overestimating the importance of small passages in the second book of the *Physics* in which Aristotle explains the end-directedness of certain biologic processes by their functions in the organism: “Roots extend downwards [...] for the sake of nourishment (199 a29)” and “sharp teeth are located in the front of the mouth for the sake of tearing (198 b24).” Jonas appropriately criticized this myopic restriction of Aristotle’s thinking to functionality when reminding us that his teleology is only “in the second place a fact of structure or physical organization, as exemplified in the relation of organic parts to the whole and in the functional fitness of organism generally” (163). Indeed, something beyond functionalism is much more important to Aristotle’s teleology: His worldview simply *forbids* considering a natural process controlled by blind, i.e., non-mental forces, as being able to achieve the kind of ordered result attained by an appropriately formed organic structure that serves the purpose of staying alive, like an organism or an organ, rather than degenerating into chaotic malformation (*Physics* II, 198 b33-199 a1). Aristotle applies to blind mechanistic progresses of events the term “automaton” (αὐτόματον), which may be translated as “senseless in itself,” since “maten” (μάτην) means “in vain” (*Physics* II, 197 b22-31). He refers to all processes not grounded in any kind of mental purpose as “automata.” These may sometimes look *as if* there were a purpose behind their movement: the roof tile that falls on somebody’s head could have been thrown at him purposefully by somebody. Only very rarely, however, do blind forces lead to an end-state which could be considered as an intentioned one. Aristotle would subsume all

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processes which we today consider to be regulated by physico-chemical interactions under the category of “automaton.” Accordingly, from the point of view of Aristotle, all phenomena of material self-organization constituting the third kind of the contemporary neo-teleological renaissance would be cases of “automatic” becoming. He would never assume that these non-mental processes would be able to produce something as ordered as even a single cell. It is crucial to Aristotle’s natural philosophy that he very clearly accentuates that a mental agent is only rarely conscious of its acting:

“It is absurd to suppose that purpose is not present because we do not observe the agent deliberating. Art does not deliberate. If the ship-building art were in the wood, it would produce the same results by nature. If, therefore, purpose is present in art, it is present also in nature” (*Physics* II, 199 b26-30).

In other words, conscious action is only a seldom-occurring special case of mental acting.

Over two thousand years later Kant reflected on biological teleology against the background of Newtonian mechanics, which had clearly shown that non-mental forces like gravitation may produce well-ordered results like the solar system. The famous résumé of his thinking about the ability of 18th century physics to explain the special inner teleology of organisms is contained in paragraph 75 of his *Critique of Judgment* (hereafter referred to as CJ):

“It is indeed quite certain that we cannot adequately cognize, much less explain, organized beings and their internal possibility according to *mere mechanical* principles of nature, and we can say boldly it is alike certain that it is *absurd* for men to make any such attempt or to hope that another *Newton* will arise in the future *who shall make comprehensible by us the production of a blade of grass according to natural laws which no intention has ordered*”³ (italics S.K.).

Obviously, although Kant was very experienced in mechanistic physics – in 1755 he had published one of the very first cosmological studies about the generation of the planets of our solar system out of the primeval solar nebula through Newtonian gravitational pull – his skepticism concerning the applicability of physics to the study of organisms is very similar to Aristotle’s refusal to consider living beings as automata. The concept of purpose is also of great importance to Kant’s theory of the organism:

“For a body then which is to be judged in itself and its internal possibility as a natural purpose, it is requisite that its parts mutually depend upon each other both as to their form and their combination, and so produce a whole by their own causality [...] In such a product of nature every part not only exists *by means of* the other parts, but is thought as existing *for the sake of* the others and the whole, that is as an (organic) instrument. Thus, however, it might be an artificial instrument, and so might be represented only as a purpose that is possible in general; but also its parts are all organs reciprocally *producing*

³ I made a minor change in the English translation: I replaced “design” with “intention” since the latter seems to me to be a more appropriate translation of the German word “Absicht.”

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each other. This can never be the case with artificial instruments, but only with nature which supplies all the material for instruments (even for those of art). Only a product of such a kind can be called a *natural purpose*, and this because it is an *organised and self-organising being*" (§65, italics S.K.).

Of course, most contemporary philosophers of biology try to interpret Kant's understanding of "purpose" and "for the sake of" in a non-mentalistic way, both in the passage quoted above and in his theory of teleology altogether. This would be misleading, since the Kantian concept of purpose implies the concepts of *will* (!) and *reason*:

"In order to see that a thing is only possible as a purpose, that is, to be forced to seek the causality of its origin not in the mechanism of nature but in a cause whose faculty of action is determined through concepts, it is requisite that its form be not possible according to mere natural laws, i.e., laws which can be cognised by us through the Understanding alone when applied to objects of Sense; but that even the empirical knowledge of it as regards its cause and effect presupposes concepts of Reason. This *contingency* of its form in all empirical natural laws in reference to Reason affords a ground for regarding its causality as possible only through Reason. For Reason, which must cognise the necessity of every form of a natural product in order to comprehend even the conditions of its genesis, cannot assume such natural necessity in that particular given form. The causality of its origin is then referred to the faculty of acting in accordance with purposes (a will); and the Object which can only thus be represented as possible is represented as a purpose" (§64).

A "faculty of action" which is "determined through concepts" can only be a mental faculty since something non-mental could never capture concepts; a "causality" that is "possible only through Reason" can therefore only arise from a mental agent. It is not possible here to elaborate on the details of Kant's epistemological (and not ontological) treatment of teleology as it is developed in paragraph 68 of CJ. Let us just say that for Kant the idea of natural purposiveness does not mirror the essence of natural things but only the constitution of human reason.⁴ Much more important than talking about Kant's emphasis on epistemology is asking

⁴ "[...] there are objects, alone explicable according to natural laws which we can only think by means of the Idea of purposes as principle [...] we speak in Teleology, indeed, of nature *as if* the purposiveness therein were intended, but in such a way that this intention is ascribed to nature, i.e. to matter. Now in this way there can be no misunderstanding, because no intention in the proper meaning of the word can possibly be ascribed to inanimate matter; we thus give notice that this word here only expresses a principle of the reflective not of the determinant Judgement, and so is to introduce no particular ground of causality; but only adds for the use of the Reason a different kind of investigation from that according to mechanical laws, in order to supplement the inadequacy of the latter even for empirical research into all particular laws of nature. [...] there should be only signified thereby a kind of causality of nature *after the analogy of our own* in the *technical* use of Reason, in order to have before us the *rule* according to which certain products of nature must be investigated" (§68; italics from me S.K.; the words "designed" and "design" were replaced with "intended" and "intention"). Kant's statement that the idea of purposiveness in nature "expresses a principle of the reflective not of the determinant Judgement" means that humans are not allowed to say that some natural things (organisms) are actually ruled by mental faculties but merely that there are natural things in consideration of which we are compelled to derive the idea of purposiveness.

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why the very thinker who introduced the concept of self-organization developed it as something distinct from physics. This question makes sense especially in view of the third neo-teleological approach which is grounded on a physicalistic conception of self-organization. Kant clearly realized that the mechanistic thinking of his day physics was only able to explain processes controlled by strictly forward-directed causal connections (§65). In such connections, which nowadays are called *linear*, “things which as effects presuppose others as causes cannot be reciprocally at the same time causes of these” (ibid.). But Kant also knew that “a causal combination according to a concept of Reason (of purposes) can also be thought, which regarded as a series would lead either forwards or backwards; in this the thing that has been called the effect may with equal propriety be termed *the cause of that of which it is the effect*” (ibid.). It is exactly this kind of causal connection which governs every organism or “natural purpose,” since “its parts [...] are reciprocally cause and effect of each other’s form” (ibid.). The reason why Kant was as certain as to whether a *Newton* of even the simplest organism will never arise is the inability of the physics of his time to operate with reciprocal causal connections. Therefore, he introduced a species of causality into biophilosophy that is based on a mentalistic concept of purpose. For us today the main question is, of course, whether Kant’s criticism is applicable only to 18th century physics: Would he agree that today’s theory of self-organization, which operates with *non-linear* feedbacks and “downward causation” without using a mentalistic concept of purpose, is able to adequately describe organisms? I hold that he would not.

3. On the limitations of the conception of organisms as self-organized dynamic systems

Kant’s use of the term “self-organizing” which he coined is clearly far more generic than its use in current physics and biosciences. For Kant “self-organization” refers to organic reciprocities. When contemporary theorists say that systems are self-organizing they refer to energetically and/or materially open systems which operate far from thermodynamic equilibrium. These systems may be living or nonliving but in any case their organization emerges out of non-mental physicochemical interactions.

Aided by the theory of dynamic systems, the modern paradigm of self-organization or complexity has become a main pillar of modern theoretical biology. However, there are good reasons to contradict theories and findings based on this development, which is the basis of the third and newest neo-teleologic approach, since it has at least one decisive weakness. In order to explain this, it is necessary to introduce some “technical details” of dynamic systems theory.

A system is defined as a *dynamic system* if its state at any given moment can be described as a limited set of time-dependent or state variables $x(t) = x_1(t), x_2(t), \dots, x_n(t)$, for which a function F can be formulated stating mathematically the connection between states at times t

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and $t + \delta t$. The properties of this function reflect the *causal* relationships at work within the system.

The set of state variables $[x_1(t), x_2(t), \dots, x_n(t)]$ spans an *abstract space*, the system's so-called "state-space."

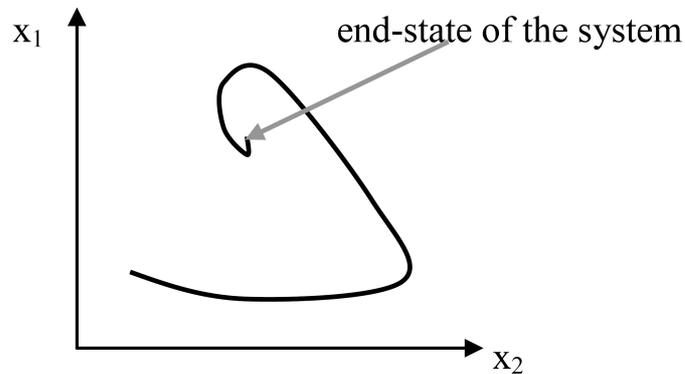


Fig. 1: State-space and trajectory of a dynamic system with two state variables.

It is important to keep in mind that the development of a dynamic system is not merely the result of the function F , but depends also on a group of externally fixed parameters. The most abstract formula for a dynamic system must therefore be (Ebeling and Sokolov 40):

$$x(t + \delta t) = F(x(t), p, \delta t); p = p_1, p_2, \dots, p_m$$

The letter p represents a set of parameters. All parameters are *externally fixed constants*; their role is to constrain the development of the state variables $x(t)$. Obviously, parameters play a very important role in dynamic systems theory.

Dynamic systems can be subdivided into *conservative* and *dissipative* dynamic systems. The energy of the latter "dissipates" – that is, it disperses and must be replaced by the environment. *Dissipative systems produce entropy*. As we shall see presently, it is precisely the fact that they produce entropy that, under certain conditions, allows dissipative systems the kind of spontaneous structuring of their behaviour in space-time which is commonly labeled "self-organization."

3.1. The paradox of self-organization: The system organizes itself in order to more efficiently oppose the causes of its self-organization.

Statistical entropy is a concept applicable only to systems with a huge number of particles and serves as a measure of disorder. Boltzmann and Planck define the statistical entropy of a system as the average value of its uncertainty (Ebeling 13).⁵ A system is uncertain if there are many possible states in which it might be. Ideally, each of these states corresponds to a point

⁵ Concerning the connection of entropy and uncertainty see Ebeling and Sokolov 85f.

in its state-space which can, with a particular probability, be the actual state of the system. The statistical entropy of a system is the average value of the probabilities of all possible states which the system might occupy. Accordingly, statistical entropy is related to the concept of *possibility*.

The order and the statistical entropy of a system which has n state variables can be depicted using an n -dimensional state-space. For each of the possible states there is a particular point in this abstract space to which it corresponds. Thus a limited area of the state-space represents all the states which the system can possibly occupy at a given time.

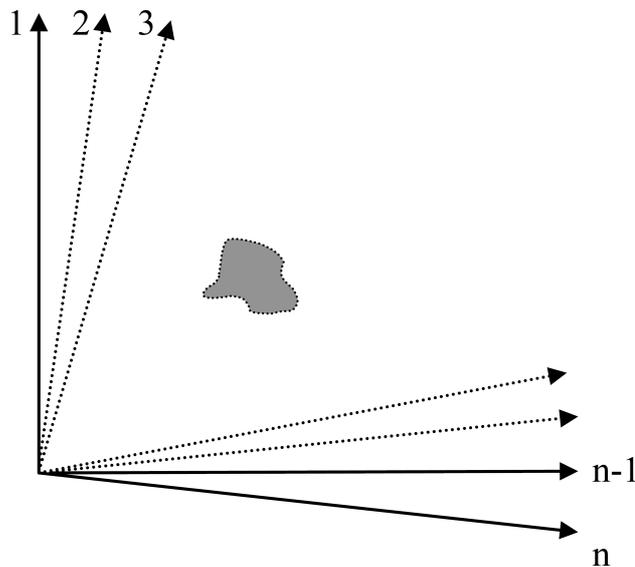


Fig. 2: The high-dimensional state-space-volume of a system with n variables at a given time. Each one of its points represents a possible state of the whole system.

The consideration of living beings as self-organized complex dynamic systems has become essential for theoretical biology in the last thirty years. “Self-organization” is a technical term. It means that the increase of a system’s order – that is, the decrease of its entropy – is the result of interactions between its elements and not the outcome of the action of a single real or ideal entity like an acting person or a program. Self-organization does not mean elimination of entropy or uncertainty, only their diminution.

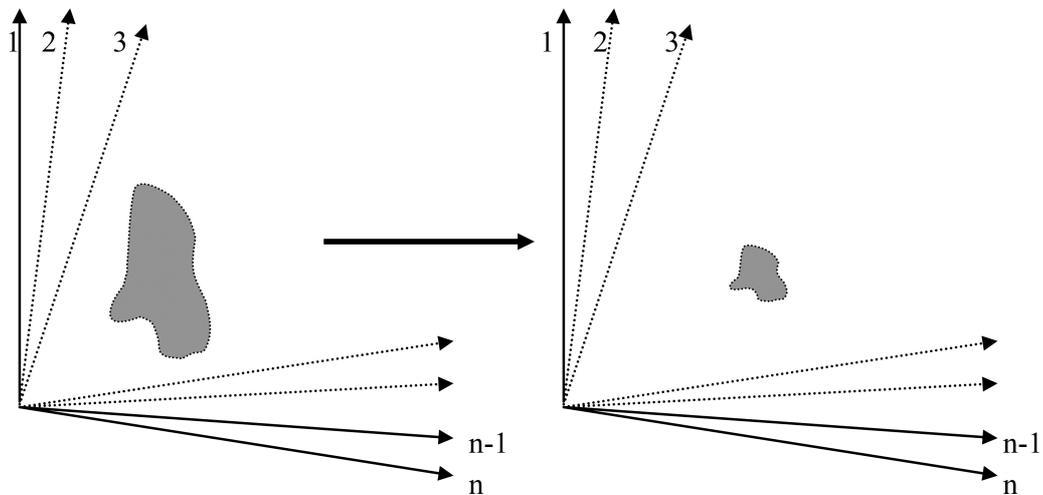


Fig. 3: The diminution of a system's entropy equals a decrease in the number of possible states.

Systems serving as models of self-organization require *gradients* of energy and/or material. A typical example of such a gradient is the difference of temperature in the so-called Bénard convection. This effect appears when the lower layer of a fluid is heated and the upper layer is kept at a cooler temperature. At a certain difference of temperature between the bottom and the top of the fluid the heat flux reaches a critical value and convection arises. Coherent macroscopic movements emerge in the fluid and form a highly structured pattern of hexagonal cells. Of course, the examples of self-organization most interesting for biology are of chemical and biochemical nature.

There is a fundamental finding in thermodynamics with consequences for the applicability of the theory of complex dynamic systems to biology; these consequences have barely been understood. It states that every form of self-organization of a physico-chemical system amounts to a *decreasing* of the gradients which are imposed on the system and which move it away from the thermodynamic equilibrium, that is, from the state of total lack of physical becoming. *Each self-organized system tends to return to equilibrium.* The hexagonal Bénard cells transport heat upwards faster than simple heat conduction thus *increasing the rate of gradient destruction.* Two well-known physicists got to the heart of this finding:

“As systems are removed from equilibrium, they will utilize all avenues available to counter the applied gradients. As the applied gradients increase, so does the system's ability to oppose further movement from equilibrium. [...] No longer is the emergence of coherent self-organizing structures a surprise, but rather it is an expected response of a system as it attempts to resist and dissipate externally applied gradients which would move the system away from equilibrium” (Schneider and Kay 165).

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All self-organized structure-formation conceivable in physics occurs only because the higher the order of the system's actions, the more efficient the degradation of the causes of this order, i.e., the degradation of the gradients.

This essential property of dissipative dynamic systems is also well known as the principle of maximum entropy production, which can be easily explained: According to the second law of thermodynamics all real (and not ideal) physical processes produce entropy. Production of entropy means dissipation or degradation of energy. Of course energy cannot be created or destroyed in a system (as this is forbidden by the first law of thermodynamics or the law of conservation of energy) and the system cannot upgrade already degraded energy (this is forbidden by the second law of thermodynamics) in order to degrade it again. Thus the system can only produce entropy if it degrades the energy with which it is supplied from outside, i.e., by means of the externally applied gradients. Therefore, the system can only efficiently degrade gradients which greatly distance it from the state of thermodynamic equilibrium if it maximizes the production of entropy in its own processes. The entropy inside the system decreases in order to enable it to produce entropy more quickly. The emergence of the higher-order macroscopic structure which exerts downward causation to the lower-order events (on the molecular level) *only serves the degradation of gradients through the maximization of entropy production*. It is important to keep in mind that, in all mathematical models, gradients are represented by a number of parameters.

3.2. About modeling biomolecular processes in systems-biology

Some bioscientists, primarily systems biologists, maintain that organisms *are nothing more* than physico-chemical dynamic systems and dream of future computer-simulations of whole organisms, possibly within the next fifty years.⁶ This development is philosophically interesting because, in doing so, these bioscientists attribute ontological and not just heuristic relevance to the theory of self-organized dynamic systems.

The solving of non-linear differential equations and concomitant computer simulations are fundamentally important to formal reductions of organismic processes. Both operations require (among other things) a special condition: the sharp distinction between dynamic and static quantities, that is, between variables and parameters. This distinction is present in an enormous number of texts within systems-biological literature.⁷ A very characteristic example can be found in Paning et al., who published a model of a very simple network of three interconnected biochemical reactions from the cell cycle of a frog's egg (498). It is important

⁶ Cf.: Wolpert, Tomita, Normile, Gibbs.

⁷ Cf.: Murray, Turing, Goldbeter, Tyson et al., Collier et al., Elowitz and Leibler, Ferrel and Xiong, Gardner et al.

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to keep in mind that the computation of the self-organization of this system with only three dynamic quantities requires 13 parameters – that is, 13 quantities which take no part in the dynamics of the modeled self-organization. For modeling the cell cycle of yeast the same authors use 36 coupled differential equations – i.e. 36 variables – to which they impose 143 parameters (499).

Parameters do not necessarily represent specific chemical substances. Some of them symbolize *gradients*, while others are *abstractions* summarizing relations between variables of the cell such as volume, temperature, pressure, pH-value etc. Some parameters represent the degree of activity of specific molecules in systems-biological simulations while others represent the rate coefficient of reactions in chemical kinetics.

In simulations the values of parameters are determined by the theoreticians. They are either experimentally derived or estimated or simply taken from literature. There are many ways to manipulate the values of parameters in experiments. They are, however, kept constant in each single experiment and corresponding computer simulation as well. The reason for this is simple: As already said, parameters constrain the self-organized processes studied by dynamic systems theory. They are one of the two factors which constrain the development of the variables. The other factor is the variables themselves since the causal connections between them allow their permanently changing quantities to actualize only a part of the possible values which would be actualized if the connections weren't there.

3.3. *Organisms are more than complex dynamic systems*

It is typical of *all* mathematical accounts which rely on differential equations – whether in physics, chemistry, or biology – to *essentially depend on a high number of externally set parameters*. Scientists set these quantities in their experiments and calculations. Within theories of self-organization and complexity there is a strict distinction between dynamic state variables and externally set parameters – in other words, between constrained and constraining quantities.

It is obvious, however, that the quantities whose causal influence on the system's dynamics in systems-biological models is summarized in parameters will, in *real organisms*, vary constantly. For example, the variation of cell volume during a real cell cycle would imply that some parameters must vary. Therefore, with regard to the sufficiency of self-organized dynamic systems theory to deepen our theoretical understanding of the organism, the crucial question is whether the aforementioned distinction between variables and parameters could ever be overcome. While this division is not problematic within physics,

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even the most primitive organisms go beyond this dimension of self-organization: in stark contrast to formal models, almost all quantities in real organismic networks are highly dependent on the network's own inner dynamics. That which Kant claims for the parts of the organism – “that its parts should so combine in the unity of a whole that they are reciprocally cause and effect of each other's form” (§65) – may, with regard to contemporary bio-mathematical modeling, be rephrased as follows: “The organism's quantities are reciprocally the cause and effect of each other”.

In order to preserve their own adaptation, organisms trigger multiple changes within themselves (Falkner and Falkner (in this book); Plaetzer et al.). In modeling them as dynamic systems, these changes ought to be described as *internally controlled* changes of many parameters if the model makers claim to have created a model that has not just heuristic value for biotechnology but gives an insight into a real organism's causality. A model which realistically mirrors the organism's autonomy must be able, at least principally, *to calculate a significant part of its (the model's) parameters*, i.e., to dynamize those quantities which in today's modeling are kept constant, or, in other words, to convert most of the parameters into variables and let the overall system's dynamics calculate their value. The model must be able to independently calculate and adjust also – but not only – those parameters which describe the organism's self-supply with energy and materials from its environment, as this is something all organisms do constantly! Accordingly, the modeling of real biological self-organization would demand of systems that their dynamics calculate the self-imposition of energetic-material gradients. But within current physics this is *impossible*, primarily because all dissipative dynamic systems have an inherent *entropic tendency* (see section 3.1). They organize themselves in order to reduce the gradients imposed on them and, therefore, cannot control these. The more the system would attain influence over its parameters – especially over those representing energetic-material openness, i.e., the existence of gradients – the more it would become disorganized.

In contemporary systems-theory there is no clear evidence that a formal system is able to vary these quantities by itself. Of course, this does not exclude the possibility that in the future a new formalism based on a more advanced mathematics will appear founding a new kind of self-organized dynamics which will be able to convert a significant part of its parameters in variables. Within current systems-theoretical formalism, however, the entropic tendency of a dynamic system can only be limited if its parameters are *externally* controlled and kept constant. Often this criticism is rejected because, in real organisms, many processes take place under constant conditions as well. This is, of course, the case, but the constant-holding of such conditions is something that cannot be taken for granted; on the contrary, it is an achievement of the organism itself: its overall dynamics hold certain quantities at least nearly constant. In terms of dynamic systems theory this could be expressed as follows: “In certain processes the overall dynamics repeatedly calculate nearly the same value for particular variables.”

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So, within current systems-theoretical formalism, systems governed only by causes without any mental capacities but able to influence most of their parameters would exhibit *an enormous number of causally indefinite states* in their state-spaces. This is the case because the considerable variation of parameters implies a change in the overall dynamics and therefore the generation of many new possible developments. Such systems would be instable to a much higher degree than some of the ordinary dynamic systems whose state-spaces have areas where closely adjacent trajectories tend to diverge strongly. Instability is a phenomenon often encountered in the theory of dynamic systems and in systems-biology – even if all parameters are firmly set and not varied by the model makers. Instable states are causally indefinite, i.e., indeterminate.

The *entropic tendency* inherent in every dissipative dynamic system means that the more the system is able to attain influence over its parameters – especially on those representing energetic-material openness, i.e., the existence of gradients – the more it will become disorganized. The development of such a system would only lead to a continual increase of the system’s own entropy, i.e., to a permanent increase of the number of its possible states.

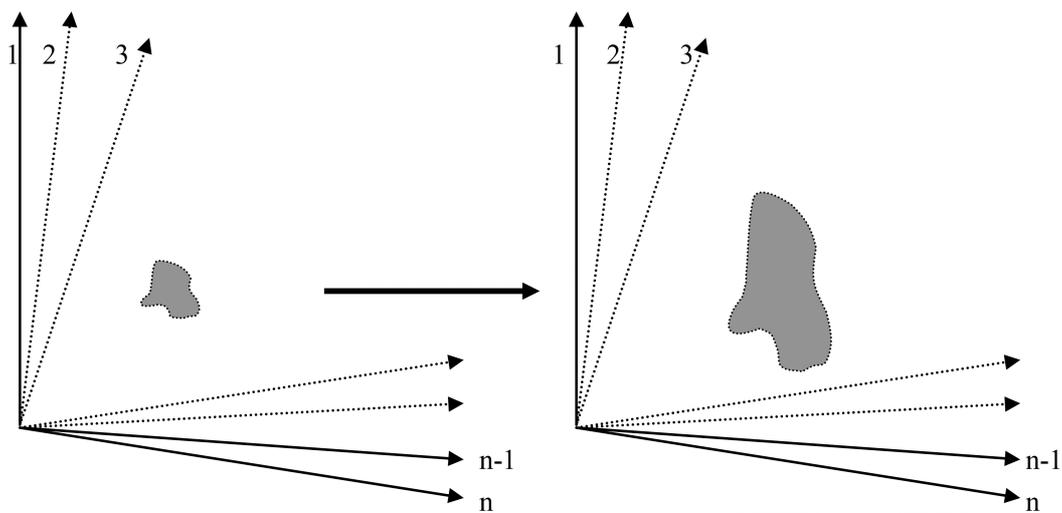
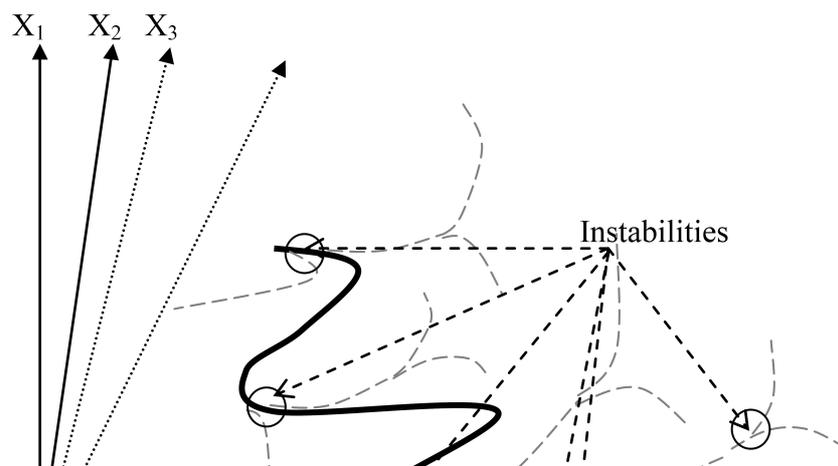


Fig. 4: The increase of entropy within a system depicted as the increase in the number of possible states.

Figure 5 shows another way of describing the increase of entropy – caused by the loss of constraints – as the increase of the number of possible trajectories.



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Fig. 5: Permanently occurring instabilities in the development of a hypothetical dissipative dynamic system which influences the value of its parameters. If understood as displaying a real organism, the variables X_1 to X_n represent important dynamic quantities, like concentrations of proteins and signal substances etc., the coherent variation of which is characteristic of an organism. The curves do not symbolize single trajectories but rather bundles of these.

If the system were a model of a real organism, *only a very limited number of these possible trajectories would be biologically viable*; in other words, *very few would represent states of being alive*. This is so because biological structures constitute only a vanishingly small number of all possible physiochemical structures. In fig. 5 the long curve represents a thin bundle of biologically viable trajectories, while the dotted lines stand for developments which are possible in terms of physics and chemistry, but fatal from a biological point of view. They show the derailment into areas of increasing entropy or uncertainty i.e. of lethal deformation of the organism's structure.

This leads necessarily to the following aporia: How does an organism succeed in avoiding *derailments* into areas of disorder if it often faces possibilities equally valid from the point of view of physics allowing a biologically adequate choice between these possibilities?⁸

There is also tried and tested experimental evidence proving that the causal order of organisms stays beyond a physicalistic understanding of self-organization. For example, biologists have known for a long time that the exchange of energy and material between real (not virtual) organisms and their environment does *not* follow the principle of maximal

⁸ In the past the answer might have been “the genes” or “genetic information”. But both these notions are much less clear today than they were some decades ago. Now we understand that genes are massively co-determined by the organisms' dynamics.

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production of entropy. This is logical, of course, since a high production of entropy means a high degradation or waste of energy. The year-long experimental and theoretical research of Gernot and Renate Falkner clearly shows that the metabolic exchange between cyanobacteria and their environment only exhibits a high production of entropy if the physiological adaptation of the bacteria to their environment has been disturbed and is merely being readjusted (Falkner and Falkner, in this book). The act of physiological re-adaptation, as they described it, effects the minimization of entropy production and not its maximization, which one would expect when starting out from physico-chemical theory of self-organization. Only an organism which is no longer in a state of optimal adaptation seems to function in a way consistent with the physicalistic conception of self-organization: it is situated at a state of low entropy but it produces a lot of entropy. But as soon as re-adaptation is reached, the organism is situated at a state of low entropy and low entropy production as well. This fact contradicts physicalism. So, while the act of physiological adaptation begins as if the organism were following the laws of a merely physical dynamics, in the latter stages it proceeds in a manner which can only be explained in biological terms. Following on from the Falkners' research with cyanobacteria, it seems plausible to assume that all organisms aim at the minimization of entropy production. Physiologic re-adaptation is a biologic act that requires the *internally conditioned* coordinated variation of many dynamic quantities or variables which, in the models of systems biologists, are described as parameters (i.e., as non-variables).

There is also experimental evidence that a process of minimization of entropy production also takes place during embryonic development. The results of numerous measurements in several studies led to the conclusion that the entropy production “indeed decreases at separate stages of the ontogenesis (if early stages of development are excluded)” (Martyushev and Seleznev 40). To sum up: Both theoretical considerations and experimental evidence make clear that *the theory of self-organization of physics is too weak to account for real biological self-organization*.

3.4. Conclusion: Teleology beyond dynamic systems theory

Every organism must act anti-entropically *without* requiring most conditions of its self-organization to be externally set. As stated above, parameters are quantities which constrain the development of dynamic systems. Thus, the simulation of a dynamic that could calculate a significant portion of its own parameters would be nothing less than the simulation of a *self-constraining dynamic*. But the latter is not conceivable within contemporary dynamic systems theory. Failing to see this (and thereby considering the models of systems biology as appropriate descriptions of organismic causality) would be a clear case of what the

mathematician, physicist, and philosopher Alfred North Whitehead calls “fallacy of misplaced concreteness”: confusing something abstract with something concrete.

This result invites us to go beyond the ontological limitations of current scientific teleology. As it is not capable of accounting for anti-entropic behavior in real organisms we should endeavor to think about concepts of teleology beyond contemporary mainstream physicalism. This brings back on the stage the idea of genetic information which seems to play no role in physicalistic reductions of organismic causality. There is need of a new concept of genetic information that is not borrowed from informatics and thus lacks any semantic aspects as it is the case in Neo-Darwinism. With that said we leave behind dynamic systems theory, which is the most advanced scientific foundation of neo-teleologism today. We will become acquainted with another way of thinking about organismic teleology and genetic information which goes beyond all kinds of neo-teleologism.

4. On the *autogen* model⁹

Deacon has introduced an abstract model system, which he calls an *autogen* or *autocell*, that exhibits self-constraintment to a certain degree. Deacon does not assume any kind of mental factors operating in autogens; rather, he developed the autogen model in order to demonstrate that a special form of reciprocity between self-organizing molecular processes is sufficient to explain both self-replication and evolvability (*Incomplete* 305-325, *Reciprocal* 141).

4.1. Autogenic dynamics: Teleodynamics

Deacon’s autogen model offers a theoretical demonstration that some organismic properties can be exhibited by systems that are not alive in current biological terms. It also clearly illuminates the fundamental difference distinguishing simple self-organizing processes from processes that exhibit the most basic features of organismic dynamics. The autogen model embodies a *partially* self-constraining self-constituting dynamic. The simplest form of autogen is an autonomous molecular system consisting of two coupled non-linear self-organizing processes – *autocatalysis* and *self-assembly* – which *mutually support and constrain each other*. The property of these structures is the result of the following reciprocity of molecular properties and interaction processes:

- 1) Autocatalysis (also known as “reciprocal collective catalysis”) requires a local concentration of substrate molecules and a source of energy (e.g., embodied in

⁹ I gratefully acknowledge Terrence Deacon’s advice and great assistance in this short description of his autogen model.

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- chemical bonds) in order to occur. It depletes these supportive conditions at an ever-increasing rate as it produces more catalysts.
- 2) Autocatalysis depends on the collocation of reciprocal catalysts, and as long as it continues it produces more catalysts that replace those that have diffused away.
 - 3) Autocatalysis thus produces a gradient of molecular concentration that temporarily generates a region of high concentration of a few molecular forms despite the tendency for them to diffuse away.
 - 4) Autocatalysis rapidly depletes the immediate environment of substrate molecules and the energy gradient to drive this reaction.
 - 5) Self-assembly is dependent on the structural symmetries of like molecules to spontaneously form regular molecular tessellations (producing crystals, sheets, polyhedrons, and tubular forms). The self-assembling molecules are byproducts of the autocatalytic process.
 - 6) Self-assembly depends on a high local concentration of such molecules.
 - 7) As a self-assembling structure grows it depletes this local concentration.
 - 8) The growth of self-assembled sheets and related structures tends to impede molecular diffusion, especially when it produces a closed or partially closed structure like a polyhedron or tube, respectively.

Notice that the persistent generation of a high local concentration of like molecules by autocatalysis (3) is a necessary boundary condition, or *constraint*, required for self-assembly (6), and that the prevention of the diffusion of reciprocal catalyst molecules (8) is the necessary boundary condition, or *constraint*, required for persistent autocatalysis (2). In rare cases an autocatalytic process produces as a byproduct a molecular form susceptible to self-assembling into an enclosing structure. In these cases enclosure is likely to encapsulate the very molecules that in proximity with one another tend to produce this containment. Both coupled processes require a gradient, both deplete that gradient and in the process produce more regularity, more catalysts, and more enclosing structure. Moreover, if such an enclosed structure is broken up by external factors in an environment with supportive conditions the whole complex will tend to reform or even produce replicas from the partially diffused components.

The dynamics of an autogenic process does not merely use the constraints that enable the utilization of local gradients – *autogen closure halts both of its component self-organizing processes before supportive local energetic and substrate gradients are destroyed*. Cessation of these processes halts depletion of the conditions that make them possible. An autogen thereby preserves the potential for future autocatalysis and self-assembly when external factors break them up. Thus, an autogen acts like a ratchet: it produces something when active and preserves it from getting lost when it is not active.

So, *autogens do not fully deplete environmental conditions, e.g., energetic and/or material gradients*, in the way that ordinary self-organizing systems do. This is the most

essential feature of autogenic dynamics since it goes beyond the principle of maximum entropy production which characterizes all kinds of self-organized dynamics. It directly results from the specific organization of autogenic dynamics which is an “additional emergent transition (...) dynamically supervenient” on self-organized processes (*Incomplete* 265). Autogenic dynamics exerts an additional and highly constraining effect on the two simpler self-organized dynamics (autocatalysis and self-assembly) of which it consists. Dynamic systems that lack this reciprocity thus exist at the whim of extrinsic parameters, whereas autogenic systems actively generate some parameters (constraints) critical to their existence (see below).

Deacon calls the specific organization of autogenic dynamics *teleodynamics* (*Incomplete* 265-287, *Emergence* 137-149) because it exhibits “end-directedness and consequence-organized features” (*Incomplete* 552). Teleodynamics is always constituted by the mutual constraint and reciprocal synergy of two or more strongly coupled self-organized processes (*Incomplete* 552).

4.2. How the autogen model could account for organismic dynamics

Deacon hypothesizes that autogenesis manifests the most basic form of self-producing. But he admits that *autogens cannot be counted as living organisms* (*Incomplete* 434). Although they preserve environmental gradients and intrinsic constraints (in contrast to self-organized systems which destroy them), they merely prevent critical gradients in the environment from being depleted too rapidly and preserve critical constraints that enable these gradients to be utilized to preserve this higher-order property. *Autogens are thus passive entities*. They preserve themselves passively since they are passive to potential changes in their environment and do not seek better environmental conditions. Furthermore, they do not maintain a persistent energetic and material openness (metabolism). They are in this sense similar to virus particles except that they are not parasitic, i.e., they do not rely on other organisms for their self-constituting and self-reproducing properties. Because of this passivity they cannot adapt if conditions should change. *They are unable to internally vary critical quantities (i.e., parameters) of their dynamics with respect to these conditions*.

But although they therefore lack any internal representation of their environment, autogens meet some of the basic criteria of the organismic mode of being. Teleodynamics is an emergent level beyond what can be understood through current dynamic systems-, self-organization-, and complexity theories. Thus autogenic dynamics exerts a constraining influence on the multitude of possible trajectories which would be allowed if organisms were nothing but self-organized dynamic systems (fig. 5). The highly constraining effect of the teleodynamical level on the lower level self-organized processes enormously reduces the

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number of possible physicochemical trajectories. On the basis of this reduction Deacon introduces even a new concept of information (*Incomplete* 371-420).

Obviously, the idea that autogenic dynamics are a unique form of self-constraint lies at the heart of the concept of autogenesis. Therefore it should be examined to what degree autogenic dynamics impose such self-constraint. In order to do this we have first to clearly identify the factors which constrain each other: They are the concentration of the autocatalytically generated and the concentration of the self-assembling molecules. In a formal description of the interconnection of autocatalysis and self-assembly as a system of differential equations, both mutually constraining quantities would be variables. There are, however, two other quantities which are very critical to the generation of both sorts of molecules: substrate-energy availability (i.e. the external gradient of matter) and diffusability. In the dynamic systems approach both these quantities would be externally set parameters. In contrast, even the simplest teleodynamics is partially able to autonomously regulate these quantities since the closure of the autogen changes both. But on the other hand, as in dynamic systems theory, the computation of the concentration of the autocatalytic and self-assembling molecules would require some other parameters or static quantities – e.g. the rate coefficient of the reactions – to be set from outside. Thus, at the present stage of its development autogenic dynamics is self-constrained in a way which doesn't extend itself over all quantities which in the dynamic systems approach to this process would be described as parameters of differential equations. But in any case an autogen can be minimally said to change its dynamics in a way that controls at least some quantities which in dynamic systems theory are parameters so that persistence is optimized. This manifests, even for the simplest autogen model, a degree of self-regulation unattainable in dynamic systems theory which clearly indicates a big step beyond neo-teleologism.

It should be noticed that as long as the autogen model accounts only for the formation of inanimate pre-biotic structures it does not need to display a dynamics able to autonomously regulate a significant part of its parameters. The reason for this is that in the simulation of pre-biotic organization parameters (e.g. the rate coefficient of the reactions) would represent quantities the values of which depend on environmental conditions (e.g. temperature) that cannot be influenced by autogenic dynamics. At present, Deacon's model can show how pre-biotic entities autonomously produce their spatial border. If the autogen model is expected to provide a scenario for the transition from pre-biotic to proto-biotic organization, it will have to be demonstrated how autogens eventually overcome the distinction between parameters and variables to a higher degree than they already do. The future development of the autogen model should show that, under the primordial environmental conditions of the early planet earth, autogens were able to evolve in such a way that would allow them to control more and more of the internal quantities which systems biologists describe as parameters in their models. To show this would mean to demonstrate that evolution would progressively provide autogens with an increasingly self-constraining and end-directed dynamics typical of real cells

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and even the first archaic cells. So the further development of autogen theory would demand the introduction of models with a complex structure of interconnected causal loops in which more and more parameters become replaced by variables.

Although at the present this problem has not been solved Deacon's theory shows a way to deal with it. In his last book *Incomplete Nature* he has introduced a new view on genetic information (and information in general) which is based on dynamics and therefore essentially defers from the Neo-Darwinistic understanding of information. Deacon describes how a lineage of teleodynamically organized entities i.e. autogens could undergo variations which in evolutionary terms would be adaptations: If the surface of the autogen has molecular features to which environmental substrate molecules supportive to the autogen's autocatalytic process tend to bind, and in so doing weaken its structural stability, then the probability that the autogen breaks up in a supportive environment will be increased. Natural selection would progressively endow autogens with the ability to break up in environments that contain substances supportive to their autocatalysis so that the probability of autogenic replication will significantly rise (442). It is possible that during this evolutionary process in environments with high concentrations of high-energy phosphate molecules some autogens produce free nucleotides as byproducts. This could lead to polymerization of nucleotides inside the autogens. Polynucleotides would form and be passed to the next generation (by the replication of the whole autogen of which they are a part). The sequence of the nucleotides of these macromolecules is of special importance because it will influence the tempo of autocatalysis when the autogen breaks up again:

“Although the order of nucleotide binding will be unbiased, the resulting sequence of nucleotides can serve as a substrate onto which various free molecules within the autogen (e.g. catalysts) will differentially bind due to sequence-specific stereochemical affinities. In this way, catalysts and other free molecules can become linearly ordered along a polynucleotide template, such that relative proximity determines reaction probability. Thus, for example, if this template molecule releases catalysts according to linear position (e.g. by depolymerization) they will become available to react in a fixed order.” (445)

The breaking up of the autogen will expose the polynucleotide to external factors that will cause its progressive dissolution. Since the dissolution proceeds from the one end to the other the different nucleotides which occupy different positions on the macromolecule will be released at different times. This will cause a non-random order of different chemical reactions between the released catalysts and other molecules (bound on the released nucleotides) of the autogen and the substrates of the environment.

“To the extent that this order correlates with the order of reactions that is most efficient at reconstituting the autogenic structure there will be favored template sequences.” (445)

In other words: The time-asymmetry of chemical reactions matters since every reaction will change the conditions under which the subsequent reactions will take place. The result will be

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that those autogens the polynucleotides of which give rise to the most efficient order of reactions will replicate faster than others. In turn this will lead to the replacement of some species of autogens by some others in the long run of evolution. Obviously the polynucleotide sequences of the faster replicating autogens happen to fit better to their environment – one could say that they *represent* better the chemical constitution of the autogen's surroundings and also that those autogens *interpret* better their environments for the purpose of self-replication.

It is noteworthy that this speculative model does not assume that autogenic adaptation and natural selection require the ability of processing information. On the contrary Deacon's hypothesis shows how internal representation of the relationship between autogen dynamics and environmental conditions can evolve out of teleodynamically organized physicochemical processes, demonstrating thus that reference and semiotic abilities could emerge from this specific form of dynamics. Instead of putting information in the very beginning of evolution he shows how it could evolve out of physicochemical interactions of teleodynamically organized entities with their environments.

So, Deacon suggests how genetic information which appropriately represents external i.e. environmental factors could emerge. Thus he shows a way how evolution could enable autogens to control to a progressively increasing degree external quantities, e.g. the influx of energy and substances, which in terms of the dynamic systems theory would be parameters since those systems are not able to control this kind of quantities by themselves. There is no reason, however, to *restrict* Deacon's intuition about the emergence of genetic information *only to the conversion of those parameters which represent environmental quantities to variables*. It is conceivable that his model could also show how evolution endows genetic information with the ability to represent with a progressively increasing degree the *internal* constitution of teleodynamically organized entities. Those entities would be able to significantly vary quantities representing the degree of activity of specific molecules inside the cell and relations between variables of the cell such as volume, pressure, free energy etc. In other words, *they would be able to vary most internal quantities which in dynamic systems theory are also described by parameters*. The emergence of such an autonomous teleodynamics would clearly mark the transition from non-living autogen to living archaic cell.

5. Conclusion: Towards a biological neo-naturalism

Deacon's theory is usually assigned to naturalism. I think, however, that this generic term is not appropriate since it suggests that the autogen model operates within the same frame of basic assumptions as neo-teleological theories. If "naturalism" means "non-supernaturalism", "non-mentalism" or "non-intentionalism", as it was initially introduced by Bacon, then the

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autogen model may indeed be subsumed into this category. But the contemporary biological naturalism cannot be captured by these very general ideas. It expresses rather the belief that all aspects of life are in principle explainable by the natural sciences as they are designed today so that they will not need to revisit their metaphysical commitment to modern materialism. This is a much more specific and rigorous conviction than Bacon's ideas, since it presupposes a concrete ontology and methodology, which Deacon doesn't follow unconditionally. He questions, for example, explanatory attempts to reduce mental activity to localized patterns of material processes in the brain. Deacon criticizes the typical figures of materialistic thought in today's neurobiological naturalism *without, however, introducing any immaterial factors*. Starting out from the assumption of the teleodynamic organization of the brain he emphasizes the importance of the *absence* of certain material configurations and patterns in the brain for consciousness (*Incomplete* 485-538) – whereas “absence” does not mean “immateriality.” Since the subject of this essay is not the nature of mind but the logic of organismic causality these insights cannot be further expounded here. Nevertheless, many of these same issues concerning consciousness have their analogues in explanations of the nature of life. In both computational and dynamical models of the brain consciousness is an epiphenomenon. Representation, anticipation, and intentionality are considered to be naïve metaphorical descriptions of neuronal computation or patterns of neuronal activity. This necessarily leads to the rejection of teleology in animal and human behavior. In perfect analogy to their psychological epiphenomenalism cybernetic or information-theoretical, Neo-Darwinistic, and dynamic systems approaches also introduced a biological epiphenomenalism: They consider any conception of biological *self* to be a vitalistic or substantialistic remnant, since they reduce organismic autonomy to DNA or complex patterns of molecular processes. In sharp contrast to those naturalistic theories of life for the teleodynamic approach the fundamental feature which discriminates life from non-life are never macromolecules or localized patterns of molecular processes but constraints. In full analogy to his rejection of epiphenomenalism Deacon criticizes the typical figures of both gene-centric and dynamic systems thought in today's biological naturalism without introducing any immaterial vital factors. These fundamental differences should have made clear that it would be disadvantageous to a better understanding of the innovation capacity of teleodynamics if it were classified as belonging to naturalism. For this reason I suggest that Deacon's ideas as well as some other congenial ideas that are introduced by this volume be considered as heralds of an arising *biological neo-naturalism*. In the following some important differences between these new approaches to organismic causality and the above presented kinds of neo-teleologism will be highlighted.

One of the most important innovations of the autogen model is that it introduces a new kind of teleological organization which *merges the logic of organismic causality with its physics*. This clearly goes beyond cybernetics and informatics. Their concepts of information (Wiener- and Shannon-information) are based in the main on the implicit assumption that the

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logic of organization is independent of its physics since it can be realized in many different physical ways. Because of their multiple realizability, cybernetic and information processing automata do not display a necessary connection between their functionality (logic) and the maintenance of their material form (physics): They can be deactivated without becoming disintegrated since their material constitution follows a static physics. The sharp distinction between hardware and software which is the most essential characteristic of all information processing machines until today necessarily includes a sharp distinction between physics and logic. Therefore information processing (logic) never serves the maintenance of the material constitution (physics) of an operating machine but serves the individuals who built or own this machine – i.e. the operations have always meaning and value for somebody outside the operating entity. For these reasons there is only syntax but no semantics in the traditional concepts of information introduced by Norbert Wiener and Claude Shannon.

Autogenic teleology also transcends one of the most important implicit assumptions of the second kind of neo-teleological theories since Neo-Darwinism presupposes a distinction between logics and physics as well. Although this distinction which was implicitly introduced by Darwin himself is a methodological one it is as sharp as in cybernetics and informatics. The idea of natural selection is the logic of Darwinian evolution. Since “natural selection is a process defined by multiple realizability” (*Incomplete* 423) it also does not presuppose a certain physical organization. One of the strengths of Darwin’s theory of natural selection is its compatibility with significantly different physical mechanisms of organismic causality, which results in being agnostic about physics. But the fact that natural selection “leaves out nearly all of the mechanistic detail of the processes involved in generating organisms, their parts, and their offspring” is also a serious shortcoming, since “it is precisely the process of generating *physical* bodies and maintaining metabolism that constitutes the coin of the natural selection economy. Variations do not exist in the abstract; they are always variations of some organism structure or process or their outcome.” (422, italics by S.K.) Organisms must maintain their far-from-equilibrium dynamics which is a physical process. But Neo-Darwinists have not been able to propose a physical model of organismic causality up to now, since they have not gone substantially beyond the scope of Darwin. Therefore Neo-Darwinists did not challenge the strict separation between hardware and software typical to informatics; on the contrary, they have rendered it a main principle of their thinking: They consider genetic information to be independent of material processes of the cell in which it would be “saved” which requires that the logic of genetic information be agnostic to physics. Thus the separation of logic and physics, essential to informatics (Shannon-information), underlies the Neo-Darwinistic concept of “genetic program.”

The third kind of neo-teleological thinking which is grounded on dynamic systems theory is certainly the most sophisticated naturalistic approach of all three. The logic of the causal relations within a dynamic system as well as between the system and its environment is dictated by pure physics. This might be the reason why this physicalistic approach does not

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pay the appropriate attention to the essential differences between biology and physics. Its deep rootedness in metaphysics and methodology of physics does not allow it to question whether both the principle of maximum entropy production and the strict distinction between dynamic state variables and externally set parameters are appropriate for accounting for organismic causality. Failing to see the limits of physics explains why most exponents of this approach do not take offense at the lack of a concept of information in their theory. Biological naturalism which is grounded on dynamical systems theory operates with a causality defined in terms of cause and effect, like all theories of physics. What clearly discriminates the theory of teleodynamics, along with other new biological ideas presented in this volume, from physicalistic approaches to organism, like self-organization and systems-biology, is that they include semiotic concepts in biological explanation. Instead of introducing ad hoc semiotic terms Deacon's thought experiment about the evolution of autogens provides a way to bridge the gap between the conceptions of causality in physics and biosemiotics. It shows how a specific physical organization (teleodynamics) gives rise to the emergence of phenomena like representation, sentience, interpretation, anticipation etc. which Deacon summarizes under the term "ententional phenomena" (*Incomplete* 549).

With this in mind "biological neo-naturalism" could be defined as the generic term referring to all kinds of biological thinking emphasizing the explanatory power of ententional phenomena in the understanding of organismic causality. It would be the attempt to re-invent semiotic biology a hundred years after its first introduction by Jacob von Uexküll. Biological neo-naturalism, as proposed here, is a scientific biophilosophy. Its metaphysical preassumptions do not leave the territory of what can be considered as a possible scientific metaphysics today, as mentalistic teleology, for example, does. But, as stated at the beginning of this essay, the borders between philosophy of biology and biophilosophy are fluid. It is much to be hoped that biological neo-naturalism will be an essential part of philosophy of biology in the near future.

Literature:

Aristotle. *Physics*. The Internet Classics Archive

<http://classics.mit.edu/Aristotle/physics.2.ii.html>

Arew, André. "Teleology." *The Cambridge Companion to the Philosophy of Biology*. Eds. David L. Hull and Michael Ruse. Cambridge, New York: Cambridge University Press, 2007: (160-181).

Bedau, Mark. "Where is the Good in Teleology?" *Nature's Purposes. Analysis of Function and Design in Biology*. Eds. Colin Allen, Marc Bekoff, George Lauder. Cambridge (MA), London: MIT-Press, 1998: (261-291).

Brandon, Robert. *Adaptation and Environment*. Princeton (NJ): Princeton Univ. Press, 1990.

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- Christensen, Wayne. "A Complex Systems Theory of Teleology." *Biology and Philosophy* 11 (1996): 301-320.
- Collier, Joanne; Monk, Nicholas; Maini, Philip; Lewis, Julian. "Pattern Formation by Lateral Inhibition with Feedback: a Mathematical Model of Delta-Notch Intercellular Signaling." *Journal of theoretical Biology* 183 (4) (1996): 429-446.
- Costa, Paolo. "Beyond Teleology?" *Purposiveness. Teleology Between Nature and Mind*. Eds. Luca Illetterati, Francesca Michellini. Frankfurt/M.: Ontos Verlag, 2008: (183-199).
- Deacon, Terrence. "Reciprocal Linkage between Self-organizing Processes is Sufficient for Self-reproduction and Evolvability." *Biological Theory* 1(2) (2006): 136-149.
- "Emergence: The Hole at the Wheel's Hub." *The Re-Emergence of Emergence*. Eds. Philip Clayton, Paul Davies. Oxford, New York: Oxford University Press, 2006: (111-150).
- *Incomplete Nature*. New York, London: W.W. Norton & Co. 2012
- Ebeling, Werner. *Strukturbildung bei irreversiblen Prozessen*. Leipzig: Teubner, 1976 (in German).
- Ebeling, Werner and Sokolov, Igor. *Statistical Thermodynamics and Stochastic Theory of Nonequilibrium Systems*. New Jersey, London, Singapore etc.: World Scientific Publishing, 2005.
- Elowitz, Michael and Leibler, Stanislas. "A synthetic oscillatory network of transcriptional regulators." *Nature* 403 (6767) (2000): 335-338.
- Falkner, Gernot and Falkner, Renate (this book)
- Ferrel, James and Xiong, Wen. "Bistability in Cell Signaling: How to Make Continuous Processes Discontinuous, and Reversible Processes Irreversible." *Chaos* 11 (1) (2001): 227-236.
- Gardner, Timothy; Cantor, Charles; Collins, James. "Construction of a genetic toggle switch in *Escherichia coli*." *Nature* 403 (6767) (2000): 339-342.
- Gibbs, Wayt. "Simulierte Zellen." *Spektrum der Wissenschaft* 11 (2001): 54-57 (in German).
- Goldbeter, Albert. *Biochemical Oscillations and Cellular Rhythms*. Cambridge: Cambridge University Press, 1997.
- Goodwin, Brian. "A Structuralist Programme in Developmental Biology." *Dynamic Structures in Biology*. Eds. Brian Goodwin, Atuhiro Sibatani, Gerry Webster. Edinburgh: Edinburgh University Press, 1989.
- Jonas, Hans. *Das Prinzip Leben*. Frankfurt/M.: Suhrkamp, 1997 (in German).
- Kant, Immanuel. *Critique of Judgment*,
<http://ebooks.adelaide.edu.au/k/kant/immanuel/k16ju/>
- Mahner, Martin and Bunge, Mario. *Philosophische Grundlagen der Biologie*. Berlin, Heidelberg, New York et al.: Springer, 2000 (in German).

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- Martyushev, L. and Seleznev, V. "Maximum entropy production principle in physics, chemistry and biology". *Physics Reports* 426 (2006): 1-45.
- Mayr, Ernst. *Eine neue Philosophie der Biologie*. Munich, Zurich: Piper 1991 (in German).
- Murray, James. *Mathematical Biology*. New York, Berlin, Heidelberg: Springer, 1993.
- Normile, Dennis. "Building Working Cells 'in Silico'." *Science* 284 (5411) (1999): 80-81.
- Panning, Thomas; Watson, Layne; Shaffer, Clifford; Tyson, John. "A Mathematical Programming Formulation for the Budding Yeast Cell Cycle." *SIMULATION* 83 (2007): 497-514.
- Plaetzer, Kristjan; Thomas, Randall; Falkner, Renate; Falkner, Gernot. "The microbial experience of environmental phosphate fluctuations. An essay on the possibility of putting intentions into cell biochemistry." *Journal of Theoretical Biology* 235 (2005): 540-554.
- Rosen, Robert. "Organisms as Causal Systems Which Are Not Mechanisms: An Essay into the Nature of Complexity." *Theoretical Biology and Complexity: Three Essays on the Natural Philosophy of Complex Systems*. Ed. R. Rosen. New York: Academic Press, Inc., 1985: (165-203).
- Rosenblueth, Arturo; Wiener, Norbert; Bigelow, Julian. "Behavior, Purpose and Teleology." *Philosophy of Science* 10 (1) (1943): 18-24.
- Schneider, Eric and Kay, James. "Order from Disorder: The Thermodynamics of Complexity in Biology." *What is Life? The Next Fifty Years*. Eds. Michael Murphy, Luke O'Neill. Cambridge, New York: Cambridge Univ. Press, 1997: (161-173).
- Töpfer, Georg. "Teleologie." *Philosophie der Biologie*. Eds. Ulrich Krohs, Georg Toepfer. Frankfurt/M.: Suhrkamp, 2005: (36-52) (in German).
- Tomita, Masaru. "Whole cell simulation." *Trends in Biotechnology* 19 (6) (2001): 205-210.
- Turing, Alan. "The Chemical Basis of Morphogenesis." *Philosophical Transactions of the Royal Society of London* (Series B, No.641, Vol. 237) (1952): 37-72.
- Tyson, John; Chen, Katherine; Novak, Bela. "Sniffer, Buzzers, Toogles and Blinkers: Dynamics of Regulatory and Signaling Pathways in the Cell." *Current Opinion in Cell Biology* 15 (2003): 221-231.
- Wiener, Norbert. *Cybernetics*. New York, London: The M.I.T. Press and John Wiley & sons, 1961.
- Wolpert, Lewis. "Development: Is the Egg Computable or Could We Generate an Angel or a Dinosaur?" *What is Life? The Next Fifty Years*. Eds. Michael Murphy, Luke O'Neill. Cambridge, New York: Cambridge Univ. Press, 1997: (57-66).