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Definitions of Life and the Resulting Draft of the Deductive Theory of Life

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Dear listeners, please forgive me, but due to my age, I will read.

#2 I recently published an article in BioSystem: "*Two coherent definitions of the life process derived from the half-chaos theory and the (unintentional) purposeful information theory.*" I'm going to talk about it today. Both definitions are "theoretical", as postulated by, for example, El-Hani. Not only are the terms used to define them derived deductively from terms understood outside of biology, but also the basic properties of the life process are derived from the proposed definitions. This forms a *Draft of the deductive theory of life*, which I summarized in a book of such title, currently in Polish, but the English version is already under review. The book's content is much broader than the scope of the article discussed today. Preprints covering the entire scope of the book are available on my website.

#3 Three competing definitions of life are currently in contention: the oldest, forgotten one, by Bauer from a hundred years ago, remarkably similar to the dissipative structures proposed by Ilya Prigogine in 1978, postulates that life is a state deviating from maximum thermodynamic entropy. This deviance from statistical entropy is called negentropy, or information, which is also the basis of my second definition. Next, we should mention the concept of "autopoiesis" by Varela et al. in 1974 and Joyce's definition in 1994, adopted by NASA. There are many newer attempts, but they contribute little new and rely mainly on collecting various aspects present in discussions. This multiplies the number of assumptions, thus destroying the purity of the concept. One of the most recent is the proposal by Vitas and Dobovišek in 2019.

#4 My definitions are Darwinian in nature, but natural selection is based on elimination, and this is understood as "ceasing to be alive." While this is 'understandable,' it nevertheless contains a tautological error. This error is corrected by my definition based on half-chaos, which is related to Kauffman's famous hypothesis, 'life on the edge of chaos and order.' The half-chaos I discovered significantly corrects this hypothesis to: 'life evolves in the half-chaos of not-fully-random systems,' but above all, it clarifies the problem of the identity of an evolving object.

The concept of evolution of anything contains the variability of some object. **On what basis do we believe that an evolving object remains the same throughout this variability, since by definition it is different?** Intuition tells us that these were small changes, but **what is the criterion for a small change?** This question has not yet been satisfactorily answered.

#5,6 So what is this half-chaos? Kauffman studied the statistical properties of a set of any deterministic, functioning, Boolean complex networks with specific parameters. Such a set contains all possible systems with such parameters. A living organism is well described by such a network. Kauffman demonstrated through simulations that a small permanent disturbance leads, depending on the network parameters, to a large or small change in functioning, called **damage**. Within these parameters, there is a narrow transition between these states, which he called the phase transition between order (small damage) and chaos

(large damage). **This means that the system could be either ordered or chaotic, but not simultaneously**. Practically, small damage—small changes in the system's functioning necessary for evolution—occurred only in systems near this phase transition. This is a statistically correct conclusion, but only for a fully random set of systems. From this he developed his hypothesis: "life on the edge of chaos and order," but living objects are the result of natural selection, and therefore they are not fully random because they are selected. Therefore, this hypothesis is too crude an approximation.

An "attractor" is a cyclic trajectory of states in a deterministic network. The length is measured by the number of steps taken to calculate successive network states. Complex networks, with hundreds of nodes, almost always have very long attractors. A short attractor is an exception. A finite network always reaches one of many possible attractors. The mathematical theory of deterministic chaos operates on continuum-type arguments, and their trajectories do not reach the attractor but approach it asymptotically.

#7 **A short attractor in a complex network defines half-chaos**. It turns out that half-chaotic networks have a similar proportion of negligible and large damage after a small disturbance, despite parameters that, in the case of a random network, practically always result in chaos (only large damage). The damage distribution for a specific such network contains two peaks simultaneously – the left peak of small damage ("ordered") and the right peak of large damage ("chaotic"), separated by a large gap. Therefore, it is neither chaos (which has only the right peak) nor order (only the left peak). The gap between the peaks provides a natural demarcation between small and large changes in functioning, defining the scope of the small change in a natural, objective, and not arbitrary way. This allows for a **natural criterion for the identity** of an evolving object, something we haven't had before. A system, functioning similarly after small damage, remains the same. Important: leaving disturbances (evolutionary changes) that produce small damage does not go out of half-chaos. But, large damage, that is a completely different functioning of the system, causes it to cease to be the same system and practically irreversibly falls into normal chaos with a long attractor. This is a good **model for the death** and **elimination**, freeing the Darwinian definition from tautology.

Because in half-chaos, after a small disturbance not only small damage occurs, such variability often goes out of half-chaos. The demand to retain only perturbations that cause little damage (and leave half-chaos) as evolutionary changes requires the rejection (elimination) of these perturbations that caused great damage. To maintain half-chaos in such an evolutionary process for a long time, sufficient reproduction rate is necessary. And so we obtain the Darwinian mechanism and the definition—**the essence of the life process—maintaining a system in a state of half-chaos under circumstances of random variability**.

#8 My second definition of the life process is more intuitive, making it easier to derive the basic features of this process. To build a definition and a theory based on it, one must identify as few common features of the phenomenon as possible, preferably one. I pointed to **purposefulness**, which has been observed "always" and is only in the life process (humans, the creator of civilization, are alive). However, this feature is extremely controversial, avoided in science with an almost panicky approach. To eliminate this phobia, Colin Pittendright introduced the substitute term "**teleonomy**", which referred to purposefulness

achieved through Darwinian mechanisms. To use the terms "purpose" and "purposefulness" explicitly in descriptions of nature, they must be properly defined within the framework of the theory being developed, but without invoking Darwin to avoid falling into tautology.

To define the concept of "purpose" without intentional being, the concepts of information and its coding, describing physical objects and their determinism in functioning, is useful.

The concept of "information" is also defined differently in different fields and for different purposes. Hartley-Shannon's "information theory" describes the quantitative aspect of information. It concerns the transfer of information, so it is commonly believed that information exists only when it is transmitted. In my opinion, this is a serious mistake. Shannon defines what is then transmitted, and I take this to be information. **Information is a choice from a set of possible choices**, and the probability p of this choice is the basis for the amount of information I in the famous formula I = -log p.

Eigen pointed out the significant lack of a teleological aspect in Shannon's approach—the value of the information for the recipient. Millikan then raised the semantic aspect, calling the area requiring supplementation "teleosemantic," while Küppers appreciating the concept of "biological information," separated the two aspects, obtaining three "dimensions": Shannonian, semantic, and teleological. Only Shannon's aspect is described exactly.

Not all information has a purposeful aspect. Where does the information about whether a given object is a conductor or an insulator lie before we examine it? We must ask the object itself, connecting it to a circuit with a battery and a light bulb. This choice already exists before we ask about it in our experiment. Of course, it is contained within the object. This information has no teleological aspect; I call it **simple information**.

Shannon rightly stated that the semantic aspect is irrelevant for the purposes of his theory. It is now widely believed that the meaning of transmitted information is the result of an agreement between the sender and the receiver. I do not share this view. For me, the feature "insulator" is **primary information**, not yet encoded into any symbol, and the lack of light in the bulb is its symbol, encoded in a different set of possibilities by a "natural encoder," i.e., the circuit with the light bulb and the battery. Returning to the meaning of a symbol in the general case is the reverse operation of coding. Typically, there is no natural decoder for a given natural coder.

#9 In the general case, we have an isolated physical system whose current state, called situation1, is encoded by physical laws into its effect—situation2—at the next instant. Therefore, situation1 is the cause of situation2. We have such a simple description of determinism. Physical laws, as code—or rather, a natural coder, operate according to time. **Do natural decoders exist?** Such a decoder seeks the cause of a given effect. What do we colloquially call an effect for which a cause is sought? Of course, it is a "goal." Identifying such a cause constitutes **purposeful information**. These definitions are nothing new. The problem remains of the natural mechanism implementing such an assignment, the natural decoder. Such natural decoders exist, for example, in vibrations; there is also an universal decoder—referred to as the **U-decoder**—but this usually requires a human. It involves testing hypotheses experimentally using a natural coder. Assuming the smoothness of the code, a good approximation of the sought purposeful information can be found relatively quickly. Does such a natural mechanism exist, and under what conditions, without human

participation? It turns out that it does exist, but for a unique purpose, which I will discuss a bit later.

To model an evolving object, we need to divide the situation in an isolated system into two parts according to some criterion. Let's call the larger part the **environment**; we assume it is statistically described, and in subsequent situations it is present and practically unchanged. The remaining part is small, precisely described, and undergoes change; let's call it the **object**. Physical laws are one and do not require specification. The environment, as a constant part, can also be neglected in the situation2. In this case, the environment takes on the role of natural code, and we examine the object's variability.

#10 [U-dec] I indicated the presence of purposefulness in living objects as the base of my second definition of life. This can now be expressed more precisely – the presence of purposeful information. If living objects arose from inanimate matter, where there is no purposeful information, we should expect that it is collected during evolution. Before attempting to investigate the mechanism of such collection, we should take a closer look at the purposeful information itself and its quantity. Together with its definition, it is a **theory of purposeful**, but not intentional, **information** that can be used to describe the process of evolution before humans arose.

#11 [3 dim] The **amount of purposeful information** is the logarithm of the probability of randomly selecting a given cause for a given purpose, means, the uniqueness of that cause. Is this the quantity we observe when assessing the accumulation of purposeful information in living objects? Due to lack of time, I will immediately point out other quantities that should be considered. The second is the **effectiveness** of purposeful information - the probability that the indicated cause will produce a purpose. But this also requires longer observation; at first glance, we see the particular **complexity** of living objects as **length of purpose information record**. **These are three dimensions of the purposeful information vector size**; these quantities do not have to increase simultaneously.

Of these dimensions, for further in-depth analysis, we will mainly examine effectiveness, the interpretation of which is fitness, as we know, particularly important in the mechanisms of evolution. In the simplest case, effectiveness is supposed to be non-decreasing – let's call it an **improvement process**. It assumes **evolutionary progress**, the variants and possibilities of which we will discuss further.

As can be seen, the dimensions of purposeful information indicated here do not overlap with those identified by Küppers. Purposeful information is similar to biological information, but is defined from a 'different end.' Biological information does not have a single, recognized definition—it depends strongly on the phenomenon under consideration.

The **preciousness** for the recipient, as noted by Eigen, clearly depends on the recipient, and is therefore not an attribute of a given purposeful information. The effectiveness of purposeful information depends on the stability of the environment. If it changes slightly since the acquisition of a given purposeful information, it will affect the indicated cause differently, and the goal will likely be less achieved. This **adequacy** of the current coder is also not an attribute of the indicated cause itself. There are many other similar factors, including the '**dead record of purposeful information**,' which has a length that influences the observed complexity, but due to a 'failure,' is no longer effective.

#12 I have already discussed the theory of purposeful information in general, and it is time to ask the question: **Can the collection of purposeful information be independent?** (i.e., without a human, etc.) That is: Can the U-decoder fit into the System? (Here we assume we are not inside it yet.) A clue to intuition might be an image based on an unambiguous code, but this unambiguity holds a trap. The code must be ambiguous, for example, conditional probability, for purposeful information to arise. Let's imagine a recursive sequence: coding generates successive hypotheses, because the next effect will be treated in the next move as the next hypothetical cause of the goal. After the natural coder transforms the cause into the designated goal, apart from the coder, which we assumed to be fixed (the environment), only the effect remains in the System – the goal (the object). Its sought cause should be present in the System to be recorded as purposeful information. This only occurs when the cause and its effect are identical. This is a fixed point in the code – from the moment this state occurs, nothing changes. This can be translated into the goal of 'continuing to exist.' **Remaining in existence is a specific form of recording/distinguishing, and at the same time, a form of positive test response**. This reasoning assumes an unambiguous code, allowing us to notice this **unique coincidence**, but we are not interested in a fixed point for now. We will deal with the record in the form of continued existence, because such objects can accumulate purposeful information for such a specific purpose. Thus, **we have the answer to the question posed – it is possible to fit a U-decoder into the System, but for now, it is a single act of finding a cause for a unique purpose. We do not yet have multi-stage collection of purposeful information**.

Acquisition is a change of the object, yet it must remain the same, so an appropriate natural criterion of identity is needed. Half-chaos has already provided this. This collecting, however, precludes the use of an unambiguous code, which allows for a single act of finding, but it allows the use of an ambiguous code. This is not easy for intuition. There are many different aspects and parameters of description. The process of single finding the cause of the goal of 'continuing to exist' well describes a finding sufficient reproduction rate. The book explores many problems and paradoxes related to this reasoning, but the suggested, albeit murky, picture correctly identifies the **specific coincidence that creates a natural U-decoder**.

#13 Life is therefore an independent process of accumulating purposeful information. From this independence, we already know that the purpose of this purposeful information is to "continue to exist." This is supposed to be a process of gradual accumulation, possibly unlimited, allowing for the accumulation of significant size of purposeful information. Therefore, we should add "long and effective" to the above conclusion. We thus obtain a hypothetical definition of life in the form: **an independent, long, and effective process of accumulating purposeful information**. To recognize this as a definition of life, we must identify the mechanisms of such accumulation and derive from this definition the properties of the process and object that prove consistent with observation.

The need to reproduce sufficiently rapidly, is the first feature and purposeful information resulting from this definition. We have thus **obtained the complete basic mechanism of Darwinian natural selection**. Changes that reduce the amount of purposeful information, rejected by elimination, constitute **degeneration leading to maximum entropy**. Note: Reproduction is a multiplication. It does not necessarily contain hypothesis-generating

variation. We do not specify the mechanism of random variation for hypothesis-generating. It may vary, but the changes in the object must be preserved.

#14 [Mech 1] A sufficiently rapid multiplication with elimination allows the objects left in the process to resist the increase in entropy. This creates a "**biotic level**" of sufficient effectiveness of the purposeful information the object possesses. The random variability of an object at this level allows it to diffuse in every possible direction within the dimensions of the quantity and length of record of purposeful information, also increasing its effectiveness, but not reducing it below the biotic level. For now, let's consider **horizontal diffusion** in effectiveness without changing this effectiveness.

Because such an object initially has a low length of record and amount of purposeful information, this space is asymmetric – the object can increase it but cannot lose more than it already has. After a time, objects of great quantity and record length of purposeful information become encountered, and such objects astonish us, **but we have drawn attention to these particular objects**. It should be emphasized that **there is no mechanism here forcing such an increase for the indicated object, but the average and**, above all, **the maximum amount and length of record of purposeful information that can be observed in a single object increases.** We don't observe a forced evolutionary progress in a given 'evolutionary strand,' but on average, we statistically expect it, and moreover, we expect it in objects that have undergone it particularly clearly and are conspicuous.

#15 [Mech 2] When we consider the omitted effectiveness increasing, we notice that the elimination rejecting inappropriate changes proves statistically insignificant—it does not affect the size of purposeful information. "**Sorting from above**" becomes important, it is an increasing share of objects that reproduce the fastest, thus **effectiveness increases** with positive feedback, leading to a **quantitative explosion**. During it, the requirements for acceptable variability clearly change, which has significant evolutionary significance. An object may significantly 'go wrong', but its reproduction rate may remain above the biotic level, then it will not be eliminated. A decrease in effectiveness also is a degeneration. Under 'normal' conditions near the biotic level, degeneracy leads to elimination, but during a quantitative explosion, it is 'permitted'—not eliminated—to a significant extent. I call this phenomenon '**permitted degeneracy**.' Within this framework, significantly larger changes are permitted, but the accumulation of such variation, called the '**reserve of permitted degeneracy**,' can be a lifesaver when bypassing the environmental capacity barrier or when emerging from a 'dead end of specialization.'

#16 [Mech 3] The quantitative explosion is stopped by the **additional assumption - limit of the environmental capacity** in many independent substrates, which creates **competition** for resources. Only here do we find the normal mechanism of natural selection by elimination. Bypassing the environmental capacity barrier for a single substrate increases the effectiveness and usually the length of the purposeful information record. However, the object encounters another barrier, and its effectiveness drops to the biotic level, which is not due to a change in the object itself, but to a change in the environment by an inadequacy of the coder. Here, the object's complexity and uniqueness of structure typically increase. Actual effectiveness, however, fluctuates around a constant value, but the object possesses an increasing number of properly functioning, purposeful mechanisms. I call this phenomenon "**inadequate increase in effectiveness, ignoring the degeneration of the environment**". In

terms of the object's achievements (relative to the moment before acquiring the given purposeful information), this is visible **progress**. The presence of progress in biological evolution is an extremely controversial issue. This stems from the lack of a broader theoretical framework that allows for a sufficiently precise definition of the various observed forms of progress. The basic understanding of progress is the increase in the size of purposeful information.

There are **accelerators** of the above shown basic mechanisms of growth in the size of purposeful information. In the book, in the chapter about the formation of higher-order integrons, they are derived as expected in the advanced stages of the improvement process. Taking them into account is an additional assumption of achieving such a stage.

The basic accelerator is the **exchange of purposeful information**, which creates a more powerful than vegetative, typical population mechanism, usually involving generative reproduction. This is a radically faster adaptation mechanism, which is important during sudden environmental changes under conditions of competition. Here species evolve.

Elimination is a test that kills when the hypothesis is inaccurate. Brutal. **Can purposeful information arise only at such a cost?** It is a mechanism based on **random changes of structure**. However, if the **change of structure is controlled a memory is created** and a new level of testing emerges, no longer killing. Now a negative test result and its tested hypothesis can be recorded. Such purposeful information, which Dawkins called **memes**, can be exchanged between individuals. This creates a shared store – a culture carried in the population's memory.

These were the most important things I had to say. The book is thick and contains many more heretical derivations. The main heresy is the postulate of allowing the use of deduction in biology.

Thank you for your attention.