Biological function and the genetic code are interdependent

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Abstract

Life never ceases to astonish scientists as its secrets are progressively revealed. In particular the origin of life remains a mystery. One wonders how the scientific community could unravel a unique past event with such low probability. This paper shows that there are logical reasons for this problem. Life expresses both function and sign systems. This parallels the logically necessary symbolic self-referring structure in self-reproducing systems. Due to the abstract character of function and sign systems, life is not a subsystem of natural laws. This suggests that our reason is limited in respect to solving the problem of the origin of life and that we are left accepting life as an axiom.

Key words: Self-reproduction, origin of life, Gödel's incompleteness theorem, emergence, irreducible complexity

1. Gödel formulas are subsystems of the mind

Logic (ancient Greek logice = sense/think) is in ordinary language the reasoning used to reach a conclusion from a set of assumptions. More formally, logic is the study of inference. Inference is the process whereby new assertions are produced from already established ones. Logic is based on assumptions about the real world that seem obvious or unquestionable like "it should not be possible to exist and not exist at the same time". If something turns out to be logically impossible we automatically loose faith in it. In 1933 Kurt Gödel proved that it was logically impossible to prove all mathematics within mathematics [2]. This theorem has been named Gödel's first incompleteness theorem. Somewhat simplified, the theorem states:

In any consistent formalization of mathematics that is sufficiently strong to axiomatize the natural numbers -- that is, sufficiently strong to define the operations that collectively define the natural numbers -- one can construct a true (!) statement that can be neither proved nor disproved within that system itself.

Gödel's statement says: "I am unprovable in this formal system." This turns out to be a difficult statement for a formal system to deal with since whether the statement is true or not the formal system will end up contradicting itself. However, we then know something that the formal system doesn't: that the statement is really true. The trick utilized by Gödel is to make the statement refer to itself (Self-reference). Later it has been developed related theorems such as Turing's "Halting problem" [3] and Chaitin's constant W, which is the halting probability [4]. Turing's halting problem parallels essential incompleteness as formulated by Nagel and Newman [5] "Gödel showed that Principia, or any other system within which arithmetic can be developed, is essentially incomplete. In other words, given any consistent set of arithmetical axioms, there are true mathematical statements that cannot be derived from the set...".

What might confuse the readers are the words "there are true mathematical statements". It sounds like they have some sort of pre-existence in a Platonic realm. A more down to earth formulation is that it is always possible to construct or design such statements. This is why some scientists have called the Gödel formula "artificial" and "synthetic". The mind is always able to construct a Gödel formula, which is unprovable in any system of question [6].

Gödel formulas are products of the human mind. However it should be mentioned that it is an ongoing discussion whether formal systems are human inventions or just a subset of a larger formality. That the rules of inference, like the laws of motion and the rules of mathematics, are larger than Homo sapiens, and we have just progressively discovered them rather than having created them.

Anyway, Gödel formulas are good examples of the fact that given a axiomatic formalized system, the human mind can always construct something that does not follow from the system's initial conditions. The factor of human creativity in mathematical theories seems to have been overlooked in the history of science. Odd and controversial results might seem less odd when this factor is taken into account.

Another interesting example of "stand-alone formulas" is something called "fixed point" (a function that yields itself). This self-reproducing function cannot copy itself directly (because it cannot read itself), but needs to be given a passive copy of itself [7]. Chaitin has demonstrated that Gödel's proof in the computer language LISP is just to use the fixed-point trick in a slightly more complicated manner. Replication systems and Gödel formulas are thus two of the same kind, since they both require internal symbolism [7]. They are both subsystems of the human mind and not subsystems of the formalized system like theorems flowing from THE rules of inference.

The ability to choose with intent and the ability to instantiate those choices into dynamically inert, yet physical configurable switches seems to be the ability that makes humans creative. This freedom makes us able to assign meaning to symbols, create rules of inference and produce formal systems. The human mind can even manipulate a formal system to create true statements that are not formally derivable from the system such as Gödel formulas.

2. Computer programs and machines are subsystems of the mind

It seems that it is generally accepted as emphasized by Hoffmeyer and Emmeche [8], that "No natural law restricts the possibility-space of a written (or spoken) text". Yet, it is under strict control, following abstract rules. Formal systems are indeed abstract, non-physical, and it is really easy to see that they are subsystems of the human mind, and belong to another category of phenomena than subsystems of the laws of nature, such as a rock, or a pond. Another similar set of subsystems is functional objects. From the Wikipedia encyclopedia we have the following definition:

In general (not in the mathematical but in the engineering sense), a function is a goal-oriented property of an entity. Function (according to the TOGA meta-theory, [9]is not a physical property of a system, it depends how this system (a distinguished process) is used. The carrier of a function is a process; therefore, the same function is possible to realise using different physical processes, and one process can be a carrier of different functions. For example, a clocks' main function, i.e. a presentation of time, can be realized by different physical processes, such as, atomic, electronic, mechanical or water movement.

The non-physical part of a machine fits into the same category of phenomena as formal systems. This is also reflected by the fact that an algorithm and an analogue computer share the same function. Polanyi writes:

A machine, for example, cannot be explained in terms of physics and chemistry. Machines can go wrong and break down - something that does not happen to laws of physics and chemistry. In fact, a machine can be smashed and the laws of physics and chemistry will go on operating unfailingly in the parts remaining after the machine ceases to exist. Engineering principles create the structure of the machine which harnesses the laws of physics and chemistry for the purposes the machine is designed to serve. Physics and chemistry cannot reveal the practical principles of design or coordination which are the structure of the machine [10].

As the logician can manipulate a formal system to create true statements that are not formally derivable from the system, the engineer can manipulate inanimate matter to create the structure of the machine, which harnesses the laws of physics and chemistry for the purposes the machine is designed to serve. The cause leading to a machine's functionality is found in the mind of the engineer and nowhere else.

3. The interdependency of biological function and sign systems

In life there is interdependency between biological function and sign systems. To secure the transmission of biological function through time, biological function must be stored in a "time-independent" sign system [11]. Only an abstract sign based language can store the abstract information necessary to build functional biomolecules. In the same manner the very definition of the genetic code depends upon biological function. This is the origin of life problem and it penetrates deeper than just the fact that organisms observed today have such a design.

An important implication of Gödel's incompleteness theorem is that it is not possible to have a finite description with the description itself as the proper part. In other words, it is not possible to read yourself or process yourself as process. We will investigate how this parallels the necessary coexistence of biological function and biological information.

The replication of machines seemed for many years an unsolvable task due to the problem of "self-insight". Von Neumann believed that life was ultimately based on logic, and so there should be a logical construct that should be able to support the reproduction that is observed in life. In order to solve the implication of Gödel's incompleteness theorem, von Neumann had to introduce a blueprint of the machine. The trick is to employ representations or names of objects, a code, which can be smaller than the objects themselves and can indeed be contained within that object. Von Neumann's abstract machine consisted of two central elements: a Universal Computer and a Universal Constructor [12]. The Universal Constructor builds another Universal Constructor based on the directions contained in the Universal Computer. When finished, the Universal Constructor copies the Universal Computer and hands the copy to its descendant. As a model of a self-replicating system it has its counterpart in life where the Universal Computer is represented by the instructions contained in the genes, while the Universal Constructor is represented by the cell and its machinery. In order to replicate, the necessity of a symbolic self-reference is a general premise in logic.

Can we really apply logical terms such as "paradox" and "consistent" to biological systems in the same manner as we do to formal systems? Even though we must admit that biological systems sometimes are more "fuzzy" than the strict world of formal systems, there are constrains on how it is possible to organize them. A hypothetical biological system trying to reproduce without a symbolic self-reference, but by self-inspection, will run into problems related to those within a formal system. Presupposing an unchanged original, problems will occur due to disruptive effects. The function of biological bodies is determined by their three-dimensional structure and how this structure relates to a whole. However, in order to copy them one would require access their internal sequence of amino acids (or nucleic acids if the body is a ribozyme), which would then interfere with their structure and function. For instance, for an enzyme to replicate itself, it would need to have the intrinsic property of self-replication "by default". Otherwise, it would have to be able to assemble itself from a pool of existing parts, but for this, it would have to "unfold" so that its internal parts could be reconstituted for the copy to be produced [13]. Thus, instead of using terms such as "paradox" and "consistent," it is more relevant to speak of what is physically and practically possible when it comes to physical construction. These constraints require the categorical distinction between the machine that reads the instructions and the description of the machine [13].

Von Neumann observes that there is a parallel to this logically necessary distinction between symbol and dynamics in measurement processes in physics. Here the function of measurement is necessarily irreducible to the dynamics of the measuring device. This logic is closely related to the separation of symbols and dynamics for control of self-replication since measurement and control are inverse processes. In other words measurement transforms physical states to symbols in memory, while memory-stored controls transform symbols to physical states [14]. Von Neumann made no suggestion as to how these symbolic and material functions in life could have originated. He felt, "That they should occur in the world at all is a miracle of the first magnitude." [13].

4. Life is not a subsystem of the laws of nature

Life is fundamentally dependent upon symbolic representation in order to realize biological function. A system based on autocatalysis, like the hypothesized RNA-world, can't really express biological function since it is a pure dynamic process. Life is autonomous with something we could call "closure of operations" or a cluster of functional parts relating to a whole (see [15] for a wider discussion of these terms). Functional parts are only meaningful within a whole, in other words it is the whole that gives meaning to its parts. Further, in order to define a sign (which can be a symbol, an index, or an icon) a whole cluster of self-referring concepts seems to be presupposed, that is, the definition cannot be given on a priori grounds, without implicitly referring to this cluster of conceptual agents [16]. This recursive dependency really seals off the system from a deterministic bottom up causation. The top down causation constitutes an irreducible structure.

In algorithmic information theory there is another concept of irreducible structures. If some phenomena X (such as life) follows from laws there should be a compression algorithm H(X) with much less information content in bits than X [17]. Biological function and sign systems, resemble the complexity of computer programs, which implies that H(X) is not less than X in bits (at least not if it is an elegant program). This is not what we normally mean by a law, since a real law should be something with much less information than the data it is intended to predict [18, 17]. This shows that Mechanism cannot explain symbol grounding, but the best it can do is to make representations of representations ad infinitum. However, as Hubert Yockey says "there is nothing in the physico-chemical world that resembles reactions being determined by a sequence of codes between sequences" [19]. Autocatalysis as the hypothesized RNA-autocatalysis is a purely dynamical process and belongs to another category of phenomena than function. Polanyi argued that; "since the structure of life is a set of boundary conditions that harness the laws of physics and chemistry their (the boundary condition's) structure cannot be defined in terms of the laws that they harness. Nor can a vocabulary determine the content of a text (a boundary condition on the vocabulary), and so on" [20]. Since biological function or "boundary conditions" are crucial also in replication, life seems not to have evolved from inanimate matter.

It is interesting to see how widespread the belief in randomness is as a scientific explanation among scientists. When it comes to the origin of life many have settled for a theory that goes something like this: "Isn't a cell just a cluster of molecules organized in a specific way? Given enough time or "trials" it should be possible for a pond of random chemical reactions and polymerizations to end up with something that reproduces." Some scientists have also done some efforts to calculate the probability for the event [21, 19]. The truth is that randomness is used in a manipulative way to a problem where it doesn't even apply. It is important that we do not throw away logic and the laws of physics even though we introduce randomness. Randomness is not equivalent to miracle, but must take place in some organized manner. Consider our model for life consisting of symbols (genes) and the cell machinery (proteins and ribozymes). As mentioned above, there is no information without an interpreter suggesting that there is no message coming from the genes without the cell machinery in place that interprets the genes. On the other hand the cell machinery must be rooted causally in the symbolic codes for at least two reasons. Firstly, the cell machinery consists of different parts that have to be produced in a number of copies depending on a memory. Secondly, functionality of the cell machinery implies a three-dimensional folding, which is determined by the intrinsic properties of the building blocks e.g. amino acids. In addition there are control mechanisms for protein folding. The production of proteins presupposes a control mechanism involving the genes that secures the entire sequence of amino acids before the folding takes place. Random polymerization may at best produce small peptides before the folding would interfere with further elongation. There is really no other alternative than first a transcription from a memory, and then a subsequent folding of the protein or ribozyme [22]. This leaves us with two mutually dependent categories of chemical structures or events (symbols and cell machinery), which does not fit with the axioms of probability that only considers one-way dependency. Thus, the structure of life has a probability of zero.

Some authors have sought the natural explanation for life's self-referring structure in quantum theory [23, 24]. Interestingly enough these theories show how far reasoning is pushed when faced with the mystery of life. Rosen found quantum mechanics too narrow to be fruitful for biology, but did not succeed in finding a better theory. Balazs explains the origin of the interdependency between biological function and sign systems as a result of "time inversion symmetry breaking". While biology is not independent of quantum physics, extrapolating an event in microphysics to an entire organized cell system should be met with some critique. The syntheses of the complex biomolecules that together defines the genetic code are certainly events that would have to be stretched out in time, complicated by the property of folding discussed in the former chapter, and cannot be understood as some sort of quantum entanglement. However, the problem of quantum measurements could indeed be related to the same kind of logic as in the origin of life; the problem of "self measurement" [25].

6. Conclusion

Subsystems of the mind as functional objects or formal systems are unique in respect to other phenomena that follow the laws of nature and are subsystems of the universe. Life express both function and sign systems, which indicates that it is not a subsystem of the universe, since chance and necessity cannot explain sign systems, meaning, purpose, and goals [26]. The human mind also possesses other properties that do not have these limitations, the property of creativity with ability to create through choice with intent. This choice doesn't violate any laws. It merely uses dynamically inert configurable switches to record into physicality the nonphysical choices of mind. It is therefore very natural that many scientists believe that life is a subsystem of some Mind greater than humans or symbolic number cruncher referred to by Svozil [25]. At least as observers we are left taking life as an axiom as Nils Bohr suggested in a lecture published in Nature [27] "life is consistent with, but underivable from physics and chemistry" [19].

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