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Epistemological Approaches on Systemic and Synthetic Biology

Olivia MACOVEI[1]

[1] PhD Student, Doctoral School of Ștefan cel Mare University from Suceava, Romania, oliviamacovei10@gmail.com

Abstract: *The classical literature in the field of biology approaches the field of life from the perspective of the mechanisms by which the interactions between living systems are managed, while the systemic approach to biology emphasizes the interconnected networks of living nodes and the ways of communication of living systems, which is the very foundation of the idea of live as exchange of information on material or energetic support. More concretely, the emphasis on the informational dimension of biological interactions transfers the research object of synthetic biology from questions regarding the functionality of living systems, to those related to the ways of encoding information inside living structures that allow their configuration and reconfiguration in different evolutionary or constructive – in the case of synthetic biology – contexts. The analysis of the living system as a whole, from a structural-constructive perspective, takes from the systems theory a series of models for understanding the whole as something other than a simple aggregation of the component parts, emphasizing the integrity of the living system in a manner close to the systems approach in the science of complexity.*

Keywords: *systemic biology; synthetic biology; epistemology.*

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1. Introduction

Louis Ujéda, in his work *Nanotechnology and Synthetic Biology: The Ambiguity of the Nano-Bio Convergence* (Ujéda, 2019), in which he studies the extent of the convergence between nanotechnology and synthetic biology, comes to the conclusion that "to address the problem of the dichotomy between the level of objects, where we observe a process of pluralization, more than a convergence, and the level of discourses, where the scenario of convergence seems to remain the dominant one", we are obliged to develop an analysis of the disciplines as "devices" - in the sense given by Foucault. Basically, the bios is instrumentalized - which allows a description of living structures in the form of the different layers that make up the biotechnological devices, the convergence of nanotechnology, biotechnology, information technology and cognitive science being achieved in the form of a complex technological context (Ujéda, 2019), in which biological entities are transformed into artifacts.

This convergence presented above represents an epistemological translation of the transhumanist program aimed at manipulating matter from the nanometric scale to the level of biological entities and even human individuals. This will eventually lead to the emergence of a new technoscientific culture, but also a new civilizational paradigm, which will extrapolate the ideals of transhumanist utopianism, which will be distorted into a pure ideology. Thus, the cultural and civilizational paradigm that the ideological mutations generated by the emergence of emerging technologies - including synthetic biology - brings, will be able to impose its own epistemological constructs on the research directions themselves, creating a grid for interpreting augmented reality - not only in a computerized way through VR technology, but also in a biosynthetic way, through syn-biotic organisms.

Just as modernity, as a cultural paradigm, imposed its epistemological visions related to progress, to the valorization of the infinite as absolute potentiality, which led to the emergence of modern science, whose axiom is the absolute convergence between the *ontic* and the *epistemic* - *there is what can be known* –, the new paradigm, which is already building its own axioms, will probably lead to a science whose ontological foundation will be: *there is what can be built/rebuilt*. As a corollary to this ontological axiom we have the epistemological axiom: *we can know what we can build*.

We see the need to investigate the possibility of an epistemological culture, from a philosophical and anthropological point of view, based on a convergence of emerging sciences and technologies regrouped in an ideological reconstruction of a transhumanist type. To answer this challenge, Louis Ujéda focuses on the specific objects and methods of the different disciplines included in this ideology and how these disciplines can generate a convergent epistemic culture (Ujéda, 2019), which would counterbalance the preponderance of the ideological over the scientific. An epistemological analysis of synthetic biology as a technoscience shows that it is rather structured around some objectives - thus responding more to ideological objectives - or some hypotheses or constructive commands, and not some paradigmatic theories or specific research methods. This epistemological diversity is criticized by Bensaude-Vincent, who even considers it an epistemic opportunism or "hard-rock optimism" (Bensaude-Vincent, 2013).

The same critic of synthetic biology from an epistemological perspective shows that, unlike researchers in other fields, those in the field of synthetic biology do not seem to be discouraged by negative results, since they do not invalidate a fundamental theory for the field, but only open new perspectives of constructive research, which will ultimately lead to the creation of artifacts. The lack of fundamental theories of the field makes the aforementioned researcher question the scientific character of the discipline, which, in her view, is rather a technological research that is not a direct derivative of a science, but the result of technological inventiveness, which raises claims of scientificity precisely in fields that belong to metaphysics - such as understanding what life is.

However, remaining in the sphere of pure transhumanist ideology, technological research in the field of synthetic biology adopts theories from molecular biology, informatics, communication sciences, invoking the claim of transdisciplinarity in order to avoid the foundation of its own theoretical apparatus. We cannot entirely agree with these views, although we note the predominantly technological effort that synthetic biology research is making. As such, we agree that this discipline is a technologically constructive one, but we consider that the lack of a theoretical apparatus only discredits it as a science when the ideological dictates over the epistemological. The theoretical system is taken from genetics, from molecular biochemistry and, above all, from systems biology. So we are talking about an epistemic pair composed of systems biology, corroborated with complexity science and, respectively, with synthetic biology, which represents the technological side of this dual discipline. Practically, this digression towards the demands of classical epistemology, which require a science to have its own field, a theoretical corpus and a specific methodology, is typical of postmodern science, which starts from the idea of deconstructing the epistemic at the expense of the pragmatic.

The philosophical literature regarding synthetic biology (Simons, 2021), when speculating on the epistemological particularities of synthetic biology, refers to the idea of postmodern thinking, which redefines epistemology, from a search for absolute and invariant truth, based on the principle of correspondence, to a truth-coherence and especially towards a pragmatic one. In this sense, the work of Jean-Francois Lyotard (1984), *The Postmodern Condition*, is often invoked, whose theses regarding the separation of metanarratives in the construction of the postmodern condition are embedded in the philosophy of technology and relevant to the understanding of current technoscience. On the one hand, we are talking about metanarratives such as the one related to the explanation of life, the demiurgic character of synthetic biology and its claims to create life, and on the other hand, synthetic biology's flight from systematicity that ends up being criticized even for its lack of adherence to the traditional epistemological "canons", which aim at the existence of a theoretical corpus and, respectively, a proper technology.

The previously mentioned metanarratives are, however, deconstructed pragmatically, the demiurgic claim not being left only at the ideological level - a level that exists and which legitimizes substantial investments in synthetic biology -, but being brought into the concrete plane through practices such as genetic editing or messenger RNA technology.

This new science is tributary to the idea of post-truth, since the ideal of the single truth no longer motivates the researcher, who is more interested in the pragmatic value of the resulting technology and its ability to respond to a current need of society. The fact that sometimes there are claims from synthetic biology to answer the question "what is life?", is only an accidental response to a metaphysical migration of this science, since the answer to the question "what is life?", which synthetic biology will be able to produce, is actually an answer to the question "what kind of artifact is life?", and as such, it will only have a phenomenological power to answer about "what life appears to be" and not about what life is in itself, a question that remains metaphysical.

It should be emphasized that most of the criticisms of the epistemic claims of synthetic biology are rather aimed at its transdisciplinary side, when a joint approach is attempted between nanotechnologies and synthetic biology, fields that have in common only the scale of the size of the technological artifacts generated, and less claims of a methodological or theoretical nature. The lack of epistemological coherence between the two sciences does not, however, make them technologically inadequate but, on the contrary, from our point of view, they demand a more careful development of both complexity science and chaos theory.

2. Complexity and chaos theory in the epistemology of synthetic biology

John Sullins places, from an epistemological perspective, synthetic biology research under the sign of complexity science and chaos theory (Sullins, 1998). The science of complexity includes a series of disparate subfields, starting from the sphere of electronic engineering or computers, to medicine (Sîmbotin, 2020). This field, also called complex systems science, aims to create frameworks for understanding complex systems, including a series of complex, efficient and adaptable profiles. This science uses multiscale analyzes of evolutionary processes for physical, biological, but also social systems (Siegenfeld & Bar-Yam, 2020), while the so-called linear sciences privilege a fragmented approach to each component or each aspect of the studied systems, the classical quantitative approach failing in the interpretation of causes and consequences, of large-scale behaviors.

Systems biology also looks at how living systems interact with each other, forming increasingly complex structures, as well as how this complexity becomes characteristic of an organism, making it different from its organic constituents, but also from inorganic ones, as well as the way in which the living system is distinguished from its constituents, integrating a new level of complexity as a constructive dimension. Like living systems, other systems - such as social or informational ones - also present a network structure, making a simple difference in the network structure generate completely different structures and different functions, starting from the way information is transmitted between network nodes. This makes the attempts to build synthetic organisms more related to changes in the architecture of the network, which give rise to a living system, than to the reconstruction of its structural components. From an epistemic perspective, we are talking about a knowledge of some topological frameworks that, by their mere presence, rewrite the way in which the information encoded in a system can be reconstituted - and as such reiterated - in the construction of other systems, biological or not.

The patterns that appear in various living networks, as well as the similarities with those that appear in neural networks, for example, but also social ones, often attract the attention of philosophers of science - as in the case of Uri Alon (2007) and Shen-Orr (Shen-Orr et al., 2002). The mentioned authors introduce the concept of *"motif network"*, in the sense of repetitive functional structural pattern within the network: "network motifs are defined as patterns of interaction that repeat in a network in many contexts" (Alon, 2007). These models, which appear inside the network, make the existence of holographic symmetry structures - types of structures that are highlighted in other networks at a macroscopic level, such as galaxies, but also at a microscopic level, in the form of crystalline molecular structures, etc. -, symmetries operating at the informational level, to question the possibility of a hierarchical structure of reality, of fractal nature (Sandu, 2021).

3. Information versus topology in systems biology

A number of theorists emphasize topological properties of living structures over mechanistic ones, suggesting that, at the cellular and intracellular level, gene activation depends on the topology of the gene in the living structure rather than its biological characteristics. As such, DNA networks (Craver, 2016) can be translated into networks for processing a genetic information, depending on the place and position of the molecule in the genetic structure and not its chemical structure (Barabási, 2002).

There is also the contrary opinion, according to which inferences about the functionality of a biological structure cannot be made based solely on its positioning in a network of information exchange between the living structure and its environment, which would make synthetic living structures (Krohs, 2002) - synthetic organisms - not to have exactly the behaviors that could be foreseen and designed by the construction of information coding systems in the synthetic organism, based on patterns from similar communication networks.

The network analysis model is used in the study of the temporal dynamics of coordinated cellular processes, as well as in the analysis of the evolutionary dynamics of gene stability (Hogeweg, 2012). The coordination of biological processes over time is relevant from an epistemological point of view, as models of the functioning of biological networks can be perceived and how they can be replicated in the form of synthetic biological networks, to build organisms with similar functionalities, from similar or completely different structural components, but aggregated in biological networks with the same genetic information communication patterns.

Huang et al. believe that biological network research should be based on a global approach inspired by Dynamical Systems Theory (Huang, Ernberg, & Kauffman, 2009), thus contradicting the opinion of those who seek to identify functional units or patterns in biological networks in a manner originating from genetic engineering (Jaeger & Crombach, 2012). Huang et al believe that the mathematical properties of the genetic information communication network constitute such a structure, which generates evolutionary properties of living systems, or rather, which limits a chaotic development of these structures, making only certain evolutionary lines possible – which allows for a series of technological developments leading to the creation of viable synthetic biological structures in agreement with viable biological structures, which can lead to a mathematical analysis of the constructed genetic network.

In other words, the construction of biological organisms must start from a mathematics of life, which includes permitted and possible structures - even if they do not currently exist in nature. The construction of synthetic living structures that contradict the mathematics of living networks is considered improbable, since these structures - although they could be chemically and physically synthesized - will not exhibit biological viability. As such, the laws of systemic biology can be operationalized mathematically, in a manner different from the simple orientation of the component molecules – precisely because of the patterns of transmission of genetic information within the respective biological structure.

From an epistemological perspective, O'Malley and colleagues believe that using *big data synthetic biology* as a way to analyze genetic data (O'Malley, 2009) could lead to the construction of "gene regulatory networks" that will allow engineers to approach systematic projects of molecular construction in a manner similar to that used in systems biology. Synthetic biology is, as such, oriented towards the living system as the core of genetic information communication, overcoming the isolationist approaches – based on molecular construction/reconstruction – of classical genetic engineering (O'Malley et al., 2008). From the same perspective, the central objective of research in synthetic biology is "modification of gene regulatory pathways", enabling the control of biochemical reactions within biosynthetic systems, in order to produce "biochemical substances of social value" (Khalil & Collins, 2010). The cited authors give as an example of the use of synthetic biology, the creation of genetically modified organisms that function as biosensors that detect toxic biochemicals or metabolize toxic compounds, thereby helping to clean up soil or wastewater.

4. Epistemological versus technological in systems biology and synthetic biology

The most well-known development of synthetic biology widely used recently is the synthetic mRNA vaccine against Covid-19 (Vickers & Freemont, 2002). The messenger RNA, once penetrated into the cell, generates the synthesis of a protein similar to the viral one, thus stimulating the immune system to recognize the mechanisms of viral protein synthesis, as well as genetic fragments that can be attributed to the viral genome, "training" the immune system to react to the similar genetic patterns, including viral ones.

In addition to the applied side of synthetic biology, which addresses the aforementioned technological concerns, fundamental research in synthetic biology is called upon to provide answers regarding the origin of life, as well as the minimum conditions for the existence of life. Finally, the most speculative, from a philosophical point of view, application of synthetic biology, which I have discussed at length in previous reports, is the creation of synthetic structures that respond to the definition of bios, of life, starting from organic components which are not originally components of a living system (O'Malley et al., 2008).

In addition to the applied side of synthetic biology, which addresses the aforementioned technological concerns, fundamental research in synthetic biology is called upon to provide answers regarding the origin of life, as well as the minimum conditions for the existence of life. Finally, the most speculative, from a philosophical point of view, application of synthetic biology, is the creation of synthetic structures that meet the definition of *bios*, of life, starting from organic components that are not originally components of a living system (O'Malley et al., 2008). It is precisely this application related to the artificial construction of life that is closely related to systemic epistemology in biology, making systemic and synthetic biology two converging articulations from an epistemological perspective, the former constructing the frameworks of possibility for the existence and functioning of a living system, while the second designs living systems and builds them in the laboratory.

Inevitably, discussions about synthetic biology raise the question "what is life itself?", bringing science, but also philosophy, closer and closer to the possibility of an answer to this question that, in one way or another, has preoccupied humanity since the first metaphysical attempts in ancient Greece. The path to understanding the biological meaning of life opened by synthetic biology is precisely the creation of life in the laboratory, making possible the appearance of structures capable of transferring and multiplying genetic information, but also exchanging information and energy with the environment and, respectively, direct multiplication without a secondary intervention to the researchers who created the original laboratory-synthesized organism (Cornish-Bowden, 2006).

With all these philosophical openings, we still do not have a definition of life entirely tributary to synthetic biology, but we do have a wide opening to systems theory and chaos theory - as predictive theoretical models capable of approaching an answer to the question "what is life itself?".

Some practitioners of synthetic biology aim to create the experimental framework for studying conditions "for minimal cells, through chemical models that combine the continuous formation and destruction of the compartment (cell membrane) with the metabolic processes inside the cell" (Zepik, Blöchliger, & Luisi, 2001). More precisely, research in the field aims at the "synthesis of lipid compartments" - in the case of the cited study, vesicles -, in order to generate and be able to study coordinated processes similar to those of self-maintenance in the prebiotic stages of life formation (Luisi, 2006).

5. Classification of technologies in synthetic biology

O'Malley and collaborators propose a classification of technologies used in synthetic biology according to the criterion of genetic implications used in technological design: devices based on modifications at the DNA level, genetic and cellular engineering based on interventions in the genome, as well as the creation of protocells (O'Malley et al., 2008).

5.1. Devices and technologies based on DNA modification

Devices and technologies based on DNA modification are also called the engineering perspective on synthetic biology (Benner & Sismour, 2005) and emphasize the exploration of how functionally distinct and structurally interchangeable components can be designed in a modular manner and implemented in broad technological projects, targeting both biocomponents and integrated non-biological structures. These examples may include products such as fertilizers, biosynthetic drugs, etc. This approach aims to create quasi-biological machines, which do not correspond to independent biological organisms but include biological components or synthetic products created with the help of biological devices.

The metaphor of the organism as a machine is common in synthetic biology, representing an ideological component on the basis of which this science develops. Expressions such as: "genetically modified machine", "genetic circuit" and "platform organism" (Boldt, 2018) have already entered the common language - and not only in the professional jargon - which were taken from the jargon of information technology and electronics being used to explain the workings of the living world. This metaphor of the organism-machine is primarily an anti-metaphysical effort, more precisely an effort to eliminate vitalism from biology because any reference to the idea of vital breath, of life as transcendent makes impossible any claim of synthetic biology to create syn-biotic organisms. Evolutionary biology, although it eliminated the idea of creationism, failed to transform the living world into objects in the pure sense of the term, there being a qualitative difference between the living and the non-living. Synthetic biology's claim to create living surrogates makes the latter bastion of metaphysics in biology, the idea of the living as something different from the non-living, even if seen as simply the result of complex molecular interactions, repudiated as not being other than an informational architecture of instances of coding genetic material. This metaphor propagates, however, becoming an ideology that is based on the rejection of the value of life as a transcendental given and, implicitly, the creation of an ethics of responsibility only for immediate consequences, which affect human beings. Technoethics based on synthetic biology displaces concepts such as duty, responsibility, replacing them with others such as efficiency, functionality, predictability, etc.

Authors such as Boldt believe that it is ethically imperative to abandon the metaphor of machines, because when machine character extends to the human being, it is emptied of its own moral agency, making it difficult to assign moral personhood to a machine (Boldt, 2018). Although we agree with the need to abandon the machine-organism metaphor as the ideological substrate of synthetic biology, we disagree with his view that a machine-organism could not have moral agency, since a singularly superior computational AI-type machine technology (Popoveniuc, 2016) could perceive the moral value of his actions, even if he would not actually understand this meaning.

The quoted author, a critic of the use of the *organism-machine* metaphor, notices a trap that the ideology built around this metaphor can bring, namely the appearance of belief "in the potential of synthetic biology to play a decisive role in solving social problems and minimizes the role of measures technological, social and political alternatives". Starting from what Boldt said, we believe that this trap consists primarily in the fact that the instrumental role of this technology is diminished, transformed into a cultural panacea that can lead to the surrender of humanity in the face of the inevitable emergence of a technological transcendence.

5.2. Genome-based genetic and cellular engineering

This approach to synthetic biology focuses on the functioning of the genome in its entirety and cells as living structures (Green, 2022). Within these types of technologies, genome transplants are carried out, the use of "chassis cells" emptied of their own genome and on which a foreign genome is implemented, possibly edited by CRISPR technology, thus allowing the cell to acquire new functions. The creation of artificial genomes and "minimum genomes" that include only those functional genetic structures for the purposes for which the cell is designed, eliminating the surplus, generally inactive genes present in a normal cell, are also aimed, at and which have functions other than those of cell subsistence and reproduction (Simons, 2022).

A number of theorists believe that the genome itself does not represent a living structure, it being the equivalent of a computer *hard drive* on which the information - genetic in the case of the genome - is stored, but which does not have an independent function and which must be activated by a reading mechanism that has its own cellular structure and memory and that encodes its genomic syntax as well as the rules of DNA replication and the starting points in the translation of the genome, when one protein or another is to be produced. This theory is justified by the fact that a cell whose DNA is excised continues to function for a while, but without carrying out new biochemical processes, and also by the fact that a cell whose genome has been excised can receive a genome transplant from to another functional cell or even a synthetic genome, and the cell subsequently functions according to the codes stored in the new genome. Likewise, the viral genome cannot replicate in the absence of a cell in which to insert its own genetic information, the virus being a structure whose viability is strictly determined by parasitism of a cellular host. According to this theory, the cell uses the genome in a way similar to how a computer uses a hard disk, storing and reading information from it, but the computing core is outside of it. Basically, the cell is treated as a bioinformatics system in which the DNA is the part that contains the software, and the cell as a whole uses the information contained in the genome, which otherwise has no relevance outside the cell. Kull draws our attention to some generally - but disparately - known elements in cell biology and the bringing together of which leads to a better understanding of the cell as an information system and, implicitly, to possible strategies for its programming / reprogramming:

(a) The cell uses a small part of its genome, the other sequences remaining inactive.

(b) In a multicellular organism, the same genome - or genome sequence - can be used by the cell in different ways, depending on specific activators related to the tissue of which the cell is a part. In fact, this mechanism is known to underlie the appearance of tumor cells, when the functioning of the cell and its replication are no longer consistent with its position and place in the structure of the tissue of which it is a part.

(c) Cells can live, including naturally, without a genome, and this does not affect their survival, only replication and protein synthesis.

(d) Not all changes in the genome – as in the case of changing the position of genes or their duplication – lead to a change in the behavior of the cell (Kull, 1999).

The practice of programming new cellular functions through technologies such as CRISPR - DNA sequencing and synthesis - is one of the most important applications of synthetic biology in medicine and is based on understanding the mechanisms of gene function and regulation, enormously expanding the set of genetic components that can be applied in cell biology programming. In order to achieve this, the invention of new research tools was pursued, especially systems of combining DNA - combining nucleotides - which led not only to practical applications, but also to the understanding of the mechanisms of the functioning and natural binding of genes in within the framework of the extended genome, "sensor-actuator devices" (Black, 2017) being created, capable of recognizing various chemical, mechanical and optical inputs, allowing the control of cellular behaviors including in a spatio-temporal context - the spatial ordering of nucleotides and the timing of gene activation and their transcription. This intervention in the genome leads to the emergence of computational synthetic biology, because the transcription of genes can be understood in the sense of computational operations based on a code - the "letters" in the genome, which are equivalent to a machine code. Genetic circuits built to perform precise functions are the replication of natural biological systems, to which changes are made both in the topological dimension of the genetic sequences and in the biochemical complexity of them, to create "oscillating networks of gene expression, switches with multiple states, logical computation, and intercellular signaling networks” (Black, 2017).

This practice of replacing the original genome of a cell was first used by Craig Venter and his collaborators in 2010, in creating the first synthetic genome and transplanting it into a cell belonging to another species of bacteria (*Mycoplasma genitalium*). The transplanted nucleus was modeled on a whole-cell nucleus with a reduced number of genes, which could be artificially replicated before implantation. The transplanted genome was built to function with only 473 genes (Sung et al., 2016), being at the lower limits of genetic complexity, so as to allow the cell to function in the form of exchanging substances and energy with the environment and its reproduction. The use of such simplified nuclei can be considered, on the one hand, as an initial practice in the creation of synthetic nuclei on which genes will later be grafted, that allow specific biological functions, thus reaching the creation of biological automata, and on the other hand, it is desired to create a basic genome for the subsequent identification of the various functions of the genes - not only correlated with their molecular structure, but also with their positioning in the genome.

At this point, the stage of simple genomic transplantation, and even the programming of autonomous circuits in single cells, has been overcome, important steps have been taken in the programming of synthetic intercellular communications, generating multicellular structures and organoids (Guye et al., 2016), thus opening a new branch of synthetic biology, namely synthetic tissue engineering, which promises to have huge applications in regenerative medicine.

Synthetic biology comes close to robotics, and especially intelligent machine technology, when research aims to create computing structures composed of biological rather than electronic circuits. The replication of a genome in a new cell, the transcription of genetic information, the transmission or inhibition of some sequences in the genome - represent the necessary elements for the creation of organic nanorobots, and the decryption and editing of the genetic code generates the premise of understanding the natural machine code, on the basis of which living things work, and of rewriting the programs of various organisms (Ginsberg et al., 2017).

The next logical step after genome decoding and genetic editing in the creation of biological machines is the coding, on biological support, of some complex languages specific to computer programming, in such a way that an interface between digital and biological machines can be ensured.

An important question is: to what extent can the so-called programming languages of life—actually genetic codes—be reduced to1010 digital codes. In the two decades since the genome was fully deciphered, significant efforts have been made in the sense of detecting the genetic causes of various diseases and the possibility of genetic interventions to reduce the risks of their occurrence. The study of genetic information taken from thousands or even millions of patients gave birth to what we can today call *digital biology* (Gibbs, 2020) and even the use of big data in biology. The identification of population genetic markers led to the emergence of studies of migrations of ancient populations and the distinctive genetic features of ethnogenetic categories. The letters of the genetic code and their ordering, although known to researchers, could not yet be reduced to binary codes, and there have been no recorded attempts to create non-binary programming languages that would use the genetic letters as the numeration basis for a language of biocomputer programming. The level of complexity of the "living codes" is not yet - it seems - reducible to numeration bases used today in computer programming. However, bioinformatics and genetic design underlie synthetic biology, and there will most likely be technological developments that allow not only the writing and overwriting of genetic code, but also the encoding of complex messages, producing biological digital automata capable of, for example, artificial biointelligence. For this, however, it is necessary to understand and reconstruct syn-biotic organisms starting from protocells or even prebiotic organic substances.

5.3. Creation of protocells

The epistemological and technological direction targeting the creation of protocells aims at the construction of approximations of living cells, which do not exist in nature in that form. Within this epistemological direction, the aim is to obtain answers to philosophical questions such as "what is life?" – which is transferred from the sphere of ontology to that of the philosophy of science, where it appears in the form of identifying the "fundamental building blocks of life". As such, this epistemological stream emphasizes fundamental research, with theories about life, evolution, living systems, and living structures being investigated experimentally (O'Malley et al., 2008).

The creation of "vesicles" similar to protocellular structures, which are suspected to have arisen in the original "organic soup" and from which life as we know it today, has been studied. Also, a series of compounds associated with life and how the respective protocellular structures become living cells are currently being studied, and on the other hand, computational simulations of gene regulation networks are being considered (Green, 2022).

In addition to the theoretical-epistemic and ontological objectives regarding the study of the origin and meanings of life, biological or non-biological alternatives that manifest a form of viability are targeted. We remind you that the study of viral mechanisms that are at the intersection between living and non-living - being quasi-biological structures capable of

DNA-regulated action, but incapable of self-reproduction - led to the emergence of mRNA technologies and the creation of synthetic messenger RNA mechanisms, which are grafted onto a living cell without being a living structure itself, but only a simple synthetic approximation of some component structures of the viral genetic content.

6. Classification of synthetic biology technologies according to the type of practice used

Another classification of technologies belonging to synthetic biology is made by Deplazes (2009) according to the criterion of the type of bioengineering practice on which it is based:

a) bioengineering,
b) synthetic genomics,
c) protocell synthetic biology,
d) unnatural molecular biology,
e) in silico approaches.

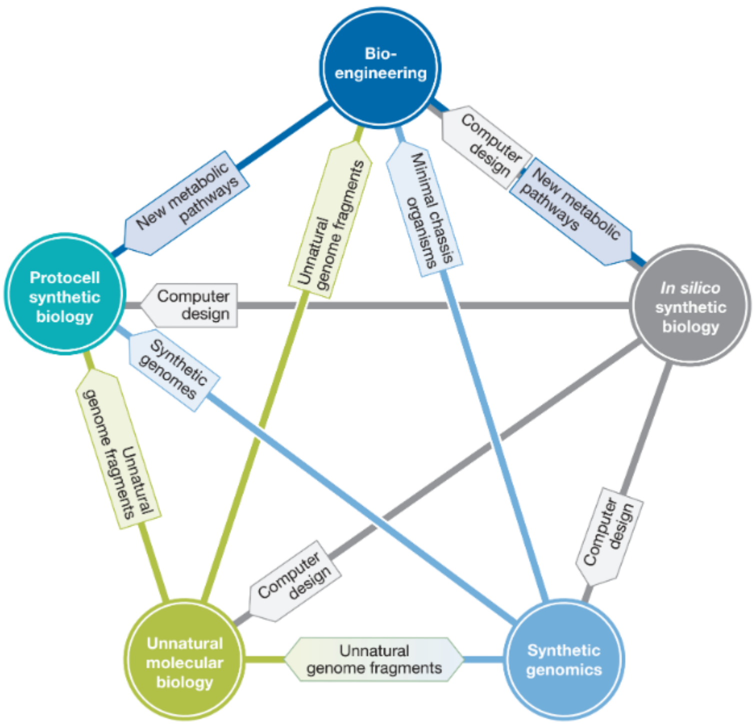

Fig. 1 Schematic representation of the five categories of synthetic biology and their connections (Deplazes, 2009).

In the case of Deplazes' taxonomy, the most important suggestion from a philosophical point of view is the proposal of work categories such as bioengineering - which considers living synthetic structures - and molecular engineering - which operationalizes biochemical technologies, which act on non-living molecules, integrated into specific structures of synthetic biology. According to Anna Deplazes, "unnatural molecular biology aims to create systems with different components, for example, artificial nucleic acids based on a different coding system" (Deplazes, 2009).

The distinction between natural and unnatural in synthetic biology, operating from a proper scientific perspective, becomes unclear when we operationalize it from a philosophical perspective, since we sometimes speak of prebiotic structures that interact with each other or with living structures, creating living or life-like processes, without the distinction between what is a living process and what is merely a life-like process still being clear. For philosophers of technology such as Lewens (2013), who considers that the term "unnatural" distinguishes synthetic biology practices from other bioengineering approaches, the question arises whether we are really talking about synthetic biology and not just a synthetic chemistry of the *bios*, due to a thinking style oriented towards chemistry and less towards informatics – as is the case with other philosophers of science, who link synthetic biology more with information science, which prevails over chemistry in the realization of synthetic biology.

The approach to biological artifacts as simple permutations of the chemical compounds existing in the biological material, specific to biochemistry as a component of synthetic biology, is opposed by a component of bioinformatics that studies the information encoded in the genome and how it is transmitted - more or less in correlation with the biochemical structures that circulate that information.

Advances in bioinformatics have led to the emergence of genetic data analysis strategies, including dedicated software capable of compiling and integrating large data sets, for example, to obtain a classification of DNA elements and "predict epigenetic signatures of functional DNA elements" (Ernst & Kellis, 2012).

In this light, we believe that bioinformatics applications should, in fact, constitute a particular field of synthetic biology and not subsume the entire synthetic biology, since most bioinformatics applications study the possibility of the existence of living systems, in agreement with the circulation of genetic information, and is not concerned with living synthetic systems or at least prebiotics. The fact that such synthetic prebiotic systems are technologically built is due to the wide funding of such research, due to the expressed social needs and especially due to the public impact that gene editing technology has thanks to the mass media. For example, the urgency of the emergence of a vaccine to prevent infection with Covid-19 was determined by the social and economic pressure on all humanity caused by the global pandemic crisis. Decoding the genome of SARS-CoV-2 has been a priority of the entire scientific world, with researchers from most countries working on samples of the viral component provided by laboratories in China at the time of the discovery of the virus and its severity. Collaborative research was made possible thanks to the open science system, through which all existing information on this subject was shared free of charge, after which the decoded genetic components of the virus were processed, artificial intelligence software identifying the best mechanisms of counteracting the viral action on the infected cell, in order to create a vaccine. Without the help of bioinformatics and Artificial Intelligence, the creation of a vaccine would have been impossible in such a short period of time - one year after the decoding of the viral genome -, the computerized design of prebiotic mRNA structures being put into practice through technologies specific to synthetic biology for the creation of previously computer-designed substances and not by genetic editing of a real virus, whose virulence could eventually be attenuated, as was the case with previous generations of vaccines.

In *The Genesis Machine: Our Quest to Rewrite Life in the Age of Synthetic Biology*, Amy Webb and Andrew Hessel (2022) state that mRNA (messenger RNA) technology is based on "informing" the immune system about specific proteins that the viral genome tries to build through the host cell for its own benefit and which are foreign to it, while instructing it how to block inappropriate protein synthesis. Such therapies based on messenger RNA will be the basis for the development of vaccines against cancer or other diseases not only of a viral nature, as information about the parasite genome or inadequate transcripts of the original genome can be transmitted to the affected cells or the immune system in the replication process, thus making unwanted genomic sequences a target of the immune system, eliminating them from the body (see, for example, tumors).

Such operations at the cellular level will allow not only the destruction of tumor cells, but also the restoration of the correct functioning of some organs affected by tumors, by correcting the transcription patterns of the genetic information, which is in accordance with the initial pattern transcribed by the messenger RNA. Of course, such an intervention at the cellular level paves the way for genetic changes – including on already existing living organisms, in a non-embryonic stage of development. If the use of CRISPR technology makes it possible to edit the genetics of the embryo, in the first stages of development, while the intervention through synthetic biology is carried out on a small number of cells, whose DNA fragments are modified, changes that are transmitted to the whole organism that will derive from initial stem cells, messenger RNA technology can produce changes in some tissues. It will be possible, for example, to restore the functionality of the pancreas affected by diabetes to restore normal insulin production, but in the future it will be possible to direct a series of cells to carry a pharmaceutical substance inside the body, generating the equivalent of biological nanobots, the nerve cells will be able to be programmed to make a greater number of synapses in certain parts of the cortex, etc. Of course, techno-pessimists may consider that this technology may also have the characteristics of a biological weapon, creating structures to modify genetic transcription, causing tissue or organ dysfunction, or even the death of the host.

One of the conspiracy theories regarding the anti-Covid vaccines had in mind precisely this possibility of using mRNA technology in the creation of biological weapons, the followers of this theory considering that the respective vaccines constitute precisely such weapons, intended to reduce the volume of the global population, either through the adverse effects of the vaccine - especially sterility - either by destroying the immune system and the body's ability to generate an immune response. When such emerging technology may have military applications, it will, to some extent, be viewed with suspicion, especially by those who believe they live in repressive societies and who express distrust of science and technology, as long as these technologies are available up to a point, including to individuals or organizations with bioterrorism predispositions.

Returning to Webb and Hessel's volume, they show that synthetic biology has already shown its transformative capacity on the functioning of the contemporary world - that of being part of the disruptive technology category -, humanity being at the stage where it is building the framework for the large-scale implementation of biotechnologies derived from synthetic biology. Just as other technologies – such as electronic communications – have transformed society from a consumer society to an information society, synthetic biology has the potential to transform humanity into a post-evolutionary civilization (Sandu & Caras, 2013). An example formulated by the cited authors is that of the production of synthetic meat, by "cultivating" in cell cultures, starting from stem cells, tissues biochemically identical to chicken meat, for example, without having some chicken be slaughtered. In this context, G. Owen Schaefer and Julian Săvulescu (2014) question whether meat obtained through synthetic biology in cell cultures is suitable for consumption by those who have adopted vegetarianism for reasons of conscience, given the fact that no animal is killed and does not suffer for the production of synthetic meat.

Webb and Hessel insist on creating a mental and cultural framework of acceptance of emerging technologies—including synthetic biology—without which synthetic biology research will not be able to advance far enough to lead to what we would call the fourth scientific revolution. Building on the findings of Webb and Hessel, we believe that synthetic biology combined with communication technologies have the potential to create a 2.0 humanity capable of a remarkable extension of life expectancy to hundreds of years, capable of living and adapting to environments seemingly completely unfit for life – such as the bottom of the oceans or the soil of other planets or, why not, in an eventual – and undesirable – post-apocalyptic world of all-out nuclear war.

The previously cited authors draw attention to the fact that there are no institutions or legislation at the level of the United States - and, in fact, globally - to ensure the protection of the population in the biocybernetic domain. There are laboratories globally that biosynthesize organic substances and compounds based on a molecular design sent by researchers via e-mail. Although there are sufficient safeguards in the academic world to prevent malicious manipulation of the products of biosynthesis, a malicious modification of the genomic structure to be synthesized – for example, by the intervention of biohackers – can lead to the opinion of the mentioned authors, upon the appearance of synthetic products with destructive potential. As such, the emergence of biosecurity interfaces is an important element in the development of the global infrastructure in which synthetic biology can operate. The development of biosecurity cannot, however, be thought outside of coherent and ethical public policies aimed at the sustainable and responsible development in terms of biosecurity of research and technological developments of synthetic biology.

7. Biological systems as constructible objects

O'Malley believes that "a distinctive feature of synthetic biology is that it aims to go beyond mere modeling and treat biological systems as fully constructible objects" (O'Malley et al., 2008). From an epistemological point of view, synthetic biology raises a series of discussions about the possibility of a distinct methodology, which would unify analysis with synthesis in a single technological research practice, and from an ontological point of view it raises questions about the relationship between the living and the non-living, biological versus synthetic, between machine and organism (Holm & Powell, 2013).

Traditionally, it is considered that the evolutionary processes of natural selection are the ones that generate the most adapted species in nature, starting from random mutations and adaptive selection, through which the most suitable species - in the context of the environment in which they live and develop - will survive. This paradigm will be partially disproved with the development of new synthetic species, whose survival is artificially engineered and which are endowed with adaptive advantages that could occur naturally in evolutionary processes that could last millions of years.

On the other hand, the systemic understanding of evolutionary biology, transposed into synthetic biology, overturns the idea of a pure Darwinian evolution based on random mutations and natural selection, showing that random mutations - even if they can lead to specimens more adapted to the environment - are often lost in nature precisely because, although more adapted to the environment, the mutant specimen cannot transmit its genetic heritage, there being no "systemic context" to propagate the mutation, thus creating a new species or subspecies (Green, 2022).

Synthetic biology projects, such as the *DARPA Biodesign project*, aim to eliminate the randomness of natural evolutionary progress by designing proteins with 99.5% accuracy. Bernadette Bensaude-Vincent (2013) points out that a rational philosopher investigating the claims of synthetic biology regarding its own transformative capacity on the biosphere and on human society at the same time should not lose sight of the difference between the possibilities that this new branch of science and engineering has them – and the actual results that researchers in the field have actually reached. We can consider that at this point synthetic biology, although it has come a long way from the first synthetic genome made by Craig Venter, to the widespread use of gene editing or vaccines based on messenger RNA, has not yet led to a Copernican revolution at the epistemological level, in other words the ideal of the transformation of nature under the impact of technology has not yet succeeded in removing the hazard from the evolution of species, a fact demonstrated by the mutations that occurred in the genome of the SARS-Cov2 virus, which developed the Omicron XE strain, which some specialists believe that they would have developed resistance precisely to vaccines based on messenger RNA, produced by synthetic biology.

We want to emphasize that an important element of the success of synthetic biology is the ability to seduce the public and not the researchers in the field - through success stories reminiscent of supernatural mythological instances, capable of transforming man into an entity endowed with demiurgic powers, in -a manner somewhat similar to what magic or alchemy was supposed to make possible. This time, technology – in this case synthetic biology – has ignited the imagination of techno-optimists, who envision a future in which certain diseases will be completely eradicated through genetic editing, longevity and the maintenance of youth being possible through intracellular operations with the help of messenger RNA technology , the food being sufficient for the entire population, produced without effort and without the need for traditional food production activities – agriculture, animal husbandry, etc. –, all this being replaced by cell culture that generates synthetic "meat", molecular constituents similar to any food, etc., reducing pollution by creating bacteria that digest plastic, etc.

Bernadette Bensaude-Vincent (2013) considers that these visions have already entered the epistemic culture of humanity, and the objections that researchers from the professional community in the field bring to these utopias are criticized as epistemic opportunism - a term that comes to replace the classical one, of technoscepticism.

8. Synthetic biology – epistemological construction on the design of life

Understanding biology as a design applied to life itself can be considered a reductionist view, as the entire evolutionary complexity is reduced to a vitalist project, as if life itself had a purpose and that was to exist and multiply. This assumption leads some researchers to try to determine the minimalist genome on which a biological entity can function—creating only those chains of protein synthesis absolutely necessary for cell life and replication. On the other hand, the DNA code of a real cell existing in nature contains sequences that generate protein syntheses that do not seem necessary for the survival of the cell, but can trigger certain contexts, functions that specialize the cell as part of a tissue - for example, by passing from to a totipotent stem cell to a cell part of a specialized tissue within an organ.

Synthetic biology allows, in reverse, the elimination of some nucleotide chains or the inactivation of some genes, transforming a specialized cell, part of an epithelial tissue, into a stem and, from here, into a self-fertilized zygote, allowing the occurrence of *solo reproduction* phenomena. The reverse engineering approach to living systems, for example by decoding the genome, then allows the study of genetic systems on the structural components of the genome and the constructive or reconstructive intervention on the various parts of the genome, which lead to the emergence of desirable and designed metabolic processes starting from genetic mechanisms only partially similar to natural ones, using bio "logic circuits".

9. Conclusions

The temptation of synthetic biology to become a post-Darwinian science, by replacing natural evolution with the synthetic one, makes this science par excellence a product of postmodern thinking, refractory to the systematic and universal, and confident in the absolute power of science and human technology to override the laws of nature, shaping nature after human intelligence. Post-Darwinian biology, with its great promises of becoming a fourth scientific revolution, is, after all, a new ideology, which is far from exorcising the world, making the gods take on human form, and instead of lightning, wear white robes.

The character of postmodern science of synthetic biology is given, on the one hand, by the theoretical eclecticism and excessive leaning on the technological, and also by the multitude of methods used in technological research in the field. The rejection of an epistemology in the traditional sense is compensated by bringing to the attention of the scientific community some theoretical models derived from systemic biology and complexity sciences which, however, do not claim to elucidate truths of a theoretical nature or at least to produce theoretical constructions considered valid, but to produce technological artifacts of pragmatic value. On the other hand, however, they try to solve some philosophical problems - such as the question "what is life?" – with scientifically acceptable instruments.

Synthetic biology is a post-Darwinian construct not because it denies the theory of evolution or even the role of random mutations in phylogeny, but because it seeks to create life based on a project with a well-defined goal, the cells and organisms created being designed to perform functions of an economic rather than evolutionary nature.

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