

The
Unplumbed
Depths of SynBio
According to Their
Language
or

*how
SynBiologists
work with faulty terms
and cause epistemic as well
as ethical issues.
Submitted
by*

Marcus Podewski



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Content

1	Introduction	3
2	Methodical Approach	4
3	Terms	6
3.1	“Artificial cell”	6
3.1.1	Meaning and Associations	8
3.2	A ghost in the shell?	12
3.3	First Conclusion	14
4	From speech to tangle	14
4.1	Misguided judgments	14
4.2	From Is to Ought	16
4.3	Emotional terms	16
4.4	Any alternatives?	16
5	Conclusion	17
	References	19

1 Introduction

The limits of my language represent the limits of my world.

WITTGENSTEIN

The human is settled into the world, which he is, of course, able to understand. Such an understanding is, however, not "pure" but filtered through concepts we have established.¹ They preform and structure our perception as well as our sensation. The meaning of these concepts is learned by society, which also *defines* the meaning of words. An understanding of the world can, thus, be possible only within a linguistic and social context. Society and speech are fundamental preconditions to understand the world and to act meaningful in selfsame. Thus, the understanding of the world depend on the ability to structure it through speech because speech expresses and mediates the concept with which we understand the world. Therefore, scientists should be very careful regarding the kind of expressions they use to explain their work.

Synthetic Biology rises the endangerment that one of the most fundamental concepts of human development, nature on the one side and culture on the other, intermingle.² In the so far history were both concepts strictly apart — apart in a way, that the one was the antipole of the other. SynBio is about to fuse these poles. The productive human, the manipulator of his environment, the *homo faber*, who gears with his technique into nature, could carry with the assistance of SynBio technologies *in* nature itself; whereby it would desist from being nature in our current understanding, as a counterpoint of culture, and the homo faber would not just be a manipulator anymore, he would become a *creator*. So fear the critic of SynBio.

This fusion shall be retraced in the paper at hand from a philosophical point of view. That means to focus on the underlying concepts and the mentioned arguments. In doing so I will approach the problem through the terms itself. According to the aim to refuse the ancient distinctness of nature and culture, SynBiologists speak often about *artificial cells*, *living machines*, *protocells as chassis*, and much more similar terms. Such terms express impressively the aim of the SynBio as well as the appearing problems. In examining them, we can see firstly, if the terms even rise the sketched problems and secondly, what kind of problems may ensue with them.

In the following we need to clarify several terms for an accurate use. I will define those terms so that we are able to deal with them in a proper way.

nature Everything that is *not* modified by humans and that is independent from human plans and design. But a strict separation between the natural and the human-determined world has never existed and was mostly a case of

¹Such concepts are, for instance, the believe in causality.

²In the following, I will use the abbreviation "SynBio" for the scientific approach and "SynBiologists" for scientists working in that field.

grade than of clear distinctions.³

culture Everything that is modified or created by humans, opposite of nature.

technique The mostly natural scientific methods and means to modify the nature.

artifact Any object developed or produced by humans.

life The scientific definition of life mostly applies to three principles: metabolism, self-reproduction and evolvability.⁴ This definition is in several points problematic. For instance, it does just matter within the biologist's community and does not fit the everyday-life experience or perspectives from other sciences. The best known example for being unable to fit common intuitions represents the problems concerning hybrids like mules or geeps (sheep-goat chimeras). They are not able to breed, but nobody would deny their state as living beings.⁵

2 Methodical Approach

The aim of the investigation is to test the terms used by SynBiologists for their ethical and philosophical issues. Such terms imply a fundamental difference from hitherto existing creatures (e. g. "artificial cell") as well as a mixture of nature and technology (e. g. "living machine"). In a first step, the used terms shall be analyzed with the methods of the philosophy of language to elaborate their *meaning* and *reference*. This allows us to spot what the terms actually indicate and how far the terms may be appropriate in their semantic manner. Afterwards, the *cultural ideas*, which are associated with the reviewed terms, will be examined. Cultural association patterns affect our actions in a variety of ways because they structure our perception of the world and thereby influence our decisions. In this sense, associations *can* also raise ethical problems, whose potential is traced in the last chapter. This indicated analytical framework, by the use of which it will be able to approach the later tasks, shall help to understand and to expound the problems of the terms and their related concepts.

The examination at hand will deal with several expressions: "living machines", "artificial cells", "minimal cells", "protocells" and "synthetic cells". To identify the *semantic value* of a term philosophers differentiate between the *meaning* and *reference* of a term.

Reference is understood as the relation between an expression and that what the speaker wants to denote with that expression. In this sense, reference picks or singles something out, be it a person, property, group or something else. Reference has an impact on the truth-value of sentences. If somebody says "Santa Claus exists" and if he actually do not refer to anything by the term "Santa Claus", then the sentence he just said is wrong. In the philosophy of

³See DEPLAZES/HUPPENBAUER: *Synthetic organisms*, 55

⁴See e. g. LUISI/FERRI/STANO: *Approaches*, 1, who see their definition directly in answer to the question: "What does 'alive' mean?"

⁵For other critical aspects according the "life" definition see TOEPFER: *Begriff*, 166-171.

language, two possibilities are discussed how such a relation between a word ("Santa Claus") and an entity (Santa Claus as living person) exactly works.⁶ I chose the so called Description Theory, according to which reference is established if an entity fits the properties related to the term.⁷ It provides itself for generic expressions, that names a class of objects in contrast to an definite object, as considered in this analysis.⁸ I prefer these theory because generics works through descriptive designation. For instance, a term belongs to a group if the properties related to the term fits with the properties shared by the members of that certain group.

To understand the *meaning* of a term, "one must have some grasp of how it applies to things in the world, and one must also be able to employ the word in an indefinite number of sentences."⁹ When the reference clarifies the relation to the specific entity, the meaning expresses the ideas or types of ideas, that underlie the expression. When I understand the meaning of a term, I know in which context it is used and to what other terms it is related. The meaning denotes certain characteristics or properties on which connections to other terms are based so that one could use the term meaningfully within a discussion even if one does not know the reference of that term.¹⁰ The meaning of a term is closely connected to its associations. Unfortunately, there are no (psychological or societal) studies of the perception of the reviewed terms. We can, however, correspond on the one hand to the existing studies of the nature-culture distinction (which the terms pick up manifold – e. g. "living machine") and on the other side to newspaper articles and research papers dealing with SynBio where those terms are used. Common western industrialized societies perceive the interference of nature through genetic engineering approach as a far-reaching impact into the selfsame naturalness. ROZIN has conducted a study concerning the perception of the naturalness of objects modified by different approaches. According physical transformation or domestication, the naturalness was - in the eyes of the participants - reduced just about 10% whereas it was reduced about 54% by genetic engineering.¹¹ Therefore, the participants associate a far-reaching impact in the naturalness of an object through genetic engineering. SynBio will not perform better. By contrast, there is evidence that society would judge or perceive SynBio worse, because it marks a more fundamental interference with a more far-reaching claim than genetic engineering.

To elaborate the meaning and reference of a term, allows us to estimate how far he is appro-

⁶The first, the so called Description Theory, assumes that a term "refers via the descriptive content associated (by the speaker) with that name" (REIMER: *Reference*, paragraph 2.1). The second is called Causal Theory and assumes, in contrast, that "reference of a name is established by a dubbing ceremony (or "baptism") at which the dubee is indicated by a demonstration." In the following all uses of the name refer to that original dubee, "even if the speaker associates the name with a description that is untrue of that dubee." (CUMMING: *Names*, paragraph 2.5).

⁷For example, I can find out who "Barack Obama" is, when I find a person who fits the description ("being the president of the US", "being born in Honolulu at the fourth of August, 1961" and so on) connected to the term.

⁸For the inclusion of generics into the description theory see LUDLOW: *Descriptions*, 9 and SHARVY: *Theory*, passim.

⁹CRANE: *Meaning*, 575.

¹⁰So could Urbain Le Verrier, a scientists and astronomer in the middle of the 19th century, who calculates the existing of the planet Neptune only by observing discrepancies in the orbit of Uranus, even talk meaningful about Neptune although he has no idea what the name refers to.

¹¹As a measure served the division into completely natural on the one side, wherefor the image of an unclimbed mountain in the Andes was used, and on the other side not natural at all, wherefor the image of a plastic pistol was used. The participants (in the first group were about 100 randomly selected Philadelphians with a mean age of 40 and in the second group were about 100 collegestudents with a mean age of 19) have to arrange now different objects within a scale from 100 (natural) to 0 (not natural at all). See ROZIN: *Meaning*, passim.

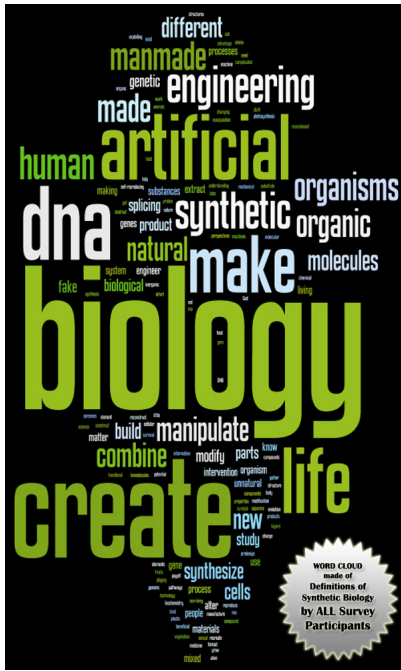


Figure 1: Word cloud by all participants

The association of the phrase "synthetic biology" and the implications of its methods appears colorful in the word clouds designed by the British Columbia iGEM team. They conducted several surveys asking people for a definition of SynBio. Afterwards the team combined the words students have used to define SynBio according to their frequency. Thus, the both central concepts the phrase is curling around are nature (organic, DNA, biology, organisms, human, life, natural and so on) and technique or culture (engineering, made, synthetic, create, manipulate and so on). The occurring problems will be analyzed in the paper at hand.

appropriate, i. e. how far he reflects the underlying concepts. That shall prevent two phenomena; first, that the term pretends to have properties which it does not have at all. Second, that the term refers to an entity with certain and definitive qualities, but we do not connect these qualities with that term generally. We have to reject both terms from a philosophical point of view, because they refer incorrectly. According to this approach, we can be sure that the terms and phrases are coherent and are based upon consensual concepts. For example: the concepts associated with "living" as well as "machine" have to be able to be combined in a meaningful way. If that is not the case the term is unable to carry a meaningful semantic function within the sentence . . . and therefore, the respective scientific discussion concerning "living machine" would be nothing but nonsense.

3 Terms

In the following, two different terms will be analyzed which are often used within the scientific community of SynBiologists. For each term a couple of example sentences will be given to exemplify the common use. Afterwards the discussed methodical approach will be applied successive to the terms. Closing, we should have a base of knowledge to consider the further approach and the related ethical as well as societal problems.

3.1 "Artificial cell"

The term "artificial cell" does not refer to a single entity, but it names a group of entities, which all share several fundamental qualities. In this sense, it is a generic expression. What the term *refers to* or what it *means* is hard to outline, because there is not a canonical definition or even everyday use of the term. The divergence appears impressively at the multitude of

various terms: “prebiotic cell”,¹² “protocell”,¹³ “minimal cell”,¹⁴ “synthetic cell”¹⁵ and so on. It is common in the corresponding papers that those terms are undefined or define each other. Apparently, SynBiologists utilize not only equivocal term but differ also how each term is to be used. Because of this undefined use, I will focus on three terms (“protocell”, “minimal cell” and “synthetic cell”) which are often described as “artificial cells”. After the examination what these three terms refer to and what they mean, it would be easier to clear this point for “artificial cell”.

The most profound ethical and social study according “artificial cells” was presented by an interdisciplinary collection edited by BEDAU/PARKE. They define “artificial cells” as follows: “Protocells are microscopic, self-organizing, evolving entities that spontaneously assemble from simple organic and inorganic materials. They are also known as artificial cells ...”¹⁶ They prefer the term “protocell”, because “artificial cell” is also used to refer to things like red blood cells while protocells emphasize their similarity to simple single-celled life forms. Despite such a separation from other cells, Bedau/Parke have a broad understanding of the term “protocell”. Not only do they use “protocell” and “artificial cell” as synonyms but they also do not differ between “protocell” and “minimal cell”.¹⁷ For them a “protocell” can be generated by two kinds of approaches, but we focus here just on one: the bottom-up approach. That is aiming to compose an organism from not living, sub-cellular parts. This could be done by two methods. First, scientists are trying to combine inorganic materials like silicium or newly created base-pairs to initiate a process chemically which they call “life”. Second, scientists (as well as the teams participating at the iGEM competition) work to develop so called “BioBricks” that are defined DNA sequences associated with a certain function and designed to work in assembly (they are similar and able to “plug” together). Some scientists intend to combine a multitude of “BioBricks” to generate a complexity, at which “life” begins. All products resulting from this approaches, Bedau defines as “protocells”.

Scientists often describe “minimal cells” as “artificial cells”.¹⁸ This is the second method to produce a “protocell” after Bedau/Triant. Craig Venter and his team presented several months ago a “minimal cell” in their view.¹⁹ In the special case of the paper the term “minimal cell” refers to *Mycoplasma mycoides* JCVI syn 1.0 - also called Synthia. But normally the term is used as generic expression and refers to cells modified and reduced from an existing cell to a point where the cell is barely alive. All organic structures which are not necessary for the survival are removed. Also Gibson et al. define their cell in a specific way although they are not talking about “artificial cells”.

However, Gibson et. al. introduce an important modification: they replace “artificial” with “synthetic”.²⁰ “Synthetic” emphasizes that the cell was synthesized by humans, i. e. the base

¹²MURTAS: *Synthesis*, 89.

¹³BEDAU/PARKE: *Introduction*, 1.

¹⁴GIBSON et al.: *Creation*, 52.

¹⁵NOIREAUX/LIBCHABER: *Bioreactor*, 17673.

¹⁶BEDAU/PARKE: *Introduction*, 1.

¹⁷All three terms are widely used and highly unclear. For example see FELLERMANN/SOLÉ: *Minimal model*, 1803 and 1811, who uses the terms “artificial cell”, “protocell” and “minimal cell” synonymously.

¹⁸GODINHO/LAM/SANTOS: *Introduction*, 32.

¹⁹GIBSON et al.: *Creation*, 52.

²⁰The term “synthetic” may occur several dozen times, “artificial” not once.

pairs were build and composed to DNA *chemically*. This a step independent from the both other approaches. A cell or parts from it could be synthesized within the bottom-up as well as the top-down approach

Until now, three different types of “artificial cells” could be outlined, whose terms (“protocell”, “minimal cell” and “synthetic cell”) refer to entities differing through the method they are produced. However, besides such a splitting of definitions one could also look for unitary explanations. After an introduction in several methods to produce “protocells” Bedau propose a definition for “artificial cells”: “But protocells are simpler than any existing bacterium. And unlike bacteria, they are not natural but artificial, and exist only through human creation.”²¹ The special character of “artificial cells” are, thus, composed of three elements: they are alive, artificial and exist only through human creation. “Alive” denotes to the three basic principles commonly associated with a definition of life or being alive: entities have to reproduce, evolve and have a kind of metabolism.²² According Bedau/Parke, “artificial cells” fit those three principles.²³ They exist further “only through human creation”, thus they are man-made — an evident point that does not seem to be explained further. So, wherein is the artificiality grounded? The term (“artificial cell”) seems to imply that the entity to be referred is more than just man-made. It pretend to go beyond. An example shall clarify this distinction: Children emerge from *in-vitro* fertilization are somehow also man-made because they would not live if not humans have combined a human egg with sperm cells in a high-grade artificial process. But nobody would call the children for this reason “artificial”. Cultured animals rise similar considerations. They also exist through an active human interference into a “natural” process. Nonetheless, nobody would call them “artificial”.

After this examination, we should be able to arrange the terms “artificial cell”, “protocell”, “minimal cell” and “synthetic cell” in a proper order. “Protocell” refers to an entity produced within the bottom-up approach whereupon two possibilities ensue for realizing such an entity. First by combining “BioBricks” to a level of complexity that they ›begin to live‹. Second by composing an organism of inorganic materials with the aid of e. g. nanotechnology. “Minimal cell” refers to a similar approach upcoming from the far side. An existing organism will be reduced to the lowest level of life conditions. “Synthetic cell” clarifies “artificial” in some points by emphasizing a method by which cells *can* be produced artificially. All of this analyzed terms are “artificial cells”. This phrase is an umbrella term that was introduced to refer to any kind of new entity produced by SynBiologists. Anyway, to be “artificial” is still vague.

3.1.1 *Meaning and Associations*

In the following, it will be the aim to consider the meaning and the cultural associations connected with the terms. Both elements will be discussed together because they coincide in several points. Furthermore, it might be possible to clarify the vague layers of meaning of “artificial” within this considerations. The aim, in doing so, would be to search for clearly defined concepts that result from the use of the words because certain names have to denote

²¹BEDAU/PARKE: *Introduction*, 1.

²²An intensified discussion according this principles will take place at chapter 3.2.

²³“[Protocells] grow by harvesting raw materials and energy from their environment and converting it into forms they can use, they sense and respond to their environment and take steps to keep themselves intact and pursue their needs, and they reproduce and ultimately evolve.” BEDAU/PARKE: *Introduction*, 1.

certain concepts (in other respect they are meaningless). Which names are connected to which concepts is due to the most frequented use of the terms.

At first it might be helpful that the term "cell" would be clarified because it is part of every reviewed phrase. Cells are small functional units of all living beings but sometimes nonetheless visible by eye. Most pupils in the industrialized countries have seen a cell through a microscope or have seen a picture or scheme of it somewhere (schoolbooks, television, billboards). Cells are connected essentially with concepts of "living" including all the broad associations outlined in chapter 2. Thus, "cell" carries the concept of living and nature within its term.

"Protocell" refers to an entity produced through the bottom-up approach (combining "Bio-Bricks" or inorganic material to an organism). The term implicates to denote a first cell that underlies all others cells. The prefix "proto-" is the Greek ordinal number for one so that "protocell" is a telling name. It pretend that humans are able to produce a cell that is a kind of archetype of all others. Moreover, it suggest that such an approach is even possible, i. e. that humans are able to design and produce a cell which has no organic ancestor but was e. g. *de novo* synthesized. Such a "creation" is not possible at that time even if scientists around the world are up to it. Moreover, the success of this approach could fail to appear in the near future or could even never occur. Thus, the term is associated to a wide rage of concepts concerning technology, interference, "creation" ("proto-") and nature, being, living ("cell"). The mixture of usually distinct concepts lays, thereby, not in the term itself but in the associated concepts.

"Minimal cell" on the other side refers to an organism that is reduced to its lowest possible form.²⁴ Scientists use, so, existing entities to minim

"Synthetic cell" was introduced as a specification of "minimal cells". They refer to organisms which are produced by synthesizing their DNA. However, one have to be careful that his associations do not misguide. By far it is not possible that synthesizing life could mean "to create something from chemical parts in an entirely new way". At the moment it could just mean "to compose subcellular elements in partially new combinations so that they build an animated cell or micro-organism".²⁵ Nonetheless, scientists as well as the media suggest or pretend that the first meaning ("creation in entirely new way") is not even possible but also achieved (as we will see below).

Considering the explanation to "cell", "artificial" has on the other side also a broad, unclear meaning. Probably the most know case where the term is used is "artificial intelligence". It designates something that is a kind of replacement for original nature products (like artificial snow, artificial light and so on). The term is, thereby, connected to concepts like technical, man-made, simulated, not natural, fabrication, static, offish, algid and others. We think of machines, factory buildings, plastic and computers. In this sense, the term "artificial cell" is

²⁴Some scientists do not distinguish between "protocells" and "minimal cells", because, so they say, both terms refer to a cell that genome is reduced to *the* absolute minimum (see GODINHO/LAM/SANTOS: *Introduction*, 32). At first, the way how such a "minimalization" is achieved, differ fundamentally and especially the method would be from an outstanding importance to consider the state and implications of such an entity. Second, it's undetermined if both approaches will lead to the same results. Thus a most obvious and separate use of terms should be considered.

²⁵See for further explanations BOLDT/MÜLLER/MAIO: *Analyse*, 49.

an impressive example of intermingling concepts of nature and technique; because how could something be static and developing, how man-made and natural, how grown and fabricated at the same time? Those mixtures do not seem to fit common beliefs.

“Protocells” and “minimal cells” do not raise criticism in the same way as “artificial cells”, because they do not intermingle different associations in a so far-reaching way like “artificial cell”. But certainly, “minimal cell” seems to be less problematic than “protocell”, because it implies just that there is a cell which could be minimized in some way; whereby “protocell” pretends the same as “artificial cell” but on a different level (just in concepts and not in the term itself). Thus the claim of both terms differ whereupon “protocell” might provoke more resentments. “Synthetic cell” highlights one of the methods which generate “artificial cells”. Certainly, also this term can not clear all of our problems related to the vague “artificial cell”. For example, a “synthetic cell” is an “artificial cell” but an “minimal cell” which is also an “artificial cell” do not have to be produced by synthesizing. And a “protocell” do not have to be produced in the ways “synthetic cells” or “minimal cells” are. At this point we can state several epistemic problems related to the reviewed terms. [??? ??? ??? ??? ??? ??? ??? ???] And further they intermingle concepts what can rise ethical problems discussed in the last chapter.

Concluding, the notions of “artificial cell” as well as the other reviewed terms imply a fundamental difference from existing organisms. The terms are obviously defined to separate natural micro-organisms from “protocells”, “minimal cells”, etc. The entity denoted by the terms turns out to be something other, different and “new”.²⁶

To criticize or even analyze this supposed novelty is not easy at all because: “In general, it is a matter of unresolved philosophical speculation at what point an entity undergoing continuous changes turn from being one entity into being a new one.”²⁷ Thus, we are not able to refer to an accepted theory but it will be possible, nonetheless, to confront the use of the terms with several issues. Therefore, I will give an example for the pretension of a new entity through SynBiologists. Afterwards, I elaborate issues related to that pretension and outline why such suggestions can be problematic in general.

The most prosper making of an “artificial cell” can help us to clarify this point. Craig Venter and his team have elaborated a bacterium that is commonly called for example an “act of creation”²⁸ or it is mentioned that “Scientists Create First Self-Replicating Synthetic Life”.²⁹ In addition such statements fit with the self-perception of the team.³⁰ The perception is clear now but what is done by Craig Venter and his team? They took the DNA of the bacteria *Mycoplasma mycoides*, analyzed, synthesized it *de novo* and copied it into the bacteria *Mycoplasma capricolum* which was emptied out of its own DNA. The transformed DNA began

²⁶To be new and novel is one of the always recurring predication of the discussion. Venter claims, for example, to create “a new cell” (GIBSON et al.: *Creation*, 52) and Bedau/Parke see “a new kind of technology” (BEDAU/PARKE: *Introduction*, 1) rise. Other predications in this way could be found at McCASKILL et al.: *Self-organization*, 1767 or NOIREAUX/LIBCHABER: *Bioreactor*, 17669.

²⁷BOLDT/MÜLLER: *Newtons*, 388.

²⁸BAHNSEN: *Schöpfungsakt*.

²⁹Mentioned by SWABY: *Scientists*, although there are critical statements in federal newspaper like this one WADE: *Researchers in the New York Times*.

³⁰See for example: “We now have combined all of our previously established procedures and report the synthesis, assembly, cloning, and successful transplantation of the 1.08-Mbp *M. mycoides* JCVI-syn1.0 genome, to create a new cell controlled by this synthetic genome.” GIBSON et al.: *Creation*, 52.

to work within the new membrane and act like a *Mycoplasma mycoides*. Following Venter, his team has created the "first synthetic cell" and a "new species".³¹

Here we are at the crucial point. At first, there are two fundamental possibilities respectively something can be "new". First, something could be "new" concerning the method of production. Second, the entity itself could be "new" because e. g. scientists used other materials for production. An example can illustrate this distinction: The impregnation with the *in vitro* fertilization is a new method to breed, to reproduce. The method is high-grade artificial but certainly the entities resulting that process are not. In contrast, when early humans had build the first statues, these were, opposite to the living humans which had been the model, totally new entity. The ontological state of the entity changed because it was produced with a new method as well as other materials. But not only the material is relevant, even more relevant are the concepts related to the material. For example the "flesh-shoe" (see figure 2) could affront our taste but will not intermingle the concepts of nature and technology. But if



The "flesh-shoe" made by Adam Brandejs and presented at the ars electronica in 2009. This shoe is a good example for our vague intuitions concerning the state of an entity respective its material. Such a shoe is just a shoe made from other material as usual, but would it not be necromass but a living and evolving organism, it would not be a shoe anymore. Than, it could be an organism who can be used as shoe, but that is an important difference. (© a_kep, flickr.de)

Figure 2: "Flesh-shoe"

the shoe would not consists of dead biomass but of an living and evolving organism (a "living shoe"), one would judge otherwise. He would be an organism that could be used as shoe but that is a difference which is at least so important as being artificial or artificially made.

The bacteria designed by Venter and his group belongs mostly to the first possibility. The process of producing an entity has changed but not the entity itself. Therefore, they had to use e. g. inorganic materials. However, Venter did more than just changing the process, the team did also interfere in the DNA and synthesized the genome. We can regard such interference in one way similarly to PID (preimplantation diagnostics) so that both resulting entities should have the same level, i. e. not being artificial. But how far the synthesis of the genome effects

³¹Already in 2007 Venter and his team claimed to have created a new species by "transplant" a genome from one bacteria to another. His team did the same in 2010 with the important intermediate step of synthesizing the DNA "and transforming that cell into a new bacterial species." See the announcement in May 2010 at http://www.ted.com/talks/craig_venter_unveils_synthetic_life.html.

the state of the entity is a question that could not be answered satisfying within the paper at hand.

However, this examples illustrates besides the mentioned issues that the transformation from one entity into an other is a gradual process that has no binary certainty. Rozin, who has conducted a study concerning the perception of naturalness, supports this thesis with his results and arrives, furthermore, at the conclusion "that [in the perception of the participants] process is more important than content in determining naturalness".³²

The terms used by SynBiologists implies a fundamental differences from hitherto existing creatures or a mixture of nature and technology. The previous subsection was conducted to elaborate the reference and meaning of the term "artificial cell". That should clarify how the term could be problematic. Thereby occur

3.2 *A ghost in the shell?*

After the examination of the first phrase ("artificial cell") with its related terms ("protocell", "minimal cell" and "synthetic cell"), it is now the aim to focus on the second selected term: "living machine". It has much in common with the first term so that it will be possible to attach to the previous considerations often. The analysis will follow the same method like "artificial cell". First, the reference will be clarified. Second, the meaning and the related associations of "living machine" will be outlined. Concluding, it shall be the aim to deal with the special character of the term which differ it from "artificial cell".

"Living machine" raises related considerations like "artificial cells". It is also used as a generic expression and expand in a multitude of expressions like "universal biosynthetic machinery",³³ "genetically engineered machines",³⁴ "organic machine"³⁵ or "artificial self-replicating machines".³⁶

"Living machine" refers thereby to mono- or multi-cellular entities that were modified or created through the methods of SynBio. This can happen within different approaches. First, scientists work on a "protocell" which could be used to assemble parts (so called "BioBricks") to "create" a "living machine". Second, an existing organism could be modified in a way to be programmable and to control its gene expression through standard parts and hence modified biochemical pathways. The manufactured and mechanic usage of the cell is prior to this approach.

A "machine who is alive", offend our common use of the terms "living" and "machine" because both differ greatly. A *machine* is something man-made to support humans in a certain way (power or energy transmission). They act mechanically and automatically and they have "no real independence or originality".³⁷ Furthermore machines are artifacts, i. e. they are designed and produced by humans out of inorganic materials to fulfill their purposes. In this case an "artificial machine" would be a pleonasm. A *living organism* on the other side consists of other properties (and is also a pleonasm). Beside the scientific definition of life, which is

³²See ROZIN: *Meaning*, 657.

³³NOIREAUX/LIBCHABER: *Bioreactor*, 17673.

³⁴The motto of the iGEM competition. See <http://2010.igem.org/About>.

³⁵NIOPEK: *E.colizenz*, 16.

³⁶NOIREAUX/LIBCHABER: *Bioreactor*, 17669.

³⁷DEPLAZES/HUPPENBAUER: *Synthetic organisms*, 57.

confront with several problems (see chapter 1), the term is commonly vague and unclear. If we take the previous definitions of life as a basis, than we have to arrive at the conclusion that the meanings of “living” and “machine” do not fit at all, but it intermingle “nature” with “technique” similar to “artificial cell”.

“The designing and fabrication aspects of these products define them as machines, but it would be hard to deny these entities are alive.”³⁸ As Deplazes/Huppenbauer states it, the notions of the two terms brings us to a paradox. That is why, Boldt/Müller refer to “living machine” as totally absurd because “the living” and “the mechanical” are, despite all analogy, strictly separated realms of objects.³⁹ Indeed, the term “artificial cell” severely tests our intuitions and associations, but “living machine” will receive the most explosiveness.

While “artificial cell” is based on a modified, synthesized or produced organism, the term “living machine”, in opposite, intend that the produced organism is prior to a machine added by elements related to concepts of “living”. A machine is thereby something create to fulfill tasks and purposes. Thus, one is not only up to unify the most distant terms with this phrase, but also trying at the same moment to disrupt the “living machine” from the natural micro-organism artifacts. Moreover, the term “living machine” implies the commercialization and making available of cells in a new quality and quantity. The humans are, of course, aiming for this for a long time. It is one of the determining definition of all biotechnologies that they want to use the capacity of nature to enhance human life. Moreover, humans treat animals in terrible ways, for instance, by mass-farming or fur-production. Certainly, the method and aim of SynBio is more fundamental and far-reaching. This point seems to be crucial: Cells will be available for humans in an entire new quality. The cell is losing its original function gained within the evolutionary process and is achieving a new one through humans. This new function has nothing to do with “being fit”, but it was designed and produced by humans for their needs and purposes. The phrase goes even beyond that as it implies to treat organisms like machines (“machine who lives”).

Unfortunately, the phrase lags behind its reflective abilities. The paradox laying into itself is not been used for a productive examination of the aims and approaches concerning the theory of science. Instead of questioning if the phrase is appropriate, what does it imply or what does it mean; the capability of the term is wasted and it is just used to express ideas of the SynBio in a pictorial and political attractive way. Moreover, the phrase could have given a clue to deal more extensively with findings of epistemology that had analyzed the relation between living beings and machines for a long time.⁴⁰

So, what do “living machines” confront us with? A “living machine” is in fact an “artificial cell” which is modified by adding “BioBricks” for fitting certain purposes favored by humans. Thereby the line between an just modified “synthetic cell”, “minimal cell” or “protocell” and a “living machine” is profoundly porous. The phrase itself offends our intuitions and associations at least as “artificial cells”. It is still mixing not only concepts of nature and culture but implies also the extensive availability of cells for the human needs on a new level.

³⁸DEPLAZES/HUPPENBAUER: *Synthetic organisms*, 59.

³⁹BOLDT/MÜLLER/MAIO: *Analyse*, 56.

⁴⁰One of the most known exponent is CANGUILHEM: *Knowledge*.

3.3 *First Conclusion*

This chapter should examine the terms “artificial cell” and “living machine”. According to the ambiguity of “artificial cell”, the analysis focused, at first, on several other terms (“protocell”, “minimal cell” and “synthetic cell”) often related to “artificial cell”. All terms denote different methodical approaches which were used by SynBiologists to produce organisms. A “protocell” is an entity produced within the bottom-up approach, where inorganic elements will be combined to produce a hitherto unknown organism. A “minimal cell” is an existing organism which shall be reduced to its lowest possible level, i. e. all elements within the cell shall be removed so that the cell is barely alive. A “synthetic cell” is a cell, whose DNA or genome was synthesized, i. e. newly combined from a subcellular level by chemistry. Based upon these considerations, an “artificial cell” is an umbrella term to name all cells produced by the methods of SynBio. The meaning of all terms differs in several points, but all have in common the intermingling of the concepts nature and technology. Moreover, the implications concerning the “creation” of new entities or even species could be outlined. Here, it was possible to clarify wherein the vagueness of the term “artificial cell” lies. It denotes to “artificially made” as well as “being artificial”. Two meanings which differ in their claim greatly and which cause confusion to those who do not know if the cell is just artificially made or if the cell is artificial.

Secondly, the term “living machine” was analysed. It has much in common with “artificial cell” but differs in several points from “artificial cell”. The term refers to a cell, which could be made by different approaches (bottom-up or top-down). A cell which could be used as a kind of “chassis” was customized with “BioBricks” which are defined and standardized DNA sequences with certain functions. The mechanism usage and the application for human needs are both crucial to this approach. The phrase itself offends our intuitions and associations at least as “artificial cells”, it is still mixing not only concepts of nature and culture but implies also the extensive availability of cells for the human needs.

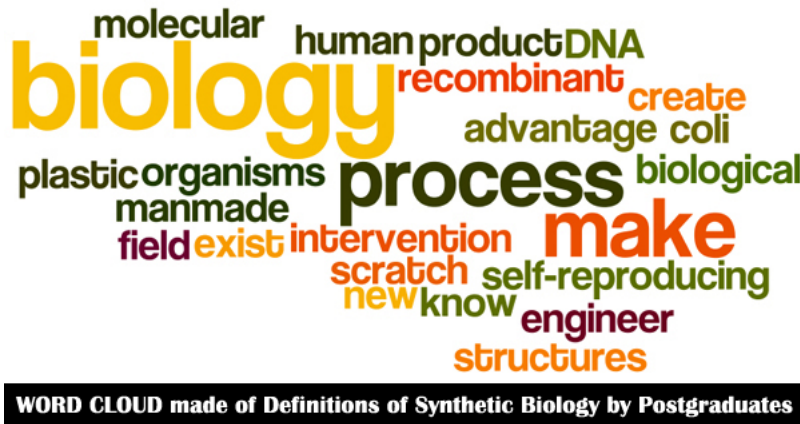
4 *From speech to tangle*

As we were able to see in the last chapter, the terms raise fundamental issues even on a semantic level. This problem gets worse. In the following, the ethical problems shall be analyzed that result from the semantic confusion sketched in the chapters before. At this juncture, the possible objection will be replied, that it is of no relevance how a scientist names the things he produces because he knows what he is doing biologically. This chapter shall deal with three main problems that arise from the inappropriate use of the terms.

4.1 *Misguided judgments*

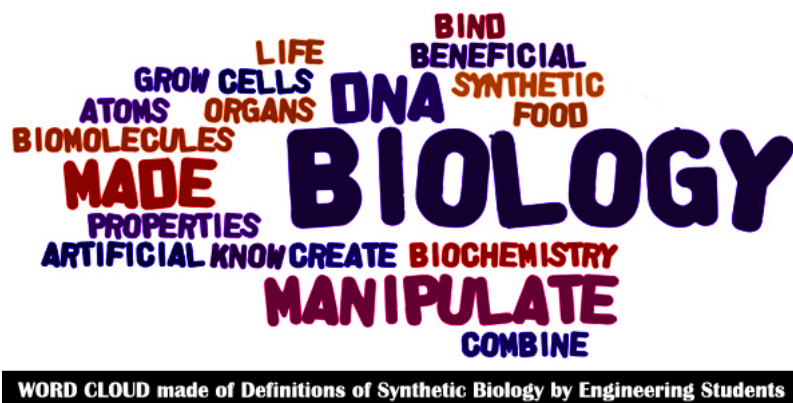
The terms do not express what they claim to express. This results in distorted opinions and ontological problems. One of these could concern the distinction in moral judgments between scientists and the rest of the society. Scientists do understand what the terms like “artificial cell” or “living machine” refer to and mean, because they understand the methods by which such cells are produced or modified. They know what those cells are about. The society does not have such knowledge or insight in the applied methods. Most people will just have a few

snippets of information and their associations related to the terms. At this point, the problem of being misunderstood appears and of conducting a discussion that can not solve problems, but widen the gap between the positions.⁴¹



This word cloud represents the frequency of certain words used by Postgraduates to define SynBio. Neither the words natural, living organism nor artificial, unnatural, machine or other charged terms were used. The definition is curling around process, make and biology. So they understand SynBio mostly as a process within biology or rather something biological is made. (© British Columbia iGEM team)

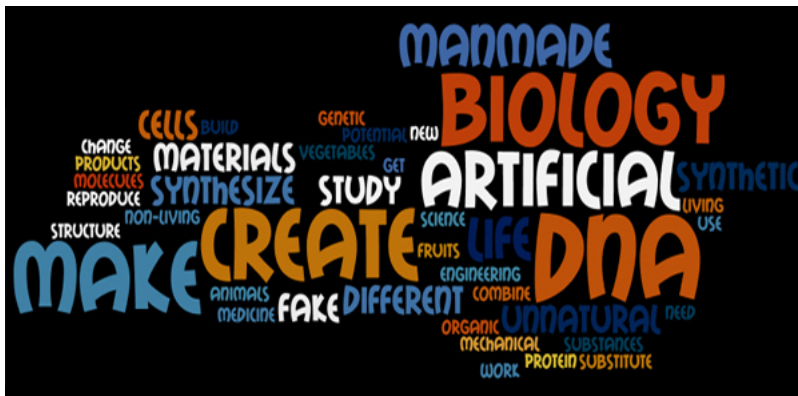
The word of the engineering students seems to be an intersection between those of the postgraduates and arts/commerce students. It entails more scientific terms and methods but picks up terms like artificial or create on a lower level, too. (© British Columbia iGEM team)



Such a development appears in the word clouds generate by the British Columbia iGEM team impressively (see figure 3 on page 16). In both clouds the definition of SynBio curls around different terms, whereby the difference between a group who has the insight and a group who have not the knowledge becomes evident. While the postgraduates pursue a more methodical and scientific definition, the arts and commerce students associate more the terms discussed in the paper at hand: artificial, man-made, create, synthetic, unnatural, cells, synthesis and so on. Such groups have, following the considerations above, a different understanding of SynBio and would judge to related problems in different ways.

This will, of course, effect also moral judgments like “‘artificial cells’ are good or evil”. For scientists, the terms mean something different than for the rest of the society. The terms of both groups will refer to the things scientists produce, but the society will have a misguided understanding founded in the inappropriate use by scientists and the media. Moral judgments

⁴¹The problem of the discursive mediation of knowledge between two groups with different levels of information can be impressively studied by Grice who elaborated the difference between speaker-meaning and sentence-meaning from an social psychological point of view. For an approach see LYCAN: *Language*, 100-114.



WORD CLOUD made of Definitions of Synthetic Biology by Arts and Commerce Students

The definition of the art and commerce students is nearly opposite to the one of the postgraduates. They use a lot of charged terms that were analyzed in the paper at hand. For them SynBio is about creating, artificiality and so on. (© British Columbia iGEM team)

Figure 3: Word clouds by the British Columbia iGEM team

could not be shared meaningfully between scientists (defined as those who have the insight) and the rest. Thus, the communication-problem causes a confusion who makes people judge about things that they misunderstand due to inappropriate terminologies.

4.2 From Is to Ought

Another ethical issue rise from terms which refer to entities changing the ontological state. Through the use of novel methods and approaches one could argue that several cells produced by SynBiologists are “new”. Instead of considering this kind of change, the opin

4.3 Emotional terms

Finally, we consider some basic problems related to the terms. No matter how the previous problems were settled, all technique-related terms pose problems and should be reviewed. SynBio is about to raise social interests and will be center of attention in the course of further research and new knowledge.⁴² Especially since the relation to genetic engineering and the perception of SynBio as an advancement of genetic engineering, SynBio will initiate a difficult and often emotional overcharged discussion. The terms and expressions are either highly metaphorical or emotionally charged, so that they will raise the people’s reservations and defensive demeanors. Not to fire the public opinion will be from an outstanding importance by reason of false associations or prejudice. But such prejudice or negative attitude is raised from the reviewed terms and it seems that they *have to* provoke rejection. Just a paradox like “living machine” seems to be made for provocation and affront the people and their views.

4.4 Any alternatives?

As an alternative especially for the umbrella term “artificial cell”, I want to introduce the term “biofact” devised by Karafyllis to clarify that also organisms could be high-grade artificial through the methods of modern biotechnology like genetic engineering. Biofact is a compound consisting of the Greek word for life (“bios”) and artifact. “Biofact” means in this way an biological or organic entity profoundly influenced by humans. The term was introduced to name the products of modern biotechnology who differ in a qualitative respect from hitherto

⁴²One just have to think about the media’s interest in Craig Venter’s bacteria.

existing modified organisms like domesticated or cultured animals. The advantage would be not to intermingle the basic concepts nature and culture in an emotional or affronting way so that the term is fitting better for a high-grade emotional discussion and do not imply serious ethical problems. However one turns the issue, one seems to be clear: SynBio has a veritable demand on serious terms.⁴³

5 Conclusion

The paper had have the aim to clarify central terms of SynBio which are often used to mediate the aims and methods of that field to the society. So, they are from an outstanding importance, because they influence the perception of SynBio within the society.

To be able to judge the selected terms, the following analytical framework was chosen: at first, the refernce of the terms was examined to identify the entities they designate. Afterwards, the meaning and the related associations were analysed to figure out what kind of concepts and ideas were related to the terms. At this juncture, it was important to comprhnd if the entity designated by the term fits the concepts the term implies. If that was not the case, the term was wrong and all its use generates just nonsense. This is even more important if we consider the importance of terms for our understanding of the world. The concepts by dint of those we are able to understand the world are learned in a linguistic and social context. If we do not have appropriate terms, we are not able to communicate ourselves or to understand the world we are living in.

Firstly, the "artificial cell" was examined, but respective its ambiguity, the analysis focused on several other terms ("protocell", "minimal cell" and "synthetic cell") often related to "artificial cell" and used as synonym. All terms refer to different methodical approaches applied by SynBiologists to produce new entities. A "protocell" is an entity generated by the bottom-up approach, where inorganic elements shall be combined to produce an hitherto unknown organism. A "minimal cell" is an existing organism which shall be reduced to its lowest possible level, i. e. all elements within the cell shall be remove so that the cell is barely alive. A "synthetic cell" is a cell, whose DNA or genome was synthesized, i. e. newly combined from a subcellular level by chemistry. Based upon these considerations, an "artificial cell" is a umbrella term to name all cells produced by the methods of SynBio. The meaning of all terms differ in several points, but all have in common the intermingle of the concepts nature and technology. Moreover, the implications concerning the "creation" of new entities or even species could be outlined. Here, it was possible to clarify wherein the vagueness of the term "artificial cell" lays. It denote to "artificially made" as well as "being artificial". Two meanings which differ in their claim greatly and which cause confusion to those who do not know if the cell is just artificially made or if the cell is artificial.

Secondly, the term "living machine" was analysed. He had much in common with "artificial cell" but differed in several points from "artificial cell". The term refers to a cell, which could

⁴³Another alternative was brought into discussion by Boldt. He recommend the expression "animunculus" as a transfer of the well-known "homunculus" popularized by Goethe within his magnum opus "Faust" to specify modern issues related to word-finding difficulties. The term goes back to the classic latin age where it was used as a diminutive for homo and means thus ›little human‹. See BOLDT/MÜLLER/MAIO: *Analyse*, 58.

be made by different approaches (bottom-up or top-down). A cell who could be used as a kind of "chassis" was customized with "BioBricks" who are defined and standardized DNA sequences with certain functions. The mechanic usage and the application for human needs are both crucial to this approach. The phrase itself offends our intuitions and associations at least as "artificial cells", it is still mixing not only concepts of nature and culture but implies also the extensive availability of cells for the human needs.

The arising problems are manifold, but the three important from an ethical point of view were discussed. First, the mixture of concepts could lead to a situation where no meaningful discussion between scientists, who know what kind of organisms they produce, and the society, who do not have such an insight, will be possible. The society could have a misguided understanding of the terms due to the use of inappropriate terms by scientists and the media. All arguments and ethical judgements will be inappropriate because scientists associated something other as the rest by the terms. The semantic confusion can, thus, cause an ethical confusion. Second, the terms could abet the establishing of a "two-class biology" because they indicate to name novel entities which are settled between nature and technology. But as long as nobody invents a working "protocell", the moral state of an entity will not be affected by a high-grade artificial process. Third, the emotional charged terms could make the arising societal debate difficult. They could evoke negative associations which will bring people to reject SynBio even if they do not know what topics SynBio deals with.

Such a development will be even worse respective the dependency of SynBio on the acceptance of the society as well as the government. SynBio depend on the funding from the public purse. Besides the epistemic and ethical problems connected to the terms, it should be in its own interest to rethink the terms used to communicate their aims and methods.

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