Explaining life

Synthetic biology and non-scientific understandings of life

Anna Deplazes-Zemp & Nikola Biller-Andorno

The question ‘what is life?’ has puzzled people for millennia. Although the term ‘life’ is used daily as if it were clearly and unequivocally defined, there are many scientific and non-scientific understandings of life. Journalists have been using the effect that can be produced by combining the enigmatic word ‘life’ with technical terms such as ‘engineering’ or ‘artificiality’ [1,2] in their coverage of the life sciences during the second half of the twentieth century. These buzzwords have been applied to a particularly high degree in the context of synthetic biology. From the outset, scientific developments in this area have been accompanied by reports pointing out that it would lead to ‘synthetic life’. Headlines such as “Life 2.0” [3], “Engineering life: building a FAB for biology” [4] or “Synthetic life” [5] illustrate this tendency—such titles would not produce the same effect, if ‘life’ was purely a scientific concept.

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The understandings of life that we discuss here—this is not an exhaustive overview—can be divided roughly into three main groups: scientific, philosophical and religious. However, these are not three clearly separable and uniform categories; they overlap with one another and each category comprises subcategories that may not have much in common with others. In this sense, we have chosen pronounced positions that represent this wide range, rather than a representative selection of the most prevalent views. We limit ourselves to positions that deal with life as what is shared by all living organisms and exclude positions that focus on life in the sense of human biography.

When biologists address the question of defining life, they usually refer to a list of characteristics that include metabolism, evolution, homeostasis, constant transformation, genetic information and so on [6–8]. In addition to these checklists, some scientists have also attempted to develop more comprehensive theories about life. The physicist Erwin Schrödinger, for instance, based his definition on the observation of a “natural tendency of things to go over into disorder”, as explained by the entropy principle [9]. He argued that living organisms escape the destiny of disordered equilibrium because they are able to take up ‘orderliness’ from their environment [9]. Alternatively, Chilean biologists Humberto Maturana and Francisco Varela developed the autopoiesis theory, which defines living organisms as self-maintaining and self-producing systems [10].

To explain life has been an aim of philosophers since ancient times. They have approached the problem from different sides, focused on different aspects of life and developed different theories. Given this variety, we have selected three aspects of life in which philosophers are interested.

Several ontological and phenomenological theories share the notion that life is not characterized by biological processes, but by subjectivity or a self, which is related to the individual life history of a living organism [11,12]. Phenomenologists hold that life can only be understood fully from an ‘insider’ perspective. Whenever we ponder about life, we need to start from our own experience as living beings to understand the subjectivity related to life [13,14].

The philosopher Marianne Schark points out that the specific aspect of living beings is that they can only persist through constant change of material. They are ‘objects

in flux’, which constantly exchange matter with their environment and thereby modify their composition. Nonetheless, they have a clear and stable boundary and the material is incorporated systematically into an organized body [12,15].

Other philosophers—so-called ‘biocentrists’—attest that all living organisms have moral standing and thus deserve moral consideration [16]. The reason for their moral standing is that they have a ‘good of their own’ [17]; living organisms can flourish if nurtured properly; and they can be harmed [18]. As beneficence and non-maleficence are central to ethics, we ought to, if possible, avoid inflicting harm on any organism. Most biocentrists are so-called ‘non-egalitarian biocentrists’, which is to say that they argue that although all living organisms deserve moral consideration, they do not have equal moral significance [19]. This means that, for instance, vertebrates with the capacity to feel pain would deserve more moral consideration than would bacteria or plants.

In addition to scientific and philosophical explanations, there are also religious views about life, which usually refer to a supernatural source of explanation such as a divine creator or an eternal law. As examples of religious views, we focus on two groups: monotheistic religions and reincarnation-based religions.

According to the main monotheistic religions, God created the world and all living organisms. This is the view of the three Abrahamic religions [20] and of certain indigenous religions, such as the religion of the Oromo in Ethiopia [21,22]. Although humans have a special status in God’s cosmos—at least according to many interpretations—they also ought to respect God’s creation and deal with it responsibly.

The belief in rebirth is found among several eastern religions such as Hinduism and Buddhism. However, regarding the concept of life, Jainism is of particular interest. Jainism entails its own taxonomy of life forms, based on the five senses: touch, taste, smell, sight and hearing. Interestingly, Jains hold that stone, earth, water and fire are life forms of the lowest order. When a body dies, its eternal soul—its so-called ‘jiva’—enters a new body depending on the karma accrued during the previous lifetime. In the Jaina worldview, karma is matter that can be positive or negative and binds to the ‘jiva’. To minimize the accumulation of negative karma, Jains practice non-violence towards all forms of life [23,24].

These understandings of life are grounded on fundamentally different world-views and address different questions about life: how does life function? How do we recognize life? What is the value of life? What is the meaning of life? How do we perceive life? The responses to these questions explain different aspects of life: biological explanations of the molecules and processes of living organisms; ontological explanations that aim to capture the essence or the abstract idea of life; phenomenological explanations for how humans perceive their own existence and that of other beings; religious explanations of non-material aspects of life such as a soul; and axiological explanations about the value of living organisms.

Most of the positions described above combine more than one of these types of explanation, and within most types there can be several explanations. There are, for example, different religious explanations of life. By explaining different aspects of life, the various theories set different priorities, but in most cases they are compatible with alternative explanations, which focus on other aspects.

Against the background of these understandings of life, we are confronted with new approaches to explaining life, such as synthetic biology or artificial life (ALife; [25]). Scientists in these fields maintain that we will understand life once we are able to build living entities. In the following, we focus on synthetic biology; however, the virtual approaches in ALife might raise another set of fascinating questions about life, which cannot be addressed here.

Synthetic biologists want to contribute to the general understanding of life [26] starting from their own idea of life. Interestingly—and characteristically for synthetic biology as a heterogeneous discipline [27]—different branches of synthetic biology start from different models of living organisms. These differences become particularly evident when comparing the bioengineering branch with the protocell branch. Although scientists from both branches aim to design and produce new life forms, they have different visions of how such synthetic life forms should be conceived.

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For bioengineers, synthetic life forms are characterized by their hierarchical organization based on standardized elements. The metabolic pathways and regulatory circuits in these organisms rest to a large extent on a rational human design. Bioengineers explain life by using the analogy of computers or other machines [28]. By contrast, researchers in protocell synthetic biology envisage a synthetic life form as a chemically synthesized lipid vesicle, containing the components that are required to fulfil the minimal criteria for life. For some protocell scientists, such minimal cells would need to be autopoietic, as defined by Maturana and Varela [29,30].

Synthetic biology with its ambitious aims of contributing to the understanding of life by ‘producing life’ piques the interest of many people. How each individual assesses synthetic biology depends on his or her underlying understanding of life. This includes the question of whether life can be considered artificial or synthetic in the first place. Critics of the notion that life could be synthetic raise objections along the following lines: although it would theoretically be possible to produce life, it is for the time being impossible, because life is too complex and humans are not yet able to produce it; life emerges under certain conditions, but it cannot be directly produced; life is a property or an activity, and it is questionable whether properties or activities—rather than objects—can be produced; it is impossible for humans to

create life because God creates life; and it is impossible to produce life because life is eternal and therefore cannot be created.

The first reason seems to be generally accepted and is based on empirical evidence. The second reason suggests that synthetic biologists can provide the preconditions for life to emerge in their products but they cannot produce life itself. The third reason refers to a related idea, namely that activities or properties, such as life, cannot be produced directly but that the entity conducting an activity or having the property is a human product. Reason four could be raised by those who believe in a divine creator, whilst the last reason could come up in the context of Jainism, according to which the ‘jivas’ have never been created but are eternal.

To assert that life *per se* cannot be synthesized does not amount to claiming that the products of synthetic biology are not alive, it simply calls into question where ‘life’ in these entities ‘came from’. Most synthetic biologists produce new organisms by introducing genetic elements into existing living organisms. In these cases, we might argue that life was already present in the source organisms and is thus not synthetically produced. But even in the case of living protocells, some of the arguments above could still be invoked to deny that life in these entities would be a human product.

When we speak of synthetic organisms or synthetic life forms, it thus seems important to keep in mind which aspect of life we describe. An entity might be considered synthetic concerning its material origin or design, but we may assert that synthetic biologists have not produced other aspects such as its meaning or value. It could be argued that it is not appropriate to speak of synthetic life at all, as even if an organism is synthetic, it still lives and carries out its life in the same manner as a ‘natural’ organism.

The underlying understanding of life might also influence the ethical assessment of the aims and claims made by synthetic biologists. Here we can distinguish between three types of ethical concern: risk-related concern, concern for the well-being of the synthetic organism and concern about the attitude towards life.

Worries about misuse or unintended consequences of synthetic life forms for humans, other living organisms and the environment are examples of the first category.

Because of a general agreement that risks should be avoided, these concerns are the least controversial. Nevertheless, there may be disagreement about the level of risk that is acceptable. Worries of the second type are usually expressed by biocentrists, according to whom all living organisms deserve moral consideration. On these grounds, it can be argued that synthetic biologists have moral responsibilities towards the organisms they synthesize [16,18]. The third type of concern comprises, for instance, worries that the manner of speaking about life in synthetic biology might not warrant due respect for life, or that the assertion that life could be produced synthetically would be presumptuous or hubris. These concerns are related to understandings of life according to which living organisms do not necessarily have a moral standing but nevertheless demand a certain respect, on the basis of, for example, their autonomous and special existence or as a creation of God.

It is important that synthetic biologists are aware of other explanations of life. One reason is that this awareness is a precondition for a genuine engagement with a broader spectrum of moral concerns; another reason is that synthetic biologists may profit from other understandings of life. Most importantly, awareness of other explanations of life will enable scientists and engineers to integrate their findings in a wider context. In the following, these three reasons are established in further detail.

As pointed out above, certain views on life may raise moral concerns about the aims and claims of synthetic biologists. It is advisable that synthetic biologists are aware of these concerns to avoid making imprudent statements. An attitude that takes moral concerns seriously would be the first step towards a responsible way of conducting research. Synthetic biologists themselves may also benefit from such an approach

because if they can reassure the public about their open and concerned attitude, it might prevent a back-lash against this emerging biotechnology.

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Moreover, synthetic biologists are well advised to be aware of other understandings of life because of the usefulness of these alternative views. As an interdisciplinary field, synthetic biology has previously profited from the combination of the metabolism- and genome-focused understandings of life in biology, with an engineering-driven view of living organisms as hierarchically structured machines.

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Moreover, there might be relevant aspects of living organisms that could be overlooked if alternative views were ignored. Philosophers, who point to subjectivity, autonomy or a self in living organisms, emphasize that living organisms might act as individuals in unpredicted ways. Related to this, living organisms, including synthetic ones, have the potential to evolve in unexpected directions. These ideas point to an important difference between living organisms and machines, which should be kept in mind when dealing with products of synthetic biology.

Ultimately, synthetic biologists ought to be aware of other explanations of life because this enables them to understand the limits of the explanatory power of their own models. This field is expected to provide important findings about the composition, function and evolutionary origin of living organisms. However, as discussed above, there are many other questions about life, which cannot be addressed by the methods of synthetic biology or science in general. Science alone cannot tell us anything about the meaning or value of life, nor can it explain the subjective perception of our own lives, because these aspects are not detectable by scientific methods. The claim that there are no metaphysical aspects to life may itself be a metaphysical statement [14]. As Gregory Kaebnick put it: “creating a synthetic cell does not show [that there is no such thing as a spiritual property ‘Life’] any more than the creation of a human being through somatic cell nuclear transfer—cloning—would show that humans do not have souls” [31]. Therefore, we do not agree with authors who claim for instance that synthetic biology could demonstrate that “mystery has been definitively banished from the realm of organisms” [32] or that the production of a bacterium with a synthetic genome would herald the “end of vitalism” [33].

Of course, the ideas of synthetic biology are in strict contradiction with

classical vitalism—a theory that assumes that biological processes are driven by a non-physicochemical ‘life force’. As vitalists make claims about the scientific aspects of life, they can be proven wrong by scientific methods. However, the claim that synthetic biology will lead to the end of vitalism seems to go beyond refuting the ‘scientific’ claims of vitalism to bring “to an end the debate about the nature of life that has lasted thousands of years” [33]. Synthetic biology, even with the production of a living protocell, could not bring an end to this debate. Those who argue that life is more than merely a scientific phenomenon would say that a synthetic organism, if it is considered to be alive, also has features that cannot be captured by the life sciences. For Jains the body of a synthetic organism carries a *jiva*. Biocentrists argue that a synthetic organism has moral value [16,18], and other philosophers claim that a synthetic organism is an autonomous system with subjectivity and a self. For those who believe that some aspects of life come from God, there is no reason why God should not have contributed to life in a synthetic organism [18].

To illustrate these different ways of explaining life, an analogy with artwork would be useful. Scientists could explain the composition of a painting in detail, by analysing the distribution of the colours and the thickness of the paint. They may analyse in which order the colours were applied or from which angle and with how much force the brush was used. But this analysis would tell us nothing about the topic of the painting, the effect that it has on the viewer, the meaning that it may convey or its aesthetic value. An art lover might be impressed by the detailed scientific explanation of the composition and the origin of his or her favourite piece of art, but such an explanation would not address those aspects of the painting that he or she considers most important. Analogously, those who espouse certain views on life might accept the findings of synthetic biology as accurate scientific descriptions of living organisms, but for them, these descriptions do not address those aspects that they consider most relevant and important in living organisms.

We advocate that synthetic biologists ought to be aware of other explanations of life and understand the limits of the

explanatory power of their own scientific models. At the same time, synthetic biology provides a new facet to the plethora of ideas of life and important new insights. The production-oriented approach might be helpful to further our understanding of the necessary and sufficient material, structural and organizational components of living organisms. Moreover, such an approach will increase our knowledge about regulatory mechanisms, metabolic pathways and their interactions. Synthetic biologists of the protocell branch have, for instance, showed that the criterion of autopoiesis may not be sufficient to characterize living entities, as there are non-living vesicles that also fulfil this criterion [34]. Researchers who work with nucleic acids that do not occur in nature have compared their unnatural molecules with DNA and RNA, and have thus learned much about the natural nucleic acids [35].

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Ultimately, synthetic biology might also raise interesting questions for philosophers or religions to answer. Examples include questions of whether life can be artificial, under which conditions we would call it artificial and whether its artificiality would have any impact on its moral status. Therefore, engaging in a dialogue between the different positions on life is mutually enriching and fascinating for all involved parties.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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