**Synthetic Biology, Definitions of Life, and Vitalism**

In the previous talks in this series, you have heard about the history of vitalism from Charles Wolfe, as well as its future from Cécilia Bognon. Today, I will answer the following question: To what extent could results from synthetic biology have any bearing on our attempts to define life, and on vitalism?

Imagine a synthetic biologist answering this question. Her answer could very well look something like the following: ‘Clearly, what synthetic biologists are going to find out in a few years is going to be relevant for our view of both the definition of life as well as vitalism. Imagine, for example, that we find out that reaction X and molecule Y *must* be present in any minimal cell for that cell to behave in a typically life-like manner. In other words, whatever we try, without reaction X and molecule Y, none of the synthetic cells we have made begin to grow and divide. Based on our experiments, it seems that reaction X and molecule Y are some of the *necessary* criteria for something to count as alive. The idea is that, as more and more research is being done, more and more criteria for cellular life are discovered and put on the list, until, at some point, we are in possession of the final list of necessary and sufficient criteria for something to count as alive. With that list, any potentially living thing – for instance, some bacteria-like, microscopic entity we found on Mars – can be put either with the living things (such plants, humans, and fungi), or with the lifeless things (such as rocks, chairs, and refrigerators). Additionally, given that the final list of criteria is complete and contains only the sorts of criteria coming from the natural sciences – so criteria about molecules, reactions, forces, and what not – vitalism, or the idea that there is more to life than what the natural sciences can show us, will once and for all be proven incorrect.’

This will be the kind of story I suspect many scientists would tell. Call it the ‘standard story’.

I think the standard story is wrong and uninteresting. My reasoning is based on rejecting a particular part of this story, namely the idea that there is such a thing as ‘*the* definition of life’, at least the sort of definition that is required for the standard story to be correct and interesting.

Before going into that objection, it is useful to start with a nowadays quite popular but failing objection to the standard story. This objection, or rather group of objections, is based on the following historical observation about definitions of life: We have been trying to define life, in various different ways, for almost two millennia, yet no generally agreed upon definition is anywhere in sight. Even with the success of molecular biology in the past seventy years, there are still as many definitions of life as there are biologists trying to define it. Certainly, biologists agree on many paradigmatic examples of life but they do not agree on which sorts of characteristics make them alive other than our commonsensical observations that they all grow, move, and reproduce in some way.

This history of definitions of life has made some philosophers and scientists pessimistic about our prospects of ever finding the definition of life. They have adopted a position that we can all ‘definitional pessimism’. The definitional pessimists argue that attempts to define life are premature, futile, useless, arbitrary or even harmful to scientific progress. Nobel Prize laureate Jack Szostak, for instance, has argued that trying to define life is like trying to define the point at which orange turns into red. People may have different opinions on where this point can be found but these differences are largely uninteresting. In the case of definitions of life, scientists may have different definitions, but these are not important for a field primarily devoted to a biological, chemical, and physical understanding of the processes inside living beings. For someone like Jack Szostak, the standard story is not so much wrong as it is beside the point. What we are interested in is the actual science, not the definitions that might come out of it.

There is no room in the present lecture to delve into the numerous and varied arguments presented by the definitional pessimists, but suffice it to say that these arguments are usually based on the right intuitions but ultimately lead to the wrong conclusions. Their pessimism about us ever finding *the* definition of life is justified, but they are wrong to think that any attempt to define life is automatically worthless. The definitional pessimists have, I think, failed to see that what is wrong with definitions of life is not our lack of success, but our insistence on finding the One, True Definition of Life for All Eternity. Once we let go of that aim, a continued discussion on definitions of life can be shown to be very fruitful.

There are good reasons to let go of this aim. The definition of life is a kind of definition philosophers usually call a ‘descriptive definition’. A descriptive definition is a list of necessary and sufficient criteria specifying what makes a particular thing into that particular kind of thing, without simply exclaiming “let the definition of *x* be that…”. Formulated differently, a descriptive definition specifies precisely the conditions of rightful application of a particular kind term. Thus, when it comes to the kind term ‘life’, a definition of life is a precise specification of when something should be called alive. It clearly separates all cases of life from all cases of non-life.

There are at least two problems with descriptive definitions. The first problem is that there exists a circular relationship between a descriptive definition and the examples on which it is based. If you set out to define life, you will need examples to base your definition on. Yet, in order to identify the right examples you will need a definition to guide you. Where do you start and how would you know whether it’s the right place to start? You might think that we can start out with a loose definition, find some examples based on this loose definition, improve our definition, and then find examples which suit our improved definition, *ad infinitum*, but that is not a straightforward solution. For one thing, it would be very difficult to know when this process is done. It is unclear when our list has been refined enough for the New York Times to run the headline: “Definition of life found!”

But even if this problem could be solved, there is another problem. Definitions, of anything, are extremely difficult to come by. A simple example can show us why. Imagine we have to explain to someone what makes a dachshund into a dachshund (also known as a ‘sausage dog’ or ‘teckel’). We describe it first as ‘a small hound with a long body and very short legs’, only to find out that someone unfamiliar with the dachshund could easily confuse our description with the description of a basset hound. So, to convey what we mean by dachshund we try to be more specific. We collect a few paradigmatic examples of dachshunds and derive several criteria from them. We specify their variety of colour, the shape or their snout, the size of their ears, and so on and so forth. However, at no point do we find a truly common characteristic amongst all dachshunds. Their colour varies widely, as well as the exact shape of their snouts and the sizes of their ears. Frustratingly, some of the dogs we examine look as closely related to basset hounds as they do to proper dachshunds. Where should these borderline cases go: with the dachshunds, the basset hounds, or yet another category? According to American philosopher Max Black, from whom I borrowed this example, the same problems that apply to defining dachshunds apply to all attempts at formulating strict descriptive definitions. According to Black: (start quote) “the demand for a necessary and sufficient criterion [or criteria] is too exacting” because “there is no sharp line between the ‘border-line region’ and the field of clear application” (end quote). So, in the case of life, whatever list of criteria we can come up with, there are going to be counterexamples or examples of entities that are not very clearly alive, nor very clearly lifeless – you can think of viruses.

I think the standard story cannot overcome this problem. Whatever new things we are going to learn about life from synthetic biology, it will never give us *the* final, strict, descriptive definition of life. At best, what we can have is a generally agreed upon description of life; one that can count on majority support but can always be replaced with yet another different description. If a strict, descriptive definition of life is what we are after, then synthetic biology and any results it may bring are completely irrelevant simply because no such definition exists.

This is where we have to be careful not to make the same mistake as the definitional pessimists have made. It may seem that if *the* definition of life can never be found, then perhaps we should stop trying to define life altogether. But that isn’t true. Even if some goal is ultimately unobtainable the attempt to attain that goal might still be valuable. Even if discussions on definitions of life might not bring us the One, True Definition of Life for All Eternity these discussions might still be useful in a different kind of way.

One could argue, for example, that our continuing discussions about definitions of life have a place in science if they are somehow conducive to scientific progress. Broadly speaking, there are two major conceptions of what constitutes scientific progress: a realist and a pragmatist conception. On the realist conception of scientific progress, the most important metric for progress is truth. Scientific progress is made if and only if our explanations, models, and theories are shown to be True with a capital T, and if not True, then at least they should be converging onto truth. This means that every new generation of theories should be a bit closer to the truth than the previous one. On the pragmatist conception of scientific progress, the most important metric for progress is use. Scientific progress is made if and only if our explanations, models, and theories provide us with more control and predictive power. To give an example, when alchemical theories based on the classical elements (fire, water, air and earth) were replaced with chemical theories about atoms, our capacities to turn one kind of substance into another greatly increased. The pragmatist would call that scientific progress because it has given us more control, whereas the realist would call that scientific progress because the atomic theory is (more) true.

My aim is not to argue in favour of one of these conceptions over the other but, instead, I want to show how definitions of life can be conducive to scientific progress in both the realist and the pragmatist sense. This would show that even if we can never have *the* definition of life, that does not mean we should stop talking about the definition of life altogether.

What would the realist and pragmatist need in order for definitions of life to have a place in science? Well, for the realist, our explicit and implicit definitions of life should help provide us with increasingly true explanations, models, and theories. This can be entirely indirect. If some discussion on the definition of life leads to a research programme that has as its result a novel, better theory of some important part of living things, then having those discussions about the definition of life is conducive to scientific progress in the realist sense. For the pragmatist, our definitions of life should help provide us with more control and predictive power. If our discussions on the definition of life lead to some research programme the gives us more control over some parts of living things, or better predictive capabilities when it comes to the behaviour of those things, then these discussions are conducive to scientific progress in the pragmatist sense.

Examples of how definitions of life are conducive to scientific progress are easy to come by. The previous part of this lecture was full of them. To pick out just one example, let’s consider again the efforts of researchers at the J. Craig Venter Institute (JCVI) to create a top-down minimal cell. They have divided the mycoplasma genome into ‘essential’ and ‘non-essential’ genes, but what makes a gene essential? The answer to this question betrays the importance of definitions of life in guiding this kind of research. Genes are essential if and only if they are necessary for growth and duplication in a laboratory environment. Genes that would otherwise be essential in the full evolutionary and environmental context of mycoplasma growth and development are no longer considered essential because they are not important for growth and division within a laboratory. There are no temperature fluctuations, droughts, food shortages, phages, and a host of other threats to worry about inside the safety of the scientist’s incubator. At the J. Craig Venter Institute, Growth and duplication have become the most important characteristics of life guiding minimal genome research. When we note again that 17% of the genes of one of the latest iterations of the minimal cell have an as of yet unknown function, it is easy to see how research into what these genes do can bring us both truth, and the capacity for prediction and control. Once we know what these genes do, we can see which other organisms have these genes and what they contribute to their functioning. At the same time, we might also be able to find some new drug that interferes with a particular gene, giving us more control over fighting mycoplasma infections, which occur regularly in humans and are difficult to treat. If our discussions on definitions of life have the potential to lead to these sorts of results, who cares what the right definition is?

To sum up the story so far, the standard story about the relationship between synthetic biology and the definition of life is uninteresting because there is no such thing as *the* definition of life. Our continued attempts to define life serve a far more useful purpose, namely our ever increasing capacity for prediction and control through scientific progress. But what does this mean for vitalism?

However, as the previous two speakers have also explained, there are different varieties of vitalism. I will not repeat their story here, but summing up their view we can say that the term ‘vitalism’ has been used throughout history to refer to different scientific and philosophical projects. The interpretation of vitalism as some sort of ‘magic thinking’ about life may be what most of us have in mind nowadays, but it is not the only option. This means that even if there is no reason to support classical vitalism this does not mean that vitalism is wrong across the board. At the same time, whatever variety of vitalism one would want to support, it is clear that it has to do more than classical vitalism did. To be relevant to our understanding of life *today*, it is not enough that vitalism fulfilled some important historical, heuristic function in shaping the language we now use to describe life. It has to provide us with some new view of life that is not already available to the modern natural sciences and that somehow enhances our understanding of life.

Currently, I am unaware of any form of vitalism which meets this challenge. Some indications of what this sort of vitalism might look like have been put forward, but they remain rather vague. Bognon and Wolfe, for instance, argue that what they call ‘functional vitalism’ could be a plausible view of life. This sort of vitalism should (start quote) “emphasize the complexities of living processes, their subtle organization and self-organization.” (end quote) Moreover, Bognon and Wolfe claim that by providing synthetic biologists with thick conceptions of terms such ‘complexity’ and ‘self-organization’, vitalism can help synthetic biologists achieve their own goals. As things stand, however, scientists have long since been using this precise terminology without the need for a broader vitalist framework. In the work of renowned chemists such as John Sutherland, Jack Szostak, and Lee Cronin, concepts such as ‘complexity’, ‘self-organization’, ‘auto-catalytic cycles’ and the like are used and discussed extensively within the context of origin of life research. If a new, functional kind of vitalism is to be relevant, then it has to be shown that it can contribute to these kinds of discussions today as much as it may have in the past. It has to be shown that vitalism is conducive to some worthwhile scientific aim. And, while this is easy to show for definitions of life, I think this has yet to be shown for vitalism. Thank you.