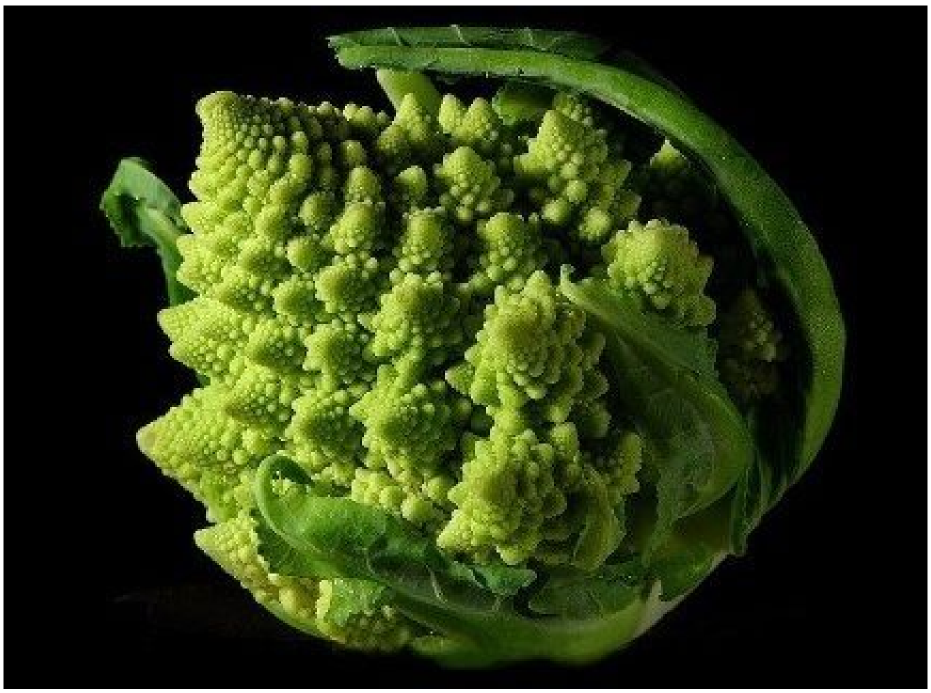
What are synthetic biologists doing to plants, and what are plants doing to synthetic biology?

September 2 2016, by Dominic Berry



Credit: PLOS Blogs

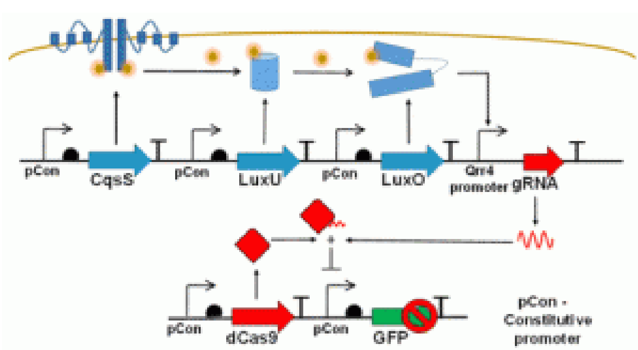
What are synthetic biologists doing to plants, and what are plants doing to synthetic biology? This question frames a series of laboratory observations that I am pursuing across the UK as part of the Engineering Life project, which is dedicated to exploring what it might mean to engineer biology. I contribute to the project through a focus on plant scientists and my training in the history and philosophy of science. For plant scientists the engineering of biology can take many forms not all of which are captured by the category 'synthetic biology'. Scientists that aim to create modified organisms are more inclined to refer to themselves as the latter, while other plant scientists will emphasise an integration of biological work with methods or techniques from engineering without adopting the identity of synthetic biologist. Accordingly, different legacies in the biosciences (from molecular biology to biomimetics) can be drawn upon depending on the features of the project at hand. These category and naming problems are all part of a larger set of questions that social and natural scientists continue to explore together. For the purposes of this post the distinctions between synthetic biology and the broader engineering of biology do not matter greatly, so I will simply refer to synthetic biology throughout.

It might seem strange that a historian is focused so closely on the present. However, I am not alone, and one recent author has picked out projects that suggest it is becoming a trend. This is only of interest for readers of the *PLOS Synbio* blog because it flags up that there are historians of science available for collaboration (hello!), and plenty of historical scholarship to draw upon to see your work in a new light, or rediscover forgotten research programs, or reconsider current practices, precisely as a recent *Nature* editorial emphasised for all sciences.

One of the main ways in which historians of science tackle their research is by focussing on certain disciplines and then recovering the lives of people who built careers in, around, and through them. Alternatively historians can analyse the potential legacies that a research field is drawing upon, precisely as some excellent historians and philosophers of science have already done in the context of synthetic biology. This post is about a complementary kind of historical work, one that anatomises contemporary science into chunks and then asks from where each has come. The three chunks that I cover here are 'experimental stuffs', 'commodities and services', and 'epistemological touchstones'. In the process we arrive at the historical anatomy of plant synthetic biology.

Experimental stuffs

I collect these 4 key examples under the playful category 'experimental stuffs' because there are a number of different ways in which we might want to define them. The list (PCR, fluorescent proteins, protoplasts, microscopy) is not meant to be exhaustive; instead, I have selected some of the most prominent features of the experimental life of synthetic biology. All four are used in different ways, often in combination with one another, and developing new uses for them is one way in which researchers can earn recognition. A focus on these experimental stuffs is a great way to highlight routes for historical research. Take fluorescent proteins for instance. They are everywhere! How did they get into practice, for what reasons, and what changes have they helped bring about? These are deeply interesting questions that we are provoked to ask by attending to contemporary science and breaking it down in this way. Likewise for equipment such as the electron microscope, and so on.



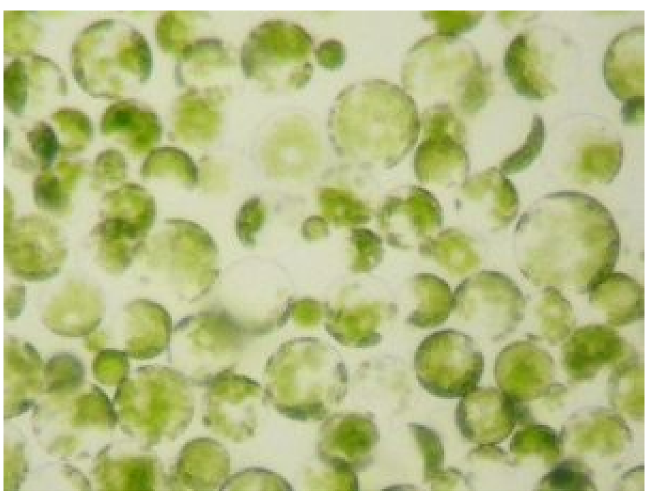
Credit: PLOS Blogs

Indeed, within the history, philosophy and social study of science there are a wide variety of ways in which we might want to investigate these experimental stuffs. For starters we might want to see them as technical objects (tools) that refine and define candidate epistemic objects (i.e. the ideas we have about what things exist and how they behave). To give an example, how do we decide when a particular construct (the name given to the complete DNA sequences that get incorporated into bacteria or plants) is well or poorly designed? The answer in the first instance is "after a series of more or less successful attempts at cloning it". But what if the cloning method used is not considered ideal for this construct? Perhaps some other method will have to be used, but in the process, by choosing to use a different kind of tool we also change the definition of what it means to be well designed (i.e. the kind of experimental object that can be expected to thrive). This perspective draws our attention to the interplay between technical equipment and novel biological phenomena, an interplay which is a fundamental feature of the biosciences and perhaps has been for some time.

Alternatively we might see experimental stuffs as part of a coherent system of practice. Over time, certain methods and techniques have been combined together as a reliable way to generate data, or new constructs, or for investigating organismal growth, and so on. Most recently we have been invited to see competency in these technologies and methods as part of a 'repertoire', whether that be the individual repertoire of a given researcher (singing, dancing, and making gels), or a broadly shared way of working (model organism research is offered as a prime example of this kind of repertoire). An exciting feature of this last approach is that it encourages greater collaboration between the philosophy of science and social study of the sciences, in particular through research using the category of 'platforms' (platform here meaning things standardised kits and pieces of equipment) and the ways of working that are afforded by widely shared tools and technologies.

The historian can take any one of these experimental stuffs and ask: What were its origins? When did it first begin to be used in this way? Who incorporated it into experimentation? What legacy travels with it? Has its use changed over time? How do the organismal products of synthetic biology relate to organisms outside of the lab, or in other kinds of biological laboratories and research stations?

We ask these questions because it will draw our attention to those people who might otherwise be overlooked (tool developers and builders) but whose efforts contribute a great deal to scientific practice and knowledge. We ask them because it means we avoid focusing on 'BIG PROFESSOR', and instead get a more rounded picture of life within and without the lab. And we ask them because following organisms or parts of organisms is often a more enlightening method than focusing on individuals or disciplines, especially when dealing with a historical subject whose edges seem to disappear as soon as we begin to define it more concretely. A historical investigation into the engineering of biology benefits from all of these questions and the approach of experimental stuffs.



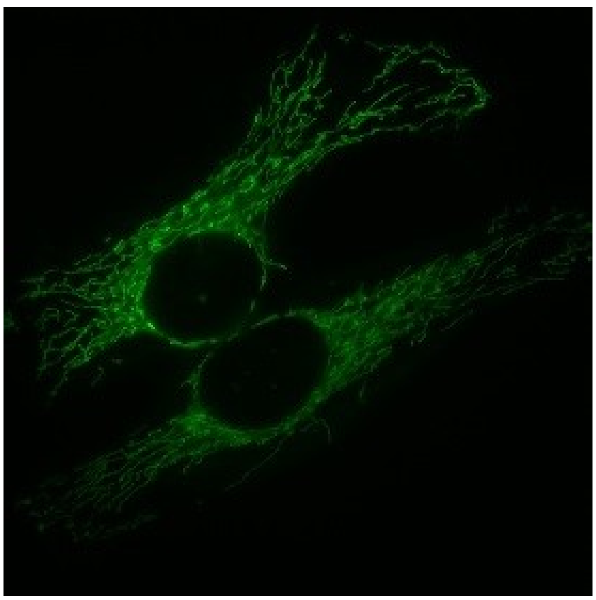
Protoplasts. Credit: Mnolf – Own work, CC BY-SA 3.0

Commodities and services

Science is a marketplace. All sorts of companies are keen to promote synthetic biology, and in the process, to promote their products to synthetic biologists. Some businesses are more essential than others to the working practices of synthetic biology, enzyme manufacturers and sequencing services being amongst the most significant. Expensive goods such as automation equipment can only go to those with sufficient resources, while other companies focus on improving established equipment, such as microscopes that offer new functions. We can think of all of these commodities entering the workspace and contributing to the identity of the laboratory, determining what roles particular laboratories can play within the wider scientific community, and what services the lab can supply. To be clear, to highlight the consumer component of the scientist is not necessarily to elevate that aspect above all others; we simply cannot overlook it. Plant scientists also gain access to different kinds of knowledge through their interactions with these companies, ranging from the practical (such as which company is best for sequencing and synthesis), to the more fundamental (such as tips and tricks about genes and enzymes).

The historian can ask: Where did these particular companies come from? What helped to build them in the first place? What are their interests (inside and outside of synthetic biology) which makes selling to these consumers/customers important? What kinds of relationship existed between bioscience suppliers and their markets in the past? How do novel commodities get accepted and adopted by scientific consumers? How have changes in public funding and institutional policies influenced the directions of research, creating demand for particular kinds of commodity and service?

We ask these questions because they force us to analyse elements of science that might otherwise seem too dull or even too obvious to be worth exploring beyond their surface. Some might even think that commercialisation is outside of science's meat and potatoes. But in actual fact the links between science and industry can be deeply revealing. We ask them because meaning can be found in every choice that gets made, whether that be which companies to invite to a conference, what tools to use in a lab, which supplier to rely on, etc. We ask them also to learn more about how the features of biological organisms continue to shape and influence the growth of companies serving bioscience and the industries referred to as biotechnological.



Fluorescent proteins in action. Credit: Simon Troeder – Own work, CC BY 4.0

Epistemological touchstones

This is perhaps the most difficult to write about. It can be hard and in many ways pointless to try to summarise the various different ideas and goals that go into synthetic biology. Any given synthetic biologist will have their own view on how immediate research questions or goals relate to broader arguments or questions in biology and engineering. Moreover, features of these different bodies of knowledge or ways of understanding plants (most readily referred to as different 'epistemologies') will be shared with researchers who do not identify as pursuing synthetic biology. For instance organism structure matters not only in the engineering of biology but also in developmental biology (a significance which has become acute at certain points in time, which explains why I have included a spandrel above). Describing some kind of distinctive research programme/thought style/way of knowing is fraught and easily undermined. Nevertheless our historical anatomy would be incomplete without something of a hint at what plant scientists appear to be pursuing with all that experimental stuff and the commodities/services discussed above. Here I offer three epistemological touchstones that appear significant in the context of my ongoing research.

Attending to the structure of plant cells and tissues is the first touchstone of synthetic biology that seems to be conserved across all the sites I have studied. Structure includes not only the shape of cells and tissues but also their material qualities (strength, flexibility, stickiness, porosity, etc.), and the arrangement of cells as a material population that grows/develops over time. This leads into the second touchstone, morphology. Linking knowledge about genomes with the eventual development of large scale plant features, or sometimes pursuing questions about morphology by looking at developed forms irrespective of genetics, are practices found across all the sites I have studied. In some cases this is so that they might be able to change and alter that morphology, in others as a way to better understand plant growth. Lastly, there is an emphasis on deploying microscopic technologies in novel ways. This might involve directing electron microscopes at plant structures usually considered too simple to bother capturing in such detail, or combining microscopy with fluorescence to track cell populations over time. Such work typically also involves making use of graphics software to produce detailed and idealised representations or models. Once again though, we can very easily ask how distinctive these features really are to just synthetic biology. I would tentatively suggest (very tentatively, as I have yet to draw any strong conclusions from research that is still ongoing) that it is perhaps the way that plant biological engineers package together these epistemological touchstones, and the arrangement of their epistemic goals and values, that gives the community definition. The epistemic goals of reproducibility, reliability, standardisation, etc. are appealed to and emphasised in synthetic biology as a way to distinguish the community. An easy way to begin thinking along these lines is to swap the question 'what do synthetic biologists do?' for the question 'what do synthetic biologists bother doing?'

The historian can ask: What traditions and legacies are these practitioners either building on or reacting against? How do these ideas cohere (or remain incoherent) for individuals and laboratories? Is a new way of understanding and investigating biology being created, and if so, where can we find evidence of it? Have biologists become increasingly concerned with controlling biological phenomena rather than understanding them? How does the desire to integrate engineering with biology sit within the long history of the establishment of biological science over the course of the 19th and 20th centuries?

We ask these questions because the history of science is sitting there up for grabs, available to whosoever wants to bring it to their aid (whether they have narrow private interests or broader ameliorative ones). At the same time they can force us to remember how recent it was that biological science came to have an identity of its own, with a status rivalling chemistry and physics, and whether or not this is now being undone. These questions can also act as guides through different research programmes, offering us new ways to understand the unfolding of science, entangled as it is with experimental stuffs, commodities and services, and epistemological touchstones.

I hope that knowing what an outside researcher sees when investigating the contemporary plant sciences also gives you fresh eyes. I have highlighted things that readers might want to spend time reflecting on, such as: what kinds of institutional arrangement they want to work in; what kind of laboratory or field space appeals to them and why; what ways of working appeal to them and why; and how the contemporary biosciences came to have this particular anatomy. You will all have opinions on these kinds of thing whether or not you realise it, so I hope to have given you new questions to ask, and perhaps even historically, philosophically, and sociologically informed people with whom to consider collaborating in the future.

More information: Nicola Williams. Irene Manton, Erwin Schrödinger and the Puzzle of Chromosome Structure, *Journal of the History of Biology* (2015). DOI: 10.1007/s10739-015-9424-5

Evelyn Fox Keller. Knowing As Making, Making As Knowing: The Many Lives of Synthetic Biology, *Biological Theory* (2009). DOI: 10.1162/BIOT_a_00005

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