HOUSE OF LORDS

Science and Technology Select Committee

Corrected oral evidence: Engineering biology

Tuesday 16 April 2024

10.10 am

Watch the meeting

Members present: Baroness Brown of Cambridge (The Chair); Lord Borwick; Lord Drayson; Lord Jamieson; Lord Lucas; Baroness Neuberger; Baroness Neville-Jones; Baroness Northover; Lord Rees of Ludlow; Viscount Stansgate; Lord Wei; Baroness Young of Old Scone.

Evidence Session No. 1 Heard in Public Questions 1 - 7

Witnesses

I: Professor Paul Freemont, Co-Director, Innovation and Knowledge Centre for Synthetic Biology (SynbiCITE); Dr Carolina Grandellis, Earlham Biofoundry Manager, Earlham Institute; Professor Susan Rosser, Co-Director, Edinburgh Genome Foundry.

USE OF THE TRANSCRIPT

1. This is a corrected transcript of evidence taken in public and webcast on www.parliamentlive.tv

Examination of witnesses

Professor Paul Freemont, Dr Carolina Grandellis and Professor Susan Rosser.

Q1 **The Chair:** I welcome the witnesses to the committee's first evidence session for its inquiry into engineering biology. We are very pleased to have you here this morning. This session is being broadcast on parliamentlive.tv and a full transcript is being taken, which will be made available to our witnesses shortly after the meeting for you to make any minor corrections.

If you think of anything that you did not get a chance to say, or you have any data that you think might be useful to us, we would be delighted for you to submit that to us as additional formal evidence after the session.

I will kick off. As the first panel in our new inquiry, could you briefly set out for us why engineering biology should be a priority for the UK? Starting with you, Professor Freemont, perhaps you could also say a bit about the major applications of engineering biology that you think have the most potential. It would be interesting if you could give any examples of ongoing projects in the UK, just to give a range of the kinds of projects that are being worked on. We are finding it hard to get our minds around the breadth of this subject. I will come to all of you. It would be really helpful if you could keep your remarks concise.

Professor Paul Freemont: Thank you very much for inviting me to give evidence today. It is much appreciated, and I hope that the information I give you will be useful.

I think that everyone realises that we are facing a rather existential problem: we have a very dramatic shift in climate, and issues around population growth and food. These are global problems, and there is a realisation around the world that a lot of countries are looking towards developing alternative solutions to address some of these issues, including moving away from a petrochemical-based economy to a more bio-based, circular and sustainable economy. Many countries have initiatives in that space. That is driven by the fact that a lot of countries have put down commitments to reach zero emissions very soon. I came back from Finland yesterday. Its target is 2035, and the UK's is 2050.

Engineering biology is not the only technology but it is very important and will allow us to address some of these issues, particularly in biomanufacturing and making all the products and goods we need in the future. However, people probably do not realise that, apart from natural products, pretty much everything is based on a petrochemical feedstock, which comes from commodity and specialised chemicals. Ultimately, we will have to transition away from using those chemical feedstocks into bio-based, more circular and more sustainable feedstocks, and one technology will be engineering biology.

The sorts of areas that engineering biology could address include the production and biomanufacturing of commodity chemicals, specialised chemicals, sustainable aviation fuel, drugs and pharmaceuticals, and alternative food systems. There will be a whole move towards creating non-animal, non-dairy products in the future that will be more sustainable—and in biomaterials, for example. Engineering biology is a platform technology, so it is the first concept. It can address these vertical industrialised application sectors and drop in solutions along the way.

I can give a few examples to give you an idea of the breadth and depth of this in the UK. There is a wonderful company in Manchester, C3 Biotech, which is an SME producing and manufacturing aviation fuel using microbial-engineered host systems—a very novel host system. There is a whole cluster of alternative food SMEs and start-up companies, particularly in the south and in London but also around the country, working on delivering non-dairy and non-animal food products for the market. Examples are Better Dairy, Multus Media and Hoxton Farms. They are all companies driven by a desire to create more sustainable food products.

On materials, I declare that I have a start-up company, Solena Materials, that is producing computationally designed protein fibres that are completely biodegradable and can be engineered and designed to have specific tensile strength and particular properties. They have applications in textiles, cosmetics and other kinds of healthcare applications.

On textile dyeing, a company called Colorifix in Cambridge has engineered organisms to dye materials directly. This is a sustainable process that it is trying to implement in various dyeing houses, particularly focusing on pilot plants in Portugal and India.

On healthcare, we have a company in London, LabGenius, which is using machine learning and AI to develop new biotherapeutic proteins. It has just raised series B funding of £20 million, to be announced. We have Bit Bio, in Cambridge, which raised over £200 million for reprogramming stem cells using synthetic biology and engineering biology techniques.

For regenerative medicine applications, we have a start-up company called Scindo, coming out of Oxford, which is using enzyme engineering and design, and machine learning and AI, for plastic degradation and revalorisation of waste from chemical waste, particularly plastic waste. We have a very interesting spin-out from the Sainsbury Laboratory called Resurrect Bio, which is trying to reactivate the natural immune systems that plants have to crop pathogens and pests, using genome editing.

As you can see from that array of applications, a large, exciting start-up SME community is building to tackle all these problems, driven by the sustainability argument.

The Chair: Regarding the example you gave of sustainable aviation fuels, is the engineering biology being used to replace the oil-based feedstocks, or does it also replace the Fischer-Tropsch process and therefore give us a much lower-energy route to producing SAF?

Professor Paul Freemont: Indeed, that is correct. There are ways of reducing the energy cost to manufacture this aviation fuel, and that is about the organism they are using. They are engineering an organism that is extremely cost effective in terms of the feedstock. When you grow these organisms at scale you have to feed them, and they are interested in particular waste streams that can feed into those to support the organisms growing to produce this fuel. The organism that they have chosen is a Halomonas bacteria that exists in the oceans and does not require the kind of cleansing and the clean environment that you normally require for a normal microbial host. They are using a number of different technologies to try to reduce the cost to manufacture at scale.

The Chair: Thank you very much for that. Dr Grandellis.

Dr Carolina Grandellis: Thank you so much for the invitation to give you evidence. To add to what Paul said, we have a range of projects ongoing in Norwich. The Earlham Biofoundry is working with Colorifix, which Paul mentioned—an amazing company located in Norwich. We work together through our Innovate UK funding. It is producing sustainable dyes to work in the textile industry. More recently, we established a brilliant collaboration with Sun Bear Biofuture, which is another company that is using engineering biology and fermentation to produce alternatives to palm oil, which is amazing. We also have projects with academia. For example, we are working with the John Innes Centre on the Norwich Research Park to produce anti-cancer peptides using synthetic biology. So we have a whole range of projects, and we engage with the local start-ups.

The Chair: You are emphasising our concern about the breadth of this area and how we will get our heads round it in what will be a relatively short inquiry, but it all sounds very exciting. Professor Rosser.

Professor Susan Rosser: Thanks for the invitation. The breadth of the applications is one of the amazing strengths of engineering biology because that platform technology can be applied so widely. In addition to the list that you have already heard, we are doing a lot of stuff in advanced therapeutics. For example, engineering biology can impact on gene therapy. If you put a new gene into somebody who has a genetic disorder, you want to be able to switch that gene on in the right tissue at the right time and at the right level. You have that fine control so that it reduces the toxicity and negative impacts.

We also work with companies such as FUJIFILM Diosynth Biotechnologies, which makes monoclonal antibody drugs. We are engineering the cells that produce those drugs to make them cheaper and higher quality, for example. Other colleagues are working with companies where there is a great interest in not just using feedstocks to manufacture products but valorising their waste, taking things such as plastic and producing flavour molecules from them, such as vanilla. There is also metal recycling: you can take lithium batteries and get the metals back out of them. It is about using the waste streams to produce things with value and using biology to take that kind of approach. I will leave it there; otherwise we will be here all day, listing applications.

The Chair: How does something biological get the lithium out of a battery?

Professor Susan Rosser: This is not my area of expertise.

The Chair: It is clearly not mine; you know more about it than I do.

Professor Susan Rosser: Some of the microbial systems can take metals out of solutions and make nanoparticles that can be used in microelectronic systems, so you get a really valuable product from a waste product.

Q2 **Baroness Northover:** From a standing start, as it were, you have addressed some of these things, but I will ask you about biofoundries. You each work with one of these. Could you briefly explain to us what a biofoundry is, how your respective biofoundries work, what capabilities they have and what they can be used for, which you have addressed to some extent? Following on from that, who are the main users of the biofoundries? Are as many types of people, companies and groups using them as you would like? If not, what is preventing them making the best use of these facilities? Coming on to the policy side of things, what changes might the Government look to in order to ensure that there is better support for the biofoundries in the future? Can we please start in the reverse order, with Professor Rosser?

Professor Susan Rosser: Biofoundries look to use automation to enhance engineering biology. We use robotic platforms to enable biology to happen more quickly. We have software to design genetic systems and robotic platforms to build those genetic constructs. We put those genetic constructs into cells and, to determine whether the cells do what we hope they do, we test the systems and then we go back through the design-build-test-learn cycle.

Our biofoundry is one of the most automated biofoundry platforms globally. It is a large robotic platform. We can build up to 2,000 genetic constructs a week. One of the unique features of our biofoundry is that we have a system for phenotyping mammalian cells. We can identify individual cells that produce products that we are interested in—they could be monoclonal antibodies. We can use them to find antibodies that bind to molecules that we are interested in, and we can use them for production of biological drugs or therapeutics. But we are organism agnostic; we can work with a whole range of organisms. We work with bacteria, yeast and mammalian systems. Our biofoundry’s application is that enabling engineering biology.

We work with all sorts of customers. I can go into the type of customer later on, but I will let these guys talk about what their biofoundries do and then maybe we can come back to that.

Dr Carolina Grandellis: Our biofoundry in Norwich at Earlham Biofoundry is quite similar. As Susan mentioned, we have these robotic platforms, mostly liquid handlers that can transfer liquids in a high-throughput manner from one place to another. A really good example is that this kind of equipment and automation, and the staff associated with it—we need highly skilled staff to work in biofoundries—gives the possibility to do high-throughput testing. As you might remember from the Covid-19 pandemic, it was very useful and important to be able to process thousands of samples daily, so this is a very good example of how biofoundries can help when there is a new global crisis. They can respond very quickly to those kinds of needs.

Regarding the challenges or priorities that we think the Government could focus on, especially in Norwich, where there is an agritech-focused research park, the bioscience community welcomed very enthusiastically the Genetic Technology (Precision Breeding) Act because of the potential to develop sustainable agricultural solutions. However, we have noticed and are concerned that there are delays with its implementation, so we ask the Government to implement this genetic technology as soon as possible. They must put through the secondary legislation immediately because there is a risk that this will not happen before the next general election. If it does not, it will block industrial investment in agritech solutions and food production innovations that are using our engineering biology.

Baroness Northover: Are you waiting for the SIs, the secondary legislation, on that?

Dr Carolina Grandellis: Yes.

Professor Paul Freemont: To follow on from what Susan said, if you can imagine you are engineering and reprogramming a cell at genetic level, that is what engineering biology does. In order to do that in a very formalised way, we have what we call a design-build-test-learn cycle, where we start designing the genetic design and what we want the organism to do, such as produce a product or a fuel or act as a kind of sensing device, we test it and learn from that, and then we apply the new tools of machine learning and AI to try to understand how to do it better and more efficiently. That is the general concept, and the infrastructure essentially allows you to do that up to a small scale.

It is global. I happen to be the chair of the Global Biofoundry Alliance. There are 36 publicly funded biofoundries all around the world. It is a growing community. I can give you some numbers, if it is useful. The scale of investment in the biofoundries is enormous. For example, in Korea, it just announced $100 million for a K-Biofoundry, as they call it. In Shenzhen in China, about $750 million—we do not know the exact number—has gone into a building in which each floor is an organism. There is huge investment into engineering biology biofoundries. In the UK, we have a wonderful, small and rather un-resourced biofoundries network, but we have been at the forefront because of the leadership role that the UK community has played in that we established the Global Biofoundry Alliance.

I will pass back to Susan and then come back to who uses our biofoundry.

Professor Susan Rosser: As for who uses our biofoundry, it ranges from academics and start-up and spin-out companies to SMEs and multinationals. We have a whole range of people using our biofoundries—all of them—for a whole range of different kinds of projects.

Baroness Northover: In terms of people wanting to come to you, that is positive. I see that there was steady funding from 2014 but then that concluded, which leaves you in a rather exposed position.

Professor Susan Rosser: We are enormously grateful to the research councils for funding the equipment for our biofoundries. What they did not fund was the staff to run the equipment. They are very expensive and complex pieces of equipment, so the issue is that we, the foundries—in my case a university—have to fund the staff. That makes us quite expensive to use because we have to run a cost recovery model. We have to cover the cost of the staff, et cetera, and the contracts to look after the equipment. One of the biggest challenges for us is that we are expensive to use because of the funding model. But it is not that we are not extremely grateful for that initial funding.

Baroness Northover: Yes.

Professor Susan Rosser: Particularly for academics, it makes it very expensive.

Baroness Northover: I can see the implied request to government in terms of policy. There was a strategy that put the original funding in place in 2014—

Professor Paul Freemont: Do you mind if I just interject to mention the users? It is important that the biofoundries are not just for academia; they are also for companies and start-ups. They act as innovation centres. In fact, most of our business model is now based on supporting companies.

Professor Susan Rosser: Yes. Most of our work is from companies as well, to be fair, but it still makes us expensive.

Baroness Neville-Jones: In this big field, do the biofoundries tend to specialise?

Professor Susan Rosser: They do for flavours; a little bit. As well as micro-organisms, we do a lot of mammalian work, probably more than the other biofoundries do. I think, Earlham, you probably do more plant work.

Dr aCarolina Grandellis: Yes, we do

Professor Paul Freemont: Yes. We try to offer a kind of one-stop shop from design to small fermentation-scale products. We are more of a kind of holistic specialisation, if you like, but, again, working very closely with companies. We try to do a lot to support instrument companies—UK companies—to put their equipment into our biofoundry at a beta level, to start testing it, learning about it, getting information on how we would use it and developing it. At the moment we have a wonderful, massive piece of equipment, which is an automated tissue culture system, which I know Susan will be very interested in, given the mammalian culture. It is from a company called Aixtron. We are testing that; we have the first one out of that company. They are not just there to serve; they are doing all this R&D, co-development and co-innovation. They are terribly exciting spaces to work in.

Professor Susan Rosser: Likewise, we work with equipment developers to enhance their knowledge about how to build the equipment. We work with a company based in the US, but we have the only piece of its kit in European academic hands, so we help to drive its workflows and look at how its systems work.

Baroness Young of Old Scone: It was really impressive when you were talking about the growth in the setting up of foundries elsewhere. Right now, where are we in the league table of quality and quantity—because that might be different?

Professor Paul Freemont: We are highly respected, but we are tiny compared with—

Baroness Young of Old Scone: Are we getting tinier?

Professor Paul Freemont: Yes. The US has launched some very large initiatives in biofoundries. It has something called the Agile BioFoundry. Of course, it has different funding policies. The Department of Energy funds over $100 million into biofoundry activities. The NSF has just launched a $30 million biofoundry corps, which it has recently concluded. Our biofoundry has had £7 million of public investment in infrastructure—that is, equipment—and we have had no funding for staff. We consider ourselves to be a start-up; we are like a start-up company. We are constantly scrabbling for cash, but we are doing great stuff. Maybe being lean is good, I do not know.

The Chair: Lord Borwick will come on to some of these issues in his questions, so perhaps he could pick up this theme.

Q3 **Lord Borwick:** How will the UK engineering biology sector develop compared with international ones? Will different countries go for different aspects of this very wide field, with some countries concentrating on energy and others on medical stuff? You mentioned a one-stop shop, which rather implies that you are not concentrating on any particular aspect of it, but you are trying to do everything for everybody.

Professor Paul Freemont: The one thing that most countries are focusing on at the moment is biomanufacturing. They see this as a huge opportunity to think about how we will make things in the future in a more sustainable way. A lot of the government initiatives that I have come across around the world when I travel are all around biomanufacturing. That leads into questions of scale-up infrastructure, fermentation capacity, feedstocks and all the industrial necessities that you require to take a lab-scale, pilot-scale microbial cell factory—because that is what they are; these microbes are like little cell factories—to scale them to the 200,000- to 300,000-litre scale to produce products at scale that would then go into supply chains and into the market. In some ways, all the countries see this as a question of how we will make things in the future, and that will be the major application space.

Professor Susan Rosser: In the medicines space, they are also looking at cell therapies, gene therapies and the manufacture of biological drugs. These engineering biology approaches are a huge industry in which the UK has a lot of strength in pharmaceuticals, but, specifically in those advanced therapeutics areas, engineering biology will be transformational because that ability to control things makes those new applications safer for patients. It is really important that we build on our pharmaceutical capabilities and take on this area of new advanced therapeutics as well. The States, China and everywhere else are going for those as well. Paul is right; it is biomanufacturing, but it is also the advanced therapeutics areas.

Professor Paul Freemont: It is biomanufacturing therapeutics.

Professor Susan Rosser: Yes. You need to manufacture the therapeutics.

Lord Borwick: So everybody will do everything, in your opinion.

Professor Susan Rosser: Pretty much.

Professor Paul Freemont: It is a race. It is very competitive. Since the Biden executive order and the Chinese five-year plan, which was altered half way through the five years—plus, last week, I think, the European Union announced a big initiative on biomanufacturing and biotechnology—it is a race. Everyone is seeing everyone as accelerating this technology.

Dr Carolina Grandellis: We talk about international biofoundries, but, speaking personally, being from Latin America, there is a lack of biofoundries in the southern hemisphere. This may also be an opportunity for the UK for science diplomacy—to maybe think about ways that we can transfer technology and expertise to the less geographically favoured regions. We are talking about the global challenges that we need to address, but they are global, so we all need to work together. It is not a problem only in the UK, the US or China but in other places such as Latin America.

The Chair: Will success in this race depend on what large industries a country has? We still have a successful pharmaceutical industry in this country, but we no longer have a huge chemical industry, whereas Germany does. Does that mean that, when it gets to needing to scale these things out of your biofoundries, we will not be at an advantage any more?

Professor Paul Freemont: You make a very good point, and one that is quite concerning. I suppose that one could rely on our friendly allies for all our scaled manufacturing in the future—until maybe in 100 years we have gone into a more bio-based economy—or do we build up our own critical infrastructure to become resilient in manufacturing the essentials we need here? Up in Scotland, we have INEOS, which produces quite a lot of our commodity chemicals. The question is: what would be the UK's position in that context? But, as Susan pointed out, there are commercial opportunities in pharma and other types of industry in which we are very well placed.

Professor Susan Rosser: One comment we get all the time from companies that come to our foundry is that they are not just interested in using bio-based feedstocks to produce the chemicals; as I mentioned, they are interested in taking their waste streams and making good use of them. The companies are very aware that there might be some sort of carbon levy coming in, so they are trying to gear up to make sure that they are prepared for that. Where there are limited resources, such as metals, as I mentioned before, you want to get all those metals back again. You do not necessarily have to have a big feedstock in the UK to be able to use biology to reduce the carbon footprint and waste, and make good commercial sense out of what we can do with that waste. It is not just big biomanufacturing: let us take corn syrup and make it into biofuel. There is very strong commercial activity in reusing waste.

The Chair: Sorry, Lord Borwick, I rather stole your question there.

Lord Borwick: I am just puzzled by the strategy here. I would have thought it more likely that you would succeed and thrive in a particular sector than in all the sectors, against other people who are funded so much better than you are.

Professor Paul Freemont: Sure. You are absolutely right. As Susan quite rightly pointed out, we have a very strong pharmaceutical biotech industry in the UK and there will be quite a lot of commercial opportunities in that space with engineering biology because they are high-value products.

Lord Borwick: Absolutely.

Professor Paul Freemont: But, in other areas, there is a growing generation of young entrepreneurs who want to do things in a different way. They want to make companies that make more sustainable products, whether that is food, materials or whatever. We need to support that whole activity as well. Ultimately, that will need to be scaled, and the question is: will we be able to scale all those technologies to become real products in the market? But you are quite right; we cannot do everything. That is absolutely right.

Professor Susan Rosser: We talked about the sugar that the Midwest in America has, for example. We will not build our economy by adding sugar to our product.

Q4 **Baroness Neville-Jones:** Your last remarks bring us straight on to the question that I want to ask you, which is about commercialisation. This committee spends quite a lot of time discussing our performance as a country in the early stages, as compared with how we get on when it comes to scale-up. Would you like to comment on your experience of, first, the early stages and then particularly the scale-up? Does your ease of getting finance depend on the sector that you are in? Are some more appealing than others?

What kind of relationship do you have with the private sector? It strikes me that a lot of the things that bioengineering can lead to are essentially of interest to the private sector and to companies. Are the companies that come along and use your foundries then interested in deepening their financial commitment so that jointly with you they develop something that can become a serious contender for a big business?

Professor Susan Rosser: I will give you some examples of companies that we work with in Edinburgh. We work with FUJIFILM Diosynth Biotechnologies. We have an £8 million project with them on developing Chinese hamster ovary cells for biological drug production, for example. The idea is that we develop a technology that they then take into their production systems to enhance their productivity. Colleagues work with Lubrizol, Johnson Matthey, Lululemon, Unilever, BASF and Diageo. We are working with some very big companies that have all expressed an interest in the area. Those are the big companies.

We work with local SMEs and start-up companies. The start-up system is different in different geographies in the UK. I am based at the University of Edinburgh. In Edinburgh, we have a fantastic talent pool, but we have an issue around lab space: where the start-up companies can physically go. That is something that we keep bringing up with the Scottish Government. I would say that that is a geographical difference between Scotland and Edinburgh and the south-east of England.

Professor Paul Freemont: As regards working with companies, Susan quite rightly pointed out that all the big guys have biotechnology initiatives. They are all just sitting there, waiting to see how they will drop into their existing value chain. They are not going to create the new transition. They will just wait and see. If more pressure is put on them through carbon taxation and green whatever, they will start reacting. They will not create the new world that we imagine engineering biology could deliver.

Small companies and start-ups believe that they can. As Susan pointed out, there is huge activity, particularly in London and the south-east, around what some would call deep biotech. That is the foundational technology and innovations that are going on to drive this technology forward, including machine learning, automation and all the companies that are applying those types of tools in specific application areas.

When it comes to funding, angel, start-up and seed investment is absolutely fine. There is a lot of money out there. There are a lot of excited investors who are very keen to get into this space. The UK has done really well in this space. There are a lot of fantastic small companies that are growing. The big problem, as always, is the valley of death and scale-up. How do they get these products on to the market? That is a problem not just here but around the world. There have been quite a few failures, particularly in the US, of companies trying to scale or get products to market that have not managed to do that.

This is our biggest challenge. We have a fantastic, exciting ecosystem of very young people who want to change the world. We have great companies. We have investors supporting them. Then, when they want to scale and get products to market, we have issues with regulatory structures, scale, fermentation capacity and pilot-scale facilities, so it all just falls apart. My strong view is that we need to build and allow these companies to scale. We have to scale. It is really important.

Baroness Neville-Jones: What stands in the way? Is it fear of failure? Some companies are bound to fail, are they not?

Professor Paul Freemont: For sure, and we have some here.

Baroness Neville-Jones: But the Americans do it.

Professor Paul Freemont: We have some here. We have a fantastically energetic ecosystem of young entrepreneurs who want to change the world, basically. We want to try to enable them.

Baroness Neville-Jones: Yes, but they are not possessed of all the resources necessary for development.

Professor Paul Freemont: Yes.

Baroness Neville-Jones: Where does the investment come from?

Professor Paul Freemont: From all over the world. We have a lot of US investment. We have some investors in the UK. We have public investment: EIS and other schemes. We have a venture fund called SynBioVen, which was set up by David Harding to invest in early-stage synthetic biology seed companies. There are many investors. There are investors everywhere.

Baroness Neville-Jones: What is the danger of the intellectual property leaving this country?

Professor Paul Freemont: You are quite right. Bit.bio is a classic example, with an investment of over $200 million in a regenerative medicine company in Cambridge. Most of it is US money. I hope that it will stay in Cambridge; I am sure that it will. But there is a possibility that it will move and that the UK will become just an R&D hub. Maybe that is a good plan for the UK. Maybe we are fantastic at R&D, but, actually, that would be dreadful.

Baroness Neville-Jones: In the end, there will not be the money to finance the R&D if we do not scale up. We have to create wealth somehow.

Professor Paul Freemont: I hate to say this, but we must have public-private investment at the technology stage, because we need to de-risk the technology for investors. Also, it is going to involve capex infrastructure investment in scale-up and pilot-scale facilities.

Baroness Neville-Jones: Does there not have to be sharing of risk?

Professor Paul Freemont: Yes.

Baroness Neville-Jones: You cannot ask the research sector to bear all the risk.

Professor Paul Freemont: No, but I do not think that VCs will fund large capex investments in the pilot-scale infrastructure that we need. It is the same in Europe. Europe is trying to do a much better job on it. Everyone is feeling their way on this. It is a really important question. I am sorry. I have not answered it very clearly.

Professor Susan Rosser: On Paul's point that we have some fantastic companies that are getting investment, there was a company just outside Edinburgh called Synpromics. It made synthetic promoters for gene therapies. It was bought out by an American company called AskBio, which was then bought out by Bayer. We take the companies to a certain level, and then they are scooped in. They still have the R&D base outside Edinburgh, but they are owned externally now.

Baroness Neville-Jones: Do you have any ideas about what we could do to prevent exactly what you have just described?

Professor Susan Rosser: There needs to be investment at the level that allows these companies to grow to the next level. I do not know where that comes from. As part of it, you need to have the public-private investment. If you want to build something that will be a big manufacturing site, a VC investor will not put in those many millions in the UK at this time. They are more liable to do that over in the US.

Professor Paul Freemont: The series A investment market is very difficult at the moment. In the UK, investors are looking for revenue streams very early on in companies' development. The trouble with engineering biology is that a lot of the companies are not producing revenue yet.

Professor Susan Rosser: Yes. It needs patient investors.

Professor Paul Freemont: It is quite a tricky space. There is also the scale of series A. Series A could be £10 million, £15 million or £20 million in the UK. It could be $50 million in the US. We will never compete with that. We cannot compete with that. What we can do is develop our own investment strategy to try to scale these companies, to get them to the next level. We need to do that.

The Chair: Are you seeing any interest from the UK Infrastructure

Bank?

Professor Paul Freemont: I would argue for affordable pilot-scale infrastructure to enable small companies to scale their products very early on, so that they can understand what their technical economic analysis and their life-cycle analysis look like very early on in their growth. UK entrepreneurs are amazing.

The Chair: Are you saying that there is a pilot-scale biofoundry concept that could be used for a number of different processes?

Professor Susan Rosser: Correct. You have fermentation facilities.

The Chair: That does not exist in the UK at the moment.

Professor Paul Freemont: No.

Professor Susan Rosser: Not at the scale that is required.

Dr Carolina Grandellis: It is important to have not only the infrastructure but the skilled people who can work, know and get training in the specific skills and disciplines that we need, such as AI, machine learning and bioengineering. That is in very short supply and is already globally competitive. Recruiting people who are trained in automation and the vital skills that we need is hard.

On that line, I would also like to mention that the Government intend to increase restrictions on legal skilled migration. That will have a cost for our field because, as I mentioned, biofoundries require trained and experienced technicians. By adding these visa fees and immigration surcharging, we are adding an extra burden on people who want to come to the UK. Being an international researcher myself, I am very keen to recommend the UK to my colleagues as an amazing place to work, but some colleagues are not willing even to look into important opportunities in the UK because they consider it a hostile environment for immigration of international researchers.

The Chair: We very much share your concerns in that area. We have written to the Government about it and very much appreciate your comments. Lord Drayson is keen to come in.

Lord Drayson: You have described really clearly the challenges that the UK faces in scaling up this exciting new area to the point where it provides a meaningful contribution to wealth. It is not viable for the UK economy to be an R&D leader and not create wealth. Could you give some sense of how long you think that the UK has got before the opportunity has passed? When we look back at history and the process of innovation, it is clear that the UK has often led a research area, been an early pioneer and been the chairman of an international consortium around something. Then the rest of the world has invested to scale, and the UK has never been able to come back. How long has the UK got?

Professor Paul Freemont: It is a very difficult question. Because of my role in the Global Biofoundry Alliance and because I travel around the world a lot, I can say that there is a huge amount of investment going into this technology, in many different countries, to a scale that is quite extraordinary. Korea has made a very big play. Although Samsung and industries of that sort are incredibly productive, it is looking to go beyond Samsung.

Lord Drayson: I am sorry to press you. To help to advise government policy, your opinion, as experts, on how long—

Professor Paul Freemont: We have five to 10 years.

Professor Susan Rosser: I would be more negative than Paul. We invested, were very forward thinking and put a lot of money into engineering biology. That was in 2012 to 2014. The foundries were funded in 2014. That is 10 years ago now. We were ahead of the game, but we have lost that leadership.

Professor Paul Freemont: Agreed.

Professor Susan Rosser: We are still there. The software from the Edinburgh Genome Foundry is world renowned. As I said, we are still one of the most automated platforms, but if we do not invest very soon we will have lost our momentum.

Professor Paul Freemont: Very soon.

Lord Drayson: Would you agree that it is single-digit years?

Professor Susan Rosser: The money is going into Korea now. The US is investing now. If we do not invest now, their foundries will be up and running and going ahead. Ours are getting old.

Dr Carolina Grandellis: I have an example of that. We had an international project going with an international company in Australia. That company has recently relocated next to the new Australian Genome Foundry, so I anticipate that this is the last project that we will do with it. As Paul and Susan mentioned, it is very important that we keep on top of the investment, to keep cutting-edge technology for the foundries and the skilled people to work in them; otherwise, we will lose our leadership role—

Lord Drayson: The broad quantum is how much?

Baroness Neville-Jones: We are witnessing very considerable catch-up from the rest of the world.

Professor Paul Freemont: I do not think that it is catch-up. I think that it is—

Baroness Neville-Jones: Overtaking.

Professor Paul Freemont: We just need investment now. We need to have a strategy, get going and really implement it.

Baroness Neville-Jones: That is very clear.

Professor Susan Rosser: We need people.

Lord Drayson: The broad quantum is how much?

Professor Susan Rosser: I beg your pardon?

Lord Drayson: If the Government were serious about implementing an industrial strategy now to make a difference, so that we were able to compete and scale up against Korea and so on, what are we talking about?

Professor Paul Freemont: Several hundred million. I think that the UK can do this. The one thing that the UK has got is that it is a very small place. We need a very integrated network of pilot-scale facilities and biofoundries, all interoperable and using the whole capacity of the country. We have not really done that properly yet. We really need to do that, because we live in a tiny little place. It is very frustrating.

Lord Rees of Ludlow: I am worried about things being taken in a rather fatalistic way. I agree with Lord Drayson that it is sad that we are in that situation. I am based in Cambridge. We had Solexa taken over by Illumina, which is now a $50 billion company, for a sequencing technique invented by someone in Cambridge. Greg Winter invented what was the world’s best-selling drug, with revenues of $200 billion worldwide since then. We have lost out hugely by not being able to develop those things to a bigger stage by ourselves. It seems to me that this is something that should be a big priority, to address Lord Drayson’s question.

Professor Susan Rosser: I could not agree more.

The Chair: At that point, can we move on to Viscount Stansgate?

Q5 **Viscount Stansgate:** The Government have announced that engineering biology is one of the five key central technologies. They have set it out in their document, *National Vision for*

Engineering Biology. How have their efforts been received so far within the bioengineering community? What would you recommend most immediately that the Government should be doing now? Obviously, you have been leading up to this, but this is the first of the questions in this area. What do you recommend that the Government should do now?

Professor Susan Rosser: One of my key priorities would be to invest in doctoral training centres for the next generation of people who can do this work. In the AI area, there has been investment in 12 doctoral training centres for PhD students. There has been one for engineering biology. We are losing trained people overseas. People from Edinburgh have moved to Singapore, the States, Germany and Austria. We are training the people, but we need more of them. If this is genuinely going to be a key part of our economy, we need the skill set trained, and as soon as possible. That would be one of my key recommendations.

Dr Carolina Grandellis: I fully agree with Susan. Funding calls for engineering biology projects have been irregular and short-term, which makes it very difficult to plan the activities and to train the staff to work in biofoundries. We would welcome a UK-wide response more specifically dedicated to biotechnology for engineering biology, with longer timescales so that we can retain talent and plan activities accordingly—a three- or four-year project, perhaps.

Professor Paul Freemont: I completely agree with Carolina and Susan. We need to have a mix. We need our fundamental research programme, particularly innovation around AI, machine learning and the reprogramming of cells in a rational, engineering kind of way. We need scale-up. We need infrastructure. We need targeted funding for innovation in certain areas of the scale-up process, such as bioreactors and downstream processing: the industrial side, which we tend to ignore quite a lot.

Finally, I would argue that we have some really great hubs. We have an amazing starting point, but we can take it to another level if we start connecting our activities in a much more strategic way. That has not been done.

Viscount Stansgate: You mentioned “several hundred million” a moment ago, in answer to my colleague. The Government have a headline ambition to spend £2 billion in engineering biology over the next 10 years. Assuming that it would be new money, where do you think that that spending should be prioritised?

Professor Paul Freemont: I have my own view, but—

Professor Susan Rosser: In the areas we have just been talking about. To be cynical, is that actually new money?

Viscount Stansgate: If it is new money?

Professor Susan Rosser: If it is new money, that is fabulous. If it is rebadged money—

Viscount Stansgate: Then we are back to where we were.

Professor Susan Rosser: —we are back to square one. I would ask that question.

Viscount Stansgate: This is your opportunity to say what you think it should be spent on.

Professor Susan Rosser: If we have new money, we need to do the doctoral training centres. We need the new infrastructure for start-ups and the scale-up stuff. We need new schemes. There used to be a scheme called the industrial biotechnology catalyst, which was a fantastic scheme. It was an Innovate UK scheme. It had different investments at different TRLs. You could have a five-year project that was just academic. Then you could have a project with industry at the next level and the levels beyond that. That was enormously popular with industry and academia. If we had something like that catalyst programme for engineering biology, that would be a really good start.

Professor Paul Freemont: With longer-term funding.

Professor Susan Rosser: With longer-term funding.

Professor Paul Freemont: It cannot be just short-term. It has to be longer-term funding. It has to be around a strategy for where we as a country want to be in engineering biology and biotechnology in five years' time. Where do we want to be, and what do we need to get there?

It involves infrastructure investment and training investment. It involves fundamental research—maintaining a fundamental base—as well. It involves developing more private-public partnerships, to be honest, to start addressing some of the large-scale infrastructure that we will need.

We also need to come together as a country a bit more. We need to network. We need to be much more interoperable. At the moment, we talk about the north, the south, the west and so on. The UK is a whole place. We can put these pilot-scale facilities all over the UK—everywhere where there is a critical mass of companies and centres. We can then interconnect them all so that there is a completely interconnected system that allows companies to go wherever they need to go to do their pilot, their scale-up, their technical economic analysis and their life-cycle analysis, and then to get investment. I think that we can do this. It just needs a clear will and strategy.

Viscount Stansgate: I have a few quick questions to finish. Is this what other Governments are doing? When you tell us that great strides are being made in other countries, is this what you think other Governments are doing: identifying this as a strategic priority and putting in the money to develop just the types of things that you have listed?

Professor Paul Freemont: Yes: 100%.

Professor Susan Rosser: Absolutely.

Viscount Stansgate: Finally, in your view, is there a marked difference in the funding and the private sector activity between different regions and institutions of the UK? Is this a technology that can truly be placed anywhere? Is it going to particular places, in an equivalent of the golden triangle, which we might not want to see? Could it develop everywhere?

Professor Paul Freemont: It can go anywhere, as long as there is a critical mass of research activity: ideally, universities that have a critical training system and doctoral training programmes.

Also, one needs to normalise. There are a lot of universities in London, so the amount of investment that goes into the golden triangle needs to be slightly normalised. It can go anywhere, and it should go everywhere. It should go to where the critical masses are. That is very important. For example, there are some great opportunities in Aberystwyth, which I went to see. They have a fantastic biocentre, at which they are doing some really cool stuff on alternative food systems. It can go anywhere.

Professor Susan Rosser: Geographically, there is no reason to have these specific areas.

Professor Paul Freemont: The geography should not matter.

The Chair: Lord Lucas, did you want to come in briefly?

Lord Lucas: If we end up doing much more biomanufacturing, where does the carbon come from? Do we have to expand agriculture a lot to get it? What do the waste streams look like? What do we have to do to make them safe and make good use of them?

Professor Paul Freemont: That is a very good question. One of the obvious waste streams is C1 gas, so C1 gas fermentation. Those are the gas waste streams that come out of some of our industrial processes. It sounds easy. There are organisms that will grow on C1 gas and produce products. There is a great company called LanzaTech that did an IPO last year in the US and is building pilot plants for C1 gas fermentation all around the world. That is one solution. It is costly. The infrastructure investment for those plants, which would sit next to normal industrial plants, is big, but they are leading the way in how we would use those waste streams.

For the UK, there are organic waste streams. There are agricultural waste streams. I have just come back from Finland, where a huge amount of paper industry and pulp production is going on. They are very interested in exploring that as a feedstock. It is technically demanding, because these feedstocks are heterogeneous, not homogeneous. Organisms need to be adapted to grow on some of these feedstocks. There is a lot of R&D that needs to be done to look at organic waste streams, agricultural waste streams and gas waste streams, such as C1 gas.

There is a company coming out of Nottingham—a really cool start-up—that is going to use methane. You would argue, "Is that sustainable?", but it has a very interesting model for how it could use methane gas for production, using organisms called methanogens. The biology is incredibly diverse. Organisms will grow on pretty much everything.

Professor Susan Rosser: There is some amazing stuff going on in Scotland. There is a company called MiAlgae, which grows algae on the waste products from the whisky and brewing industry. The algae produces Omega 3, which is really healthy. The company uses that to produce fish feed, to feed the salmon industry. There are other companies using the waste from the brewing industry to make feedstocks for cattle and so on.

The feedstocks are extraordinarily valuable. One of my colleagues has done a project using fatbergs from sewers: genuinely—fatbergs. This is amazing. The fatbergs have a lot of fatty acids in them. You can use biology to turn those fatty acids into products for the perfumery industry. The perfume molecules are extraordinarily expensive.

Professor Paul Freemont: These feedstocks need to be renewable, of course.

Professor Susan Rosser: A fatberg is pretty renewable.

The Chair: The quantity of fatbergs will not be something that solves our problem of making aviation fuel and so on. Can I move on to Lord Rees?

Q6 **Lord Rees of Ludlow:** I want to ask a bit more about skills at the various levels: apprenticeships, graduate degrees in relevant subjects and the question of exceptional talent. What can we do to ensure that we gain more than we lose at the top level? These are all important issues across the economy. Do you have anything to add to earlier remarks on what the Government and the education system should be doing?

Professor Susan Rosser: I have an example of an apprenticeship for you. At our foundry, we took on a modern apprentice. He had worked in Kentucky Fried Chicken. He came to work in our foundry. He did part-time training at a college and became an expert in running and fixing our robots. He saved us tens of thousands of pounds. He left us, sadly, because the robotic manufacturing company took him on to work full-time. We were devastated to lose him, but it is an amazing trajectory, from Kentucky Fried Chicken to a really highly skilled automation biologist. We want more of that.

Professor Paul Freemont: To follow on from that, we focus a lot on PhDs. That goes without saying. We need more doctoral training programmes. However, as Susan has just pointed out, we also need to focus more on the BTEC skills. If we are going to develop biomanufacturing as an industrial process, we will need trained people to run these machines. Those will not necessarily be at PhD level.

Professor Susan Rosser: It is a challenge to keep these people. The people whom we have trained in the foundry have that automation experience. They are extraordinarily valuable. There is staff turnover, because companies take them on. We have lost people to Germany, Austria and the States.

Professor Paul Freemont: When it comes to AI and machine learning, we cannot compete.

Lord Rees of Ludlow: Dr Grandellis, from your bio, you are someone who came to this country at a certain stage. I wonder whether you would still come here now. What is your perspective on this question of attracting senior expert talent?

Dr Carolina Grandellis: I fully agree with Paul and Susan. We would like the Government to invest. They should support the technician’s career, but they should also invest in higher education. We have noted that, because of the increasing cost of living, it is really hard sometimes to access higher education at universities. I am talking about university degrees. It is important to focus on the necessary skills for engineering biology: AI, machine learning, biochemical modelling, computational modelling, statistics, and bioengineering. We need to make sure that we support this career.

As I mentioned, we must also attract people internationally so that they can join the UK, because they are in very short supply. These are highly skilled people who are looking for opportunities abroad so that they can have more opportunities in their career and professionally.

Lord Rees of Ludlow: You are happy to stay here?

Dr Carolina Grandellis: Yes, I am happy to stay here. Norwich Research Park and the Earlham Institute have supported my personal development in my career. I am raising my family here. I have two British daughters. I think that this is an amazing country, but I would like this country to continue being this amazing to international colleagues so that I can recommend it to them.

The Chair: That is very reassuring to us. I move on to Baroness Young.

Q7 **Baroness Young of Old Scone:** The Government have been fairly clear that they want us to be world class in this area, covering a big spectrum of outcomes. From what you have said so far, I am searching for where you think the leadership for this will come from. We have had the vision for engineering biology. We have had the Prime Minister’s Council for Science and Technology reporting on engineering biology. They both seem to say the same things about what is required, and they chime very well with what you have said is required, but who is in charge? Is there anybody driving this?

Professor Paul Freemont: The Department for Science, Innovation and Technology is establishing an engineering biology steering group, which will be co-chaired by a Minister and, as far as I know, will have representatives from all parts of our engineering biology ecosystem. That steering group will be quite important in driving some of the developments—or at least, in advising on driving some of the developments forward.

Baroness Young of Old Scone: Is that getting a move on?

Professor Paul Freemont: Apparently. We have all applied. We will find out quite soon, I think. That is one area where there is something tangible, at least.

The Chair: Do we need a high-profile government-appointed sector champion, as we have for the offshore wind sector, for example?

Professor Paul Freemont: I could not agree more.

Professor Susan Rosser: That would be great.

Professor Paul Freemont: It has always been on the back burner a little. Now we need to put it on the front burner.

Baroness Young of Old Scone: If we did have that leadership group and a high-profile champion—you have talked about a number of existing barriers. Are there any barriers of which we should be aware, other than things such as sustained funding, pilot-scale facilities, fermentation labs, production facilities, skills, et cetera? Are there any others that you think we should be aware of that this group needs to solve?

Professor Paul Freemont: Society. We have taken our eye off the ball a little bit in engaging with broader stakeholder groups—our publics. I think we need to re-engage with that. When we started this whole field many years ago, we really did go out there and ended up with various dialogues and reports. Now we need to get the technology and biotechnology products and products produced by biotechnology into the public domain so that the general consumer and citizen can begin to understand what this technology is and what it can do. We need to reactivate that. That is one major barrier. This will not work if customers, consumers or people do not accept it, or do not buy the products. We just will not have that engineering biology growth that we need. So I think that is really important.

The second very important thing is standards—we have not had a chance to talk about that—and regulation, which are both interlinked. What is really bizarre is that in the biotechnology ISO, the International Organization for Standardization has a committee called TC 276. That committee is involved in making all the standards for biotechnology. You would be horrified to know that in biotechnology, a multibillion-dollar industry, we have 36 ISO standards. That is slightly problematic, given that, if you are in the aviation industry or any other industry, there are thousands of standards. We have some significant work to do in looking into that. I am involved in a project that is doing that, but I just want to bring that to your attention. That is another whole area we need to look into. That ties in with regulatory systems. The new products that will come on to the market will have to be regulated in a way that consumers are very comfortable with, so that is another whole area.

Baroness Young of Old Scone: Does anybody want to add anything more to that one? I think there is a good quid pro quo between consumer acceptance and a clear, understandable regulatory process.

Dr Carolina Grandellis: I would briefly emphasise regarding regulation, especially in the Norwich Research Park where we are working with the John Innes Centre and Sainsbury Lab working in crop science, that it is very important that we speed up the secondary legislation for the Genetic Technology (Precision Breeding) Act; otherwise, this will be lost and there is a high risk that products developed in the UK will be marketed elsewhere outside the UK.

Professor Susan Rosser: I think Paul is absolutely right. We need to engage with the publics. As he said, we did a lot of that in the early days of synthetic biology, but in a way it has gone off the agenda over recent years and it needs to be brought back on to it.

Baroness Northover: One thing that comes across is that the industrial strategy that emerged despite the economic situation in the period 2010 to 2014, which kickstarted all of this, was not sustained. Looking forward to what may happen with any new Government coming in, what you seem to be saying is that there needs to be a strategy that decides where we will prioritise things and funding put behind it in the way that that industrial strategy did at an earlier stage. Obviously, Brexit then happened, which must have affected your ability to attract in the technicians at the very least, if not funding, that resulted from that. From your nodding, I take it that that had a negative effect. That is where we are now, so any new Government coming in need to seize this. If they are going to say that this is an area where we have potential, we therefore invest in it and support it in all those different ways. That seems to be coming through from what you are saying.

Professor Susan Rosser: I agree 100%.

Professor Paul Freemont: We are trying to achieve a long-term transition.

Professor Susan Rosser: It is the long term. A mistake was made. We were given the last tranche of money for six centres of excellence. At the end of that term, we lost a lot of staff because the funding dropped off a cliff. They have paid a small amount of transition funding to keep things going until now with the most recent investments, but in that period we lost a lot of the people we had already trained to overseas.

Professor Paul Freemont: The investments are very non-strategic. They are just dependent on a panel on the application day. There is no strategy on what we are investing in. It is a pot-pourri of, in the moment, on the day, who gets funded. That is no way to deal with this technology. This is super-important. Having a bunch of people around a table saying, "We'll fund that one and not that one", is just crazy. I do not think this is the right thing for this technology. We need much more focus.

Professor Susan Rosser: We need specific calls, saying, "This is the problem we want to address using engineering biology. How are we going to do it?"

The Chair: Thank you very much, all three of you, for what has been a really interesting session. We have come away with a lot of messages. I have certainly come away with very strong messages about skills, but also the scale-up issues and the fact that we do not have long if we really want to benefit the UK, not just the world. We want to see economic benefits to the UK from the brilliant science that we obviously have and continue to have.

I remind you that you will get the transcript to look at. If there is anything else you think of that you would have liked to have said to us, we will still be pleased to have that in evidence. The meeting is now suspended. Thank you very much indeed.