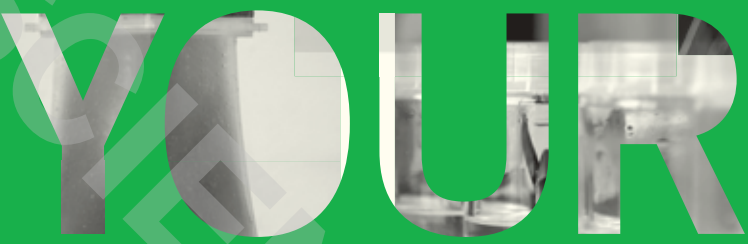
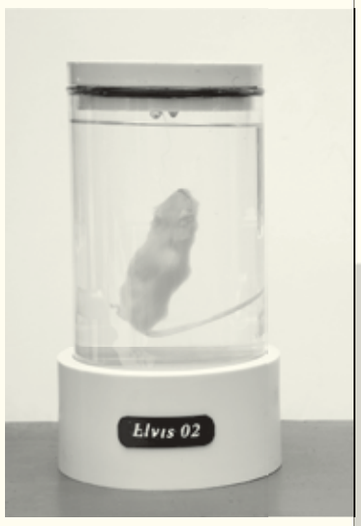
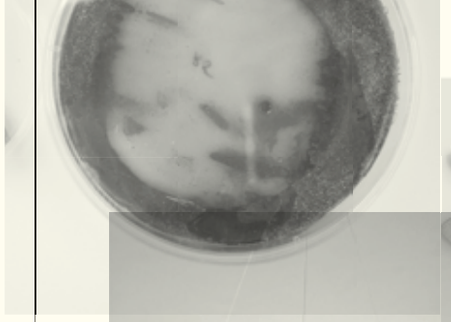
GROW YOUR OWN...

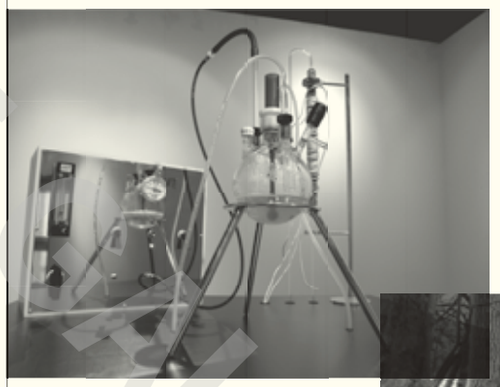


LIFE AFTER NATURE

ALEXANDRA DAISY GINSBERG
PAUL FREEMONT
ANTHONY DUNNE
CATHAL GARVEY
MICHAEL JOHN GORMAN







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LIFE AFTER NATURE

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MICHAEL JOHN GORMAN

Director, Science Gallery

WHY GROW YOUR OWN...?

A few months ago, a project to create glowing plants 'using synthetic biology' was proclaimed as the first step towards 'sustainable natural lighting'. The project received almost half a million dollars in funding on crowdfunding platform Kickstarter. Funders in the US only were to be rewarded with seeds allowing them to grow their own glowing plants at home. Although the potential illumination provided by such plants won't be enough to provide lighting, this is one powerful demonstration of our growing appetite for designed living organisms as consumable commodities. In Utah, 'spidergoats' have been created: spider DNA is inserted into their genomes causing the goats to produce a protein in their milk which can be spun into spider silk, a material ten times stronger than steel.

Synthetic biology is an exciting, and occasionally frightening, emerging field, bringing together engineers and scientists and even designers, artists and biohackers. As in many new fields, the language we use to talk about synthetic biology is still in the process of being resolved—should we apply engineering metaphors to living organisms? Is life really just a "DNA software system" as Craig Venter defines it, waiting to be reprogrammed at will? Or should we focus our attention on the potential risks of releasing living factories into the wild? What regime of intellectual property is appropriate for the code for synthetic organisms? Should we 'jailbreak' commercially-controlled forms of life?

Many of these questions are not new, but the communities that are connecting around synthetic biology constitute a different and more heterogenous group of practitioners than those who were responsible for framing the earlier discourse about genetic engineering. From iGEM (the International Genetically Engineered Machine competition) which is built around a shared library of reusable DNA parts in the form of BioBricks, to DIYbio communities which favour an open source approach to sharing, to well-funded government research programmes, corporate labs and venture capital-funded accelerators, synthetic biology is often portrayed as a kind of new alchemy, with the alluring prospect of living things becoming factories for drugs or fuel, and even resurrecting extinct species such as passenger pigeons, Tasmanian wolves and woolly mammoths. One of the works in GROW YOUR OWN... pushes this alchemical metaphor to its logical conclusion, through a bacterium that transforms toxic gold chloride into glistening gold leaf.

Because the debate around synthetic biology is still in the process of being framed, it is especially urgent to begin an informed and open discussion around the futures that it might enable. As the 2009 Royal Academy of Engineering report on Synthetic Biology stated, "public dialogue must begin 'upstream' before the parameters for debate have been narrowed down and decided upon", something that failed conspicuously in public engagement efforts concerning genetically modified organisms (GMOs) in the early 2000s, leading to a lack of nuance and a heavily polarised debate around the boundary between natural and unnatural. Speculative designers are particularly adept at confronting us with unexpected futures, and the work of two of our curators Anthony Dunne and Alexandra Daisy Ginsberg, and many of the designers represented in GROW YOUR OWN... exemplify this approach. From growing a dolphin in a human uterus (rather than an environmentally-irresponsible human baby) to the release into the wild of synthetic 'companion species' by conservationists to protect endangered species, the artists and designers involved in GROW YOUR OWN... invite us into synthetic futures that we may not have imagined, going beyond knee-jerk reactions and the 'ick' factor and considering how synthetic life might even turn out to be our best tool for caring for nature. Professor Paul Freemont of Imperial College London is one of the leading researchers working in the field of synthetic biology, and has embraced the realm of design fiction while ensuring a grounding of ideas and speculations to lead to meaningful conversations. Cathal Garvey, inventor of the acclaimed 3D-printed Dremmel centrifuge is a key proponent of DIYbio and biohacking, adding a distinct voice to the curatorial team.

Synthetic biology is a field characterised by creative and critical tensions. Grown or made? Evolved or designed? Utility or exploitation? The discussions between the curators have correspondingly been intense and vigorous. Consensus about anything has often been a challenge—words, images, artefacts, all have been objects in debate, not yet blackboxed. Playful works help to defuse some of the tensions. The mouse incorporating DNA allegedly taken from Elvis Presley's hair—does it have a propensity for obesity and addiction? Human cheese, produced from the microbial residents of armpits, toes and navels of eminent individuals—could there be a market? Such projects also point to the experimental and occasionally mischievous community that has coalesced around competitions such as iGEM, vibrant bazaars for the modular components of life.

This project was enabled through the support of a number of entities: the European Commission Framework 7 funded project, StudioLab, allowed us to work closely with the Royal College of Art on the theme of synthetic biology, and to learn and share approaches with the Ars Electronica Futurelab in Linz and Le Laboratoire in Paris, with whom we ran the Idea Translation Lab on the theme of synthetic biology, allowing undergraduate students to develop cross-disciplinary projects in this area. The Wellcome Trust supported the project through a generous Society Award. The Science Gallery team has supported the development of this challenging and exciting project, and I would like to especially thank Alexandra Daisy Ginsberg for her work on the front line as lead curator of the show.

GROW YOUR OWN... is an invitation. Whether you are interested in using bacteria to clean up oil spills or turning plants into factories, you can help us shape the discussion about what we can and should do with synthetic biology. The potential futures of synthetic biology are still open. As the tools of the trade become more and more available, we urgently require your creative and critical responses.

Let's have the conversation.

ALEXANDRA DAISY GINSBERG

Designer, artist & writer researching synthetic biology

What is synthetic biology to you?

At lab benches from NASA to the US Defense Advanced Research Projects Agency, from corporate labs in Silicon Valley suburbs to prestigious university departments, from do-it-yourself collectives to Kickstarter-funded start-ups, biologists, engineers, computer scientists and others around the world are streaking out bacteria, designing DNA, modelling biological 'circuits', measuring biological 'parts', and imagining future products and manufacturing technologies. Together, they are working towards an engineering vision of a designable biology.

Synthetic biology is an invisible technology that today is, arguably, still a 'technoscience.' We're told that it has the potential to transform our lives. We read that it could fuel our cars, target our tumours, and produce the chemicals that make the products we enjoy, feed an exploding global population, clean up polluted landfills and oceans, and even enable travel to Mars.

While these promises are world changing in scale, synthetic biology is a technology that you cannot see or touch. Its fundamental building blocks are microscopic strands of DNA, pieced together using engineering ideals such as standardisation, abstraction, decoupling and design. These are some of the principles that, since the Industrial Revolution, have made our modern, high-tech world possible. The aim is to make biology programmable, predictable, and controllable, using the same logic as the zeroes and ones of digital computation that powered the information technology revolution. In what is called the 'top-down' approach, DNA is treated like code, with sequences copied from nature redesigned and reassembled on computers, printed out on synthesisers and inserted into existing cells to instruct them how to behave, what to make, and even when to die. Biology could become a design material unlike one that we have ever known before: a self-replicating technology that is everything from hardware to software, the factory and product too. But 'natural' biology is complex and changing. It lives and dies, it reproduces and evolves, which makes it unlike any 'material' we have known before.

As a designer and artist, I'm interested in whether biology can ever truly be designed, and if it can, asking what we should—or shouldn't—be designing with it.

So is this new, and if it's not, why is it important?

Synthetic biology is both an evolution and a revolution. We've been designing with biology for ten thousand years to make our lives healthier, easier or more pleasurable, through the meticulous selection and breeding of desirable traits, from bigger corn to bulkier cows. For the last 40 years, scientists have been using genetic modification (GM) to make yeast produce insulin for diabetics, higher-yielding crops, or things we don't even think about, like washing powder or vegetarian rennet. Synthetic biologists are engineering life for the same reasons: to make useful stuff for humans to consume. Seeing synthetic biology as a continuation of what has come before is, for some, desirable, making regulation easier. GM is already a complicated enough issue legally, politically and socially.

As a designer and artist, I'm interested in whether biology can ever truly be designed, and if it can, asking what we should—or shouldn't—be designing

Alexandra Daisy Ginsberg

But synthetic biology is also revolutionary, beyond the hyped promises of resurrected mammoths or sustainable fuel made by bacteria digesting plant matter. While GM is not new, applying engineering thinking to control biology poses novel and difficult questions. Purpose-built, living machines challenge human-made boundaries between nature and culture, between design and evolution, and between creator and product. Utopian and dystopian visions drive the discussion around synthetic biology. Dreams of sustainable futures powered by a green technology are contrasted with bio-catastrophes of life out of control, misused in biological weapons or monopolised by corporations. In reality, what can be done now is limited in terms of applications: huge exertion has been required to engineer bacteria into simple on/off switches; companies hoping to grow large vats of fuel are putting their efforts into microorganisms that can secrete expensive ingredients for face creams or medicines, which make more commercial sense. But research is being conducted in labs all over the world on algae, plants, worms and mammals, in designing expanded or alternative genetic codes and even building 'protocells', making life from scratch (the 'bottom-up' approach).

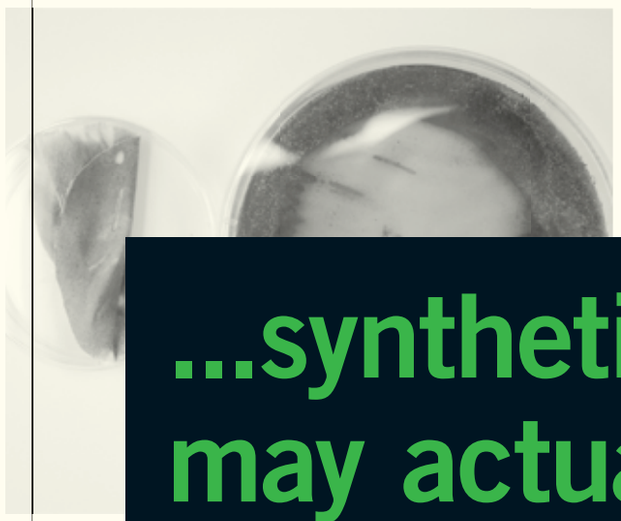
All of these highlight unresolved questions around the commoditisation of life, safety, ethics, governance, the total industrialisation of nature, and issues that we can't even yet imagine. Some of the works in GROW YOUR OWN… highlight what has been done, such as Howard Boland's *Banana Bacteria*, which uses bacteria designed by MIT students for the International Genetically Engineered Machine competition (iGEM) in 2006, whilst others, like Ai Hasegawa's *I Wanna Deliver a Dolphin…*, delve into these unknowable and uncertain futures.

Synthetic biology is entering its second decade and is still described in terms of dreams and nightmares—neither of which may come true. But if synthetic biology does power a twenty-first century biotechnological revolution, its effects will not only be scientific, economic and industrial, they will be political, ethical, ecological, and above all, personal. Designing with the materials of life may present questions that have no right answer, but will require a balancing of risk for a global society and our shared natural environment. This is why it is so important for us all to consider what synthetic biology means to us now, as laws are being written, biomass feedstock planted, and technologies imagined.

So where do we go from here?

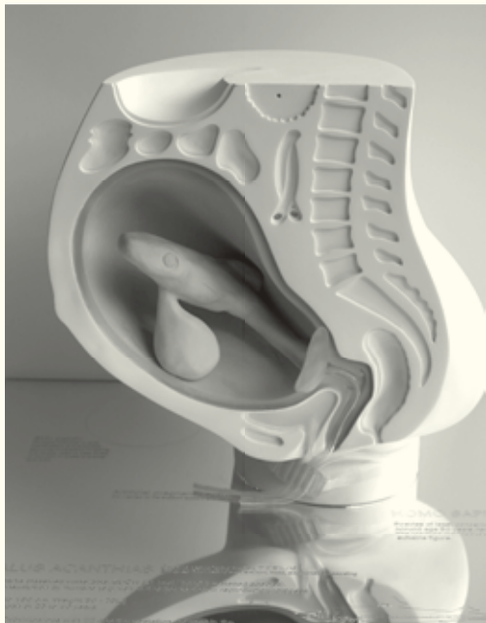
The works in GROW YOUR OWN… use a breadth of approaches from fine art, bio art, design research, speculative design and DIYbio to address these questions and more. There are works that deal with questions of intellectual property, genetic privacy, the manufacture of life, activism, ecological implications, our definitions of sustainability, and with the role of the designer in the lab and the role of the lab in the gallery. No design or technology exists in isolation; context is everything. Synthetic biology is a field in which the biggest funders include the Chinese, US and UK governments and corporations. These societal questions are an integral part of the technology itself.

I sometimes describe synthetic biology as a promising disruptive technology, one that is also promising to disrupt nothing. Reimagining biology—and life with it—into a fully engineerable and designable material is no small matter, technically or ethically. We may be undertaking the biggest engineering project man has applied to nature yet, at potential risk to the ecosystem we live in, and we're planning to make jet fuel and non-biodegradable plastics. Instead of perpetuating the present, how might we reimagine our future?



…synthetic biology may actually offer future solutions to some of the worst man-made problems

Paul Freemont



PAUL FREEMONT

Co-founder and co-director of the EPSRC Centre for Synthetic Biology and Innovation at Imperial College London

What is synthetic biology to you?

Synbio is an exciting new field that fuses the practice of engineering design with the manipulation of biological systems at the genetic level. There have been several major technological advances in life sciences that have resulted in an unprecedented understanding of biological cells at the molecular level. One profound technological development called DNA sequencing allows the rapid automatic 'reading' of genetic code or genomes from any living organism (including humans) by a machine. Over the last five years, different technological developments have led to machines that can automatically chemically synthesise large pieces of DNA from its basic building blocks. In fact, it is now technically possible to synthesise and assemble an entire genome for a small microbe in a test tube. This 'writing' of DNA has lead to a complete rethink about how we might re-engineer the genetic code of simple cells like microbes and yeast. Synbio builds upon these advances and brings together the practice of engineering design and construction with molecular and cellular biology to allow the building of new genetic programs, and new cells driven by specific applications.

The most amazing thing about synbio is that the engineering approach, which necessitates developing new experimental and computational tools, can actually be applied in many different application areas. For example, we now realise that we need to think about more sustainable approaches to energy provision, food production and even industrial manufacturing to remove our dependency on fossil fuels. Using synthetic biology, many of these problems could be considered and I can see, in the not too distant future, manufacturing processes that are based primarily on engineered microbes and cells growing in large sealed vats producing a range of products—everything from fuels, commodity chemicals and pharmaceuticals to new materials such as bioplastics or silk. I can also see synbio providing new opportunities for vaccine development, infectious disease detection and novel drug delivery systems. It's possible to imagine synbio tackling environmental applications, like cleaning up polluted land and water areas, producing sustainable crops to increase productivity and the ability to survive in extreme conditions, or even providing more environmentally sensitive ways to extract metals from minerals using engineered microbes or photosynthetic organisms that will harness sunlight and fix carbon dioxide to produce renewable energy products such as hydrogen.

What is your role in the field as a biologist and how is that different to an engineer?

I don't think there is a distinction — I am a synthetic biologist, not a biologist. However, I do see myself as more focused on the experimental side of synbio rather than on the detailed mathematical modelling side. I would redefine 'role' as expertise, which is clearly biological. By bringing my expertise into the field, I hope I can provide the detailed mechanistic insights of biological processes that will enable colleagues on the more computational or mathematical sides to appreciate some of the complexities of biology.

Many synthetic biologists talk about engineering biology to make useful things for "the benefit of humanity". Can we even think about biological organisms as 'living machines' designed to meet human needs?

This is a sensitive and tricky issue. Living systems are extraordinary, beautiful, elegant and highly complex. I personally don't perceive such systems as impersonal machines. As we learn more and more details of how biological systems work, we keep finding surprising explanations as to how natural systems survive and replicate, evolve and adapt. As a synthetic biologist, I firmly believe that we need to be sensitive to the beauty and complexity of living systems. On the other hand, mankind has been exploiting living organisms for thousands of years for our own purposes—from the domestication of animals for food and companionship, to the use of microbes to make bread, alcohol and, more recently, drugs. Mankind has also completely altered what we perceive as the 'natural environment' with our continuous interventions, but we still call it 'natural'. I see synthetic biology as an extension of our utility of nature. Perhaps paradoxically, synthetic biology may actually offer future solutions to some of the worst man-made problems.

Do we need to change the way that we understand the engineering of life? Do you see the practice of synthetic biology changing as it develops?

Yes, and this is what synthetic biology aims to provide by developing a formal engineering and design framework for the genetic manipulation of biological systems. This framework has built-in checkpoints and design conditions to facilitate the responsible development of synbio applications. As the field develops, I can see this practice changing because one aspect of synbio is to de-skill some of the development and design steps, as well as to fully automate some of the building and testing stages. In the future, I see much of synbio being computer based, where the creative design can be used to access databases that hold genetic blueprints for many organisms. The synbio professional of the near future will draw upon this detailed knowledge base to design and construct new genetic circuits and ultimately new cells for purposeful applications.

How do you see synthetic biology fitting into a wider political, cultural, economic and industrial debate?

I believe that synbio will promote a re-engagement of humans with the natural world, and also provoke a debate on how we move towards more sustainable human activities. Even in the world of environmental conservation, people are excited about the concept of de-extinction—bringing extinct species back using synbio technologies. Whilst this may not be widely accepted or even desirable, it has reinvigorated the extinction debate and has prompted synbio researchers to consider other opportunities in conservation. It always strikes me that society, perhaps even the majority, does not really appreciate where and how everyday products come from. The synthetic materials and chemical building blocks that make up almost every man-made object around us come from fossilised fuels and the petrochemical industry. It will not be too long before some of these chemical processes will become biological and more environmentally friendly. I see a hybrid chemical-synbio industry developing, where economics and politics will hopefully drive the uptake of synbio technologies and processes.

One interesting cultural ethos of synbio is the establishment of an open source model for biotechnology development that challenges some of the existing biotech and pharmaceutical corporate models for privacy, piracy and protection. Combined with the growing DIY biology movement, I can see synbio technologies becoming very accessible, but this will bring with it serious issues and difficulties in terms of regulation and global governance.

As synbio offers potential step changes in so many application areas, it already provokes vigorous debate and discussion. It has inspired artists and designers, political and social scientists, and ethicists and philosophers to focus on the potential future outcomes of synbio, never mind the bioengineers and biologists actually doing the technology development. I don't know of any other field of science and engineering that has crossed over so many boundaries.

ANTHONY DUNNE

Head of Design Interactions at the Royal College of Art, London

What is synthetic biology to you?
For me, synbio is about genetic engineering moving out of the laboratory and into the messiness of everyday life via the marketplace. This could potentially lead to all sorts of benefits and improvements in the quality of our lives; but in making this shift it also has to engage with all the stuff that comes with market-led capitalism—rampant consumerism, fantasies and desires rather than needs, irrationality and the profit motive. Somehow, we need to make sure that the short-sighted values currently driving technological development do not destroy the genuine potential of this technology to enrich life.

What parallels do you see with previous technological frontiers?
Many people claim that synbio is similar to digital technology in that you can build complex systems from simple components, but of course once you begin to work with life, it's not so easy to control things. What is to stop these new biological products and devices from evolving and mutating? Also, for digital technology, society has been treated as a bit of a laboratory. New products and services are released and companies watch to see what happens. There is very little speculation about the possible consequences of digital technology. When we are dealing with living or semi-living materials, devices and systems, it's a very different situation. In this case, we need to explore potential risks, consequences and the possible negative implications of building a world where animals become factories, human bodies produce raw materials and everyday objects are potentially alive. It would be extremely risky to let the values driving the development of digital technologies determine how synthetic biology enters our lives.

What is the role of speculation by designers and artists around synthetic biology?
Artists and designers are very sensitive to the human aspects of new technologies; we are tuned into people's hopes, dreams and anxieties. We're also very good at making abstract philosophical and ethical issues concrete—giving them form so that we can have more open and public conversations about what we want from synthetic biology, and of course, what we do not want. Designers in particular can use their experience working with industry to present ideas as imaginary consumer products that connect with people's everyday lives.

But speculating through design is more than just materialising possible futures for biotechnology and synthetic biology. Its real value is in materialising alternative ways of being, of identifying new values, priorities, beliefs, hopes and fears, our basic ideologies, and combining them with technology to highlight how different worldviews might lead to very different realities.

We need to explore potential risks, consequences and the possible negative implications of building a world where animals become factories, human bodies produce raw materials and everyday objects are potentially alive

Anthony Dunne

How do we differentiate between the 'real' and the fictional?

This is a very interesting question. Design theorist Björn Franke has suggested that one of the main differences between science research and design research is that science focuses on existing reality, while design explores realities that do not exist yet, and maybe never will.

For me, the real is something actual, something that exists in the same space as we do; it could be in an exhibition, a shop or a home. A fictional design expressed as a physical object is real, but the world it is designed for might be fictional in the same way worlds portrayed in sci-fi literature and cinema are fictional. It's this coexistence in the here-and-now and a fictional world that makes design fictions or speculative designs so interesting. Just as artefacts in history museums make us wonder about the societies they belonged to, speculative designs can prompt us to imagine what future, or yet-to-exist societies might be like.

When confronted with an imaginary product the viewer needs to suspend their disbelief. So for designers, there is a strong temptation to make speculative designs look 'real', as if they were manufactured today, in order to meet our expectations of what a product should look like. But this creates all sorts of problems, as the viewer is essentially being tricked into believing they are real. This is how props in films are designed, but we know they are not real because we are watching a film. In a gallery, we can assume they are not real, but once objects like these circulate in the media and their original context is lost, they can become borderline hoax objects creating all sorts of problems and confusion. I think it is more interesting to invite the viewer to willingly suspend their disbelief by subtly signalling through the design of the object that, although actual and physically present, it is not real and belongs to a fictional world, or a yet-to-exist reality. I call this the 'aesthetics of unreality', and believe it also provides a more interesting experience for the viewer in an exhibition where they can spend as much time as they like with the design, unmediated by press or other people's interpretations.

How have you seen the role of artists and designers engaging with synthetic biology change, or how might it change?

Artists and designers are experimenting more with fiction and moving beyond working with actual materials; the visions being put forward are more ambiguous, and it's harder to say if they are utopias or dystopias, which I think is a good thing. Instead of being sold a dream or presented with a cautionary tale, we are invited to unpick their proposals and explore their social, cultural and ethical trade-offs.

Working with real materials, although technically impressive, can also mean that artworks are constrained by the science and protocols of reality. It's possible sometimes to have a little too much reality in a project. When designers and artists embrace speculation, whole new realities can emerge. This way of working requires aesthetic rigour, intellectual discipline and a dose of plausibility. Design speculations need to be skilfully crafted to avoid becoming ungrounded fantasies of little interest to anyone.

I think the best speculations serve as 'useful fictions' for developing new perspectives on existing situations; as platforms for discussing preferable futures with both experts and non-experts; and as catalysts for interdisciplinary imagining about how the world could be.

CATHAL GARVEY

Biohacker and Science Gallery Leonardo

What do you see as the role of biohacking or DIY biology?

Biohacking, or DIYbio, has to be one of the most exciting subcultures active today. A network of people worldwide are taking biotechnology out of the lab and making it easier and more hackable. They can then use it to repair, rebuild or replace equipment and protocols to fit the low-budget and sometimes messy world of basement labs. Most people do it for fun, or out of pure curiosity. Others do it to solve problems not serviced by the traditional arms of biotechnology and academia. Others still, do it for political or intellectual reasons. Most have no formal training in biology beyond secondary school (if that), and many are in countries whose institutions don't have the resources to do much better.

I work with others around the world on a great, shared project to make biological science something, not only understandable to the general public, but into a skill or hobby that is accessible and useful to anyone with a passion and enough patience to learn. The study and manipulation of life is a skill as ancient as civilisation itself, but the last century has seen an unprecedented trend where people effectively abandoned living technologies in favour of inert ones: we aim to reverse that, and push back.

Tell us more about your practice and networks of collaborators and how you work to do biology outside the conventional lab.

My 'practice' is a converted ensuite bedroom, where I have built a lab bench abutting a teetering computer desk. Atop the desk is a collection of constructed, cobbled or recycled equipment, and below it is a selection of incongruous food ingredients and abused pharmacy-brand chemicals. In the fridge and the polystyrene box that serves as an incubator, you'll find the biological components: the bacterial cells and DNA samples that comprise my ongoing research into 'distributed biotechnology'.

My current goal is to create and provide a set of systems for the easy production of critical lab enzymes, using equipment and ingredients you'd find in the supermarket. The 'price by weight' for the cheapest lab enzyme, EcoRI, is higher than for weapons-grade uranium, and yet the costs to produce it are negligible. So make, don't pay! I want to help trigger a wave of 'Free or Libre Biotech' that will topple the myth of inaccessible biotech for good.

My collaborators are a loosely affiliated group of postnational hackers, who share ideas, feedback, protocols and sometimes even physical stuff, by high-volume mailing lists, blogs and even on Twitter. We don't all share a mission. Many—perhaps most—are in this for fun, not to fulfil some overarching political or social goal. But I find it's hard not to develop a grand vision, faced with this much possibility.

Do you believe that science will shift to non-institutional practice, or do you think non-institutional practitioners will become increasingly professionalised to work with synthetic biology?

When computers escaped the labs, computer science did not shrink. Far from it, scientists were freed to focus on the pure science of a field that began to boom and expand exponentially. On the other side, hackers didn't turn into academics in order to understand and push boundaries. Similarly, I think that as the engineering of life escapes the labs, academics will thrive on a newfound ability to focus on 'big' science, perhaps at lower cost due to biohacker-made equipment and reagents. Meanwhile, some biohackers will remain scientific and methodical as they ask and answer questions, but many will leave the scientific method behind in favour of creative or technical work. Their different outlook will lead to technology we can't yet imagine.

Do you think that this approach can survive in the current political framework?

What challenges are posed to DIYbio by politics and society? Regulatory, certainly. We currently exist in a very tightly constrained environment in Europe. Despite abundant opportunities for external funding, only a small handful of the community in Europe are legally permitted to conduct productive research, and

so European biohackers have focused more on niche (but nevertheless excellent) projects like directed water snail evolution, microbial fuel cells, bioplastics, DNA fingerprinting, and outreach and education activities. While this constraint is forcing us to be creative in our approaches, it's holding us back, while biohackers elsewhere attract larger and more active communities and advance more ambitious and impressive projects. Europe is a fundamentally hostile place to do science, but that is likely to change in coming years. I think scientists have generally realised that the platonic ideal of a passive, unopinionated and unpolitical scientist is not only impossible, but fundamentally unwise. People respond better to anecdote, story, passion, mission. When we remain silent, proponents of false science prevail: vaccine scares, agricultural vandalism, false remedies made of water. More and more scientists are starting to speak out, and it is having a real effect. Not only do I expect this to benefit biohackers, I expect biohacking to benefit science as a whole in Europe. What better way to dispel anti-GM hysteria than to let people learn to understand and even create their own GM organisms? Similarly, what better way to rebuild trust in vaccines and real medicines than to let people learn about bacteria, antibiotics and the mechanisms of resistance first-hand? Looking inward, how better to hold bad science to account than to have a larger group of science-literate citizens scrutinising the news and demanding better evidence?

Do you think that parallels with information technology can work with a biological substrate?

The 'hacker ethic' inherited from the hacker community has been the most influential cultural influence on DIYbio and biohacking, in my view. The computer metaphor, too, has been potent. Not only in legitimising the potential for DIYbio, but also in guiding the direction of research and improvements in current practice. But, there are stress points in the metaphor.

For one thing, the digital-to-biological model leads to the false assumption that DNA behaves linearly and does not exhibit context sensitivity. In other words, that computer programming paradigms can be directly transposed into biology and used without adaptation. However, life does not conform to this assumption at all. While cells can be 'programmed', the way we must think about these programs is dramatically different to how we approach computers, and we're being forced to create new systems from the ground up to follow the dream of cellular computing.

The culture of information technology is constructive at the technological end of synbio and biohacking, but I feel it is less appropriate when applied socially to the impacts and human factors. A hacker's pet project online is avoidable to others, a curio or webapp that can be simply ignored. A biohacker creates a thing that can breed, grow, spread and invade. Although vastly overblown by special interest groups and false-science proponents, the risks in biology have little parallel in computers, and vice versa.

And yet, the fact that biology has real-world consequences may prove the redemption of biohacking and put the lie to fearmongers. A computer virus can crash thousands of servers without harming a single person, so there is no strong moral consequence to dissuade a talented, if misguided, programmer from writing one. The same personality does not necessarily lend itself to creating malicious works of nature. In that case, our parallels are inappropriate in a positive sense. We cannot claim biological viruses will be as common as computer viruses. As nobody has yet maliciously hacked a hospital or pacemaker, despite ample opportunity, we might surmise that malicious bio-viruses simply won't occur in our lifetimes; not until long after the means to counter them becomes widespread and efficient.

Finally, the parallels only go so far for basic reasons of structure and physics. While a biological aerial is entirely possible, it's easier to make from metal or silicon. While a biological x86 processor is equally possible, it would be slower and less efficient than a chip. Biology is simply better at making parallel computers in which many calculations are carried out simultaneously, such as brains. Biology will always be more mutable, adaptable and, essentially, more 'wet' than silicon. As we outgrow the silicon metaphor and learn to harness this squishy technology more effectively, we'll cease to need metaphors entirely; biology will simply be technology, as it was before.

I find it's hard not to develop a grand vision, faced with this much possibility

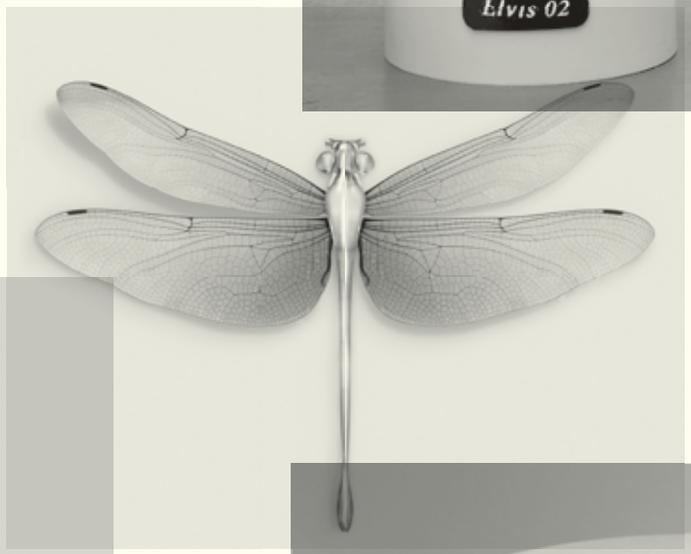
Cathal Garvey

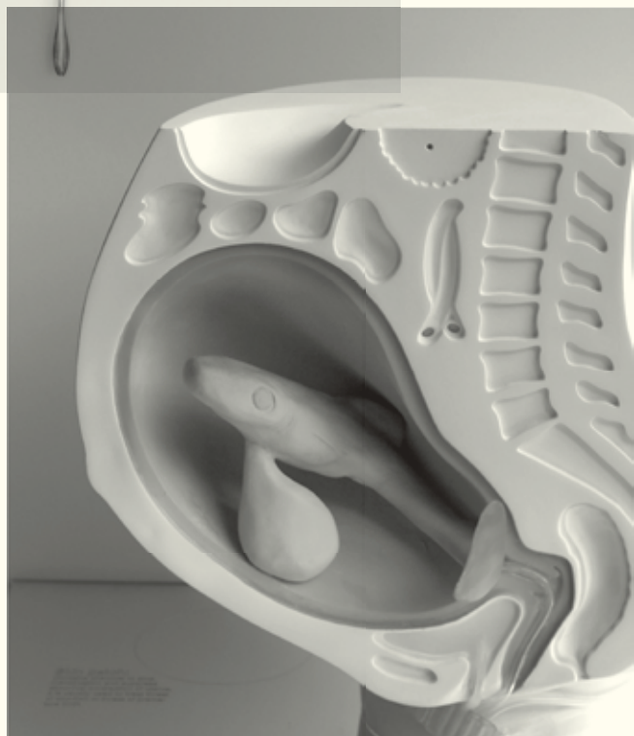
GROW YOUR OWN...

Life

As the foundations of a ‘synthetic’ biology are built, how might designed life merge into our own? Where is the boundary between our things and our selves: the designed products that we consume, and our own bodies and identities? We imagine ‘nature’ as something untouched by human culture; synthetic biology may dissolve the divide, if it ever existed.

The works here include ‘real’ organisms, both unmodified and designed, and their fictional relatives. They all ask us to consider blurring species and even living kingdoms, and test where our limits lie: *E. coli* smells like banana to smell ‘better’ from a human perspective, cheese is made using bacteria collected from our bodies. As our bodies are infiltrated by designed life to meet our needs, animals are designed for human desires, and cities are hacked with architectural parasites. Is this a future where “we are what we eat”, or “we eat what we are”? All of this takes place around the *Community Biolab*, where synthetic biologists and biohackers invite you to become implicated in the redesign of life.





BANANA BACTERIA

Howard Boland (UK)
Installation, 2011

Banana Bacteria is an olfactory work that explores the paradox of having the foul smell of *E. coli* bacteria exchanged with the sweet smell of banana. Engineered *E. coli*, designed by the MIT iGEM 2006 team, have been genetically altered by removing a gene responsible for the foul smell commonly found in bacteria and adding a genetic design that enables them to synthetically produce banana oil. With these scents prompting a rethinking of the human race's microbial relationship, *Banana Bacteria* investigates how synthetic biology can bring new experiences of organisms and, in this case, new scents.

Upon receiving a library of standardised parts from the MIT Registry of Standard Biological Parts, the process of putting plasmids containing the genetic parts into cells began. Using antibiotic selection, colonies were picked and grown in liquid culture. Cultures were scaled up to grow in 200ml bottles and once turbid or dense, these were placed on ice and a small amount of isoamyl alcohol was added, allowing the conversion process to commence. The setup uses round shaped flasks as vessels for the liquid culture, mounted on a laboratory stand with a glass cap. In order to harness the experience and ensure the smell's clarity, a special odourless knockout strain (a strain that has inactivated, or 'knocked out', an existing gene by replacing it or disrupting it with an artificial piece of DNA) was obtained from the University of Lausanne in Switzerland. Because lysogeny broth, a nutritionally rich medium used for the growth of bacteria, produces a sweet caramel-like scent, a scentless growth medium was prepared.

While scientifically *Banana Bacteria* illustrates how synthetic biology can impact the flavouring industry, artistically it offers an olfactory awareness that both confuses and challenges our senses; the foul warning smell of bacteria is exchanged with the sweet smell of banana. Speculative scenarios are posed about future applications, such as how bacteria inhabiting humans could be made to produce synthetic odours, like possibly replacing bad breath with minty fresh breath. The focus, however, is on the intimate experience of this setup, in terms of the audience interacting with genetically modified (GM) organisms and enabling such access by publicly staging the work. In contrast, the smell as an interaction provides an actual and immediate experience beyond speculation that renegotiates the way bacteria are thought of aesthetically.

"As an artist working with synthetic biology on a material level, a key question has been: How can I enable actual experiences and how would I go about doing this in a public setting? I look at tiny cells and invisible processes and ask how we can experience this world through our senses—be it seeing or smelling. Ultimately, I ask if we could produce real-time interaction with real-time biological processes. *Banana Bacteria* enables the strange and wonderful experience of moving a gene and adding a new quality to a material, and also how this confuses our senses. Putting such material in public spaces can be challenging, but the importance of being able to experience such matter in its actual presence rather than being mediated through videos or photographs invites us to get closer to both natural and unnatural organisms."—Howard Boland

***Banana Bacteria* at Techfest 2012, IIT Bombay**
Photo: C-LAB

ALL THAT I AM

Koby Barhard (IL)
Installation, 2011

To create *All That I Am*, hair samples belonging to Elvis Presley were bought on eBay, and then sent to a gene sequencing lab. The sequenced DNA was used to identify different behavioural traits, which varied from sociability and athletic performance to obesity and addiction. This information was then sent to a lab, which produces transgenic (meaning it contains genetic material into which DNA from an unrelated organism has been artificially introduced) cloned mice, with specifically tailored genetics. The result is an 'Elvis mouse model', made-to-order mice clones possessing parallel traits to the King of Rock 'n' Roll. Using a combination of three online services available to anyone, a strand of hair is transformed into Elvis Presley's mouse model.

The genetically cloned mouse models of Elvis are then tested in a number of contemporary mouse model environments, cages that simulate some of the significant biographical circumstances of Elvis' life. By exposing the mice models to similar experiences as Elvis, can they become closer to him via not only nature, but nurture too? One cage has a distorted mirror to give a false sense of self-importance, representing the effects of fame. Another has a sloped treadmill where the mouse model runs until it falls off, symbolising Elvis' death.

All That I Am is a speculative work that examines the cultural day-to-day interactions with emerging genetic technologies, and its ramifications on the way we choose to represent and understand life. Is it possible to quantify life through a series of conditions and events? What aspects of life are responsible for making us ourselves? Is a model more real than reality itself? Does buying a pre-owned item give someone the legal right to another individual's genetic data? Can a mouse be Elvis? What makes us believe it can?

"I've always been fascinated with humanity's eternal need to quantify and define life. Be it biology or physics, philosophy or biography, psychology or fiction—from Frankenstein to 'the God particle'. In my research I came across a private lab service that offers mice that are "genetically modified for your needs". From that point I was just wondering whose behavioural mouse model I would like to design. That, of course, led me to eBay, the DNA sequencing labs and to historical and contemporary behaviouristic science. I'm raising questions so that we, as the general public, can get a better understanding of the issues that we'll soon have to deal with"—Koby Barhard

Elvis mouse—installation detail
Photo: Matthew Booth

E. CHROMI

Alexandra Daisy Ginsberg (UK), James King (UK) & the University of Cambridge iGEM 2009 team
Installation, 2009

E. chromi is a collaboration between designers and synthetic biologists. In 2009, seven Cambridge University undergraduates spent the summer genetically engineering bacteria to secrete a variety of coloured pigments, visible to the naked eye. They designed standardised sequences of DNA, known as BioBricks, and inserted them into *E. coli* bacteria. Each BioBrick part contains genes selected from existing organisms spanning the living kingdoms, enabling the bacteria to produce a colour: red, yellow, green, blue, brown or violet. By combining these with other BioBricks, bacteria could be programmed to do useful things, such as indicate whether drinking water is safe by turning red if they detect a toxin. *E. chromi* won the Grand Prize at the 2009 International Genetically Engineered Machine Competition (iGEM).

Designers Alexandra Daisy Ginsberg and James King worked with the iGEM team to explore the potential of this new technology while it was being developed in the lab. They designed a timeline proposing ways that a foundational technology such as *E. chromi* could develop over the next century. These scenarios include food additives, patenting issues, personalised medicine, terrorism and new types of weather. Not necessarily desirable, they explore the different agendas that could shape the use of *E. chromi* and in turn, our everyday lives.

One speculative use for *E. chromi* is the *Scatalog*, set in the year 2039, which asks: Could cheap, personalised disease monitoring work from the inside out? Engineered *E. coli* bacteria would be ingested as yoghurt, and they would then colonise the gut. These *E. chromi* bacteria would keep watch for toxins or the chemical markers of diseases, and produce an easy-to-read warning signal upon detection, with different coloured faeces diagnosing different conditions. This fictional interface challenges our understanding of a biological computing interface. The collaboration between the designers and the iGEM team has meant that *E. chromi* is a technology that has been designed at both the genetic and the human scale, setting a precedent for future collaborations between designers and scientists.

"We made the *Scatalog* to challenge the depiction of biology as cogs, computer parts or Lego. It was intended as a critical, provocative intervention: we took it to iGEM and asked synthetic biologists about the gut as a computing interface. But by imagining the future, even in a critical way, you might make it more likely. I've met scientists who are trying to bring this idea to life. Would it work? Bacteria can produce colour pigments; designing bacteria to detect different levels of concentration is a reality too. Ingesting bacteria that could reliably detect different chemicals and produce colour signals, within the complex ecosystem of the body, is less easy. Stopping them evolving and keeping them reliable enough to risk your health on is further away. The *Scatalog* was set in 2039 to ask, even if the technology comes soon, will the cultural barriers be less penetrable?" — Alexandra Daisy Ginsberg

E. chromi*: *The Scatalog
Photo: Åsa Johannesson

NEW MUMBAI

Tobias Revell (UK)
Film, 2012

This fictional documentary tells the story of the fungi that ended up hugging the walls of Dharavi. During the Indian Civil War, the Dharavi slums of Mumbai were flooded with refugees looking to escape the conflict. The Mumbai authorities, distracted by defence of the city and facing an already overpopulated and poverty-stricken slum, could do little to maintain a semblance of civilised life in the area and it rapidly became lawless and dangerous to outsiders.

Sometime later, a cache of genetically engineered fungal samples appeared from the Netherlands through the criminal networks of Mumbai. Originally a prototype of a product intended as a new type of building material for rich European firms, criminal gangs harboured a vain hope that it might provide new marketable narcotic opportunities. Although this endeavour failed, the collective drive and expertise of the refugees managed to turn these genetically engineered fungal samples into a new type of resource providing heat, light and building material for the refugees. Dharavi rapidly evolved its own micro-economy based around the mushrooms.

Through interviews with key people—policing authorities, the original creators of the material and the people who re-engineered it—the life story of this strange infrastructure is revealed. The documentary also examines what this innovation has meant for the slum and how it has led to it forming itself around its own micro-economy, separate from the maligned governance of the city.

"In order to best understand a technology, it's important to consider unintentional uses. While synthetic biology and genetic engineering have well-publicised prospects of enhancing the lives of people in developed communities and lowering environmental impact, very little has been done to understand how this will trickle down into less developed areas. *New Mumbai* comes from a culture of what the Indians call 'Jugaad' (a term applied to a creative or innovative idea providing a quick, alternative way of solving or fixing a problem); but we can consider the cheap cell networks of central Africa, the small arms manufacturers of the Middle East, and the bicycles of China. It's the lower end of the glamour spectrum where innovation and change happens most vitally and viscerally."—Tobias Revell

The mushrooms of Mumbai
Photo: Tobias Revell

SELFMADE

Christina Agapakis (US) & Sissel Tolaas (NO)
Installation, 2013

The growing awareness of human microbial ecology and its influence on health is leading to wider understanding of the body as a superorganism; a collection of human and microbial cells that interact in numerous and unexpected ways. In this paradigm, notions of self and other, and of health and disease, are shifting to accommodate more ecological concepts of diversity and symbiosis.

Selfmade is a series of 'microbial sketches', portraits reflecting an individual's microbial landscape in a unique cheese. Each cheese is crafted from starter cultures sampled from the skin of a different person. Isolated microbial strains were identified and characterised using microbiological techniques and 16S ribosomal RNA sequencing. Like the human body, each cheese has a unique set of microbes that metabolically shape a unique odour. Cheese odours were sampled and characterised using headspace gas chromatography-mass spectrometry analysis, a technique used to identify and/or quantify volatile organic compounds present in a sample. A short film documenting the process of cheesemaking, along with interviews of the bacterial donors accompanies the cheese display and the data from microbiological and odour analysis. Visitors to the gallery are exposed to the diversity of life in their food and bodies, and a diversity of visions for future synthetic biologies.

This project explores possibilities for a relational synthetic biology through the practices of cheesemaking. Cheesemaking involves a complex coordination of microbial life, promoting the growth of beneficial *Lactobacillus* strains that protect milk from more dangerous spoilage and the ecologies of microbes on the rind that create the prized flavours of different cheese varieties.

Those involved with synthetic biology are intent on transforming microbes into the useful machines of a new bioeconomy. In the short term, this is accomplished by isolating engineered strains and limiting microbial interactions in stainless steel reactors. However, the appeal of potential medium-term applications in the production of foods, environmental biosensors, or 'smart' living therapeutics demonstrates the power of thinking beyond the bioreactor. Such approaches require addressing ecological concerns about the safety and complexity of interactions with other organisms, highlighting the need for a more relational synthetic biology. Understanding the biological networks inside cells as well as the networks of organisms, regulatory systems, economic structures, and cultural practices that shape the life of an engineered organism in the world will be crucial to the development of synthetic biologies in the long term.

"We not only live in a biological world surrounded by rich communities of microorganisms, but in a cultural world that emphasises total antisepsis. The intersection of our interests in smell and microbial communities led us to focus on cheese as a 'model organism'. Many of the stinkiest cheeses are hosts to species of bacteria closely related to the bacteria responsible for the characteristic smells of human armpits or feet. Can knowledge and tolerance of bacterial cultures in our food improve tolerance of the bacteria on our bodies? How do humans cultivate and value bacterial cultures on cheeses and fermented foods? How will synthetic biology change with a better understanding of how species of bacteria work together in nature as opposed to the pure cultures of the lab?" — Christina Agapakis

Smelling an aged cheese
Photo: Alexandra Daisy Ginsberg

I WANNA DELIVER A DOLPHIN...

Ai Hasegawa (JP)
Installation, 2011

Humans are genetically predisposed to raise children as a way of passing on their genes to the next generation. For some, the struggle to raise a child in decent conditions is becoming harder due to gross overpopulation and an increasingly strained global environment.

This project approaches the problem of human reproduction in an age of overcrowding, overdevelopment and environmental crisis. With potential food shortages and a population of nearly seven billion people, would a woman consider incubating and giving birth to an endangered species such as a shark, tuna or dolphin? This project introduces the argument for giving birth to our food to satisfy our demands for nutrition and childbirth, and discusses some of the technical details of how this might be possible.

Would raising this animal as a child change its value so drastically that we would be unable to consume it because it would be imbued with the love of motherhood? The Maui's dolphin has been chosen as the ideal 'baby' for this piece. It is one of the world's rarest and smallest dolphins, classified critically endangered by the International Union for Conservation's Red List of Threatened Species (version 2.3) because of the side effects of fishing activity by humans, its size (which closely matches the size of a human baby), and its high intelligence level and communication abilities.

I Wanna Deliver a Dolphin... imagines a point in the future, where humans will help this species by the advanced technology of synthetic biology. A 'dolp-human placenta' that allows a human female to deliver a dolphin is created, and thus humans can become a surrogate mother to endangered species. Furthermore, gourmets would be able to enjoy the luxury of eating a rare animal: an animal made by their own body, raising questions of the ownership of rare animal life, and life itself.

"This project is about growing your own food in your uterus with the help of synthetic biology technology. Humans always take from nature, but this time they try to donate their reproductive resources. This could be seen as win-win relationship, since the animal embryo held in the woman's uterus also consoles the woman's unsatisfied reproduction desire if, for example, the woman believes that having more human babies is not ethically sound, given the overpopulation of the earth. Also, they might be able to eat this expensive delicacy after the end of these rare animals' natural lives. On the other hand, if they release them to nature, they will be investing in the future food supply. This point, however, will give rise to the same issues as the release of GM life forms into the wild."—Ai Hasegawa

Spiny dogfish embryo in the human female womb
Photo: Ai Hasegawa

POST NATURAL HISTORY

Vincent Fournier (FR)
Photography, 2012

Post Natural History is a collection of imagined 'upcoming living species' presented in the form of old-fashioned encyclopaedic entries. The intention is to reinterpret the idea of the 'cabinet of curiosity' through a journey in time, rather than through a physical space. As during the Renaissance, when strange creatures returned with the explorers of distant and unknown countries, these images show species as 'newcomers' from an imagined future based on current synthetic biology research.

The species featured have been reprogrammed by humankind for man's own needs and desires, and also so that they can adapt themselves to the biological changes of the planet. They have integrated new DNA fragments and artificial elements like metal or electronics. They have new properties to better adapt to new environments created by climate change and accompanying events such as drought, stress, disease, and predators.

These creatures are simultaneously familiar and strange: we 'know' the rabbit, lizard or dragonfly we see, but upon closer inspection, we realise there are certain differences. For example, the ibis has metal legs to resist extreme temperatures. The dragonfly possesses a transparent glass belly in which a luminescent sensor measures the rate of pollution. Together, they surmise how humans could intervene in evolution.

"These creatures are coming from the future; an imagined future caught between memory and projection, and based on current synthetic biology research. It is important to me that my stories are based on science, so that they can potentially be true. I like to play with the idea of a true or false archive, like a Jorge Louis Borges novel with several levels of reality. Staging the pictures like encyclopedia entries fills them with confusion. It's not clear if it's true, if it's not true, if it's serious, or if it's ludicrous."—Vincent Fournier

***Leporidae cognitiva*—intelligent rabbit**
Photo: Vincent Fournier

COMMUNITY BIOLAB

Lab and workshops, 2013

What would happen if everyone could participate in hands-on synthetic biology? *Community BioLab* is an open-access laboratory facility created within Science Gallery that is hoping to answer that question. Using borrowed, recycled and home-built equipment, it recreates a typical do-it-yourself biology (DIYbio) lab and brings synthetic biology to the public. This lab reframes the laboratory as a shared space, deliberately informal and inviting rather than sterile and cloistered. Through audience participation, the intention is to demystify synthetic biology and radically lower the barrier to participation in modern bioscience, allowing anyone to innovate and explore. This environment also encourages thoughtful examination and discussion of the implications and ethical questions surrounding cutting-edge DNA-based technologies.

The DIYbio movement, a global community that connects people and non-institutional labs, hackspaces and home practitioners, is enabled by the abstraction component of synthetic biology: a person does not have to be a biologist to build a biological machine. Community lab spaces support not only science research projects, but also artists who want to incorporate synthetic biology into their work. By engaging the public directly through hands-on participation, it is hoped that a dialogue will be opened around synthetic biology that will be founded on knowledge and understanding.

During the course of GROW YOUR OWN..., the *Community BioLab* will be inhabited by various DIYbio practitioners who will work on their own projects and also provide opportunities for public participation through workshops and discussions. Curated in part by Ellen Jorgensen, the director of the world's first community biolab, Genspace, the lab will play host to synbio and open source biology groups including Hackteria, Genspace, (Art)ScienceBLR, La Paillasse, and MadLab. Artists and scientists will include Christina Agapakis, Sissel Tolaas, Conor Courtney, and GROW YOUR OWN... curator Cathal Garvey. This collection of international and local artists, scientists, biohackers and synthetic biologists will take up week-long residencies in the lab, offering the public unique and varied opportunities to participate in real synthetic biology research, experiments, and workshops.

"Synthetic biology was, in part, responsible for the rise of the DIYbio movement. If you make reading and writing 'the code of life' easier for non-biologists, like engineers and computer scientists, then you also make it easier for everyone. The concept of DIYbio was promoted by people who had participated in the iGEM competition and wanted to keep inventing new and better biological machines in their spare time. Creating community lab spaces and reverse-engineering lab equipment were logical next steps, since shared infrastructure lowers the cost of doing synthetic biology."—Ellen Jorgensen

Open Source PCR Machine
Photo: Ruža Leko

How might synthetic biology change the way we live?

HOWARD BOLAND
BANANA BACTERIA

"Synthetic biology is changing the way we relate to genetic engineering in its approach to science and is gaining a broader cultural acceptance. The consequences of this shift have opened new material opportunities, not only in the sciences, but also in areas such as art and design. The impact will be felt in how we relate to nature and biomatter, from our own body to biomedical products, and the ability to create and use new material never found previously in nature."

KOBY BARHAD
ALL THAT I AM

"We're going to see a lot more of ourselves in nature, then we'll see more nature in ourselves."

ALEXANDRA DAISY GINSBERG
E. CHROMI & DESIGNING FOR THE SIXTH EXTINCTION

"The UK government says that, "synthetic biology will heal us, heat and feed us". These are big promises for a technology, when biology already does these things. I suspect much of the change will be imperceptible for consumers, with industry shifting to using biological factories– microorganisms – to make chemicals in big vats, fed by biomass grown far away. The hope is that shifting towards a more bio-based economy would encourage sustainability. But rather than perpetuating our existing, damaging modes of consumption, I think using biology to reimagine more sustainable approaches to the way we consume will be the only way we might actually change the way we live."

TOBIAS REVELL
NEW MUMBAI

"Synthetic biology might do very little to affect the way we live, but trickle-down mechanisms may well mean it affects the lives of the people we least expect it to. Very often there are unexpected side effects of new technologies and synthetic biology will be no different."

CHRISTINA AGAPAKIS
SELFMADE

"Synthetic biology might change the way we produce commodities and deliver medicines, but we are more interested in how synthetic biology has already shaped how we think about the living world: our bodies, our microbes, our food and our wider environment. Machine metaphors, determinism and programmability are emphasised, largely to the exclusion of more biological, ecological and dynamic understandings of organisms, their variability, and their potential design. Perhaps as synthetic biology puts more life into our technologies and our commodity supply chains, these metaphors will slowly change, creating more biological technologies."

AI HASEGAWA
I WANNA DELIVER A DOLPHIN...

"I suspect that synthetic biology will not change our lives dramatically in the next five to ten years. In addition, ethical issues might hold us back for now, but this barrier might be broken by new scientific discoveries. As with many human projects, political and monetary issues will always be an obstacle. After we have overcome all this, we might live as in the world of a sci-fi novel. What we previously only imagined would become a reality. As with sci-fi, this could be either a dystopian or a utopian future."

VINCENT FOURNIER
POST NATURAL HISTORY

"I would not dare to give any answer or express personal opinion as I don't have enough concrete scientific knowledge. My project is more about questioning the frontier between the living and the artificial in an aesthetic way. My work is usually inspired by the world of science, and different forms of utopia. I found within science, and some forms of utopia in general, the material to imagine possible fictions and generate a collective psyche. It is the imaginary and dream side of science that I am interested in, its fictional and extraordinary potential"

ELLEN JORGENSEN
COMMUNITY BIOLAB

"This is the age where biology is technology. Cells become factories and living machines do work. There is not one area that will be unaffected by synthetic biology, from medicine to fuels to materials to foods"

CHARLOTTE JARVIS
BLIGHTED BY KENNING

"In the future there will not be technology, there will be only biology. Synthetic biology will change every aspect of our lives and bodies."

DAVID BENQUÉ
THE NEW WEATHERMEN

"The DIYbio approach is very interesting and promising, but it is under such scrutiny from the authorities that it has to self-regulate and ensure it's only going to do 'good' and 'safe' things. Of course regulation is necessary when dealing with such a potentially dangerous material, but who sets the agenda?"

HEATHER DEWEY-HAGBORG
STRANGER VISIONS

"I think it already has. Look at 23andMe in the US. Already, couples query each others genetic profiles before committing to serious relationships. Already, people are discovering that the person you called your father for decades may in fact not be a biological relative at all. So the impact is already pervading our culture and will certainly grow and evolve, amplifying certain cultural practices and diminishing others."

SHIHO FUKUHARA
& GEORG TREMMEL
COMMON FLOWERS/FLOWER
COMMONS

"Synthetic biology as an engineering discipline aims for greater control of living entities by increasing the understanding of their individual 'parts'. The gain in bottom-up understanding should allow the recombination of desired threads, which should be reflected in the production of better drugs and in better treatments of illnesses. Synthetic biology is also the younger, nicer-looking sibling of genetic modification. It does not yet come with the heavy, negative image of its older sibling, it still promises a bright future. Let's hope it fulfills its own expectations."

TOBIAS REVELL
INTO YOUR HANDS THEY ARE
DELIVERED

"Synthetic biology will doubtlessly provide many 'wicked' solutions to many 'wicked' problems and, as a technology, it has the ability to dazzle and shock. It poses a deeper problem to humanity as a whole though, one that is more existential. Control over life itself raises questions about where the dominion of man extends to, if such a thing even exists."

STEFAN SCHWABE
XYLINIUM CONES

"We envision a future where people rethink their relationship with nature, taking a modern and progressive perspective. We actually see a risk in the engineering approach of controlling biology and would like to encourage a thinking where we see ourselves more as gardeners or nurses, instead of consumers or engineers of nature."

ORON CATTS
THE MECHANISM OF LIFE—AFTER
STÉPHANE LEDUC

"Having control over life and its processes may have always been an ambitious human endeavour. What is changing, however, are attitudes towards life resulting from the accumulation of scientific knowledge and technological capabilities, and the increasing speed and scale of manipulation.
A choreographed interplay between hype and actuality is overlaid on a public that is bombarded with information that should excite but is also easily forgotten. It seems that where biologists previously applied their understanding of engineering to the life sciences, now it is the engineers who force-fit engineering methodologies onto living systems; life is becoming bio-matter, waiting to be engineered."

ADAM W. BROWN
THE GREAT WORK OF THE METAL
LOVER

"As an artist of the 21st century working with biological systems, alchemy feels like an appropriate model of reference. At the height of alchemy during the time of the European Renaissance, the world appeared to be much less defined. Artists were simultaneously engineers, architects, alchemists, and chemists. It was possible for someone to strive to be the universal person and have a relatively deep knowledge of many fields. Times have changed, complexity has grown and specialisation has become more necessary. Newer technologies, including augmented memory and instantaneous access to information, have changed the way artists work. Now instead of being 'the total person', one can employ collaborative practice to venture into territories that were previously inaccessible."

SASCHA POHFLEPP
ZERO PARK

"Synthetic biology has the potential to generate profound change, both in the way we regard the natural world (and indeed ourselves), as well as the way in which we think of technology.
I believe most of the initial change brought forth by synthetic biology will happen in the industrial world, but as the technology becomes more accessible there will be a lot of surprises."

AGATHA HAINES
CIRCUMVENTIVE ORGANS

"Synthetic biology has the potential to make us look at life on earth as another material, which can be used in many ways that haven't been thought of before. For the last few million generations, organisms have been nicely 'designed' or 'fitted' by the blind force of natural selection. Perhaps we are now just taking control of our own evolution by extending our idea of the human body. When we create new environments we change our future by editing the way we live. Perhaps the next phase of evolution is 'directed' evolution or design, where we are intentionally altering the physiological forms that inhabit our planet. I suppose the main question is, are we prepared to accept our god-like ability to manipulate the plasma of life with unprecedented power?"

NATSAI AUDREY CHIEZA
FABER FUTURES: THE
RHIZOSPHERE PIGMENT LAB

"First let's take an optimistic view: synthetic biology has an immense capacity to change how we live, the food we eat, what our homes look like, how we manufacture energy, how we educate young people, and much, much more. To take a pessimistic view, some 'future scenarios' include humans being parasitised by home-cultured organisms, or a quietly ominous market for genetic products that has the potential to render our bodies as future farms."

GROW YOUR OWN...

Society

Synthetic biology might change our understanding of design and nature, but it could also change the cultural and biological ecosystems we are part of. Synthetic biologists are engineering organisms, but they are also designing and agreeing the standards and the legal and commercial frameworks that underpin a new technology. Biology doesn't adhere to laws or country borders. Today, patented genetically modified organisms are already grown in many countries. Their tendency to spread or evolve has to be managed using laws and regulations.

Science and society together have to decide whether we need different rules for synthetic biology: from what can be owned to what can be put into the environment, to what new laws might be needed to control biology and human interests in it.

The artists and designers here use a wide range of approaches to open up questions about these interactions between science and society. Together, they make visible the difficult questions about biodiversity, conservation, intellecttual property, corporate responsibility, privacy, piracy, politics, biological pollution, and the interaction between knowledge and technological progress.

BLIGHTED BY KENNING

Charlotte Jarvis (UK)
Installation, 2011

Blighted by Kenning centres on bioengineered bacteria that has The Universal Declaration of Human Rights encoded into its DNA. The DNA was extracted from the bacteria and used to 'contaminate' apples grown at The Hague, the seat of the International Courts of Justice. These 'forbidden fruits' were then sent to genomics laboratories around the world. Participating scientists were asked to sequence the DNA, find the message hidden within and send back a translation. They were also invited to eat the fruit.

The process for encoding text into DNA is not new. Each letter of the alphabet is represented by one DNA codon: a tri-nucleotide unit consisting of a specific combination of adenine (A), thymine (T), guanine (G) and cytosine (C). Helpfully, most codons already correspond to an existing amino acid, each of which is designated by a single letter of the alphabet, known as the single-letter code. Because not all letters are represented by amino acids, but some amino acids are encoded by multiple codons, it was necessary to slightly adapt the 'meaning' of some codons. For example, the words "Article One" are written into the genome as "GCTCGTACTATTTGTTTAGAAAGAATAAATGAA", where the codon AGA is used to designate a space and the codon ATA is used for the letter O, which has no associated amino acid. Once the DNA was sequenced, it was extracted from the bacteria and made into a solution which was sprayed onto the surface of the apples. In nature, amino acids are strung together to make proteins. Therefore, when a DNA code for The Universal Declaration of Human Rights is made, a hypothetical 'human rights protein' is also produced.

The structure of this protein has been visualised as part of the project. Although inherently political, the work does not take sides. The agenda is not to trumpet human rights nor GM foods, but instead to examine the way in which intellectual progress and scientific knowledge are infectious. The apple, one of the most cultivated fruits in the world, symbolises knowledge, temptation, and sin. It is the ideal carrier, and by literally contaminating the 'forbidden fruit' with knowledge, *Blighted by Kenning* challenges the concept of whether knowledge can ever be evil. In eating the infected apples, scientists around the world are given the opportunity to affirm their belief in their field and consequently in intellectual progress.

"*Blighted by Kenning* proposes an alternative scenario to those usually associated with GM foods. By reversing the idea of forbidden fruit, it seeks to directly challenge some of the religious rhetoric that is employed in the press when reporting on GM issues. In the Book of Genesis, knowledge leads to evil and suffering. My belief is that the abstract pursuit of knowledge (including synthetic biology and GM research) can never be 'evil'—it is how we choose to apply that knowledge that can be dangerous, but not the knowledge itself. The purpose of creating and ultimately consuming 'apples of knowledge' is to assert that belief and to allow scientists working in these controversial fields to publicly 'put their money where their mouth is'."—Charlotte Jarvis

***Blighted By Kenning*—installation**
Photo: James Read

THE NEW WEATHERMEN

David Benqué (FR)
Installation, 2013

In the face of impending climate crises, environmentalists are becoming increasingly polarised in their ideas and beliefs. Bioconservatives argue for a curbing of consumption, a return to nature, and are suspicious of new technologies. Techno-progressives, on the other hand, adopt an optimistic trust in progress, and promise to solve problems with newer and better technologies.

A number of emerging factors suggest possible alternatives for the relationship between environmentalism and science. Among these are the DIYbio or biopunk movements and the campaign for open access to science, as well as efficient, headless and cell-based networks of activists such as Anonymous.

This project explores relationships between ideology and science and how an alternative to current options might manifest itself. *The New Weathermen* is a fictional group of activists who embrace synthetic biology to push for radical environmental change. Challenging the borders between activism and crime, their actions aim to disrupt the status quo and propagate an ambitious vision for the greater good. The project consists of a series of test rigs and small scale experiments that reflect much bigger, radical and slightly deluded ambitions. Deliberately radical and ambiguous, they provide a starting point for discussion about our existing beliefs and ideologies.

"*The New Weathermen* are a fictional group of activists; they don't exist. The goal of the project is to encourage discussions on the relationship between science and environmentalism, as they are so often opposed. What would happen if environmental activists started to use science and DIY biology to support 'green' ideology? The models on display are like test rigs. They are fictional experiments that the Weathermen would carry out to test and fine-tune their bioactivism. They give us a sense of their ambition, but we can also tell that they are slightly delusional. This project includes A4 handouts, an imaginary manifesto for the public to take away. These are the basic rules driving *The New Weathermen's* actions." — David Benqué

***The New Weathermen* — installation**
Photo: David Benqué

STRANGER VISIONS

Heather Dewey-Hagborg (US)
Sculpture, 2013

In *Stranger Visions*, portrait sculptures are created from the analysis of genetic material collected in public spaces. Working with artefacts strangers unwittingly leave behind, this work demonstrates the possible future of forensic DNA phenotyping (a method of determining appearance from DNA), and points to the emerging privacy issues related to the increasing accessibility and decreasing costs of biotechnology.

Samples—traces of human DNA found on cigarette butts littering the streets of Dublin—were brought to a lab and a DNA extraction was performed. Certain regions of the DNA were amplified using a technique called PCR—polymerase chain reaction. This makes it possible to study certain regions of the genome that tend to vary person to person, known as single nucleotide polymorphisms (SNP).

The allele present for a particular SNP on each sample is determined. Using a custom computer program, this information then determines the values that correlate with physical genetic traits and renders a 3D model of a face to represent them. The model is then exported and sent to a rapid prototyping machine which prints the model in full-colour 3D.

Intended as a provocation, *Stranger Visions* is art, not the development of a new product or company. The intention is to confront the viewer with the possibility that someone might be able to examine their DNA and inspect their identity from detritus they didn't even notice that they had left behind. The point isn't that the artist knows everything about a person from a cigarette butt, a hair, or a piece of chewing gum; rather that she, an amateur, knows as much as she does. And can potentially find out a whole lot more.

"The question behind *Stranger Visions* came to me as I was sitting in a therapy session. Staring at a generic print on the wall, I noticed that the glass covering the print was cracked and in that crack was lodged a single hair. I became fascinated by this hair. Whose hair was it? What might they look like, act like, think about? How much could I know about a person from a single hair? Like a detective story unfolding before me, I became entranced by this question of what I could learn about a person from a carelessly shed hair. On my way home that afternoon, I began to notice all these genetic artefacts, all these clues, littered on the sidewalks, subway benches and streets. It occurred to me that if I could extract DNA from these kinds of items, I would have a pretty good indication as to who left them."—Heather Dewey-Hagborg

***Stranger Visions*— installation**
Photo: Heather Dewey-Hagborg

DESIGNING FOR THE SIXTH EXTINCTION

Alexandra Daisy Ginsberg (UK)
Installation, 2013

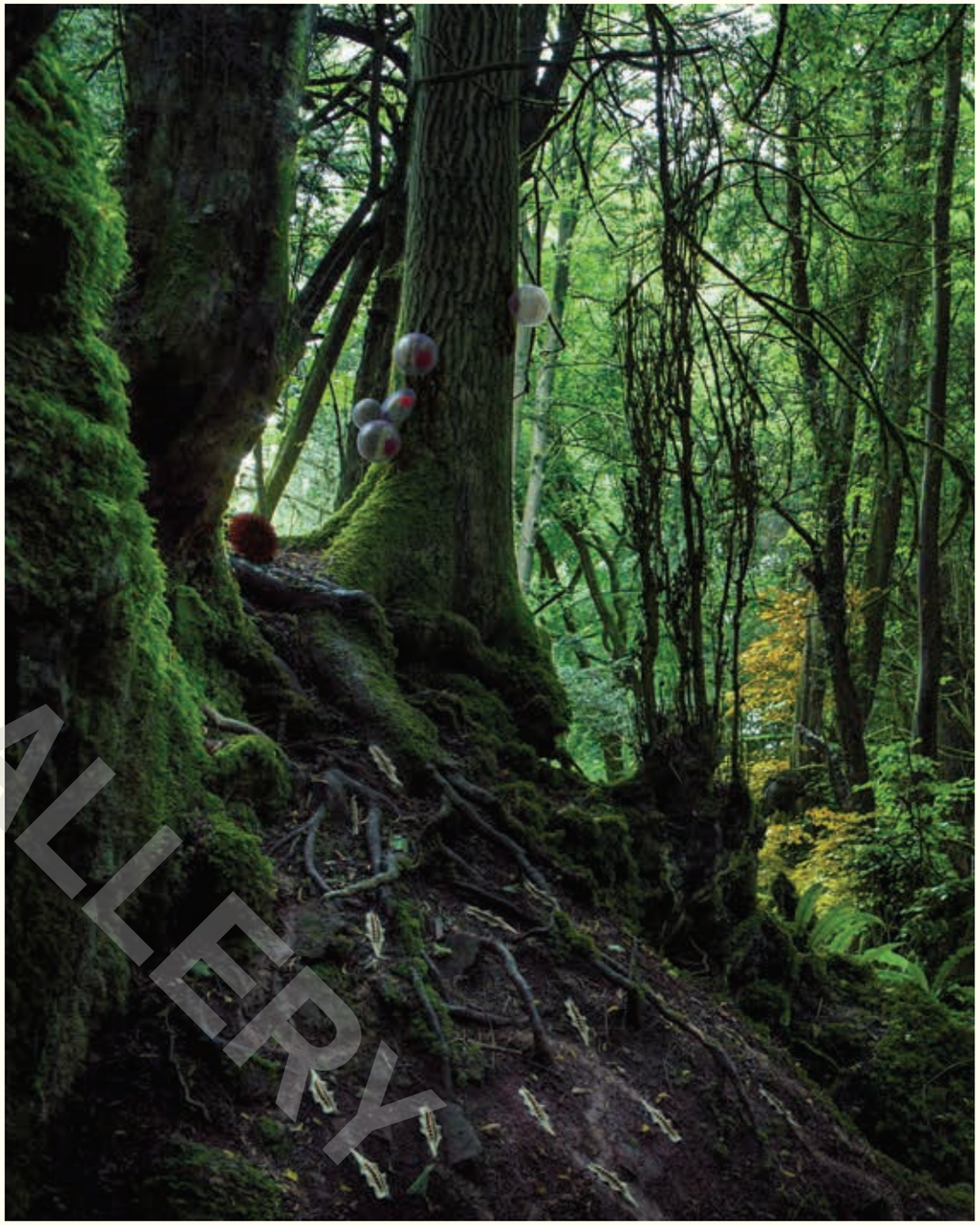
Can we 'preserve' by looking forwards? The sixth great extinction event in the history of biology is underway, and we humans may be its cause. While conservationists struggle to protect existing 'natural' species and reverse the effects of the Anthropocene (the human epoch), synthetic biologists are busy designing new organisms for the 'benefit of humanity'. What might the 'wilds' look like in a synthetic biological future?

Designing for the Sixth Extinction investigates synthetic biology's potential impact on biodiversity and conservation. Could we tolerate 'rewilding'—the conservation movement that lets nature take control—using synthetic biology to make nature 'better'? Letting synthetic biodiversity loose to save the 'nature' that we idealise would disrupt existing conventions.

In this future, novel companion species designed by synthetic biologists support endangered natural species and ecosystems. Financed by corporate 'biodiversity offset' schemes, patented species released into the wild compensate for biodiversity lost elsewhere due to widespread monoculture farming of biomass for biofuel and chemical production. In the bioeconomy, the preservation of natural biodiversity is worthwhile not just for sentimental reasons, it is also a valuable DNA library for future biological designs.

Modelled on fungus, bacteria, invertebrates and mammals, the designed and functional species are ecological props that fill the void left by vanished animals, or offer novel protection against foreign species, diseases and pollution. Constructed using an expanded DNA code that produces non-biodegradable proteins, these living machines are hardy in the face of wild predators that have not yet evolved to digest them. They form their own enclosed ecosystems, the outcome of decades of political negotiation around biosafety and release. Corporately-designed organisms used to preserve or revive disappearing ecosystems would demand a relaxed attitude to biological control, risk and ownership. The taxonomic status of organisms that are technologically isolated with no purpose except to save others is also uncertain. Are they even 'alive'? If nature is totally industrialised for the benefit of society—which for some is the logical endpoint of synthetic biology—will nature still exist for us to save?

"*Designing for the Sixth Extinction* investigates an area that has not yet had much scrutiny: the relationship between conservation, biodiversity and synthetic biology. In October 2013, for the first time, an advisory committee of the Convention on Biological Diversity (the agreement signed by 150 countries in Rio in 1992) is discussing synbio, as environmental NGOs call for a moratorium on the technology. *Designing for the Sixth Extinction* reflects on a future total instrumentalisation of nature by synthetic biology. Could we see existing biodiversity simply as a useful resource for spare parts? The despair found in conservation contrasts with the world-saving optimism found in synthetic biology. The project is also an aesthetic exploration of this technology. What might synthetic biology look like and how would it be managed if it were let loose in the complex context of the 'wilds' rather than controlled in industrial vats? Is this still nature if it runs on a 'safer' expanded DNA code, and doesn't fully interact with the ecosystem?"—Alexandra Daisy Ginsberg



Rewilding with synthetic biodiversity
Image: Alexandra Daisy Ginsberg

TEEN GENE POEMS

(Art)ScienceBLR (IN)
Installation, 2009–2013

Teen Gene Poems is drawn from a collection of work done in India between 2009 and 2013. During this time, these projects have brought together synthetic biologists, artists, designers, students, hackers, farmers, environmental activists and even chefs. Together they have created artworks, design artefacts and discursive contexts that investigate critical discourse and politics around synthetic biology, citizen science and bioethics. Part history lesson and part exploration of the intersection between art, science and pedagogy, *Teen Gene Poems* is primarily concerned with hybrid forms of practice that give an overview of the work done in synthetic biology in a non-western context. It addresses the popular notions and hysteria in the public consciousness and the media about biohacking and points to the diverse, remarkable community of practitioners from around the world that have worked both within and outside institutions to produce these projects.

The first project is *Teenage Gene Poems* (2009), which harnesses a sequence of DNA called BBa_K221000, one of the first BioBricks produced by artists, that produces an enzyme called geosmin. Geosmin is responsible for the smell of wet earth when it begins to rain. When BBa_k221000 is transformed (injected) into the DNA of *E. coli* bacteria, it transforms the bacteria into 'living machines' that produce the smell of rain. The mystique surrounding the aroma of the Indian monsoon is encoded as a genetic sequence. This is an artistic investigation into the narrative and promises of synthetic biology.

The second project, *Synthetic/Post Natural Ecologies* (2009, in collaboration with Alexandra Daisy Ginsberg and James King) investigates the consequences of a synthetic ecology, or an ecology in which organisms created in a technoscientific environment interact with organisms in the wild. The soil-living roundworm *C. elegans* lives on a diet of a variety of bacteria, *E. coli* being one of them. Genetically modified *E. coli* are fed to *C. elegans*, which then express any double stranded RNA of interest. The dsRNA can knock off specific genes, which causes marked visual changes in *C. elegans*.

On a utilitarian level, this project investigates the use of *C. elegans* as a visual marker for changes in environmental conditions. On a more critical level, the *C. elegans* here can be used to study the consequences of interactions between engineered organisms and the 'natural' world.

The final project, *Searching for the Ubiquitous Genetically Engineered Machine* (2011, in collaboration with the Center For Genomic Gastronomy), proposes alternate reappropriations of the BioBrick by using existing BioBrick primers as random polymerase chain reaction (PCR) primers in investigating soil samples. This random PCR will provide a succinct signature of the biological diversity present in these samples. These BioBricks may end up in our environment and may very well show up as bands in a gel electrophoresis (a method for separation and analysis of macromolecules) when soil samples are analysed. By imagining a world in which the BioBrick has become the accepted standard for synthetic biology, and where these engineered products are ubiquitous in our lives and environments, the samples we archive will serve as the baseline from which the subsequent extent of human influence can be measured.

"*Teen Gene Poems* was developed by art and design students from the Srishti School of Art, Design and Technology under the guidance of artists, designers and scientists, and within the context of the International Genetically Engineered Machines (iGEM) competition, which is primarily for undergraduate science and engineering students. As an exploration of the poetic promises and perils of synthetic biology, these projects addressed many ethical and philosophical questions. These questions, of course, are not new and relate to the very nature of technology itself. Most remain unanswered, and are still vague and ambiguous."—(Art)ScienceBLR

***Searching for the Ubiquitous Genetically Engineered Machine*—soil sampling**
Photo: Catherine Kramer

COMMON FLOWERS/FLOWER COMMONS

BCL [Shiho Fukuhara (JP) & Georg Tremmel (AT)]
Installation, 2008

The *Common Flowers* project is based on the first commercially available GM flower, the blue-mauve Moondust carnation. Developed and marketed by a Japanese beer-brewing company, carnations with blue petals were created by inserting genes from other flowering plants into the genome of the *Dianthus caryophyllus* (carnation). The Moondust carnation was the very first commercially available GM consumer product intended purely for aesthetic consumption. Unlike previous GM products introduced to the general markets (such as Flavr Savr Tomatoes), the GM carnations are not used as human food nor as animal feed and therefore bypassed any potentially damaging discussions and sensationalist uproars in the media. The plant and its transgenes are not considered part of the food chain and are therefore considered 'environmentally safe'. However, like any other GM product it was subjected to strict scientific testing to ensure that the flowers pose no threat to animals and wildlife, and can be kept under control.

Common Flowers grows—technically, clones—new plants from purchased cut flowers via basic plant tissue culture methods, techniques used to grow plant cells, tissues or organs under sterile conditions. The slowly dying cut flowers are brought back to life using DIY biotech methods involving everyday kitchen utensils and materials.

Because the Moondust carnations are officially considered not harmful, it is not illegal to release them into the environment. Therefore, the artists decided the next logical step was to introduce (and in a poetic sense: set free) the blue GM carnation to its natural environment—the outdoors. This action raises questions about the state of intellectual property, ownership and copyright issues surrounding the biohacking and biobending of plants. *Common Flowers* makes these flowers available as shared 'common flowers' and gives the plants access to spaces where they can grow happily: *Flower Commons*.

The *Flower Commons* act as a self-sustaining source for *Common Flowers*. Until now the only choice to propagate the blue carnations was to purchase them as cut-flowers. With *Flower Commons* the artists introduce another—free and open source—choice.

By freeing or 'jail-breaking' the flower from its destiny as a cut flower and establishing a feral and more 'natural' population of blue carnations, the flower will be given a chance to reconnect to the general gene-pool and to join evolution through natural selection once again. What *Common Flowers* hopes to touch on is the question of patents on plants and on life forms in general. In particular, what form of legal protection for their plants are companies granted, and does the act of simply growing plants constitute a copyright violation? Is this reverse biopiracy?

"We came across the blue GM carnations during our research in Japan for another project, *Biopresence*. Having lived in the UK before, we were surprised by the lack of any critical response to the introduction of the blue GM carnations in Japan. After deliberating what we, as artists, could do with the flowers, we decided the strongest statement would be not to work with the flowers as ornaments or decor, but to highlight the legal processes at work behind the scenes. An important aspect of the work is the ability to "grow your own" blue GM carnations. They are available at flower shops across Ireland and Europe, and the tissue culturing of the plants can be done DIY-style by virtually everybody—we believe that to be an important part of the process of turning these 'special flowers' into 'common flowers'. The moral question of releasing the cultured GM carnations is in the hands of the audience and the home growers."—Shiho Fukuhara & Georg Tremmel

Day one of genetically-modified blue carnation plant tissue culture experiment
Photo: Belinda Grehan

INTO YOUR HANDS ARE THEY DELIVERED

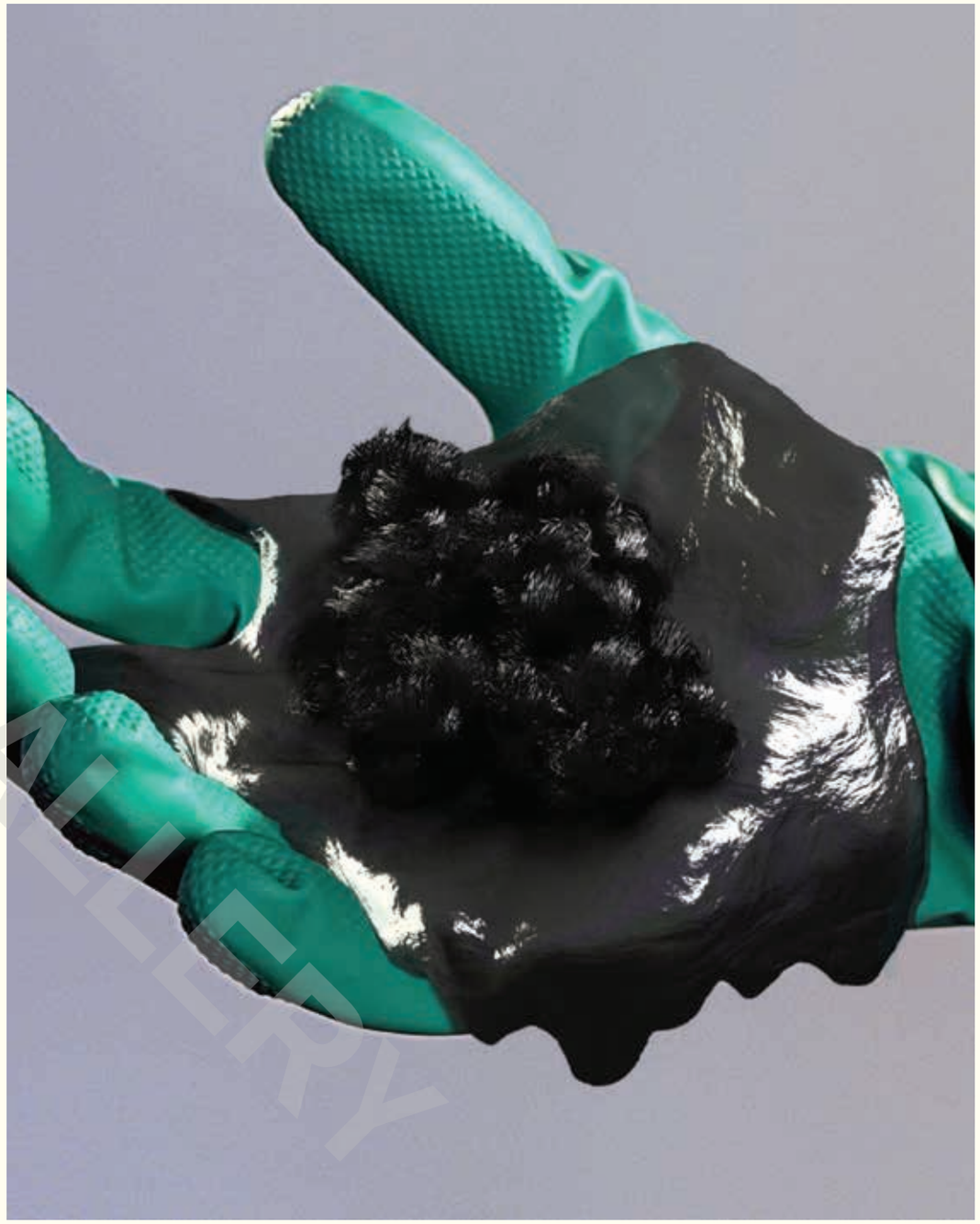
Tobias Revell (UK)
Installation, 2013

Deep in the Texan swamps, a new species of parasitic wasp is discovered by the T-SEE expedition, and buried in its extensive collection of insect specimens. Years later, Global Petroleum, the nation's largest petroleum company working in the Gulf of Mexico, suffers from blockages in its pipeline network. To their horror, Global Petroleum scientists discover that a new species of parasitic wasp is incubating its eggs in the petrochemicals the company manufactures and distributes. It becomes clear that the wasp discovered by T-SEE has evolved rapidly to develop a parasitic relationship with synthetic chemicals, wreaking havoc on the scientific, industrial and political status quo.

Into Your Hands Are They Delivered is a fable presented as a series of images and documents reframing the short story that forms the core of the project. It takes its name from chapter 9 of the Book of Genesis, where God resigns himself from interfering in the affairs of humanity and grants dominion over all life on Earth. This assumed relationship with nature has permeated society in everything from natural philosophy through to advertising. The idea that man is somehow separate, above or outside nature and the idea that nature can be used as some sort of moralistic compass where 'natural' is synonymous with 'good' and 'unnatural' with 'evil' is deeply ingrained in contemporary culture and forms the centre of the debate around synthetic biology.

Into Your Hands Are They Delivered aims to challenge this narrative consensus, to demonstrate how the ideas of nature and unnature, good and evil, faith and science are constructs of cultural heritage. Using the parasitic wasp — an already contentious creature in natural sciences — as a wildcard in an all-too-familiar allegorical world, the project invites the audience to play with the fable presented and reconstruct their own rules and interpretations of humanity's position in relation to the 'nature' they believe themselves to be alternately caretakers and abusers of.

"I wanted to create a piece that treated the advent of synthetic biology at a time when we need to readdress the constructs and boundaries that shape science and the human understanding of the world. These constructs form the basis of debate around synthetic biology — whether it is inherently 'good' or 'bad.' But even these frameworks are inherited from ideas that pre-date the technology to such an extent that they are irrelevant. Dabbling with nature multiplies the complexity levels and crossing points of the discussions because we have such a complex inherited moral code based around our relationship with it. I want to highlight the flaws of the accepted narrative of science and nature through proposing a creature that breaks this narrative." — Tobias Revell



Eggs in crude oil
Photo: Tobias Revell

What new or unexpected challenges might designing biology present?

SCIENCE

HOWARD BOLAND
BANANA BACTERIA

"The ubiquitous expansion of computer technologies and innovations has served as inspiration for synthetic biology. To succeed in a similar way synthetic biology would need to be made available not only to a few experts, but to a broad and diverse community of practitioners. Dealing with living matter, sensitive, and sometimes hazardous substances comes with many risks and rewards. With a growing DIY community, many questions are raised. Such as, what risks exist and why is biological material different to those found in the digital domain? What are the differences in learning and being able to adopt knowledge of synthetic biology and what can be produced by those situated outside scientific institutions?"

KOBY BARHAD
ALL THAT I AM

"Economy, ethics, aesthetics, philosophy, politics, communication, culture, geography, day-to-day lives — everything will be vulnerable and will, at some point, have to re-adapt itself to the new changes."

ALEXANDRA DAISY GINSBERG
E. CHROMI & DESIGNING FOR THE SIXTH EXTINCTION

"Synthetic biology and the engineering of living matter raises issues that I think we haven't even begun to imagine. Resolving the political, ethical, social and economic structures around the ownership of living matter—the patenting of DNA and how the ownership of biology is organised and shared—will be as much a barrier to synthetic biology's success as the technical issues of designing and controlling biology itself. How we approach the release of synthetic biology into the wider ecosystem, and how we avoid corporate monopolisation of living matter that increases inequality are two further major challenges that cannot be avoided and will have massive ramifications for the future."

TOBIAS REVELL
NEW MUMBAI

"Trying to discover who the user is. Synthetic biology is marketed as a novelty, a spectacle, something for us to be shocked or astounded by, but we haven't yet found applications that directly alter our lives. Perhaps that's because we're not the right user."

CHRISTINA AGAPAKIS
SELFMADE

"The power of biology as a design medium lies in its ability to self-replicate, adapt, grow, evolve, and change. This power also presents a tremendous challenge for design and engineering. It must also be dynamic and adaptable to guide, maintain, monitor, and change along with biological technologies and their relationships to other organisms and to the environment."

AI HASEGAWA
I WANNA DELIVER A DOLPHIN...

"This issue is similar to those presented by nuclear technology, in that we do not have total control. Nuclear technology allows us to make clean energy, but on the other hand, when mistakes are made, the side effects will extend far in space and time. The equivalent could be something like genetically modified animals or diseases accidentally being released into the wild."

VINCENT FOURNIER
POST NATURAL HISTORY

"It can change the way we see what is natural and what is cultural."

ELLEN JORGENSEN
COMMUNITY BIOLAB

"Synthetic biology relies on standardisation. Living organisms are complicated and everything is contextual. Living things are not always completely predictable and it's much more difficult than you would imagine to get synthetic biology to work well. Designing biological machines is easy—tweaking them so they actually perform with any success is hard."

CHARLOTTE JARVIS
BLIGHTED BY KENNING

"We will have to redefine where our bodies begin and end; to re-evaluate what we mean by the concept of 'natural' and actively decide how we want our world and ourselves to be."

DAVID BENQUÉ
THE NEW WEATHERMEN

"The idea that living organisms can be 'designed' using a system of replicable and standardised components is promising and interesting. However, life may not agree to fit in our system of Lego blocks, as it evolves and mutates."

HEATHER DEWEY-HAGBORG
STRANGER VISIONS

"The challenges we face in the coming 'century of the gene', as Evelyn Fox Keller called it, are enormous. To my mind, there is no bigger challenge than deciding where we will stand as a society on the question of determinism. Do our genes tell us who we are and to what extent? With what complexities? Already science has moved away from strict forms of determinism to more nuanced complex models. Ultimately the impact of genetic surveillance is culturally defined. If we think genes determine who we are, this information is very sensitive. It has as much power as we give it."

(ART)SCIENCEBLR
TENE GENE POEMS

"The challenges lie in the speed of its proliferation and the unexpected consequences on our eco-system. The challenge also lies in the acceptance that manipulation of what is 'natural' and our environment has always largely had an aesthetic motivation."

SHIHO FUKUHARA
& GEORG TREMMEL
COMMON FLOWERS/FLOWER COMMONS

"'Designing biology' is happening on grand scales at the research labs of universities and companies around the world, although they would not call it 'designing biology'. Artists and designers exploring biology can create positive disruption through their speculations, but I believe it's necessary to follow up on the speculation and turn them into realities."

TOBIAS REVELL
INTO YOUR HANDS THEY ARE DELIVERED

"Synthetic biology, in whatever form, presents crossovers that blur our descriptions of the world. These date back millennia and have become an embedded and almost unnoticed part of human culture. We will have to reframe what is 'natural' and 'unnatural'."

STEFAN SCHWABE
XYLINIUM CONES

"Breeding a tiny dog with giant ears and creating the DNA of a bacteria that eats oil implies the same principle. It just differs by the choice and sophistication of tools. Given the fact that we could do anything, it becomes essential to understand the context and complexity of organisms and to ask for the right sense before taking actions."

ORON CATTS
THE MECHANISM OF LIFE—AFTER STÉPHANE LEDUC

"A future dominated by the single engineering paradigm might be upon us; bio-matter is increasingly used as raw material. If this is the case, the engineering approach should not be allowed to monopolise life. One way to emphasise and attract attention to alternative frames of thought is to open up the very same tools and spaces that serve this future to other disciplines, including art."

ADAM W. BROWN
THE GREAT WORK OF THE METAL LOVER

"There are many questions. How will the ability to alter biology and complex biological systems change the way we see ourselves? How will they change our culture? What are the long-term effects? There is still so much that we don't know. Learning how to "grow your own" is a process that artists can use to reveal a deeper understanding of the constraints, myths and realities of science."

SASCHA POHFLEPP
ZERO PARK

"The unexpected challenges may be the ones that are maybe not that unexpected after all: the complexities of biology in contrast to the realm of computer technology, challenges of evolution versus human design, economic competition between living and non-living technologies, and challenges of politics and public acceptance. However, there are a lot of historical precedents of seemingly unlikely technologies which by now have changed our world."

AGATHA HAINES
CIRCUMVENTIVE ORGANS

"After completing this project I have realised the main issue with designing biology is acceptance. New possibilities may give people the opportunity to design amazing things but will the public accept these things? The common view of biology is often tainted by macabre depictions of mad scientists in films. As some of the research into synthetic biology seems like something we might see in science-fiction, it may take a while for the public to accept these technologies into everyday life."

NATSAI AUDREY CHIEZA
FABER FUTURES: THE RHIZOSPHERE PIGMENT LAB

"The challenges of designing biology are numerous, however one of the biggest is the threat to our civil liberties and ownership of life. Bioethics will become the political football of the day and elections will be fought on the societal, ecological, cultural and economic impacts of making with the living. It will become a mainstream issue when those who are more economically empowered are engaging with genetics to outcompete the rest. Policy makers will continue to be lobbied but the consequences may be graver as a life science industry arms race reaches its peak."

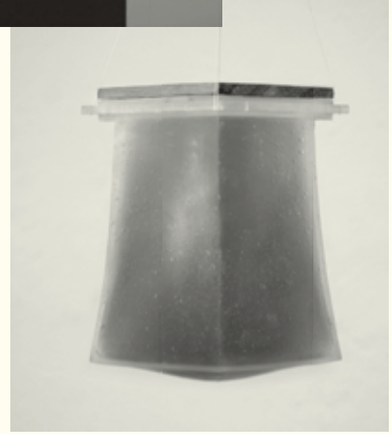
GROW YOUR OWN...

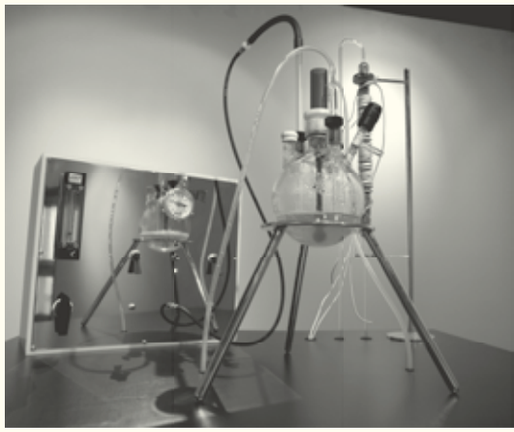
Machines

What is a machine? Mechanical parts put together to perform a useful function? Synthetic biologists believe that those parts can be made from biology. Living things were part of machines for thousands of years, from oxen driving ploughs to horses pulling carts. As synthetic biology transforms life into living machines, will mechanical machines, powered by long-dead biology like oil, coal or gas, be a quirk in history?

The works here investigate the use, design and creation of living machines — from aesthetics to ethics. Wild bacteria are collected to produce pigments to meet our aesthetic desires, while extremophiles perform alchemy, seemingly producing gold from nothing. Designers use bacterial 'workhorses' to produce new materials and manufacturing processes. These products may look very different to those built by industrial robots that we know today.

Perhaps all of nature will become a useful machine, as landscapes are transformed to produce rocket fuel, and our faulty organs are replaced with life-saving biological machines. Meanwhile, a machine prints protocells at the touch of a button and the proto-life forms quickly dissolve back into the liquid they emerged from.





XYLINIUM CONES

Stefan Schwabe (DE) & Jannis Hülsen (DE)
Installation, 2013

The *Xylinum Cones* project presents a production line that uses living organisms to grow geometrical objects. The installation is part of a research project that uses bacterial cellulose to explore our perception of new biotechnological materials. Cellulose, an insoluble substance, is the main constituent of plant cell walls and vegetable fibers such as cotton, as well as being used to produce paper. Bacterial cellulose has different properties from plant cellulose and is characterised by high purity, strength, mouldability and increased water-holding ability.

Exhibiting both the growth process as well as its yield, the installation consists of a production rig and a sculpture. After a growth period of fourteen days, the cellulose cones are dried and added to a sculptural assembly. The shape of the single cones, as well as the way they are assembled, is inspired by natural patterns of regularity, such as reptile scales or flower seeds. Similar but not the same, each single part is following a defined system. At the same time, one can find related adoptions in architecture, such as roof tiles, clapboards or bricks.

The main motivation of *Xylinum Cones* is to prove the reproducibility of organically grown objects, but also to find a balanced level of geometric precision and organic diversity. There are standardisation systems or 'norms' for nuts and bolts, but does it make sense to apply such norms to potatoes or apples? How much freedom would grown artefacts need to thrive? In order to culturally implement new manufacturing routines into our daily lives, the aim of the project is to create a transparent production cycle along with tangible objects that allow us to build a relationship with a new and less culturally loaded material.

"The fascination behind the *Xylinum Cones* project lies in the idea of making things by simply growing them. In our case, we found a microorganism that produces cellulose material from sugar. Taking this as the base for a new production culture, things started to get really interesting. Are these objects actually alive? What parameters need to be set to create an intentional shape? What would it mean for our daily lives if we were surrounded by such a material culture? Our experience during the hands-on process, along with people's reactions, made us think differently about products, production, and the general perception of unfamiliar materials."—Stefan Schawbe

***Xylinum Cones*—silicon mould filled with nutrient**
Photo: Stefan Schwabe, Jannis Hülsen

THE MECHANISM OF LIFE — AFTER STÉPHANE LEDUC

Oron Catts (FI), Ionat Zurr (UK) & Corrie van Sice (US)
Installation, 2013

At the time that Henri Bergson wrote *Creative Evolution* and developed the concept of *Élan vital* (French for 'vital force'), a hypothetical force once thought to cause the evolution and development of organisms, others were attempting to dismiss the metaphysical notion. One significant endeavour, taken by Stéphane Leduc, set out to prove that life is merely a chemical process. In *The Mechanism of Life*, published in 1911, Leduc proposed a series of chemical experiments showing the emergence of life-like phenomena of different degrees of complexity. Using seductive imagery of mainly diffusion and osmosis, Leduc attempted to prove the mechanistic aspects of life and challenge vitalism, the theory that the origin and phenomena of life are dependent on a force or principle distinct from purely chemical or physical forces.

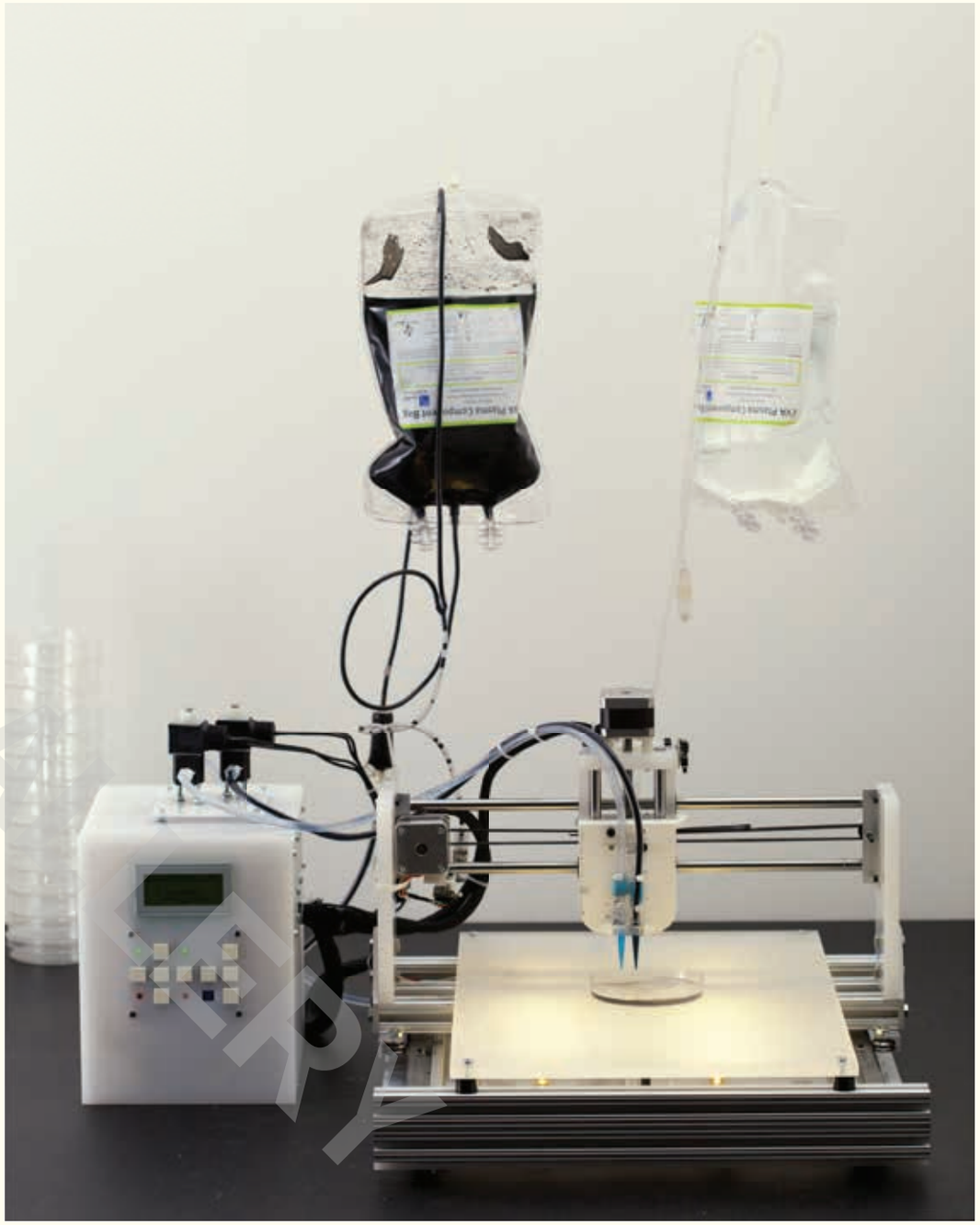
With the recent advent of synthetic biology, where the engineering mindset is set to dominate approaches to life, we see a rehashing of similar stories from a hundred years ago. One such story is the creation of the basic unit of life, the cell, out of non-living materials. The so-called 'protocells' are becoming a major field of study, complete with the rhetorical hyperbole about their potential applications.

This piece reappropriates one of the simplest protocell protocols offered by Leduc, working with the diffusion of two concentrations of solutions that create temporary cell-like droplets. The droplets resemble cells with membrane and nuclei, and last for a few moments before succumbing to entropy and dissolving into a murky liquid.

This protocol is automated using another currently hyped technology: three dimensional printing. Heralded as the next industrial revolution, there is much discussion about 3D printing technology; something that parallels the assembly line of Fordism at the time Leduc was working on *The Mechanism of Life*. The promise of 3D printing technology is based on information transfer, as with the business model; the focus is on the instructions and the data as the currency, while the materiality is merely an optional manifestation. This is problematic as, simultaneously, the 3D printing industry suggests the ability to print actual life, or at least parts of the living. This very seductive scenario of printing life from scratch is played off in this work against the unstable, uncontrollable and transient nature of the protocell droplets as a material.

To a large extent, this piece deals with issues of cultural amnesia and reimagining; pointing attention to the use of certain visuals and expressions to persuade, hype, and then disappoint. In a time when the idea of creating synthetic life is at the forefront, it is important to culturally probe current and past approaches to the idea of *The Mechanism of Life*. The printed 'protocells' are unstable and temporary, take on forms that appear organic and then disappear. More than a proof on the mechanism of life, they are a suggestion for a humble approach to the question of what life is and how far are we willing to make life into a raw material for our own ends.

"This piece recreates Leduc's experiments using a custom-made, rapid prototyping printer to create 'protocells'. With current attempts in creating synthetic life, it is important to culturally examine the ideas of *The Mechanism of Life*. What would capture the public's imagination? The precise movement of the machine? The perfect arrangement of the droplets? Or the off-putting murky outcome of entropy?" — Oron Catts



***The Mechanism of Life — after Stéphane Leduc* — installation**
Photo: Ian Hobbs

THE GREAT WORK OF THE METAL LOVER

Adam W. Brown (US), in collaboration with Dr. Kazem Kashefi (US)
Installation, 2012

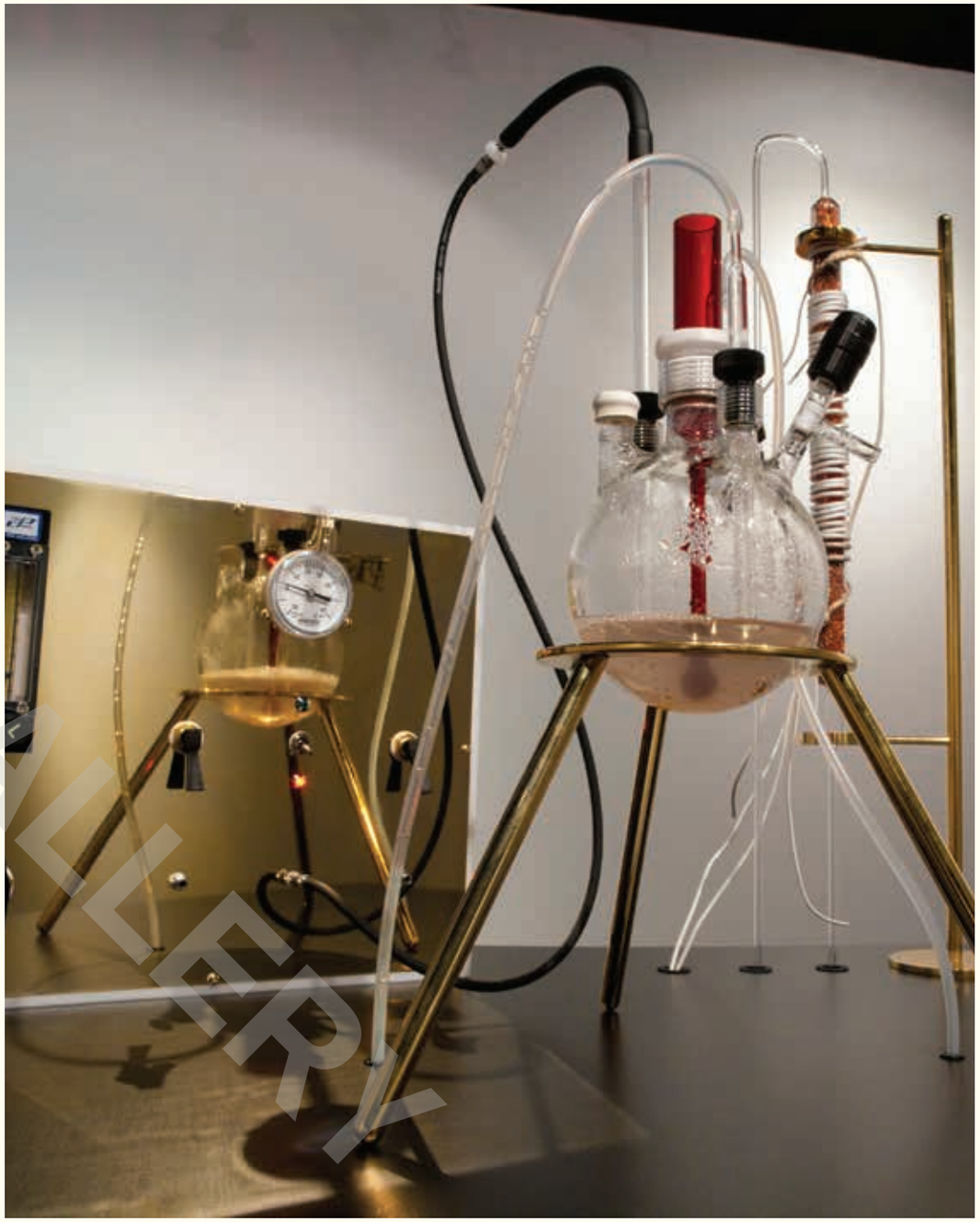
Historically, *magnum opus* (Latin for 'great work') was an alchemical process that incorporated a personal, spiritual and chemical method for creating the Philosopher's Stone, a mysterious red coloured substance that was capable of transmuting base matter into the noble metal of gold. Discovering the principles of the Philosopher's Stone was one of the defining and at the same time seemingly unattainable objectives of western alchemy.

The Great Work of the Metal Lover is a live biochemical installation that transposes the alchemist's historical attempt to synthesise gold into the present, and combines it with today's increasing interest in primitive but robust organisms that played a crucial role in the origin of life on Earth — extremophiles. Extremophiles are microorganisms that are able to survive and flourish in physically and/or chemically extreme conditions that would kill most of the life on our planet. It is believed that extremophiles hold the key to understanding how life may have originated due to their unique ability to metabolise toxic substances like uranium, arsenic and gold chloride. They are currently being studied in order to transform them into cleaning devices for industrial sites that mankind has polluted with heavy metals and other toxic substances.

Unlike the ancient medieval alchemical process to create the secretly composed *magnum opus* substance, this piece makes use of extremophile bacteria that can survive under the most hostile conditions: within a reducing atmosphere of carbon dioxide and hydrogen in a glass bioreactor. *Cupriavidus metallidurans* bacteria metabolise toxic gold chloride and produce gold deposits on biofilms, which can then be harvested, extracted and transformed into 24 karat gold leaf.

The installation solves the ancient riddle, but at the same time shifts the focus from the human-centric obsession with life creation, to the creation of wealth by overlooked life forms. *The Great Work of the Metal Lover* speaks directly to the scientific preoccupation with trying to shape and bend biology to our will within the post biological age, essentially questioning the ethical and political ramifications of attempting to perfect nature.

"*The Great Work of the Metal Lover* is a work where a specific colony of anaerobic microbes are literally grown in a synthetic biological system resulting in the precipitation of gold out of a solution consisting of high concentrations of soluble gold compounds, like gold chloride. The colony biologically processes the 'toxic' solution resulting in 24 karat gold. Interestingly, the earth's lakes and oceans contain vast quantities of dissolved gold, perhaps as much as ten trillion dollars worth, though in dilute concentrations. Because of its form, it is virtually unusable. There is now compelling evidence suggesting that many of the Earth's gold deposits are formed not through heat, pressure and geochemical processes alone, but are indeed formed by microorganisms."— Adam W. Brown



Custom alchemical bioreactor and gas manifold
Photo: Adam Brown

ZERO PARK

Sascha Pohflepp (DE)
Installation, 2012

Zero Park is a narrative installation that focuses on a fictitious landscape in northern California. Here, the flora and fauna have been restored to their natural state of wilderness, and the viewer is faced with nature's beauty. Yet, the longer someone listens to the voice of the narrator, the more it becomes apparent that what on first glance looks like a natural landscape, may in fact be artificial.

The installation adopts the historical depiction of landscape as a diaphanorama, a nineteenth century device consisting of a transparent (or diaphanous) painting, usually of a landscape, that would appear to move or change before the viewer's eyes. On the screen, we see an anthropogenic ecosystem. It has been meticulously designed to emulate natural wilderness, which hides its true intention and purpose — the private production of rocket fuel to be used to accelerate a small spacecraft beyond the gravitational pull of Earth. The narrator could thus be a naturalist, a synthetic biologist involved in the project, or the billionaire CEO of a technology corporation who is combining his ambitions as a conservationist with those of leaving the planet.

Juxtaposing the extremes of our current technological capability through the depiction of landscape — a seemingly old medium which has always been traversing the space between what we perceive as natural and the realm of the man-made — *Zero Park* explores key questions which will need to be addressed for synthetic biology to find its role in the world.

What do we, at this point in time, consider to be the natural state of an ecosystem? Where do we draw the line between natural and artificial, and what role do aesthetics play in our distinction between the two? What are the different human agendas at work in the design of nature and how will we harness flow of energy through the natural world for our goals in the near future?

"The development of this work was largely inspired by the contemporary debate around the design of nature. I have a great interest in the plasticity of our notion of nature and our control over it, which at the dawn of synthetic biology is becoming an ever more important question. High-profile synthetic biology projects, such as the production of medicine and fuel, are as relevant here as the recent de-extinction ambitions. The choice of the seemingly old medium of the diaphanorama was deliberate, and is meant to introduce a degree of confusion in the viewer on their first watch." — Sascha Pohflepp

Zero Park
Photo: Sascha Pohflepp

CIRCUMVENTIVE ORGANS

Agatha Haines (UK)
Installation, 2013

With the introduction of bioprinting, the possibility of creating new organs may become a reality. The ability to replicate and print the cells that make up complex structures might possibly mean that different cells with various functions could be put together in new ways. This could hypothetically create new organs that would otherwise take humans millions of years to evolve naturally. Frankenstein-esque hybrid organs could be put together using cells from different body parts or even different species. *Circumventive Organs* is a series of speculative designs that imagine which parts of various animals could be used in combination with human tissue to solve common health problems.

The first concept, *Electrostabilis Cardium*, is a defibrillating organ using parts from an electric eel that can discharge an electric current to the heart when it recognises it going into fibrillation or cardiac arrest, returning the heart to its normal rhythm. The second, *Tremomucosa Expulsum*, is an organ that uses the strength and vibrations of rattlesnake muscles to release mucus from the respiratory system of a person who suffers from cystic fibrosis and dispels it through the stomach and into the body's digestive system. The third, *Cerebrothromba Dilutus*, contains cells from the saliva gland of a leech and releases an anticoagulant when it feels the pressure of a potential blood clot in the brain, as a way of avoiding a stroke.

As new medical technologies begin to become the norm, they could be viewed not only as a way to enrich health but also as a new route into designing products. If it's possible to replicate human material, which consists of many practicable substances, then why not go beyond the human body? This project aims to show the messy reality behind commoditising biological material, and its potential to help people in need. Based on the aesthetics of the weird and wonderful things that already exist inside us, is this what the future of designed biology might look like?

"This project, like GROW YOUR OWN..., aims to open questions to the public about the future of designing biology and the ethics and choices behind new biological technologies. The project intends to make people consider the motives of the companies funding this sort of research, and the potential outcomes. What might this research then be used for? People can also consider the potential benefits and drawbacks of such procedures or technologies. Would they decide to have such an operation if it meant it might extend or better their life? Mary Shelley's *Frankenstein* is a kind of paradigm for the issues discussed in this project, along with lots of the current arguments about the future of biological technology. They point the way to the excitement of what humans can achieve and, at the same time, constitute a dire warning of the dangers of transgressing the natural."—Agatha Haines

A still from the surgical film of what it might be like to have the *Electrostabilis cardium* organ fitted
Photo: Agatha Haines

FABER FUTURES: THE RHIZOSPHERE PIGMENT LAB

Natsai Audrey Chieza (UK), in collaboration with Professor John Ward (UK)
Installation, 2013

The human race has entered the age of scientific mastery: *Homo faber* (Latin for "Man the Creator") has begun to craft with 'the living', and scientific disciplines are now in an active state of exchange with the humanities, arts and design. Driven by an interest in ecological material, this piece sees a microbiology laboratory become a design studio. An intriguing library of materials suspended in time at -80°C wait to be reawakened, reimagined and redesigned.

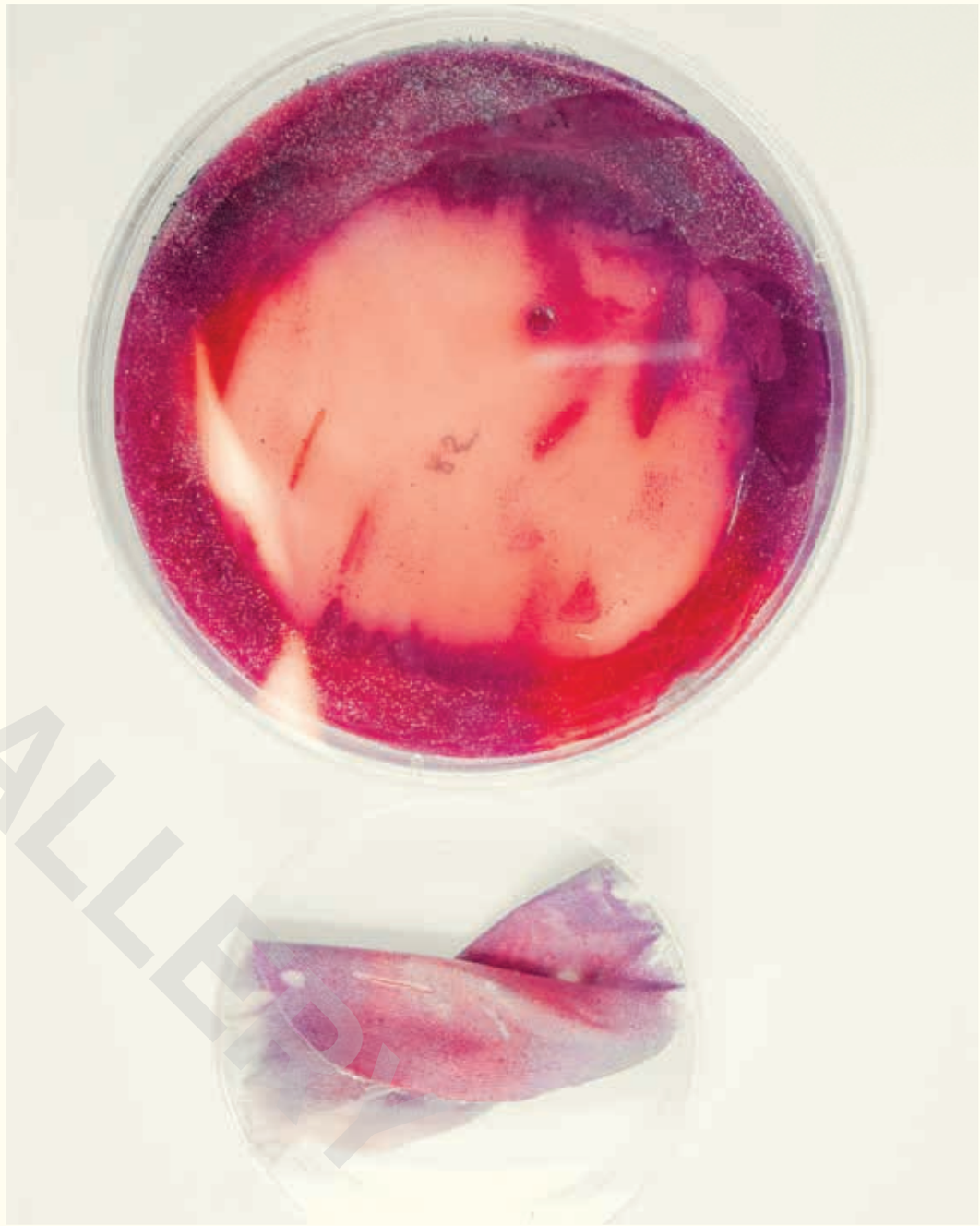
Faber Futures is an on-going research project that aims to find design strategies that appropriate living bacteria in our material world. The project focuses on learning how to train *Streptomyces*, bacteria commonly found in soil, to produce pigment for the use in textiles. The bacteria have been found to yield a range of colours when controlled via the manipulation of their nutrient media and growing conditions. *Faber Futures* is the first collection of textiles produced by traditional screen printing methods but using dyes produced by bacteria.

The Rhizosphere Pigment Lab, a piece commissioned by Science Gallery, has been inspired by two things: the notion that practical scientific enquiry can be interpreted as a craft discipline; and the concept of rhizosphere microecology. The rhizosphere is the section of soil that is directly influenced by root secretions and associated soil microorganisms, and part of this piece's inspiration comes from examining the microbial ecosystem of a plant's root structure unique to that species.

This piece begins to articulate the unique protocol involved in determining what colour a tarragon plant might provide within its microecology that a rosemary or mint plant cannot, and vice versa. A three-stage experimental set-up illustrates: the botanical provenance of the bacteria, the evaluation of pigment produced by the microbial colonies from each plant, and, the corresponding selected samples which actively dye silk scarves *in vitro* (Latin for 'in glass').

The Rhizosphere Pigment Lab invites the audience to witness the alchemy of the 'unseen' emerge through a unique collection of biologically coloured and patterned silk scarves. Whilst charting the progress of this live experiment, these fluid fabric forms illustrate how research, science and design are defining new craft processes with the living.

"*Faber Futures* is relevant to GROW YOUR OWN... because it highlights how the future of designing with the living is here now. You don't always have to splice genes to design with the living. It is a working example of a very practical application of crafted wetware. It sits comfortably in a threshold of extremes, but highlights a radical approach to manufacturing and how we conceptualise industrial endeavours. If we could grow our own pigment from bacteria, what protocol does the designer follow, how is their craft defined, and is it an ecologically robust endeavour? *Faber Futures* also highlights the immediate impact on design practice and aesthetic development that working with biology has on our material world."—Natsai Audrey Chieza



***Streptomyces* pigment on silk satin**
Photo: Natsai Audrey Chieza

GROW YOUR OWN...
CURATORS

ANTHONY DUNNE
Anthony Dunne is Professor and Head of the Design Interactions Programme at the Royal College of Art in London. He is also a partner in the design studio Dunne & Raby. Anthony studied Industrial Design at RCA before working at Sony Design in Tokyo. On returning to London, he completed a Ph.D. in Computer Related Design at RCA. He was a founding member of the CRD Research Studio where he worked as a Senior Research Fellow leading industry and EU funded research projects. Anthony's work with Fiona Raby uses design as a medium to stimulate discussion and debate amongst designers, industry and the public about the social, cultural and ethical implications of existing and emerging technologies. Dunne & Raby's projects have been exhibited and published internationally, and are in the permanent collections of MoMA, New York, and the Victoria and Albert Museum in London. Anthony and Fiona have written several books including *Design Noir* (August/Birkhäuser), *Hertzian Tales* (The MIT Press) and *Speculative Everything: Design, Fiction and Social Dreaming* (The MIT Press, forthcoming). Anthony was awarded the Sir Misha Black Award for Innovation in Design Education in 2009.
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PAUL FREEMONT
Professor Paul Freemont is co-founder of the EPSRC Centre for Synthetic Biology and Innovation at Imperial College London. The centre is the first of its kind in the UK and aims to develop foundational technologies to enable synthetic biology research in application areas like biosensors, bioprocessing, metabolic and genome engineering. He is also co-founder of the newly formed Innovation and Knowledge Centre for Synthetic Biology whose mission is to facilitate the industrial translation of synthetic biology research working in partnership with industry and academia. Previous to this, he was head of the Division of Molecular Biosciences at ICL and Principal Scientist at the Cancer Research UK London Research Institute. He is author of over 160 peer-reviewed scientific publications, co-founder of the spin out company Equinox Pharma Ltd and holds a number of external positions including chair of the Diamond Light Source Scientific Advisory Committee and member of the UK Medical Research Council's Molecular and Cellular Medicines Board.
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Cathal Garvey is the creator of Indie Biotech (indiebiotech.com), a blog that provides tools, materials and learning resources for biotechnology to individuals worldwide. Worldwide, the DIYbio movement is taking hold and generating renewed interest in community biotech. Cathal provides affordable, open-source DNA development platforms, kits and strains for beginners, which helps them to learn the engineering of bacteria easily, and later facilitates the engineering of plants and simple bugs such as Sea Monkeys. He hopes to change the face of biotech, and perhaps change some lives for the better in the process.
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Alexandra Daisy Ginsberg is a designer, artist and writer exploring the implications of emerging technologies and seeking new roles for design. As Design Fellow on Synthetic Aesthetics (a research project run by the University of Edinburgh in Scotland and Stanford University in California) she curated an international project investigating the 'design of nature', developing novel modes of collaboration and critical discourse between art, design and synthetic biology (*Synthetic Aesthetics*, available from MIT Press in 2014). She studied Architecture at the University of Cambridge, Design at Harvard University, and Design Interactions at the Royal College of Art in London, where she is doing doctoral research. Her work has been exhibited and published internationally, including in MoMA New York, the Art Institute of Chicago, the Israel Museum and the National Museum of China. In 2011, her collaborative work *E. chromi* was nominated for Designs of The Year and INDEX Awards, and she won the World Technology Award for Design. Daisy received the first London Design Medal for Emerging Talent in 2012.
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Michael John Gorman is the Founding Director of Science Gallery and the CEO of Science Gallery International. Currently, through a gift of €1M from Google.org, he is developing an international Science Gallery network in partnership with leading universities in urban centres worldwide. Michael John is also Adjunct Professor of Creative Technologies at Trinity College Dublin, Director of the Idea Translation Lab (in partnership with Harvard University) and Coordinator of the European StudioLab project. Prior to coming to Trinity College Dublin, he worked at Stanford University where he lectured in science, technology and society, and has held postdoctoral fellowships in Harvard University and MIT. He has authored numerous publications and articles on aspects of the relationship between art and science and the history of science. He holds a Ph.D. in seventeenth century history of science from the European University in Florence.
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Scott Burnett at Aad & Renate Henschke

GROW YOUR OWN...
ARTISTS' BIOGRAPHIES

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Koby Barhad is a designer and researcher working in London. He has an M.A. in Design Interactions from the Royal College of Art, and has taken part in design research for Microsoft Research and StudioLab. Koby is the co-founder of kn-studio, awarded Israel's Ministry of Science, Culture and Sport Design Award 2008. His work has been exhibited in venues such as the Saint-Étienne Design Biennale, MUDAC, and The Victoria and Albert Museum during the 2013 London Design Festival. His work has been published in *Wired*, *Dezeen*, *MSNBC*, *Frame Magazine* and *Scientific American*. He is part of the Fixperts team, a design initiative by Daniel Charny and James Carrigan.
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HOWARD BOLAND
Howard Boland is a multidisciplinary practitioner working across art, science and technology. With strong technical and innovative creative skills, his experience spans from artistic and scientific research contexts to leading projects and teams in the interactive industry. Howard is artistic director of C-LAB, specialising in biological art. His Ph.D. (funded by the Arts and Humanities Research Council and the University of Westminster) titled *Art from Synthetic Biology* combined synthetic biology and art to produce novel visual expressions in bacteria, culminating in the UK's first art exhibition that featured live genetically modified microorganisms at the Royal Institute of Great Britain. He has extensive experience in the digital creative industry, leading creative and technical teams on award-winning projects.
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CHARLOTTE JARVIS
Charlotte Jarvis is currently artist in residence at The Netherlands Proteomics Centre (NPC). Last year they collaborated on *Blighted by Kenning*, which was exhibited in the UK, Amsterdam and toured around the Netherlands. This year Charlotte and the NPC have made *Ergo Sum*, in which Charlotte has created a second self using body parts grown from her stem cells. This project is on display at Naturalis Biodiversity Centre in Leiden, The Netherlands until December 2013. Most recently, Charlotte received the Designers & Artists 4 Genomics Award and also exhibited at the Wellcome Trust, Kinsale Arts Week, The Gate Theatre and Saint-Étienne Design Biennale. Charlotte's new project *Music of the Spheres* is a collaboration with mathematician and genome scientist Dr. Nick Goldman and composer Mira Calix. It was launched at ARS Electronica 2013.
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AGATHA HAINES
After completing her B.A. in Graphic Design, Agatha Haines attended the Design Interactions program at the Royal College of Art. She has also worked as a sculptor, studio hand and production assistant for a range of artists and filmmakers. The main focus of her work is the design of the human body, and she examines how people might respond to the possibilities of our body as another everyday material, and how far can we push our malleable bodies while still being accepted by society. She often discovers new ideas and concepts through material testing and uses her own body as a source of textures and visuals. She enjoys researching projects through sketching with fabrication and effects, while recording these results with film.
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SHIHO FUKUHARA & GEORG TREMMEL
Shiho Fukuhara received a B.A. (Hons) in Fine Art from Central Saint Martins College of Art and Design and an M.A. in Design Interactions at the Royal College of Art in London. Shiho was artist in residence at the Le Pavillion at the Palais de Tokyo in Paris in 2004, at IAMAS in Japan in 2006, at ISEA in Singapore in 2008 and AmbientTV in the UK in 2008. Georg Tremmel studied Visual Media Art in Vienna and Interaction Design at the Royal College of Art, where he and Shiho formed the artistic collaborative research framework, BCL. He currently works as a researcher at the University of Tokyo's Laboratory of DNA Information Analysis.
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NATSAI AUDREY CHIEZA
A practicing independent designer and researcher, Natsai Audrey Chieza is a Design Futurist inspired by material innovation and emerging technologies. With an M.A. in Architectural Design from the University of Edinburgh, and an M.A. in Textile Futures at Central Saint Martins College of Art and Design in London, her design practice has been cultivated with a sensibility in aesthetics and material research, and a sensitivity to context. Natsai has worked on projects for Microsoft, Nissan, Unilever and EDF Energy, and has been published in numerous publications including William Myers' *Bio Design*, *Material Futures 01*, and *Heimtextil*. Natsai's work has exhibited at Victoria and Albert Museum in London, Audax Textile Museum in Tilburg, Salone Internazionale del Mobile in Milan, London Design Festival, and most recently at the En Vie—Alive exhibition at Fondation EDF in Paris.
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AI HASEGAWA
Ai Hasegawa uses art and design to present a solution to the challenges encountered in our daily lives. At the same time, the solution itself questions our perception of living in this world. Having studied Computer Graphic Animation and Interactive Media Art at the Institute of Advanced Media Arts and Sciences in Japan, she moved to London and began working as an animator, character designer and illustrator. At the same time, she worked as a designer for audience-participatory interactive public art at Haque Design and Research. In 2012, she graduated with an M.A. in Design Interactions at the Royal College of Art in London. Her recent works are *The Extreme Environment Love Hotel* series and *I Wanna Deliver a Shark...* series.
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TOBIAS REVELL
Tobias Revell is a designer and futurist, with a B.A. in Design for Interaction and Moving Image from the London College of Communication and an M.A. in Design Interactions at the Royal College of Art in London. Apart from working with Superflux as an associate on a number of future-facing projects, Tobias is also a designer and researcher for ARUP's Foresight and Innovation in London, and a tutor in Design for Interaction and Moving Image at London College of Communication. He has exhibited work at Ars Electronica in Austria, Salone de Mobile Milan and Z33 in Belgium.
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VINCENT FOURNIER

Born in Ouagadougou in Burkina Faso in 1970, Vincent Fournier grew up in France on the coast of Brittany. After his undergraduate studies in Sociology and an M.A. in Visual Arts, he graduated from École Nationale Supérieure de la Photographie in Arles in 1997. His work is represented by a number of galleries and is regularly shown at international art fairs. Vincent currently lives and works in Paris.
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CHRISTINA AGAPAKIS & SISSEL TOLAAS

Christina Agapakis is a synthetic biologist interested in the structure, evolution, and design of microbial communities. She is a research fellow at UCLA in the Department of Molecular, Cell, and Developmental Biology and the UCLA Art|Sci Center. Sissel Tolaas is an odour researcher using science, art, and design to explore how smell is involved in human communication. In 2004 she established the SMELL RE_searchLab in Berlin, a studio for cataloguing and creating smells. Christina and Sissel began collaborating in 2010 as part of Synthetic Aesthetics, an interdisciplinary research program initiated through Stanford University and the University of Edinburgh, to explore shared new territory between synthetic biology, art and design.
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HEATHER DEWEY-HAGBORG

Heather Dewey-Hagborg is an information artist who is interested in exploring art as research and public inquiry. Traversing media ranging from algorithms to DNA, her work seeks to question fundamental assumptions underpinning perceptions of human nature, technology and the environment. Heather has shown work worldwide at events and venues including the Mediations Biennale in Poland, Jaaga: Bangalore Art & Technology Space in Bangalore, the Monitor Digital Festival in Guadalajara and MoMA PS1 in New York. Her work has been featured in *The New York Times*, *The Wall Street Journal*, *The Guardian*, *Wired*, *The Huffington Post*, and *Gizmodo*, among many others. Heather has a B.A. in Information Arts from Bennington College and an M.A from the Interactive Telecommunications Program at Tisch School of the Arts, New York University. She is currently a Ph.D. student in Electronic Arts at Rensselaer Polytechnic Institute.
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ADAM BROWN

Adam Brown is a conceptual artist whose work incorporates living systems and emerging technologies. Working collaboratively with scientists, his recent project, *The Great Work of the Metal Lover* sits at the intersection of art, science and alchemy. It received an Honorary Mention at Ars Electronica 2012 and an Award of Distinction from Vida 14. His Origins of Life: Experiment #1, is a working scientific experiment using simulated lightning, heat and primordial gases placed in an art context. He has exhibited internationally, with his work appearing at SigGraph, Ars Electronica and the Brazilian Biennial Emoção Art.ficial 5.0. Adam's work has been written about widely in publications such as *The New York Times*, *Wired*, *Nature*, *Sculpture Magazine*, *The Washington Post*, and *Discover Magazine*.
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ORON CATTS, IONAT ZURR & CORRIE VAN SICE

Oron Catts is the director of SymbioticA, the Centre of Excellence in Biological Arts at the School of Anatomy, Physiology and Human Biology at The University of Western Australia. Oron is an artist, researcher and a curator at the forefront of the emerging field of biological-arts, whose work addresses shifting perceptions of life. Dr. Ionat Zurr is an artist, researcher and the academic coordinator at SymbioticA. Together with Oron, she formed the internationally renowned Tissue Culture and Art Project (TC&A) in 1996. Corrie Van Sice is a creative researcher and engineer. She develops technologies through partnerships with biologists, artists and designers. Her work applies concepts of biomimesis to the production of fabrication methodologies, which identify the inherent potential for matter to become functional, and human curiosity's creative influence on natural systems. Corrie has partnered with synthetic biologists at Brooklyn's citizen science lab, Genspace, and began work with Oron Catts and Ionat Zurr via the Finnish Bioart Society at the Kilpisjärvi Biological Station in 2011.
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DAVID BENQUÉ

David Benqué is a designer and researcher working in London. He is a research associate and visiting lecturer at the Design Interactions department of the Royal College of Art in London. His work has recently been exhibited in venues such as the Ars Electronica Centre in Austria, the National Museum of China in Beijing, Glitch Fiction at Paris Design Week, Biennale Internationale Design Saint-Étienne in France, and Z33 House for Contemporary Art in Belgium. He has lectured in art and design schools across Europe, such as the University of Applied Arts in Vienna, ENSCI les Ateliers and École Estienne in Paris, and Trinity College Dublin.
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STEFAN SCHWABE & JANNIS HÜLSEN

Stefan Schwabe was born in Apolda in Germany. He has an M.A. in Design Interactions from the Royal College of Art in London. He teaches at the Berlin University of the Arts, where he leads the Mechatronics Workshop. Jannis Hülsen was born in Hanover in Germany. He studied Industrial Design at the Braunschweig University of Art and has worked at the Jerszy Seymour design workshop. Their previous work, *Xylinum*, was featured in the SKIN—Material Future exhibition which toured Munich, Vienna and Graz.
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(ART)SCIENCEBLR

(Art)ScienceBLR's work is at the intersection of art-science and pedagogy, creating spaces of dialogue and interaction between artists, designers and scientists. Since 2009, the group has focused on building low-tech laboratories and low cost equipment, making it easier for outsiders to explore the life sciences. Their work has been awarded prizes and recognition in both the arts and the science contexts.
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JAMES KING

James King is a speculative designer whose work in the field of biological science investigates the implications of future biotechnologies. James collaborates with scientists and works between the lab and studio to design potential applications for their research. Together, they imagine what might be possible if these technologies developed in the lab become adopted by people in their everyday lives. This results in objects, films and images that are exhibited in order to elicit debate on the desirable and undesirable qualities of future biotechnologies. James' work has been shown in MoMA s Design and The Elastic Mind exhibition in 2008, at the Wellcome Collection in 2010, and reproduced in many publications such as Wired, SEED and The Guardian. His project Dressing the Meat of Tomorrow was subsequently acquired for MoMA s permanent collection. James also presented his work at several scientific meetings and conferences throughout 2009 and 2010.

SASCHA POHFLEPP

Sascha Pohflepp has worked with numerous artistic and scientific collaborators on projects ranging from the microcosm of synthetic biology to the macrocosm of space exploration. Grants and residencies include a residency in the Synthetic Aesthetics project, a residency at Art Center College Pasadena and at Eyebeam New York. Recent exhibitions include Talk To Me at MoMA, New Order at the Mediamatic Foundation Amsterdam and Photographing the Future at the Moscow Centre for Contemporary Art. His work will also be part of the upcoming group shows The New Atlantis at km temporaer Berlin and an essay on the notion of living machines will be published in a forthcoming book *Synthetic Aesthetics* by MIT Press. Sascha Pohflepp holds an M.A. in Design Interactions from the Royal College of Art London and a degree in Media Art from The Berlin University of the Arts.
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BANANA BACTERIA
Created with the help and support of Dr Mark Clements and Dr Tom Corby. The constructs for converting isoamyl alcohol to isoamyl acetate were developed by the MIT iGEM team in 2006, with thanks in particular to Dr Reshma Shetty. The genetic construct was originally developed by Stephen T. Payne, Veena Venkatachalam, Kate Broadbent, Delbert Green II, and Boyuan Zhu, Barry Canton, Austin J. Che, Jason R. Kelly, Samantha C. Sutton, Thomas F. Knight Jr., Drew Endy, and Reshma P. Shetty. The MIT Registry of Standard Biological Parts provided an invaluable library. Special thanks to Sara Tocchetti at London School of Economics who helped obtain a special indole inefficient strain (YYC912) through the University of Lausanne (Switzerland). The knockout strain was developed by Y.Y. Chang, A.Y. Wang, and J.E. Cronan. The research was supported by the Arts and Humanities Research Council and University of Westminster.

ALL THAT I AM
Programmed by Michail Vanis.

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Produced with the support of Science Gallery. Concept and design by Alexandra Daisy Ginsberg, research and design development by Gemma Lord, and photography and computer generated imagery by Tommaso Lanza and Tom Mawby. Special thanks to Kent Redford.

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BLIGHTED BY KENNING
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INTO YOUR HANDS ARE THEY DELIVERED
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THE MECHANISM OF LIFE—AFTER STÉPHANE LEDUC
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THE GREAT WORK OF THE METAL LOVER
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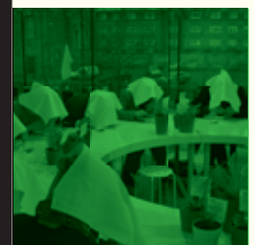
CIRCUMVENTIVE ORGANS
Thanks to Beatrice Haines for the anatomical drawings of organs.

FABER FUTURES: THE RHIZOSPHERE PIGMENT
Produced with the support of Science Gallery. Created in collaboration with Professor John Ward at the Department of Structural Molecular Biology at University College London.

SCIENCE GALLERY

Science Gallery at Trinity College Dublin is a dynamic and vibrant cultural space where science and art collide, ideas meet, and curious minds connect. Featuring work by both national and international scientists, artists, engineers, designers and technologists, Science Gallery explores broad themes that can be interrogated from a variety of disciplines and perspectives. With a primary audience of young adults from 15 to 25 years old and a strong community that visits regularly, Science Gallery provides a lively social space for public engagement with science. Through an ever-changing programme of exhibitions, events and workshops, the space serves as a porous membrane for ideas and connection between the university and the city around it.



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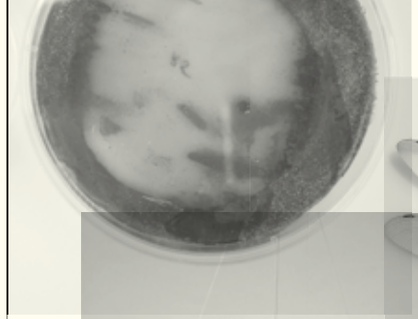

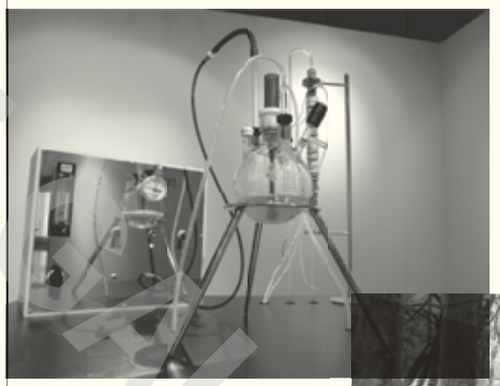

Synthetic biology is an emerging approach to genetic engineering, bringing together engineers, scientists, and even designers, artists and biohackers to design 'living machines'. GROW YOUR OWN... invites you into synthetic futures that we may not have imagined, to consider some of the potentially ground-breaking applications and uncertain implications of synthetic life. As an accompanying publication for this seminal exhibition, this book tackles the provocative questions that designing life raises, giving you the opportunity to help shape future discussions around synthetic biology.

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