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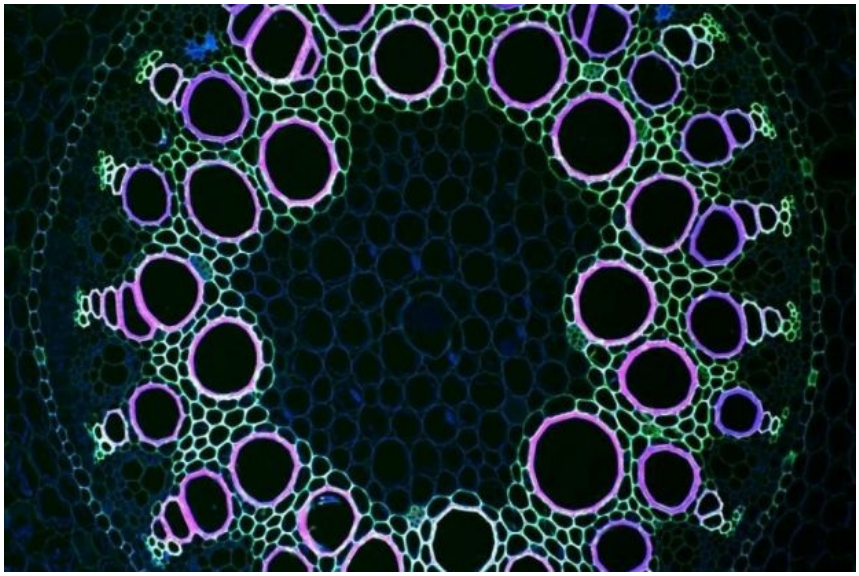
A design for life



Edd McCracken

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The story of Scotland's next industrial revolution begins down a poisonous well in Bangladesh.

It is a tale with microscopic origins but one which has the potential to alter the very fabric of the living world, and turn Scotland into a global engine room.

In 2006 a team from the University of Edinburgh decided to help Bangladeshis whose water supply was laced with arsenic. A quarter of the country's wells were contaminated, leaving thousands plagued by skin lesions and cancers from drinking poisonous water.

To solve the problem, the Edinburgh team took a micro-organism and changed its DNA so it would perform a specific, new task. This new organism changed the water colour if it contained dangerously high levels of arsenic. The scientists fundamentally altered a small living piece of nature to make it obey the will of humans.

This was one of the first Scottish examples of the power of a new science, one which alters the very molecules of life: synthetic biology … the ability to make and control living machines. It is a discipline that could create sustainable and pollution-free fuels, cheap vaccines to treat the most stubborn of diseases, micro-organisms that could clean the atmosphere of greenhouse gases. Just as in previous centuries when it came to steam and engineering, with the science of synthetic life Scotland is already a global leader.

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>
> *Nature magazine*

"This century will be home to the biological revolution," said Professor Jim Haseloff of Cambridge University. He is taking part in a debate on Tuesday at the Edinburgh International Science Festival about the new science called Designer Life: Scotland's Next Industrial Revolution?

"The technologies that underpin everyday life will be heavily influenced by biological systems," he said. "In the same way software and micro-electronic systems have impacted our lives in the last couple of decades, a similar impact will be seen by reprogramming biological systems. I find that very compelling."

Scientists such as Haseloff regularly draw parallels between synthetic biology and computer programming, not just its potential ubiquity but in the nuts and bolts of how it works. Cells are hardware; genetic codes and DNA are software. By applying engineering and computing techniques to biology, the scientists claim in future we will be able to reprogramme, reboot, and upgrade living cells.

Put simply, by combining elements of engineering, computer science, chemis-try and molecular biology, synthetic biology seeks to redesign the living world.

The divine touch of a Creator or the arduous trial and error of Darwinian forces could be usurped. If synthetic biology delivers on its huge potential, this century humanity could overtake evolution.

Amongst the blue-sky thinking about the enormous potential for this field, including talk of creating life from non-living material, there are some concrete practical applications already being explored. Molecules could be turned into miniature factories, designed to produce specific drugs or cheap, clean fuels. This kind of work is already going on in Scotland.

For example, at the Scottish Association for Marine Science in Dunstaffanage scientists are working on manipulating marine organisms to create biofuels. The Universities of Edinburgh, Glasgow and Dundee have teams dedicated to synthetic biology. And the Government is getting involved too.

In 2006 Scottish Enterprise concluded that synthetic biology had the potential to generate billions of pounds for the economy. But one of

the main bottlenecks for the discipline is assembling small DNA fragments into longer more complex pathways. At present it is time consuming and inefficient. So in August 2009 Scottish Enterprise launched the £2.4 million Genome Segment Assembly (GSA) research programme at Edinburgh's Heriot-Watt University. Scheduled to finish in 2011, the GSA programme aims to solve this problem and at a stroke shift synthetic biology up several gears.

Professor Joyce Tait from the University of Edinburgh, a member of the Scottish Science Advisory Council, described Scotland's potential in the field as "an open goal".

"It's not that there are four or five disciplines that you need, and we need to develop two," she said. "We have the full set in place. We just need to join them up. It's very important. Talk of a new industrial revolution is not hyperbole. But it won't just be Scotland's next industrial revolution … it will be the world's. And if we want to have a place in it we have to make the investment and make sure we stay at the forefront and capitalise on the opportunity."

The principles behind synthetic biology are arguably not new. Man has been modifying nature for thousands of years. When you sit down to dinner tonight and maybe bite into a butter-sodden corn on the cob, you are not chewing on a 'natural' vegetable. The science of agriculture has developed, cultivated and modified it from a wild weed to a hearty meal. Similarly, through targeted breeding programmes, domesticated animals such as dogs have been changed to conform to human whims.

But this type of manipulation of biology is imprecise, laborious and most of all time consuming … corn's development has taken millennia, for example.

"Instead of several thousand years we would be talking about generations," said Professor Haseloff.

In the realms of medicine, synthetic biology could bring a more targeted approach to treatments. According to Professor Ben Davis, who will also be taking part in Tuesday's debate, in 10 years synthetic proteins could be built that will selectively treat only the diseased cells in our bodies, thereby reducing side effects associated with some medication.

Work is also going on to modify cells to light up in response to disease, making it easier for doctors to see affected areas. It is the equivalent of an army swapping seige warfare for laser-guided missiles.

"Anything that biology does already we can make synthetics to do our bidding," said Professor Davis. "That's not meant to sound dictatorial, but we could make molecules deliver a specific drug or help a patient. The nice thing is that anything biology does itself, we could do the same and perhaps make it more useful for us."

The more speculative side of synthetic biology is a colourful, if sometimes unsettling place. In an interview with the New Yorker last year Drew Endy, professor of biological engineering at Stanford University, asked: "What if we could liberate ourselves from the tyranny of evolution by being able to design our own offspring?"

Another well-known character is Craig Venter. In 2008 the US scientist created a synthetic organism made solely from chemical parts and DNA fragments. He concluded that it was possible to assemble any combination of natural and artificial DNA in any desired order. This was the sound of a man finally working out how to use nature's biggest ever box of Lego. However, this is still one step away from creating a truly, new synthetic life form, but that's exactly what Venter plans next. One outcome already mooted could be an organism that would digest carbon in the atmosphere.

On UK soil, Haseloff foresees plants being modified not just to resist the effects of climate change, but also to produce biodegradable plastics, a potentially vital development as oil supplies dwindle. This is just the start.

"We haven't fathomed the potential for the technology," he said. "When you look at the biodiversity in the natural world, and you look at the small fraction of that which has been sampled for human use, and think of how that might be harnessed, the capacity for new products and approaches is extremely high."

With all great scientific leaps forward, a great ethical unease is not far away: witness the reaction to genetically modified crops or the warnings from literature, such as Frankenstein and The Island of Dr Moreau.

In 2007 even the editors of Nature magazine, not usually given to hyperbole, admitted synthetic biology might change everything.

"Many a technology has at some time or another been deemed an affront to God, but perhaps none invites the accusation as directly as synthetic biology," they wrote. "For the first time, God has competition."

Richard Holloway, the former bishop of Edinburgh and another contributor to Tuesday's debate, said: "If you were a strong religious positivist you would have problems with people interfering with the building blocks of life. I personally don't, but you can anticipate the furore that might arise if certain things are done. Remember the hysteria of the cloning debate after Dolly the Sheep? But that is the way it always is. Once the frontier is crossed it takes the rest of the wagon train to pluck up its courage and drive into the river."