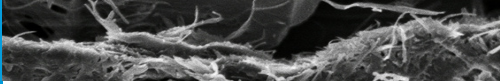
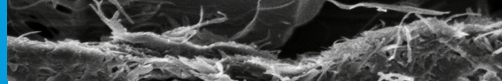


## B1 Synthetic Biology's Vision and Challenge



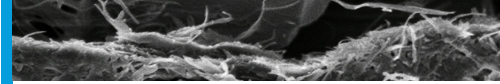
A prominent geneticist said of genetic engineering, 'This is where biology begins; until now we've been classifying butterflies.' Synthetic biology takes this the next step – the challenge to add whole new systems to living organisms, even to devise new genomes.

## B2 Should we Treat Biology like Engineering?



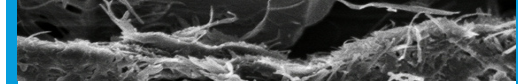
Synthetic biology would treat biology as a branch of engineering. But are there important differences between these worlds and their values, which we lose sight of at our peril?

## B3 Precision Engineering of Living Organisms?



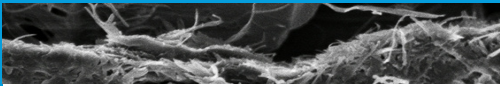
Because it uses well defined parts, synthetic biologists claim they will make much more precise and controlled changes in living organisms than genetic modification has been able to do.

## B4 Old claims for New Science?



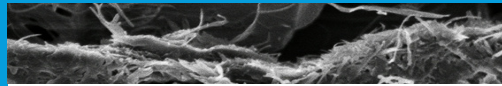
Synthetic biology is making exactly the same claims for 'precision and predictability' as geneticists made 10 years ago to promote genetic modification. If GM wasn't so precise after all, should we trust this new claim?

## B5 'Creating Life' is Hype!



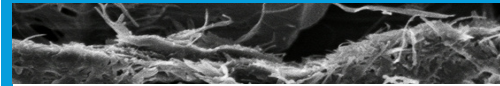
The rhetoric of scientists claiming they are 'creating life' is hype. We might rearrange the components of existing living organisms into new life forms, but that's not creating life.

## B6 What is Life?



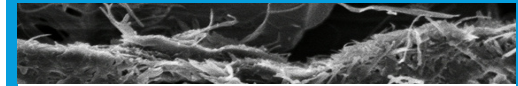
'It would be a service to more than synthetic biology if we might now be permitted to dismiss the idea that life is a precise scientific concept.' (Editorial in the leading scientific journal *Nature*)

## B7 Playing God? A Theological Question



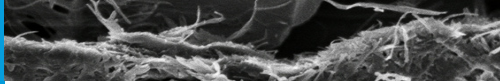
If God created everything, including life, is it 'playing God' to think that we can outdo God's age-long processes of evolution, and rapidly design our own organisms? Or is it a good use of God-given skills?

## B8 An Ethical Objection to Not Proceeding



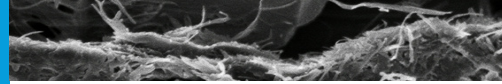
The prospect of designing and creating new living organisms with precisely the functions we want opens up so many exciting possibilities in the fields of medicine, energy, materials, and much else, that to hold back would be ethically wrong.

## B9 Making Machines ... but What About Living Organisms?



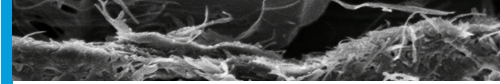
We think it's OK for humans to make all kinds of inanimate machines. But should we also design and make new living organisms that can reproduce themselves?

## B10 Can Humans Re-design Evolution?



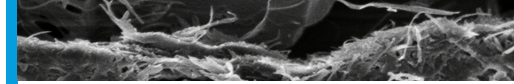
Evolutionary theory stresses that there is no design or designer in the life forms in nature. They are just the ones which adapted best. So should humans really try to 'design' new species? Can we claim to do better?

## B11 Tinkering Too Much with Nature?



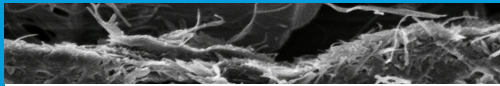
Some synthetic biologists speak of trying to rewrite the genetic code of living organisms. Is this sort of aim seeking to 'tinker' too much with nature?

## B12 The Next Logical Step ... or One Step too Far?



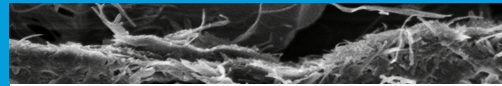
We've changed living organisms by selective breeding over many generations, hybrid seeds and genetic modification. Is it different if we could create radically new organisms according to our own designs? Is there a limit somewhere?

## B13 Synthesising an Organism – So what?



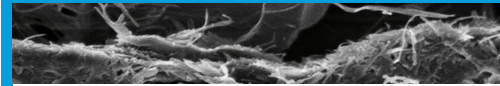
A molecular biologist wrote, 'I have no doubt that if we synthesised all the genes of a simple organism the result would be a fully functional genome. But would that prove anything we didn't already know?'

## B14 How Radically Different an Organism should we Make?



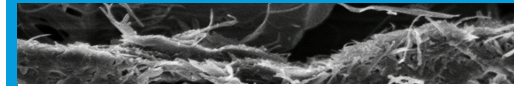
We probably can't create a completely synthetic organism. But is it wrong to create a modified organism that is radically different from the one we started with? Is this crossing a moral boundary that we should not cross?

## B15 Being Synthetic with which Species?



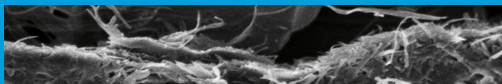
Most of synthetic biology is about altering simple micro-organisms. Suppose one day we could go further. Would we draw lines about remaking maize, mice, monkeys ... or humans? If so where, and why?

## B16 Research and Responsibility



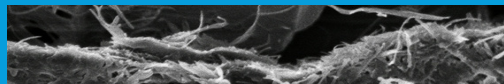
A Royal Society meeting report said, 'The extent to which the genome can be redesigned to produce a radically novel synthetic organism is of considerable interest.' Is this goal justified just because it's scientifically interesting? What else might have a bearing on it?

## B17 What Values should Drive the Research?



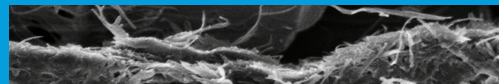
In a society with mixed views, what values, ideas and needs should shape the direction and priorities of synthetic biology research?

## B18 Over-reacting



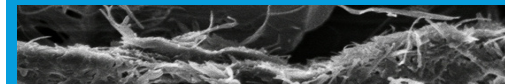
Most scientists in this field acknowledge there are important ethical and social issues. But some fear that the promise of synthetic biology might be lost to unwarranted media or public controversy, or inappropriate regulation.

## B19 Hype, Reality and Public Discussion



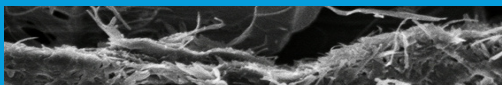
There's a lot of hype about synthetic biology. No one knows what will really be feasible, or economic. Quite a lot, but maybe less than its enthusiasts hope or its critics fear? How soon should we talk about this, if the picture is so unclear?

## B20 Do We Know What We're Doing?



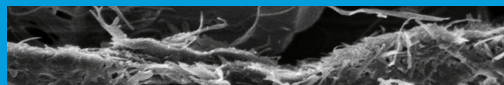
Do scientists indeed understand enough to modify biological systems substantially, or even synthesise new organisms? Or is it safer to 'leave it up to nature'?

## B21 How Do We Know if We Know Enough?



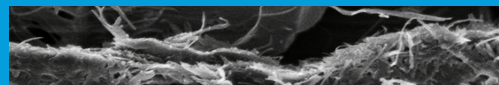
If we claim we can redesign species that have evolved by mutation and natural selection, by what criteria should we judge if scientists know enough to make radical changes to an organism and release it to the environment?

## B22 Is Technique Running Ahead of Understanding?



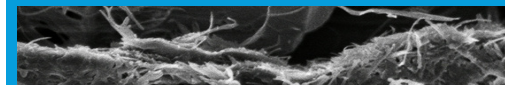
Some fear that commercial pressures, or environmental and humanitarian needs, will hurry scientists to make clever technical devices, but without understanding enough detail about the underlying science.

## B23 How do you Assess Risks of Novel Organisms?



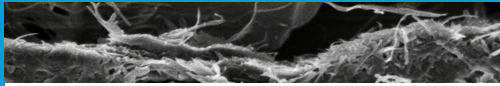
With GM crops we could compare risks with an unchanged or conventional crop. With radically altered bacteria there may be no close organisms to use as a baseline for comparison.

## B24 How Precautionary should We Be?



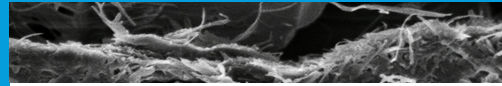
How precautionary should we be about the 'unknowns' of synthetic biology? ... proceed with caution? ... don't proceed till you know more? ... proceed with certain areas but not others? ... or what?

## B25 Would an Uncontrolled Release Actually Matter?



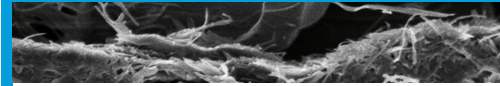
Some scientists say a 'synthetic' bug would not cause havoc if it escaped from the lab, because it's too weak to survive out in the wild. Other scientists point to cases where introduced organisms have pushed out the existing ones (like grey squirrels over red).

## B26 Can Synthetic Organisms be Made Inherently Safe?



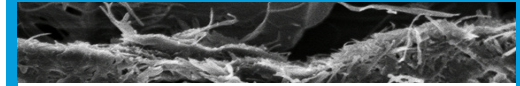
Some synthetic biologists claim that 'inherently safe' organisms can be developed with functions built in that ensure they would not survive and propagate in nature. Critics say nothing is inherently safe, including synthetic organisms. What do you think?

## B27 Engineered Bugs to Clean up the Environment?



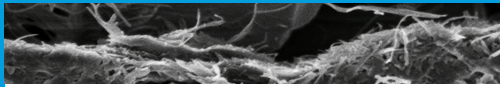
Synthetic biology may be able to modify bacteria which can not only detect toxins in the environment but remove them as well ('bioremediation'). But can we avoid posing new risks from the modified bugs?

## B28 Super-GM Crops?



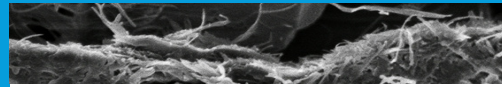
If the tools of synthetic biology could one day also modify plants, say, to make pharmaceuticals and biofuels, can this also be done without adverse environmental impacts, or displacing food crops?

## B29 What about Risks of Weapons and Terrorism?



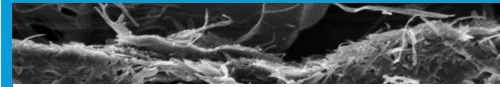
There is much concern that synthetic biology could also be used to make deadly bioweapons or for terrorism. Is making novel bugs more or less likely than using existing ones like anthrax? The risks are uncertain and contentious.

## B30 Governing Synthetic Biology for Security and Risks



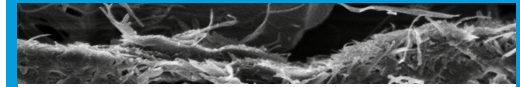
Most proposals for how we should govern and oversee synthetic biology depend on scientists' awareness and reporting of its risks and potential misuses. But is this enough? What else would we do?

## B31 Virus Research for Pandemic Protection



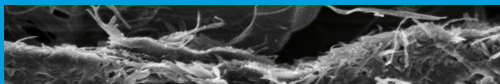
Researchers synthesised the polio virus from scratch, just by joining the right short sections of DNA. Other groups remade the 1918 pandemic Spanish Flu virus. Is this irresponsible, or is it justified to find what makes some viruses pandemic?

## B32 Uncontrolled Access to Partial DNA Sequences



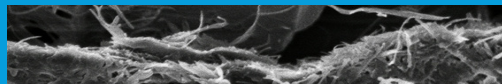
A journalist posed as a scientist and obtained partial DNA sequences from different suppliers, enough to start making a deadly virus. Would co-ordination among DNA supply companies control this enough?

### B33 Is Self-regulation by Synthetic Biologists Enough?



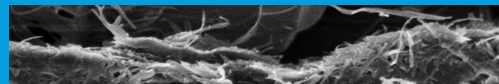
The synthetic biology community proposes professional codes and advisory bodies to oversee what goes on. Some NGOs are suspicious of this, and argue that self-governance isn't enough. Who's right?

### B34 Garage Biotech (Biohacking)



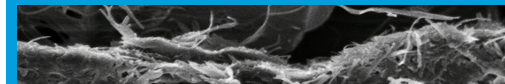
A 'Primer for Synthetic Biology' is available on the Web in non-technical language, raising concern that anybody could do synthetic biology in their garage. Should there be regulation to control who uses it?

### B35 Who should do Synthetic Biology?



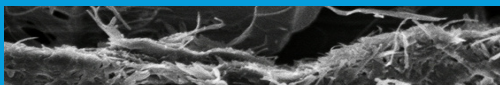
Given the risks and uncertainties involved, who should be allowed to practise synthetic biology and what obligations do they have?

### B36 Justice and Equity



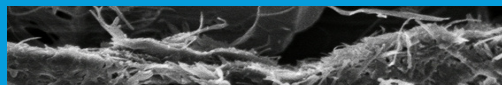
Will these developments make a positive difference to the rich-poor global divide, or will they tend to make it worse?

### B37 Artemisinin for Malaria: Distribution and Justice



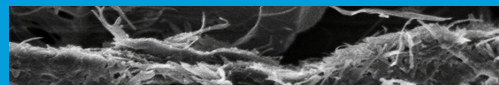
Artemisinin derived from yeast may be on the market soon to treat malaria (Story Card 1). It should be cheaper and more widely available. But it will undercut traditional producers in Asia. How can they be compensated?

### B38 More Enterprise or More Accountability?



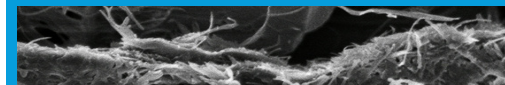
There is considerable private funding of synthetic biology. What is the right balance of commercial opportunity and public accountability for what's being developed – e.g. organisms which might make our future energy supplies?

### B39 Should the Synthetic Biology 'Tool Kit' be Public or Patented?



If synthetic biology develops like a common tool kit and parts, who should own them? Should the 'know-how', parts and devices be mostly free for all to use, or mostly patented by organisations for commercial development?

### B40 Patents and Monopoly in Synthetic Biology



Serious concerns have been voiced if patent offices grant patents on key inventions in synthetic biology, if they could give effective monopoly to a single company over, for example, biofuel production, akin to that in computer software.