Synthetic biology

Science background: Bacto-Lab

What's the issue?

Should we genetically engineer bacteria to manufacture new products?

By taking genes from one species and putting them into another, scientists can create new organisms. Today, *E. coli* bacteria are engineered in the lab to carry genes that make them produce useful substances such as fuel or insulin.

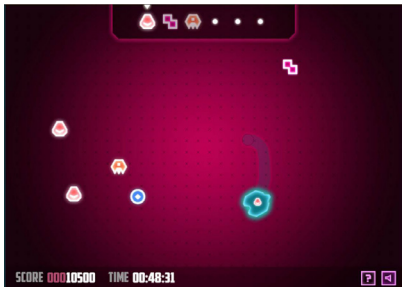
But genetically modified food is banned across Europe because of safety fears. Will consumers feel the same way about modified bacteria? Or should we pursue this route for cheaper and more widely available medicines, fuels and other useful products?

Key terms

Genetic modification or genetic engineering means inserting genes from one species into another to give the organism new abilities or characteristics. For example, scientists can put daffodil genes into rice to make rice plants that produce beta-carotene, so people eating the rice get plenty of vitamin A.

Synthetic biology is the fusion of biology and engineering – in other words, using living things to manufacture useful products.

E. coli, a bacterium, is one of the most studied organisms in the world. Most naturally occurring strains are actually harmless. It breeds well in a lab, making it ideal for experiments and mass biosynthesis.



Engineer *E. coli* in the right order to make new useful products.

What's all the fuss about?

Genetically engineered *E. coli* is already used to make human insulin for people with diabetes. This biosynthetic insulin has replaced the animal insulin that used to be available. It's considered just as safe as animal insulin, but is cheaper to make.

The potential for using *E. coli* to produce a range of biological products is huge, but many people are uncomfortable with the idea of altering living things by adding the genes from one species to another. Furthermore, some are unhappy with the idea of actually putting products from engineered organisms into their bodies.

People also worry that genetically modified organisms will not remain contained in the laboratory or industrial setting, and could spread into the environment if they got out. However, scientists can build genetic 'safety switches' into the *E. coli*, making it impossible for them to survive outside the lab because they need a certain nutrient.

Synthetic biology could be an important part of future manufacturing by making it cheap, easy and environmentally friendly to produce important substances. But it involves using genetically altered organisms on a large scale, which causes a lot of controversy.

Will consumers have to overcome their fears and accept the benefits of genetically engineered bacteria? Should biosynthetic products be clearly labelled? Are there limits on the living things we should use in synthetic biology?

Key facts

- The first biosynthetic insulin went on sale in 1982.[1]
- About 70% of the insulin sold worldwide is produced by engineered organisms, either *E. coli* or yeast.[2]
- *E. coli* can be engineered to produce acrylic acid, a key component of paints, nappies and adhesives, generating 75% less emitted carbon dioxide than making the same amount of acrylic acid from petroleum.[3]
- The US government has spent around $430 million on research into synthetic biology since 2005. The UK has invested $160 million during that same period. Less than 5% of that money has been spent to explore ethical, legal and social implications of synthetic biology.[4] Do you think it should be more?

Isn't *E. coli* dangerous?

There are many different strains of *E. coli* and only a few are actually harmful. Some live naturally inside the human body and help keep other more harmful bacteria under control. They can even help manufacture vitamin K in our bodies.

What else can *E. coli* do?

E. coli is being researched to manufacture biofuels. Scientists hope genetically modified *E. coli* will convert sugar directly into usable fuel without the need for processing the fuel afterwards. Scientists have even used *E. coli* to manufacture haemoglobin so the *E. coli* itself acts like a red blood cell. They have also created *E. coli* that can act as a biological sensor and change colour. *E. coli* may be used in the future to deliver anti-cancer drugs, by bonding to a specific molecule in a malignant tumour.

Image: shutterstock/Whatie

E. coli bacteria can be genetically engineered to produce useful substances, for example insulin. They multiply quickly in the right conditions, and pass on their new genes so the entire colony is able to produce insulin. The insulin is then extracted and purified for human use.

How do scientists give bacteria new abilities?

Bacteria contain a single chromosome (strand of genetic material) which contains all the information that the bacteria need to survive and reproduce. As well as this, they have extra rings of DNA called plasmids. Plasmids work on their own inside the bacteria, giving the bacteria certain extra abilities, such as immunity to antibiotics or the ability to make a toxin.

By altering the genes in bacteria's plasmids we can get the bacteria to produce different substances. In the case of insulin, human genes for insulin production are inserted into the bacterial plasmids, so the microbes will make the insulin hormone.

Can we make anything this way?

E. coli can only be used to make proteins. These can be enzymes, transport proteins (such as haemoglobin) or hormones (such as insulin). And only the genes for proteins that we know about can be inserted into the bacteria. *E. coli* can make a wide range of biological molecules, but there is a limit!

Who owns the genetically engineered organisms?

Currently, new organisms are patented by the companies that develop them, so people wanting to use them have to pay a fee. This doesn't mean the people who create the organism are responsible if something bad happens whilst using the organism.

What else can we do with biosynthesis?

Synthetic biology can be broken down into four categories:

- Medical applications, for example making antibiotics
- Energy applications, particularly biofuels
- Food applications, such as developing crops that provide more vitamins or bananas that contain a vaccine
- Environmental applications, for example engineering bacteria to clean up oil spills

Image: Shutterstock/Keith Publicover

Goats have been genetically engineered to produce milk containing a protein found in spider silk. The protein can be extracted and spun into spider silk thread, one of the strongest fibres in the world.

You could discuss...

- Would you put products from engineered bacteria in your body? Would you feed them to your dog?
- What would you like to see produced by engineered bacteria?
- Is it OK to engineer *any* organism?
- Are the benefits of genetically engineered bacteria too great to be ignored?
- Should people be allowed to use engineered organisms for biosynthesis in their own homes? What if they get out into the environment?
- Who should own new organisms? How far does their responsibility go?
- Does the world really need this technology?

Links to the Science Museum

Biosynthetic insulin is featured on the *Brought to Life* website.
www.sciencemuseum.org.uk/broughttolife/objects/display.aspx?id=93197

The *Antenna* website explores the risks and benefits of genetically modified foods.
www.sciencemuseum.org.uk/antenna/futurefoods/debate/debateGM_CIPbusiness.asp

A pair of genetically engineered mice are on display in the *Making the Modern World* gallery.
www.sciencemuseum.org.uk/images/I018/10284109.asp

Further information

BBC radio discussion programme on *Synthetic Biology*:
www.bbc.co.uk/programmes/b00ljy2g

For current research in the UK have a look at the Imperial College Centre for Synthetic Biology and Innovation:
www3.imperial.ac.uk/syntheticbiology

The J Craig Venter Institute's website contains an overview of its research into synthetic biology:
www.jcvi.org/cms/research/groups/synthetic-biology-bioenergy

An article from *Genetic Engineering & Biotechnology News* on fighting cancer with *E. coli*:
www.genengnews.com/analysis-and-insight/synthetic-biology-delivers-cool-tools-but-new-therapeutics-are-a-ways-off/77899473

Sources

1 Suzanne White Junod, 'Celebrating a milestone: FDA's approval of first genetically-engineered product', *Update* (September – October 2007), www.fda.gov/AboutFDA/WhatWeDo/History/ProductRegulation/SelectionsFromFDLIUpdateSeriesonFDAHistory/ucm081964.htm

2 *Diabetes Atlas*, 2nd edn (Brussels: International Diabetes Federation, 2003), www.idf.org/diabetesatlas/downloads/previous-editions-idf-diabetes-atlas

3 'Better bugs to make plastics', *Technology Review* (20 September 2010), www.technologyreview.com/energy/26313

4 'Government funding for synthetic biology on the rise', *ScienceDaily* (8 June 2010), www.sciencedaily.com/releases/2010/06/100608092108.htm