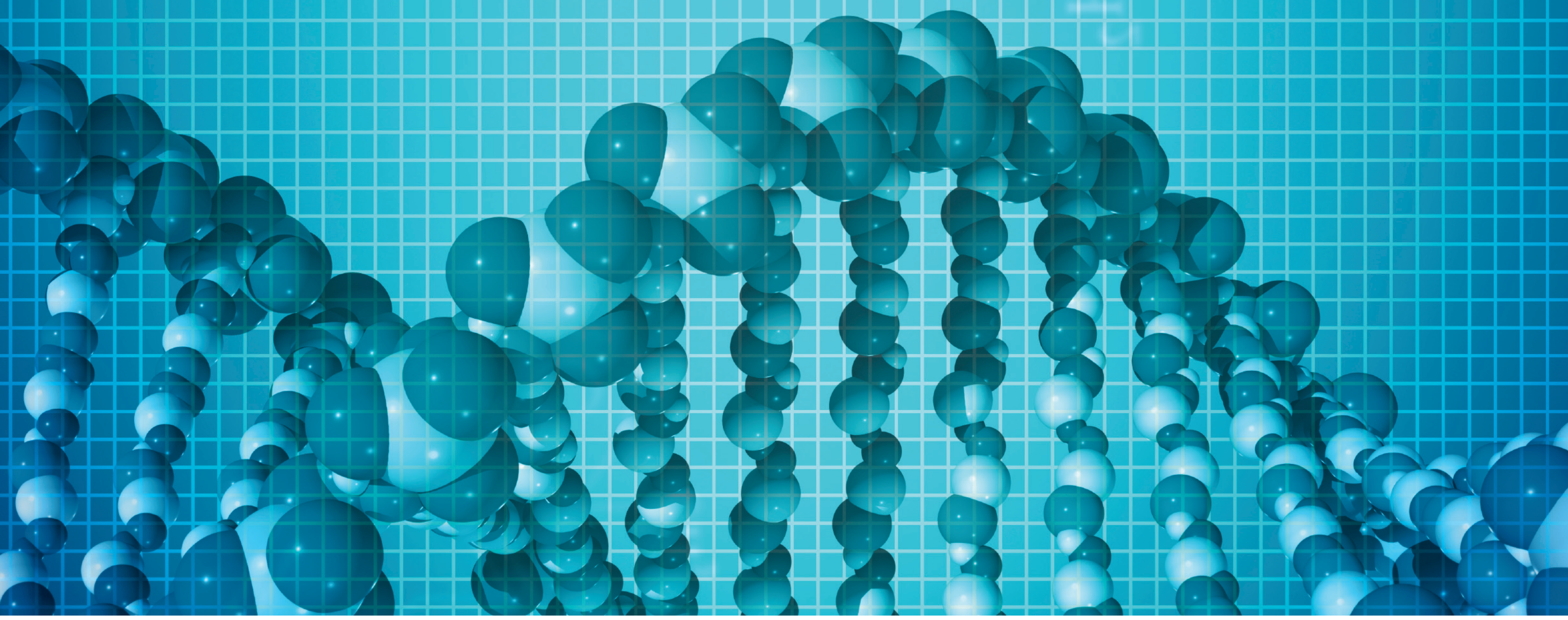
Ri Aus PDplus

Teacher Notes: Synthetic Biology



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INTRODUCTION TO THE GUIDE

RiAus PD*plus* Teacher Notes is a new initiative of RiAus that has been designed to assist middle school (Years 7 – 9) teachers engage and involve their students.

The notes supplement a PD*plus* presentation hosted by RiAus on synthetic biology, which will allow teachers to have access and put questions to scientists about their research and careers.

RIAUS PD*plus*: SYNTHETIC BIOLOGY
Creating life in the lab
Wednesday 6 April, 3.45pm-4.30pm
Presented by Desmond Lun (Rutgers University) and Claudia Vickers (University of Queensland)

Teachers view live online via Centra Virtual Classroom at *http://bit.ly/peterlangridge* or *www.riaus.org.au/PDplus.*
The briefing will be archived at *www.riaus.org.au/PDplus.*

TEACHER'S ★★★★★ RESOURCE

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HOW TO USE THE GUIDE

The notes offer both variety and flexibility of use for the differentiated classroom. Teachers and students can choose to use all or any of the five sections – although it is recommended to use them in sequence, and all or a few of the activities within each section.

THE 'FIVE ES' MODEL

The guide will employ the 'Five Es' instructional model designed by Biological Sciences Curriculum Study, an educational research group in Colorado, USA. It has been found to be extremely effective in engaging students in learning science and technology. It follows a constructivist or inquiry based approach to learning, in which students build new ideas on top of the information they have acquired through previous experience. Its components are:

Engage Students are asked to make connections between past and present learning experiences and become fully engaged in the topic to be learned.

Explore Students actively explore the concept or topic being taught. It is an informal process where the students should have fun manipulating ideas or equipment and discovering things about the topic.

Explain This is a more formal phase where the theory behind the concept is taught. Terms are defined and explanations given to models and theories.

Elaborate Students develop a deeper understanding of sections of the topic.

Evaluate Teacher and students evaluate what they have learned in each section.

Useful Websites

The J. Craig Venter Institute homepage: *www.jcvi.org*

CSIRO page on synthetic biology: *www.csiro.au/science/Enzymology-Synthetic-Biology.html*

Are we close to creating synthetic life?:
www.riaus.org.au/science/questions/elements_chemical_reactions/are_we_close_to_creating_synthetic_life.jsp

RNA computer' creates zombie cells: *www.cosmosmagazine.com/news/2258/rna-computer-creates-zombie-cells*

The new biology

Biology is generally thought of as the study of living things and their interactions. But what if scientists had the power to actually alter living things in order to have them do new things. This is the basic idea behind synthetic biology – the alteration and creation of things that don't exist in nature. And it's a field that will change the way we use biology.

WHAT IS SYNTHETIC BIOLOGY?

Synthetic biology is all about creating things that don't currently exist naturally, or re-designing organisms and genomes to do different jobs. These jobs can range from creating medicines for humans to breaking down pollution in order to help clean up the environment. Synthetic biology is also involved in genetically modifying food in order to make it more nutritious or grow more efficiently.

At the extreme end, synthetic biology can also result in the creation of entirely new, artificial life forms.

HOW DO YOU MODIFY LIVING THINGS?

The genome is the key to modifying living things. A genome is all of an individual's genetic information that gets passed down from generation to generation. For example, you inherited your genome from your parents, and it controls many things in your body, from your height to how likely you are to develop certain diseases.

DNA and the genome

Genomes are made up of chromosomes, which are packages of deoxyribonucleic acid (DNA). This DNA contains genes, which control certain traits, for example, there are genes that control eye colour.

Other than the reproductive cells, every cell in an organism's body contains its entire genome.

Scientists work on an organism's genome in order to get them to do new jobs, or produce different products. They can do this by inserting genes from other species into a genome, altering a genome, creating unique genes and inserting these into a genome or even creating a new genome from scratch and then inserting this into a cell that has had its natural genome removed.

Transcription: accessing DNA

DNA controls things happening in the body through two processes - transcription and translation. During transcription, a section of the DNA unzips. One part of a single strand of DNA is then read by a protein and a complimentary strand of ribonucleic acid (RNA) is created.

Translation: making proteins

The new strand of RNA is read by a small organelle called a ribosome. The ribosome translates the RNA code into a protein by reading codons - codons are a set of three nucleotides (the building blocks of RNA and DNA). Each codon translates for a different amino acid. Because each strand of RNA contains many codons, a chain of amino acid builds up and this is then folded into a protein. These proteins control important events in the cell and around an organism's body, such as growth, development and digestion.

Changing parts of the natural process

By manipulating different stages of this process, which is occuring constantly, scientists are able to control what happens in a cell and what it produces. If you imagine a cell as a computer, synthetic biology is similar to tinkering with this computer - upgrading certain features and changing settings so that a certain program works the way you want it to. By doing this, scientists hope to provide benefits to society.

Timeline

Some of the important moments and discoveries in synthetic biology.

1943 – American scientist Oswald Avery proves that DNA carries genetic information

1953 – James Watson and Francis Crick describe the three-dimensional 'double helix' structure of DNA: two spiralling strands held together by complimentary base pairs.

PREOCCUPATIONS/FLICKR

1977 – Geneticists begin sequencing DNA.

1980 – A U.S. Supreme Court decision allows genetically modified organisms to be patented.

1986 – Researchers begin talking about an ambitious project: mapping the human genome.

WHAT CAN WE DO WITH SYNTHETIC BIOLOGY?

There is a huge amount of potential in the field of synthetic biology, and as it is a new field, scientists still don't know the extent of what is possible.

Generally, scientists believe it will help society by creating organisms that can perform a beneficial role or produce a useful product.

In the future, scientists may also be able to create entirely new organisms that have improved properties. In 2010, geneticist Craig Venter produced the first example of artificial life. This was a cell known as 'Synthia'. His team created a custom genome on a computer and then inserted this into a cell which had had its genome removed. They then jumpstarted this cell and it began to grow and divide. Creating artificial life is still in its early stages, but it is only a small part of the field and isn't the main focus of scientists.

Currently, the majority are working on 'tweaking' existing genomes and also controlling how cells work. For example, synthetic biologists are trying to regulate how carbon flows through a cell - usually it consumes carbon in some form, and then this carbon is broken down and used for energy and to build cellular parts. Scientists are hoping to direct this carbon to produce something else, such as a drug or an industrial chemical.

The extent that we can alter cells and organisms is still being explored, but scientists believe the potential is going to continue to grow.

ARGUMENTS AGAINST SYNTHETIC BIOLOGY

As with more emerging technologies, there are people who are against synthetic biology. This is for several reasons. Many people are concerned that synthetic biology is not safe for humans or the environment. They worry that these altered organisms may cause damage to health in the long term, and that altered species may escape into the environment and cause damage. So far there is no scientific evidence for these concerns, but further research needs to be done over a long period of time before they can be completely disproven.

There are also people who argue that scientist are trying to 'play God'. This is an ethical question that scientists need to make up their own mind about depending on their beliefs. And there is concern over the continued regulation of synthetic biology - who will own these altered organisms? Could people one day make money off them?

There are still many questions to be answered in this new field.

Future facts

Potential applications of synthetic biology.

1 It could be possible to create microorganisms that break down environmental contaminants, which could help to clean up oil spills and land that has been polluted.

2 Bacteria and other cells can be changed so that they produce medications. This can be beneficial as this process is often extremely expensive and can also be unpredictable. This can reduce the cost of medications so that people in developing countries can afford them.

3 Synthetic biology can be used to alter crops, so that they're more nutritious, or grow more efficiently. This can also benefit people in developing countries, many of whom struggle to obtain enough nutrients.

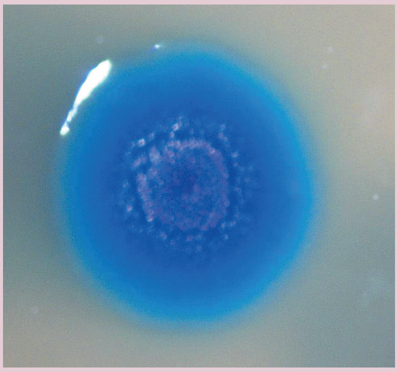
4 Scientists are working on altering bacteria and yeast so that they will metabolise plants such as sugarcane into biofuels. Biofuels are a renewable fuel source, as opposed to fossil fuels. This could have significant environmental benefits.

1994 – The first genetically engineered food is approved for human consumption.

1996 – Scientists successfully clone the world's first mammal from an adult somatic cell - a sheep named Dolly.

2003 – Nearly two decades after the idea was formulated, the Human Genome Project is completed.

2010 – Renowned geneticist Craig Venter builds what some people call 'new life' and the media name it 'Synthia'. He created a unique genome and transplanted it into a host bacterium. Once inside the host cell the genome began functioning like a normal bacterial cell. Venter was criticised by some for trying to play God.



2010 – Venter's company Synthetic Genomics begins growing algae for the purposes of creating cleaner, more efficient biofuels that are also more resistant to disease.

WIKIMEDIA; J. CRAIG VENTER INSTITUTE

Want to shape the future?

Synthetic biology is an exciting field that could take you around the world and see you pioneering biological breakthroughs and shaping life as we know it.

HOW CAN I BE INVOLVED SYNTHETIC BIOLOGY?

As our knowledge of genomes improves, so will our ability to alter existing life forms. There is a lot of potential to be involved, from working to better understand the genomes of existing species and developing new DNA-transferral techniques to optimising the products made by synthetic bacteria and creating new genomes.

What will I do?

The majority of synthetic biology jobs are in research and early on in your career you may spend a lot of time in the lab, making new discoveries and trying to find the answers to questions. However, as you progress you could work in more of a decision-making role, where you will make choices about what to research.

This is one of the most rewarding parts of synthetic biology according to Claudia Vickers, a synthetic biologist at the University of Queensland.

"You're basically in control of your career, you're working for yourself a lot of the time."

There will also be an increasing demand for people who understand science to work in policy-making and regulation of synthetic biology.

Exciting opportunities

Regardless of how you want to be involved with the field of synthetic biology, you will be at the forefront of discoveries that could one day change life as we know it.

WHERE YOU COULD WORK

Research really is a global pursuit. If you want to work in synthetic biology, there is no limit to the places that you could work. There are also a number of industries available to you - synthetic biology has the potential to benefit fields as diverse as environment, health care, engineering and mining.

A young industry

One thing that is important to keep in mind if you want to work in synthetic biology is that currently, the majority of non-academic jobs are overseas.

"There really isn't an industry for synthetic biology in Australia right now – not the way that there is in the U.S, Europe or the UK," says Vickers.

However, there are research jobs around and she thinks the private sector will soon grow. "The only reason it hasn't taken off is because the environment hasn't been right, but now it is."

In the meantime, there are great opportunities to travel the world with your research. "Once you've got a PhD you can live and work anywhere in the world where you fancy," says Vickers.

Will there be jobs?

Currently there are already lots of jobs in synthetic biology, with the majority being overseas, says Vickers. But she believes that within the next three to five years there's going to be a lot more movement in the field. Vickers believes that biology is definitely the field to be in in the coming years.

> "This is the dawn of the biological revolution."

"The last century was the age of industrial revolution and then we had the mechanical one and the computer revolution. This is now being considered the dawn, or a little past the dawn, of the biological revolution and using biology in a whole new way."

WHAT TO STUDY

Synthetic biology is still very new in Australia. Currently there are no specific courses on the subject but according to Vickers a bachelor of science or engineering will provide you with the basis to work in synthetic biology. But she says it's important to choose a university that has a reputation for producing good research in genetics, bioengineering and synthetic biology, as not all universities are created equal. Look out for campuses that offer subjects such as molecular biology, and genetic and biochemical engineering.

And despite the industry being small in Australia, it's a great place to study. "We have a really good reputation for training our students," adds Vickers.

In South Australia:

Flinders University
Flinders University offers both single and double degrees in science and engineering, and has a major in nanotechnology available to science students. This new field of science observes molecules on a very small scale and has the potential to link in with synthetic biology. The university also offers a bachelor of biotechnology.
www.flinders.edu.au

University of Adelaide
The University of Adelaide offers both a bachelor of science and a bachelor of engineering, and also has double degrees in the two subjects that can allow you to major in subjects such as biotechnology.
www.adelaide.edu.au

University of South Australia
The University of SA offers single degrees in science and engineering.
www.unisa.edu.au

Around Australia:

Universities in every state offer degrees in engineering and science, but the following have strong links to synthetic biology research: the **University of Queensland**, the **University of Melbourne**, **Monash University** and **Macquarie University**. According to Vickers, Queensland is particularly good place to study synthetic biology due to government funding.

Portrait: synthetic pioneers

AUSTRALIA: CLAUDIA VICKERS

The best part about working in synthetic biology is getting "paid to learn new and cool stuff and create new knowledge," says Claudia Vickers at the Australian Institute for Bioengineering and Nanotechnology at the University of Queensland. "It doesn't get much better than that."

Vickers currently works in the field of synthetic biology, which is very much in its infancy in Australia, she says. She is currently running a research group that is engineering yeast and *E. coli* bacteria to produce biofuels from sugarcane that could one day be used to power jets – and are more environmentally friendly than traditional fuels.

"We're interested in making replacements for industrial petrochemicals – which are currently made from non-renewable sources. And making them from renewable sources."

Vickers and her team are using sugar cane as their source, which is one of Australia's largest agricultural exports.

Vickers' team is still investigating the extent of the fuel's benefits. But it's thought that it will have less of an environmental impact and be more efficient, she says.

Vickers has always been interested in how plants work, and originally studied a bachelor of science at the University of Queensland. "In the last couple of years I specialised in plant and fungal molecular biology and did an honours year in the same field," she adds. Vickers went on to complete a PhD in molecular biology, during which she tried to improve the nutritional content of cereal crops.

She then lived in the UK for three years where she studied isoprenoids – a group of biochemicals with medicinal and industrial properties. They also happen to be in the fuels that Vickers' group is currently working on.

"Every now and then you discover something that's completely new."

"After coming back to Australia, I spent the first three years developing a better understanding of microbial biological processes and now I'm applying that to jet fuel prospects."

According to Vickers, she gets to spend all day doing something that she loves - the novel aspect of synthetic biology keeps her constantly interested in her research.

"It's a hugely fascinating area, I get really excited about creating new things and the reason that I'm doing research science is that every now and then you discover something that's completely new. You're the first person who knows it and you get to go out and tell people about it."
– *Fiona MacDonald*

DESMOND LUN
RUTGERS UNIVERSITY

TITLE: Associate professor at the Centre for Computational and Integrative Biology at Rutgers University

WHAT HE DOES: Lun is working to alter the genetic makeup of *E. coli* in order to produce biodiesel fuel from fatty acids. Originally from Australia, Lun studied science and engineering with honours at the University of Melbourne before moving to the U.S. and doing a masters.

JAY KEASLING
UNIVERSITY OF CALIFORNIA, BERKELEY

TITLE: Professor at the University of California, Berkeley and director of their synthetic biology department.

WHAT HE DOES: *Discover* magazine's 2006 Scientist of the Year, Keasling is best known for engineering bacteria to produce the anti-malaria drug Artemisinin. He is now working on engineering microorganisms to digest environmental pollution.

CRAIG VENTER
J. CRAIG VENTER INSTITUTE

TITLE: Founder and president of the J.Craig Venter Institute

WHAT HE DOES: One of the first people to sequence the human genome, Venter created the first example of synthetic 'life' in 2010 when he inserted a synthetic genome into a cell with no DNA and got it to grow and divide. His not-for-profit institute works to help solve energy problems and prevent infectious disease.

[Task] What do you think?

It is the Year 2050. A new piece of technology has recently been released called "Make a Cell". You buy it from the local department store for $99.95 and you put in a few pieces of left-over food, hit a button and it will engineer any type of cell you want it to. The machine will then grow more of the new cell as well. What are the consequences of this new technology and is it good or bad for society?

Answer the following questions below to investigate this hypothetical situation.

1. What type of cell/cells would you make with your new machine? For example; would the cells fight bacteria? Combat rogue cells such as cancer cells? Produce a chemical? If so, what chemical? Would the cells assist other cells to do things? Could they be fast growing, digest fat, or receive light so it can be put in the retina of blind people? The sky is the limit.
2. Make a list of your new cell's characteristics and draw a diagram of your new creation.
3. How would this new cell change your life?
4. What were the motives of the company that designed this new machine? Do you think they designed it to help society, make money or help individuals?
5. What applications can you think of for this new technology that could help society?
6. What applications can you think of for this new technology that may harm society?
7. List some of the ethical issues in designing and making a new life form.

Teacher's information

The aim of the Explore section is for the students to investigate some of the ideas around synthetic biology and ponder its possible impacts on humans. It is intended that the students make their own discoveries as they work around the stations in the room.

Many of the activities will need preparation a couple of weeks before the start of the unit. The table below lists the equipment and preparation required.

Station name	Materials list
Genpets	A computer to access the Genpets Website: *www.genpets.com* Teacher's note: this website is very well designed and set up, so some students may think it is real. It is a hoax and was designed by artist Adam Brandejs in response to the current trends in genetic engineering. To find out more about the Genpets website and its creator go to: *www.brandejs.ca/portfolio/Genpets/Why* AND *www.museumofhoaxes.com/hoax/weblog/comments/genpets_shrinkwrapped_pets*
Quoting Venter	A computer to access: *www.cosmosmagazine.com/news/1416/genome-switching-turns-one-bacterium-another*
Sweet DNA!	A variety of soft lollies
DNA replication and protein synthesis	A computer to access: *www.pbs.org/wgbh/aso/tryit/dna*
Synthetic biology simulation	Pipe cleaners and plasticine in red, blue and at least two other colours
Biological systems	A model of the human body showing different organs, a model of a cell showing the organelles and a model of DNA
Biological definitions	Dictionary
Enzyme action	Five test tubes, a test tube rack, hydrogen peroxide, safety goggles, a sample of tripe (cow's stomach) and small cubes of potato, liver, carrot, spinach leaf and hamburger mince.

Station: Genpets

[Task] Go to *www.genpets.com* and answer the following questions in your work book.

1. Describe what the Genpet is in your own words.
2. What are its main features?
3. Would you buy one of these pets?
4. What are the advantages and disadvantages of buying such a pet?
5. What do you think are the motives of Bio-Genica, the company that makes Genpets?
6. Do you think it is ethical to create this type of animal? Why/why not?
7. What could the production of this type of life form mean to society?
8. Suggest how a pet like this might be made.

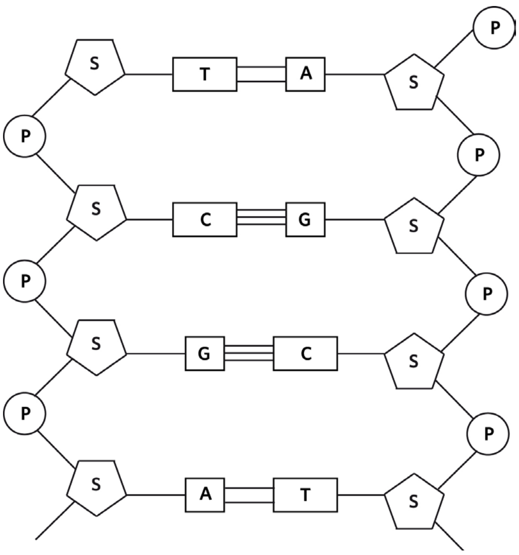
Station: Quoting Venter

[Task] Read the article found at *www.cosmosmagazine.com/news/1416/genome-switching-turns-one-bacterium-another* and answer the following questions in your work book.

1. Venter says that the transplantation of one whole bacterial genome into another species is the "equivalent to changing a Macintosh computer to a PC by inserting a new piece of software". Do you agree with Venter? Why/why not?
2. How do you personally feel about the process of switching parts of the genomes of plants and animals?
3. Do you think money should be spent on this type of research?
4. What do you think about scientists artificially making genes?
5. How do you think the artificial synthesis of genes and also life forms might benefit or harm society?
6. What type of things do you think scientists might want engineered cells to do that they couldn't otherwise do?
7. How might the production of artificial life affect your life personally on a day-to-day level in the future?

Station: Sweet DNA!

[Task] Look at the image below of DNA and in your work book complete the following activities.



Each nucleotide is made up of a five-carbon sugar, a phosphate molecule and a type of nitrogenous base (cytosine, thymine, adenine or guanine).

Nucleotides link together via complementary nitrogenous bases to form DNA.

Key:
P= phosphate
S= sugar
C=cytosine
G=guanine
T=thymine
A=adenine

1. Use the materials provided to create a model of DNA. You only need to show two codons (six nucleotides) in your model.
2. Draw a diagram or take a photo of your lolly model and include a key that shows which lollies code for which molecule.

Station: DNA replication and protein synthesis

[Task] Go to *www.pbs.org/wgbh/aso/tryit/dna* and complete the following activities in your work book.

1. Carry out the workshop activity on the site.
2. Create a flow chart that summarises the steps involved in DNA replication.
3. Create a second flow chart that summarises the steps involved in protein synthesis.

Station: Synthetic biology simulation

[Task] Using plasticine to represent strands of DNA, complete the following activities.

Part 1 - DNA splicing/insertion of DNA

1. Take the blue plasticine and use it to make a long worm-like shape about 15 cm long. Take the red plasticine and make a similar worm-like shape and then make a ring with it by joining the two ends.
2. Use the knife to cut out a 1 cm section from the middle of the blue plasticine. Reseal the blue plasticine.
3. Break apart the red ring at one point and insert the fragment of blue plasticine into it and seal the ends together.
4. Make a flow chart using drawings to show the steps you took.
5. The red 'DNA' now has some of the blue 'DNA' in it and is said to be transgenic. If this were DNA from a living organism, the organism would now produce proteins made by both the red and blue DNA.
6. Inserting bits of DNA into different organism's genomes, as you just replicated, is carried out in many industries such as when engineering genetically modifies foods. Tomato genomes, for example, sometimes have a gene from salmon inserted into them to help the tomato survive frosts. What might be the advantages/disadvantages of this process?

Part 2 – Synthetic biology simulation

1. Start off with a ring of blue plasticine on a piece of paper. This represents a plasmid – a ring of DNA that occurs naturally in bacteria – inside a bacteria (the piece of paper).
2. Make another ring out of pipe cleaners. You can choose the colours and how you make it. The pipe cleaner ring represents an artificially made plasmid – a genome made in the lab by mixing different bases and other chemicals together to make DNA strands.
3. Place the pipe cleaner ring on the paper next to the plasticine.
4. Remove the plasticine and destroy it.
5. You now have an organism that has an artificial genome. This genome will make any proteins that you have determined.
6. What type of organism would you make if you could? Why?
7. What are the advantages and disadvantages of this type of technology?

Station: Biological systems

[Task] Synthetic Biology is concerned with engineering complex biological systems that can be manipulated in ways that wouldn't occur in nature. So what is a biological system? Have a look at the three models provided by your teacher and complete the activities below.

1. Complete the questions in the table below (or create a similar one in your work book).

Question	**Human body (pick one organ system such as the digestive system or the respiratory system)**	**Cell**	**DNA strand**
List the system and the organs/organelles/ molecules that make it up.			
What is the role of the system?			
Give a brief summary of how each of the systems work. How does each of its components interact? How do they assist each other in the running of the system?			
What happens if something goes wrong with one of the components of each system? Give an example.			
How do each of the systems interact with each other to form one big system?			

2. What are some other examples of biological systems?

Station: Biological definitions

[Task] In the table below, predict the definitions for the terms listed then look up the terms in the dictionary and list the definitions. Draw a diagram that represents each term and think up an analogy that could help describe the term.

Word/term	Predicted definition	Dictionary definition	Diagram	Analogy
DNA				
GENES				
BIOLOGY				
BIOLOGICAL SYSTEM				
ENGINEERING				
ENZYME				
CHROMOSOME				
PLASMID				
TRANSGENIC				

Station: Enzyme action

[Task] An enzyme is a protein that is coded for by a gene. Enzymes are biological catalysts, this means that they speed up chemical reactions. Enzymes are important because without them chemical reactions that happen in our body and keep us functioning would be too slow and we would die.
Complete the following activity to investigate how an enzyme works.

Investigating the role of catalase

Hydrogen peroxide is produced by our body's cells as a by-product of many chemical reactions taking place. If the hydrogen peroxide were to build up in our cells, it would become toxic and we would die. Our cells have an enzyme called catalase that works to break down the hydrogen peroxide into harmless oxygen and water.

This experiment shows the effect of the catalase produced in living cells on hydrogen peroxide.

1. Place a piece of each sample provided by your teacher in a test tube.
2. Pour 10 mL of hydrogen peroxide on top of each sample.
3. In the table below (or a similar one in your work book), record the rate of bubbling in each sample. Make up your own scale out of five, with zero being no bubbling and five being the most vigorous bubbling.

Sample	**Rate of bubbling out of five**
Carrot	
Liver	
Hamburger mince	
Potato	
Spinach	

4. More bubbles represent more catalase in the sample. Put the samples in order from the one containing the most catalase to the least catalase (the one with the most bubbles to the one with the least bubbling).
5. What is the gas being given off in the bubbles?
6. Have a look at the sample of the cow's stomach lining that your teacher has provided. This is where many chemical reactions involved in digestion that are controlled by enzymes take place. Describe the surface of the lining. Why do you think there are so many folds in it?
7. List some other chemical reactions in the body that are controlled by enzymes.
8. If you could design a new enzyme that could speed up any reaction what would it be? How would you use it? Where would you use it? What applications might it have to help society?

Teacher's information

In this section, we explain the science of synthetic biology by getting students to read *Cosmos* articles about issues and applications of synthetic biology. This section suggests discussion topics and activities linked to those articles.
Each article will have its own literacy activities, which includes:

- Brainstorming
- Glossary
- Comprehension and summary
- Questioning toolkit

The articles include:

Article one – Second nature (first published in *Cosmos* 36 on 27 November 2010)
This article describes the research being conducted by geneticist Craig Venter and his team to create a prototype organism with an engineered genome that could behave like a production line in a factory and make a designated useful product.

Fast facts:
- Theoretically, it might be possible to make biofuels, vaccines, drugs, food stuffs and anything else genetic engineers can program the new genomes to produce.
- Venter's team is the most advanced in the rapidly expanding field of synthetic biology – a field that applies engineering to the molecular design of biological systems in order to build components that don't already exist in the natural world.
- One of their goals is to make greater quantities of 'better' biofuels, which have resistance to more diseases, consume less energy and have lower net carbon dioxide emissions than conventional biofuels.
- They admit there's a danger of the technology falling into the wrong hands and being used to create bioweapons.

Article two – Cows' stomachs the key to biofuel (first published on *cosmosmagazine.com* on 28 January 2011)
This article explains that scientists are studying how the microbes in a cow's stomach can breakdown cellulose. They are using this as a model for the artificial breakdown of switchgrass cellulose in order to create biofuel.

Fast facts:
- The microbial mix inside a cow's stomach has revealed genetic clues to more efficiently turn grass into ethanol biofuel.
- Scientists placed a nylon sack full of switchgrass through a hole in the cow's skin into the stomach.
- For years switchgrass has been grown for biofuel production, as it can yield 540% more energy than is needed for it to grow.

Second nature

One hundred years ago, Henry Ford revolutionised manufacturing with the assembly line. Peter Lavelle asks, is Craig Venter the new Henry Ford?

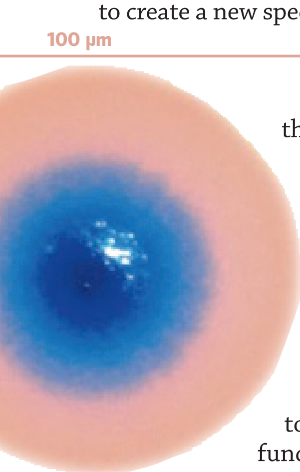
J. CRAIG VENTER INSTITUTE; SANDY HUFFAHER/NEW YORK TIMES

IT WAS THE BIGGEST science news story of the year – possibly the decade. In May 2010, Craig Venter and his team of scientists at the J. Craig Venter Institute in Rockville, Maryland and San Diego, California, published a study in the U.S. journal *Science* announcing that they had created a new bacterial species. It instantly generated a media frenzy and propelled the terms 'synthetic biology' and 'genomic engineering' into water cooler conversations the world over.

Venter, the maverick scientist who helped drive the sequencing of the human genome in 2000, was back in the news, this time with an even bigger bang: "Scientist creates synthetic life!" and "Venter plays God!" the headlines shrieked. The new species, *Mycoplasma mycoides JCVI-syn1.0*, was quickly given the more media-friendly name of 'Synthia', while reporters questioned the wisdom of creating life and what it would mean if this new technology got into the wrong hands.

In fact, the process described in *Science* had little to do with 'creating life' (see box on following page, "How Synthia was made"). Synthia wasn't even a wholly new genome, as you might expect from the headlines, but was instead derived from a naturally occurring bacterium – with some minor modifications (mostly the addition of identifying markers plus some gene deletions and mutations).

MICROSCOPIC PRODUCTION LINE



The aim of the Venter team wasn't *just* to create a new species, to play God, or even to astound the scientific community (though they did that), but to build a prototype for a microscopic production line.

If a microorganism could be engineered to include genes that direct the cell to do a number of functions, it would be possible to use this cell for a range of industrial tasks, such as making proteins or carbohydrates or any compounds to order, depending on demand. Theoretically, it might be possible to make biofuels, vaccines, drugs, foodstuffs and anything else genetic engineers can program the new genomes to produce.

It's possible to build the world's smallest production line, inside the world's smallest factory.

What Venter's team *really* set out to do, and achieved, was show it's possible to build the world's smallest production line, inside the world's smallest factory.

Venter was not so much playing God, but following in the tradition of the great industrial pioneers of last century. He's closer to a latter day Henry Ford – the man who in the 1910s developed the production line that eventually put a car in almost every home in the Western world and became the *de novo* engineering tool for the mass production of everything from ice cream to tweezers.

What happens next depends on how scientists tool up this tiny production line.

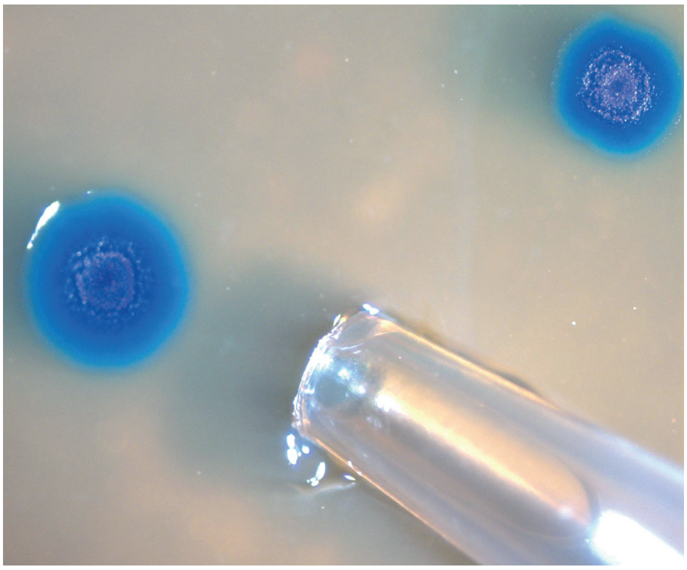
A LONG WAY TO GO

Venter's team is the most advanced in the rapidly expanding field of synthetic biology – a field that applies engineering to the molecular design of biological systems in order to build components that don't exist in the natural world.

Nevertheless, the Holy Grail that Venter imagines is still a long way off, argues Robert Sparrow from the Centre for Human Bioethics at Monash University in Melbourne. "The applications that Venter imagines, involving synthetic organisms designed to achieve various medical and environmental benefits, are a long way yet from being realised," he says.

"It's one thing to be able to modify or synthesise genes, it is quite another to understand, let alone control, the outcomes of these modifications in a living organism ... taking this next step in the biological sciences will require understanding a lot more than scientists currently do about the functions and interactions of genes and the way they work in different cellular environments."

To create Synthia, Venter's group used the simplest possible biological system they could find – *Mycoplasma*, the world's smallest known species of simple-celled organism, with no nucleus or cell wall and only 485 genes in its genome.



But getting the microbial production lines to make the complex compounds Venter envisages will mean building larger, more complex genomes and putting them inside more complex organisms such as plant and animal cells, with more sophisticated gene regulatory systems. The more complex a system becomes, the greater the potential for error.

Venter himself says that while extending the technique to higher organisms such as plants might be possible, to apply it to animal cells will be more difficult. "I don't think we'll be applying this technology to animal cells any time in the near future," he told the BBC in May 2010.

The problem is, our understanding of what genes do and how they work is rapidly increasing, but we still don't know a lot about how they are actually expressed within cells, says John Mattick of the Institute of Molecular Bioscience at the University of Queensland.

Instead of transplanting whole genomes as Venter did, an easier first step will be to modify existing biological systems and adapt their natural functions, says Mattick. This approach is already widely used in agriculture and medicine. Still, even with these existing traditional gene technologies we still have more to understand, he says. "We know how to cut and paste genes into fruit genomes to accelerate a fruit ripening, for example, but we have a long way to go before we have the knowledge to engineer its internal systems to do more sophisticated things, such as change its shape or flavour."

CHEAPER, BETTER PRODUCTS

But the ability to modify genomes that already occur in nature, and the technique Venter has pioneered of transplanting entire genomes, will both continue to develop and will give rise to a whole range of new industrial processes, many of which will replace traditional bricks and mortar industrial processes. "It's inevitable, it's just a question of how quickly it happens," Venter says. "If the technology can produce cheaper, better products more efficiently, then market forces will drive the research and the industrial applications."

In the meantime, Venter is not waiting around. In July 2010, a Venter company, Synthetic Genomics, in a joint venture with ExxonMobil, announced the opening of a test facility to grow algae (some naturally occurring, some genetically engineered) in open ponds and closed photobioreactors under varying temperatures, light levels and nutrient concentrations. Their goal is to use algae to make greater quantities of 'better' biofuels, which have resistance to more diseases, consume less energy and have lower net carbon dioxide emissions than conventional biofuels. The group is also working with drug company Novartis and the U.S. National Institutes of Health, and have announced their intention to have a flu vaccine on the market next year.

SAFETY CONCERNS

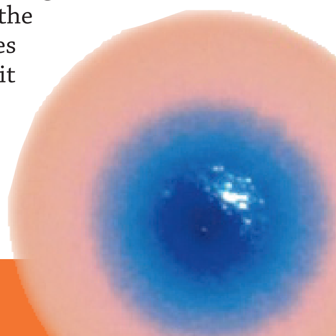
Despite such potential, Venter's research – and indeed the whole field of synthetic biology – still makes some people distinctly uneasy. They argue there's a danger of the technology falling into the wrong hands and being used to create bioweapons. "There is huge potential, but the risks are also unparalleled," says Julian Savulescu, Uehiro Chair in Practical Ethics at the University of Oxford. "The technology could be used in the future to make the most powerful bioweapons imaginable. We need new standards of safety evaluation for this kind of radical research and protections from military or terrorist misuse."

But Mattick dismisses these arguments. He says it's not possible to biologically engineer toxins or dangerous processes; we simply don't have the know-how to achieve such feats.

"Over 30 years of research and over a billion experiments have failed to produce any toxin or process that's harmful," he points out. Regulation will only stifle innovation, he argues. He predicts that once the technology becomes commonplace and it improves people's lives, the new field will be readily accepted.

– *Peter Lavelle*

The technique will give rise to a whole range of new industrial processes.



How Synthia was made

VENTER'S TEAM FIRST made a digital version of the known DNA sequence of the bacteria species *Mycoplasma mycoides*. They then altered some of the DNA sequences and added some 'marker' genes – to identify it as a new genome from a commercial lab – and had strands of DNA (each about 1,000 base pairs long) made up. Then, inside a yeast cell, they built these into progressively larger and larger strands until the new genome was fully assembled. The completed strand was then removed from the yeast cell and put into a 'host' bacterium from which the native DNA had been removed. Once inside the host cell, the new genome switched on and began producing proteins and dividing just like a normal bacterial cell.

By the time of publication in *Science* in May 2010, the new species, called *Mycoplasma mycoides JCVI-syn1.0*, had divided over a billion times.

J. CRAIG VENTER INSTITUTE

Brainstorming

[Task] Use the following words to create a mind map showing what you know about genes and synthetic biology. The mind map should show how the word or terms are connected.

Genes, nucleotides, adenine, guanine, thymine, cytosine, DNA, chromosomes, enzymes, protein synthesis, engineering, function of DNA, structure of DNA, life, characteristics, genome, synthetic biology.

Glossary

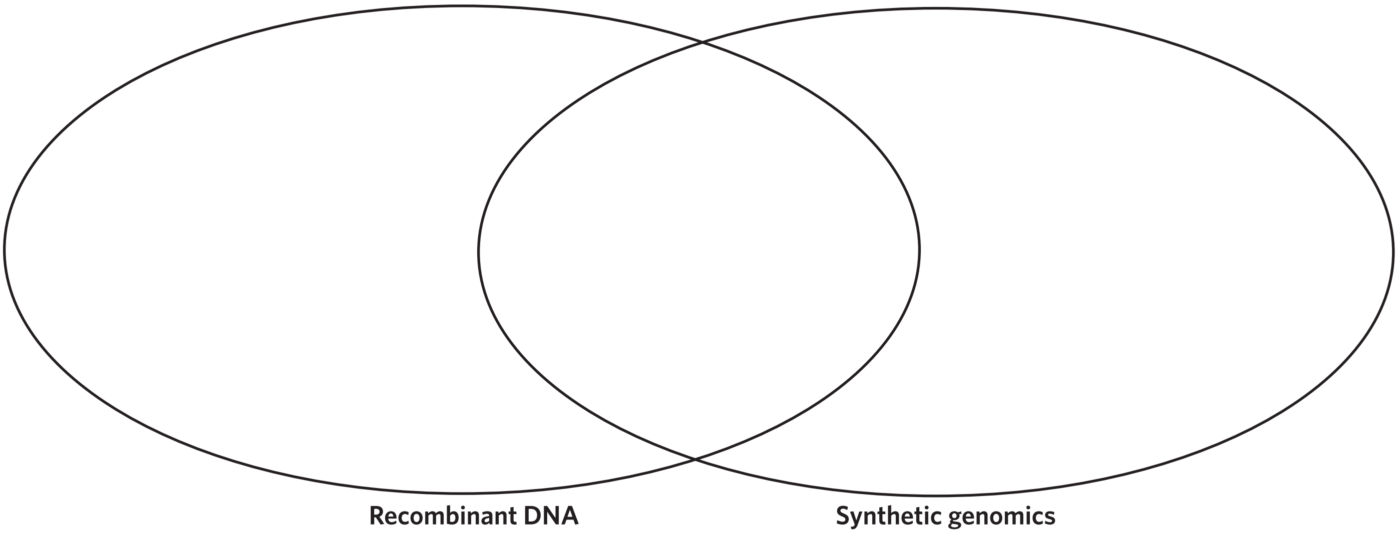
[Task] Use the following table to define any science words that are related to this article.

Word	Definition
Bacteria	
Synthetic biology	
Prototype	
De novo	
Gene transfer technology	
Metabolic pathways	
Biofuels	
Flu vaccine	
Bioweapons	
Genome	
Deletions	
Mutations	
Chromosomes	
Synthesis	
Recombinant DNA technology	

Summarising

[Task] In your exercise book, complete the following activities related to "Second Nature".

1. What was Craig Venter most famous for in 2000?
2. What is 'Synthia'?
3. How was Synthia made?
4. What is the aim of the Venter team in synthesising whole genomes?
5. Describe the work of a "Synthetic Biologist".
6. Why does the author compare Craig Venter to Henry Ford?
7. Why does Robert Sparrow believe that Venter's goal involving synthetic organisms is a long way from coming to fruition?
8. Describe the process of synthetic genomics.
9. Draw a Venn diagram (similar to the one below) to compare synthetic genomics to recombinant DNA technology.



10. What are some of the advantages and disadvanages of Venter's discoveries to society?

Questioning toolkit

[Task] Below are a series of discussion questions in the form of a questioning toolkit. Choose some or all of the questions, or ask some of your own.

Write your ideas and opinions relating to each of the different types of questions.
Inspired by Jamie McKenzie's Questioning Toolkit - McKenzie, Jamie (2000) *Beyond Technology*, FNO Press, Bellingham, Washington, USA (*www.fno.org/nov97/toolkit.html*).

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Question:** What is synthetic biology? What are the promises that synthetic biology has to offer?	
Sorting and sifting questions These questions take us to the heart of the matter, like an archaeologist digging for clues. **Questions:** What is life? What is new life? What is a transgenic organism? How are genes transferred from one organism to another? What are some of the benefits of producing organisms that become little production lines for a particular job? What are the drawbacks?	
Hypothetical questions Questions designed to explore the possibilities, the 'what ifs'? They are useful when we want to test our hunches. **Questions:** What if scientists are able to one day design entire genomes from scratch – what kinds of creatures would be made? What if you could have a skill or characteristic that another organisms has, such as being able to breathe underwater or being able to feel echoes, what would you choose?	
Provocative questions Questions to challenge convention. **Questions:** Could the development of this technology one day help create a biosynthetic weapon? How will we really know that the organisms created with this technology are safe? Is Craig Venter more interested in the science or the money that can be made from his research findings? Is getting a cell to do something it normally wouldn't a way of playing God?	

Cows' stomachs the key to better biofuel

Scientists are working to harness a skill perfected by cows' stomachs – breaking down plant cellulose – to improve biofuel production.

THE MICROBIAL MIX inside a cow's stomach has revealed genetic clues to more efficiently turning grass into ethanol biofuel, according to scientists in the U.S. who have carried out an unprecedented scale of genetic sequencing.

The research, published in *Science*, used a supercomputer to identify new enzymes from a sample size of millions, expanding the known catalogue of genes and genomes that can break down cellulose.

"My colleagues and I could assemble these tiny pieces of DNA and verify both experimentally and with alternative computational methods that what we had was a real picture," said lead author Matthias Hess from Washington State University. "This would not have been possible five years ago."

COWS' EXPERTISE

Inside a cow's rumen – one of the four compartments of its stomach – dwells a complex community of bacteria. Evolved over thousands of years, they turn otherwise indigestible plant cellulose into sweeter, simpler sugars and other products. This is the first and hardest step in creating cellulosic biofuel.

To learn how to replicate it, scientists placed sacks full of switchgrass – a tough, fast-growing American grass – through a hole in the cow's skin into its stomach.

After 72 hours they removed the grass, along with bacteria in the midst of a digestion frenzy, and analysed them as a group using metagenomics. "Metagenomics means analysis of DNA taken directly from environmental samples," said Hess.

ELUSIVE BACTERIA

As only about 1.5% of bacteria found in nature can be cultured, this technique allows research to be carried out on the majority that resist cultivation in the lab.

The result was 270 billion base pairs of genetic code, almost 100 times more than the human genome, and around two million potential genes to be investigated.

To find which bacteria could digest cellulose, the researchers compared codes with known cellulose-associating regions of Carbohydrate Active Enzymes called CAZymes.

The group made 15 draft genomes never before sequenced.

Having identified over 25,000 genes with the right regions, they produced almost a hundred potential CAZymes for testing. Over half could break down cellulose.

For years, switchgrass has been grown for biofuel production, as it can yield 540% more energy than is needed for it to grow.

Every tonne can produce 300 L of ethanol, and it is inedible and resistant to pests, flooding and drought, making it a good candidate for biofuel production.

15 NEW GENOMES SEQUENCED

To sequence genomes, DNA is smashed to pieces and reassembled like a jigsaw. As the cow rumen contains hundreds of different bacteria, it's like taking a hundred jigsaws, mixing up the pieces, then trying to build the right pictures, said Hess.

Using computer algorithms the group made 15 draft genomes never before sequenced. "We are highly confident that these assemblies are real," said Hess, as a real sequence obtained from a single cell compared closely to one of their drafts.

It is hoped that this research can speed up the process of breaking down switchgrass into sugars including glucose and xylose to be fermented into ethanol. Ethanol blended petrol like E10 is found across Australia, with sugar cane molasses and waste grain as major biofuel sources.

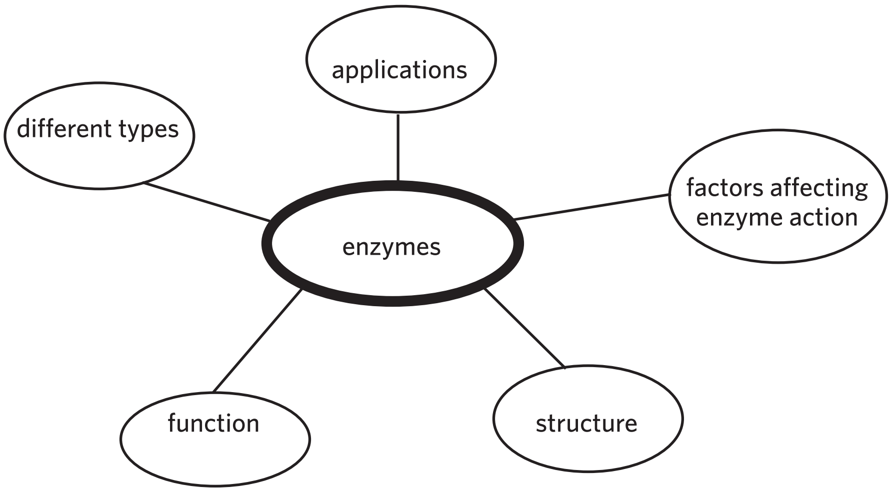
UNPRECEDENTED SEQUENCING

"There's no way you could do the scale of sequencing they've done without the new technological advancements which have been made," said Stuart Denman from the CSIRO, who was not involved in the study, adding that they've picked a very complex environment.

Improving cellulosic biofuel production has been the researcher's focus during this study, but the technique could also be used in agriculture to improve crop efficiency.
– *Sarah Kellett*

Brainstorming

[Task] Use the words in the mind map to help you brainstorm all you know about enzymes. Use arrows to connect ideas. You can write along the lines to explain connections.



Glossary

[Task] Use the following table to define any science words that are related to this article.

Word	Definition
Plant cellulose	
Biofuel	
Microbial	
Genetics	
Genetic sequencing	
Enzymes	
Genes	
Genomes	
Rumen	
Selective breeding	
Indigestible	
Switchgrass	
Metagenomic	
Cultured	
Base pairs	
Regions	

Summarising

[Task] In your exercise book, complete the following activities related to "Cows' stomachs the key to better biofuels".

1. Make a list of the substances you think would be in a cow's stomach.
2. Describe the things that the article mentions are in the cow's rumen.
3. Scientists are looking for genes that can do what?
4. Which type of organism are scientists studying that has the genes they are after?
5. Why are these organisms so hard to study?
6. What do the bacteria do in the cow's stomach?
7. How is this bacteria related to the production of biofuel?
8. Explain the procedure that scientists use to create biofuel.
9. Do you think it is ethical to experiment on the cow in this way? Why/why not?
10. How much ethanol can be produced by one tonne of switchgrass?
11. Where do you think switchgrass gets the energy to grow?
12. How could this new technology be used in agriculture?
13. Draw a flowchart of the experiment the scientists are conducting to make biofuel from switchgrass.

Questioning toolkit

[Task] Below are a series of discussion questions in the form of a questioning toolkit. Choose some or all of the questions, or ask some of your own.

Write your ideas and opinions relating to each of the different types of questions.
Inspired by Jamie McKenzie's Questioning Toolkit - McKenzie, Jamie (2000) *Beyond Technology*, FNO Press, Bellingham, Washington, USA (*www.fno.org/nov97/toolkit.html*).

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. **Question:** How do cows digest cellulose? What do scientists hope to learn from this process? Why do scientists want to mimic the behavior of the bacteria in the cow's stomach? How is this biosynthesis?	
Sorting and sifting questions These questions take us to the heart of the matter, like an archaeologist digging for clues. **Questions:** Why do we need to develop biofuels? What other organic matter can be used for biofuel? What are the benefits of using cellulosic biofuels? What are the drawbacks?	
Hypothetical questions Questions designed to explore the possibilities, the 'what ifs'? They are useful when we want to test our hunches. **Questions:** If scientists can one day mass produce biofuels such as ethanol, what will our future cars, buses and aeroplanes look like?	
Provocative questions Questions to challenge convention. **Questions:** Is it unethical to put a permanent hole in a cow's stomach for the sake of an experiment? Should we even worry about spending money on biofuels when we could be researching ways to harness the energy from the Sun, which is a more renewable source (for example, we don't need to use grass as a primary resource for fuel and can leave plants to collect carbon)?	

Bringing it all together

[Task] In your exercise book, complete the following activities to summarise the two articles.

1. In your exercise book, draw a mind map to show the relationship between the articles.
2. List five big issues that you have learnt about from the articles.
3. Make up five questions that you now have.

TEACHER'S RESOURCE

About the COSMOS matrix

What is the COSMOS Science Matrix?
A learning matrix such as the COSMOS Science Matrix is a flexible classroom tool designed to meet the needs of a variety of different learning styles across different levels of capabilities. Students learn in many different ways – some are suited to hands-on activities, others are strong visual learners, some enjoy intellectually challenging, independent hands-off activities, while others need more guidance. The matrix provides a smorgasbord of science learning activities from which teachers and/or students can choose.

Can I use the matrix for one or two lessons, or for a whole unit of study?
Either! The matrix is designed to be time flexible as well as educationally flexible. A time frame for each activity is suggested on the matrix. Choose to complete one activity, or as many as you like.

Is there room for student negotiation?
Yes! Students can be given a copy of the matrix and choose their own activities, or design their own activities in consultation with their classroom teacher.

Can I use the matrix for a class assessment?
Yes! You can set up a point system – perhaps one lesson equals one point. Students can be given a number of points to complete. If they choose less demanding activities, they will have to complete more of them.

What do the row headings mean?

Row heading	Description of activity
Scientific procedure	Hands-on activities that follow the scientific method. Includes experiments and surveys. Great for kinaesthetic and logical learners, as well as budding scientists.
Science philosophy	Thinking about science and its role in society. Includes discussion of ethical issues, debates and hypothetical situations. An important part of science in the 21st century.
Being creative with science	For all those imaginative students with a creative flair. Great for visual and musical learners and those who like to be innovative with the written word.
Science time travel	Here we consider scientific and technological development as a linear process by looking back in time or travelling creatively into the future.
'Me' the scientist	Personalising the science experience in order to engage students more deeply.
Communicating with graphics	Using images to communicate complex science ideas.
ICT	Exploring the topic using computers and the Internet.

What do the column headings mean?

1. Read and revise	2. Read and relate	3. Read and review
Designed to enhance student comprehension of information.	Gives the student the opportunity to apply or transfer their learning into a unique format.	Involves the more challenging tasks of analysing, and/or assessing information in order to create and express new ideas and opinions.

	1. Read and revise – one or two lessons	2. Read and relate – three or four lessons	3. Read and review – four or five lessons
Scientific procedure	Examine a range of specimens to try to understand the characteristics of living things. See Experiment 1.	What does DNA look like? Conduct an experiment to extract DNA from wheatgerm. See Experiment 2.	The enzymes in a cow's stomach help speed up the reactions that break down the cellulose. Conduct the experiment in Experiment 3 to investigate the effect of pH on enzyme activity.
Science philosophy	Why do you think the media labelled Craig Venter's new versions of *Mycoplasma mycoides* as a form of 'synthetic life'? Is it 'new life'? How much would something have to change to become 'new life'?	If the techniques developed by Craig Venter and his research team were used for evil, such as to create a synthetic bug that could only harm certain people or races, should he in any way be held responsible? For example, for not thinking through the consequences of his findings and technologies before he developed them. Use examples from history to help support your argument.	Pretend you are the producer of the ABC show *Hypothetical*. You must put together a show about the pros and cons of synthetic biology and its possible effects on society. Make up a list of guests to invite to give their views on the show. Include why you have invited them onto the show. Also collate a list of basic questions that you will use to kickstart the discussions on the show.
Being creative with science	Create a model of DNA replication to show how DNA can make an exact copy of itself.	Create a model of protein synthesis showing both the stages of transcription and translation.	Create a model of the process of transformation of a bacterial plasmid so that a new gene can be incorporated, such as the insertion of the insulin gene.
Science time travel	List some of the products or applications that synthetic biologists predict will be available in the future.	Create a timeline of the major discoveries or milestones in the field of synthetic biology. Include at least 10 events on your timeline. You can include predicted future events as well.	If artificially created genomes are able to be widely produced and manufactured, what do you think the future holds for current practices in industries such as agriculture and medicine? In a report for a *Futures* magazine, discuss the possibility of patents on new life forms and how product testing, product competition, product marketing and general consumer access to products might be different with artificial life forms.
'Me' the scientist	Pretend you are Craig Venter. Write a journal entry about your newest breakthrough in creating a completely new genome. How does it make you feel? What hopes do you have for this technology in the future? What is your next step from here?	You are a molecular biologist who has a great deal of background knowledge about some of the techniques used when working with genes. Design a visual or interactive lesson to teach people about a molecular biology technique, such as: how to recognise a gene; how to use restriction enzymes; how to sequence a gene or section of DNA; how to locate a gene on a chromosome; how to insert a gene into a plasmid or viral vector, or any other technique such as PCR, DNA hybridisation, Southern Blot, Gel electrophoresis, DNA microarrays.	Pretend you are a scientist working in the field of synthetic biology. What project in this area of research would you like to be working on? What goals would you like to achieve and why? Think through an experiment you would like to conduct and then write a research proposal for an experiment you would like to conduct. See Experiment 4.
Communicating with graphics	Create a Venn diagram comparing the normal version of *Mycoplasma mycoides* with the genetically engineered one created by Venter and his team.	Create a KWL chart about synthetic biology so that you can summarise what you already Knew about synthetic biology, what kinds of things you are Wondering about synthetic biology now, and what you Learnt from reading the article.	Do a SWOT analysis on the creation of Synthia. If you haven't done a SWOT before there are plenty of explanations and examples on the internet to help you.
ICT	Create a brochure, an advert or a podcast using Microsoft Word that could be used to show people the benefits of synthetic biology.	Create a flash animation or use Garage Band to show how 'Synthia' was made by Craig Venter's team.	Identify the key points and relationships of the information in the article, or on the topic of biosynthesis in general, and create a Prezi presentation to display your ideas (see *http://prezi.com*).

Experiment 1

IS IT ALIVE?

BACKGROUND INFORMATION

Biology is the study of living things. Synthesis relates to the creation of something new, or to build something. Synthetic biology is related to the synthesis of new systems that are not found in nature. It is thought that the creation of man made genomes produce products that can benefit medicine, agriculture and the environment. In making new genomes, scientists are technically able to make new forms of life. So what is life?

AIM

To consider the characteristics of living things.

MATERIALS

- A collection of specimens such as: a piece of fruit, an insect, yoghurt, radish seeds, dirt, lichen on bark, fungus, wilted celery, bark, rubber bands, leaves, leaves with galls, onion sprouting, beer, bacteria, yeast, other microbes.
- Labels showing the numbers 1 to 15 to match with the specimens in the order that they appear above.

METHOD

1. Establish the characteristics of living things with your teacher and your classmates.
2. Move around the room and examine the 15 specimens for signs of life. The specimens can be examined in any order.
3. Decide whether the specimen is currently living, whether it was once alive and is now dead or whether it was never alive in the first place. Record your ideas by ticking the appropriate box in the results table on the following page.
4. Write a few sentences to justify your response.

(Experiment continued on the next page)

RESULTS

Fill in the table below as best you can, or create a similar table in your exercise book, as you examine each item.

Specimen	Living	Dead	Non-living	Justification
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				

DISCUSSION

Complete the following activities in your exercise book.

1. Compare your responses with the rest of the class. Did everyone agree or disagree? Were the reasons for classifying something as living, dead or non-living the same?

2. Which items did you have problems classifying? Explain why you had difficulty classifying these items.

3. What were the common features of the organisms you considered as living?

CONCLUSION

In your exercise book, write a conclusion that responds to your aim and summarises your results.

Experiment 2

DNA EXTRACTION

BACKGROUND INFORMATION
The 'germ' part of wheatgerm is the embryo and it contains the plant's DNA.

AIM
To visually examine the characteristics of DNA.

MATERIALS
- One teaspoon of wheat germ
- 20 mL of tap water heated to 50°C – 60°C
- A beaker to heat and measure water temperature
- A thermometer that measures up to 60°C
- Apparatus for heating water, such as a kettle or Bunsen Burner (if tap water is not hot enough)
- 1 mL eye dropper or syringe filled with liquid detergent
- 20 mL syringe or a measuring cylinder
- 14 mL of ethanol
- 50 mL test tube in a test tube rack
- Wooden stick or glass rod
- Clock or stopwatch with a minutes hand
- Pipette or a strip of paper towel

RISK ANALYSIS
Complete the following table before you start the experiment.

Risk	Precaution	Consequence
Ethanol		Toxic if drunk.
Sharp broken glass	Check glassware for cracks before starting. Do not place glassware on the edge of benches.	
		Can cause scalding and burns.

METHOD
1. Place the teaspoon of wheat germ in the 50 mL test tube.
2. Heat the 20 mL of water to 50°C – 60°C and pour it into the test tube with the wheat germ. Stir constantly for three minutes using a wooden stick or glass rod.
3. Add the 1 mL of liquid detergent and stir gently for five minutes. Try not to make bubbles. If bubbles are made, remove them with a pipette or a strip of paper towel.
4. Measure 14 mL of ethanol with the syringe or measuring cylinder. Tilt the test tube and slowly pour the ethanol down the inside of the test tube so that it sits on top of the wheat germ/water/detergent mix. Do not mix this solution.
5. Slowly place the test tube upright and rest it in the test tube rack. The DNA will immediately begin to precipitate in the ethanol just above the interface of the two solutions. Monitor for 10 minutes and watch as the DNA gradually clumps and floats to the top of the ethanol.

RESULTS
1. In your work book, describe the appearance of the DNA in your test tube.

DISCUSSION

Answer the following questions in your work book.

1. Comment on how accurate you think you were when making your measurements by outlining how you went about taking them.

2. Were your results reliable? That is, were your results the same as everyone else's?

3. What is the role of DNA?

4. If a friend was about to conduct this experiment in their science lesson, what advice would you give them so they could carry it out easier?

5. What did you enjoy the most about conducting this experiment?

CONCLUSION

In your exercise book, write a conclusion that responds to your aim and summarises your results.

iSTOCKPHOTO

Experiment 3

UNDERSTANDING ENZYMES

BACKGROUND INFORMATION

All enzymes have a specific pH that they work optimally at. Most enzymes in the human body will have an optimum efficiency at a pH of around 7. If the enzyme is put into an environment outside its optimum pH range it will alter the shape of the proteins that make up its active site and it will become denatured, hence decreasing its level of activity.

The optimum pH of each enzyme depends on the environment it catalyses reactions in. Enzymes working in the stomach, which has a pH of approximately 2, will have an optimum pH in the acidic range (pH less than 7), whereas enzymes that work in the small intestine will have an optimum pH in the alkaline region of the pH scale (pH greater than 7).

Cells produce hydrogen peroxide (H_2O_2) as a by-product of cellular metabolism. If hydrogen peroxide builds up in the cell it can become toxic, and therefore it must be broken down. Catalase is the enzyme that will break down hydrogen peroxide. It breaks it down into water and oxygen as shown in the equation below.

$$2H_2O_2 \xrightarrow{\text{catalase}} 2H_2O + O_2$$

The activity of catalase can be determined by the amount of gas produced by the reaction. The more gas, the faster the enzyme is working.

AIM

To test the effect of pH on the activity of the enzyme catalase.

MATERIALS

- A test tube rack
- Nine test tubes
- 9 x 1 cm^3 cubes of potatoes
- 30 cm ruler
- 20 mL hydrogen peroxide
- 20 mL 2M HCl
- 20 mL 2M NaOH
- 20 mL water
- A pH probe, litmus paper or a universal indicator

RISK ANALYSIS

Complete the following table before you start the experiment.

Risk	Precaution	Consequence

METHOD

1. Label the test tubes 1 – 9 using a permanent marker
2. Add 5 mL of hydrogen peroxide solution to all nine test tubes.
3. Add 5 mL of 2M HCl to test tubes 1 – 3.
4. In test tubes 4 – 6 add 5ml of water
5. In test tubes 7 -9 add 5ml of 2M NaOH
6. Measure the pH of the solutions with the pH probe. Record this in the results table below.
7. Add one cube of potato to the first test tube.
8. Measure the level that the bubbles rise up in the test tube with your ruler and record the result in the results table.
9. Repeat the experiment in test tubes 2 to 9.
10. Record all the results in the results table.
11. Find the average bubble height for test tubes 1 – 3, 4 – 6 and 7 – 9. Record these in the results table.

RESULTS

Test tube number	pH	Bubble height (cm)	Average height of bubbles
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

DISCUSSION

Complete the following activities in your work book.

1. Complete a line graph showing the height of the bubbles and the pH of the solution.

2. Explain the effect of pH on the activity of the catalase.

3. What happens to the catalase when it is put into solutions outside its optimal pH?

4. What other environmental factors may effect enzyme action?

CONCLUSION

In your exercise book, write a conclusion that responds to your aim and summarises your results.

Experiment 4

SCIENCE & TECHNOLOGY GRANT PROGRAM

AIM

To write a fake research proposal for a synthetic biology experiment you would like to conduct.

1. Project title: ______________________________

2. Name of applicant (s): ______________________________

3. Company (if applicable): ______________________________

4. E-mail address: ______________________________

5. Address: ______________________________

6. Brief summary of the situation or problem to be addressed:

7. Purposes (objectives) of the project:

8. What work do you intend to do, and how do you plan to accomplish it?

9. Explain how the expected results will address the problem and/or enhance current resources:

10. Explain how the expected results will be made available to the SCIENCE & TECHNOLOGY GRANT PROGRAM:

11. Briefly summarise the qualifications/interests of each participant:

12. Budget and costs:

a. Personnel costs (time x unit cost) ______________________________

b. Travel (trip or mileage x unit cost) ______________________________

c. Supplies ______________________________

d. Equipment (items more than $500) ______________________________

e. Contractual ______________________________

f. Other costs (itemise) ______________________________

g. Total project costs ______________________________

13. Budget justification and/or explanation:

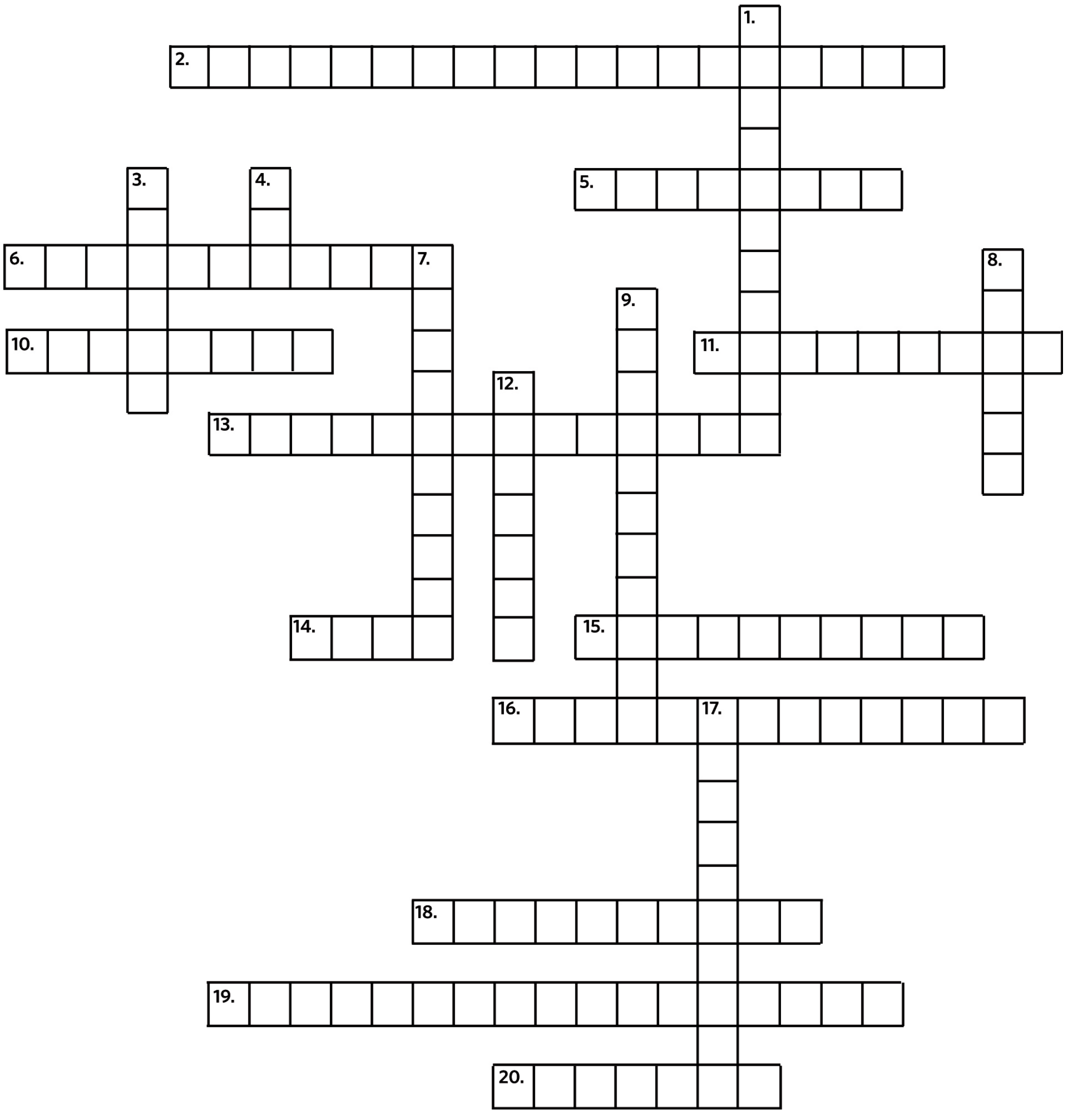
14. Time line. When you expect to start and finish the project.

(Attach additional pages if needed.)

Signature: ______________________________ Date: ______________

TEACHER'S RESOURCE

Food security crossword



Across: 2. genetic engineering, **5.** bacteria, **6.** translation, **10.** genetics, **11.** mutations, **13.** synthetic life, **14.** gene, **15.** bioweapons, **16.** transcription, **18.** technology, **19.** synthetic biology, **20.** enzymes.

Down: 1. temperature, **3.** Venter, **4.** DNA, **7.** nucleotide, **8.** genome, **9.** replication, **12.** biofuel, **17.** chromosome.

Across

2. technologies that permit the direct manipulation of genetic material in order to alter the hereditary traits of a cell, organism, or population (two words with space)

5. simple procaryotic unicellular organism

6. the process whereby the code on the RNA is synthesised into a protein

10. study of heredity in organisms

11. changes or alteration that can happen to chromosomes

13. life form manufactured by humans (two words with space)

14. the basic unit of heredity that is made up of DNA

15. living organisms, for example a bacteria or a toxic product manufactured from it, used to kill or incapacitate someone

16. the process by which genetic information on a strand of DNA is used to synthesise a strand of complementary RNA.

18. the application of scientific knowledge in order to develop new equipment or create material objects

19. new area of biology that combines biology and engineering to produce manmade biological systems (two words with space)

20. biological catalysts

Down

1. property that can affect enzyme activity

3. surname of the man who helped to code the human genome and sythesis the first man-made genome of an organism

4. shortened term for deoxyribose nucelic acid

7. the single units that make up DNA

8. a complete set of DNA for an individual organism

9. process whereby a DNA strand copies itself during mitosis

12. fuel that is made from biological matter such as vegetables rather than fossil fuels

17. threadlike structures that carry genes in a cell

Food security word search

T	X	S	T	C	V	S	S	R	E	X	E	M	T	A
R	R	B	N	E	I	L	L	D	O	C	N	S	E	I
G	E	A	N	O	E	T	I	V	H	K	G	I	C	R
X	T	T	N	U	I	T	E	R	N	S	I	L	H	E
G	E	N	F	S	O	T	O	N	Y	X	N	O	N	T
R	E	O	O	E	C	M	A	N	E	S	E	B	O	C
G	I	N	L	I	O	R	T	T	E	G	E	A	L	A
B	E	C	E	S	T	H	I	M	U	R	R	T	O	B
A	U	N	O	T	E	A	Y	P	V	M	I	E	G	I
N	O	M	O	T	I	Z	C	T	T	W	N	M	Y	O
D	E	O	I	M	N	C	V	I	S	I	G	O	T	L
S	Z	C	J	E	E	X	S	B	L	E	O	F	L	O
B	I	O	W	E	A	P	O	N	S	P	N	N	M	G
N	O	I	T	A	L	S	N	A	R	T	E	E	B	Y
E	P	Y	T	O	T	O	R	P	N	F	N	R	G	G

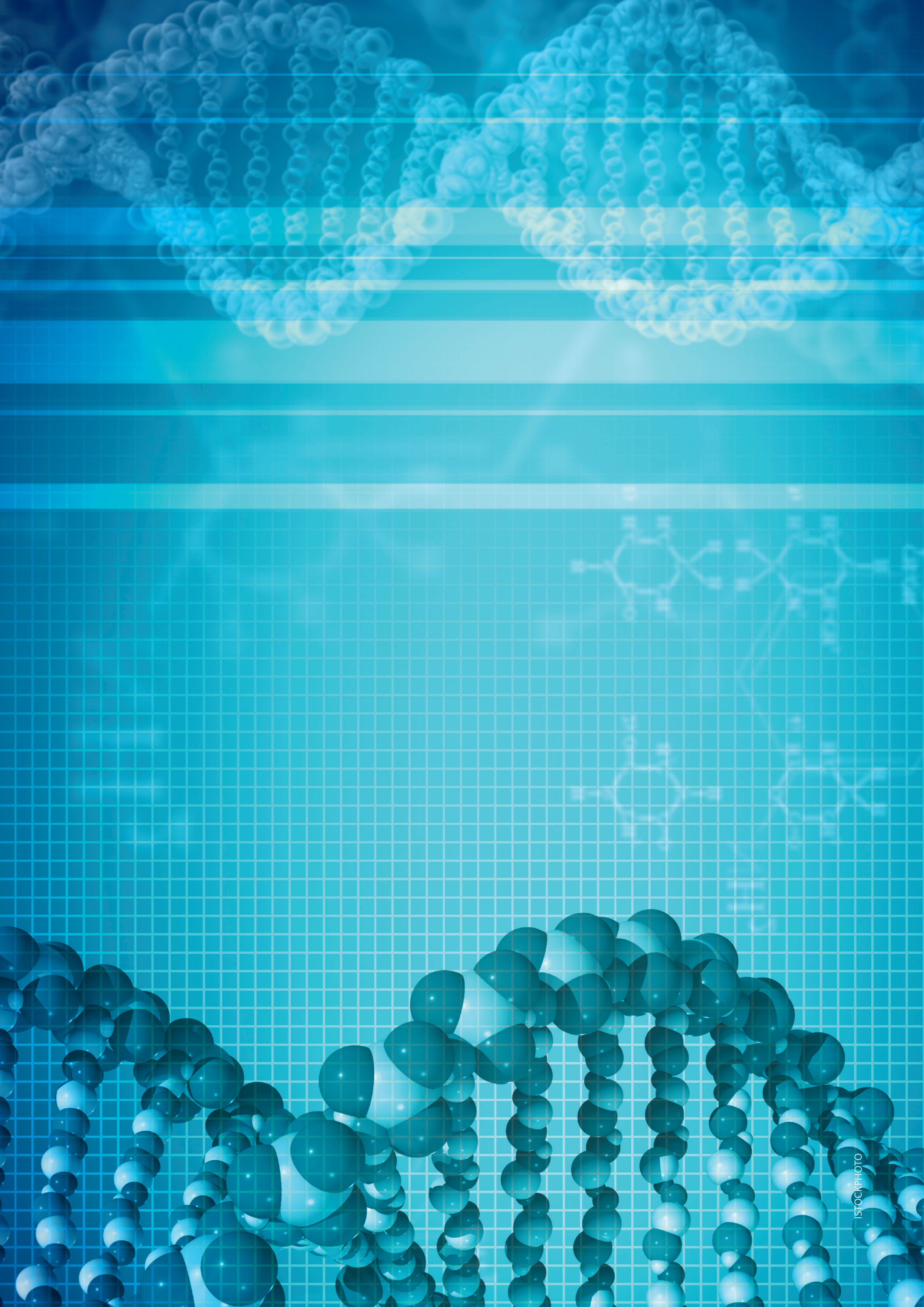
Find the following words hidden backwards, forwards, diagonally, downwards and upwards.
bacteria, biofuels, biology, bioweapons, chromosomes, DNA, engineering, enzymes, genes, genetic, Venter, genome, metabolism, mutations, nucleotide, prototype, replication, synthetic, technology, transcription, translation

Create your own synthetic biology quiz

1. Ask each student to call out a word related to synthetic biology. Record these on the board.
2. Each student must pick six words from the board and write a definition for each.
3. Students then pick four more words from the board and write a paragraph describing them. They should highlight their chosen words in the paragraph.
4. Students create a concept map showing all they have learnt about synthetic biology using at least half the words from the board. They should show links between words and write along lines connecting words to show how the terms are related.

Synthetic biology individual unit review

Personal food security summary	**Where to now?**
Make a dot point summary or a mind map of all the things you learnt while completing these activities on synthetic biology. Highlight or underline a couple of things you found the most interesting.	Write at least five questions that have come up when studying this unit of work on synthetic biology.
Something ethical	**Something political**
List as many ethical issues you can think of that arose during your study of synthetic biology and then propose ways that some of these issues could be alleviated.	If you were a science leader in the world today and money and borders were not an obstacle, what are the positive changes you would like to make to remove current and possible threats related to synthetic biology so that the world is a better place for all?



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