strange NATURE

EDUCATIONAL
RESOURCES

2015

THE UNIVERSITY OF
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Purpose of this Package

This resource introduces teachers and students to synthetic biology and provides resources for teachers to facilitate their student's participation in the Strange Nature writing competition. The resource was made by the 2013, 2014 and 2015 University Of Sydney International Genetically Engineered Machine (iGEM) teams for Strange Nature, the Synthetic Biology Writing Competition. It is designed to stimulate discussion and further research of this field, and to act as a resource for our writing competition. This booklet provides information about the advances enabled by synthetic biology and their potential – the topic students are asked to address this year. Further information can be found at our website http://strangenature.org/

The Writing Competition: STRANGE NATURE

This competition is relevant for students in many different disciplines, not just science. An English class could focus on the writing aspects of the task, on doing thorough research and constructing an argument. A History class could look at the developments and impacts of technological revolutions like synthetic biology. Religion and Ethics classes could examine the morality and ethics behind the pro and con arguments of this technology. We encourage you to use this competition in a manner that suits your area of expertise as it is a great tool to develop the basic skills of critical thinking, research and creativity whilst giving students an introduction to a technology that will have huge impacts on the 21st century. We value your contribution, not only in promoting this competition but in your taking on the role as a mentor and sounding board for your students. The best responses last year clearly showed the guidance of teachers.

In 2015 Strange Nature will comprise of two separate competitions: written and multimedia. Students are asked to answer the question: **"Identify a current biological, environmental, or medical issue and design a genetically modified organism to provide a solution".**

Students wishing to partake in the written competition are asked to submit a maximum of **1000 word** piece of writing in a style of their choice addressing the question above. Submissions are on an **individual basis**.

Students wishing to partake in the multimedia competition are asked to submit a video, podcast, documentary or any other video media in a style of their choice addressing the question above. The maximum length of the entry is limited to 5 minutes. Submissions are to be completed as a **team** consisting of between **2 to 5 students**.

Applicants will be in the running for one of two prizes. **The winning entry of each competition will be awarded $500.00 and the first runner up of each competition will receive $250.** Please note that the prize money will be split evenly amongst the members of the winning team in the multimedia section (i.e – if the winning team consists of 5 members then each individual member will receive $100).

The winning pieces will be engaging, well explained, and demonstrate research, understanding and imagination. Work should be scientifically credible and not devolve into fantasy. This means entries include only established science or a logical extension of established science. The best entries will clearly show an understanding of genetics and synthetic biology, as well as engaging with ethical, technological, environmental or social issues that may arise in the future.

The terms and conditions, as well as a formalised list of rules and requirements can be found on the website.

What is Synthetic Biology?

Synthetic biology is the process of designing life.

More precisely, it is the design, construction and standardisation of new biological systems, or the redesign of existing natural systems for useful purposes.

Here is a link to a wonderful introductory website:
http://www.synbioproject.org/topics/synbio101/

Applications of Synthetic Biology

Recombinant DNA, or traditional genetic engineering, has been used for decades for many useful purposes. Insulin is a good example as it was as early success-story. Diabetics can stabilise their blood-sugar levels with injections of insulin. Prior to recombinant DNA, the only way to get enough insulin for an injection was to harvest it from cows and pigs. In the 1970's the human insulin **gene** was introduced to bacteria and yeast, allowing the more efficient harvest of a more effective product - human insulin rather than cow and pig insulin. This has improved the well-being and life-style of many people. Many medical products such as antibiotics and drugs are produced in a similar way using recombinant DNA.

Recently more profound advances have been made. Rather than moving a gene from one organism to another, it is now possible to synthesize (or 'print') DNA and then introduce it. This is becoming cheaper and more accessible every day. Synthetic DNA expands the range of possible genes that can be used to include enormous online databases of genetic information, and also entirely artificial genes. In 2003 a **virus** was created from entirely synthetic DNA by the J. Craig Venter Institute, and in 2010 this was also achieved with a whole bacterial cell, named 'Synthia'. Importantly, this feat involved a sequence of synthetic material almost entirely inspired by a natural sequence, and was not 'creating life' but replacing the original DNA with synthetic DNA.

Concerns about Synthetic Biology

There is a great deal of uncertainty about the possible harms and benefits of Synthetic Biology. These fall into a few basic categories:

Release
What is OK to leave the lab? Who decides and who wears the cost? Should we accept a synthetic environment? Is it ok to use products of synthetic organisms outside the lab?

Property
Who owns a physical sample of DNA? Or a gene? Or a synthetic sequence of DNA? Should we be concerned that Synthetic Biology may be driven by commercial interests? Will there be equal access to enabling biotechnologies?

Intentional Harm
What is the potential for bioterrorism? What if states use Synthetic Biology in wartime? Could there be a biological arms-race?

Recent advancements in synthetic biology

March 2014 – A yeast chromosome was synthetically created, which corresponds to around 270 thousand base pairs of DNA. The team responsible plans to create a fully synthetic yeast genome (with 16 chromosomes) within 5 years.

October 2013 – Genetically modified E. coli, designed to use two codons (3 letter DNA codes) differently was found to have increased resistance to the T7 bacteriophage virus. Thus, synthetic organisms can be engineered to have incompatible genetic codes, which can confer resistance to viruses.

August 2012 – 700 terabytes worth of data was successfully encoded into 1 gram of DNA, further demonstrating the potential of biomolecules such as DNA as a medium for data storage.

June 2012 – Insertion of mouse heart cells into a silicon scaffold with eight arms was able to "swim" when an electrical current was applied to a water bath, in a similar manner to how a jellyfish swims.

June 2010 – A team of scientists created a synthetic genome for the bacteria *Mycoplasma genitalium*, with many of the unessential genes deleted for

efficiency. Additionally, the researchers encoded their names in the synthetic genome as a “watermark”.

Learning Activities

DNA is frequently explained as a 'blueprint' or 'instruction manual', so people often forget the fact that DNA is a physical thing. It is difficult to comprehend how three feet of DNA (the approximate length of the **human genome** from end to end) could exist within almost every one of the ~30 trillion cells in your body. Try communicating this by having students play with models, such as lengths of string or velcro, and act out some of the basic genetic processes such as **replication**, **cell division**, or **inheritance**.

There is also much confusion about whether the traits people have are determined by their genes, by their environment or by chance. In reality, organisms are too complex to be described by a dichotomy between nature and nurture. Try exploring this dichotomy with the class. Ask which of their traits they believe are affected by genetics - sex, eye colour, height, athleticism, eyesight, smile, sense of humour, etc.

The concept of natural selection has changed not only the study of life, but also society and culture. Sadly, the relatively simple concept is often misunderstood or misrepresented. There are three essential observations that underpin the concept: the exponential growth of populations by reproduction, the inherited variation between individuals, and the existence of a non-random environment such that individuals unsuited to their environment are less likely to leave descendants. Try explaining this. Ask students why it affects religious beliefs, or what it means that *Homo sapiens* have begun directly manipulating DNA.

Finally the goal of this project is to stimulate learning and conversation about synthetic biology. Once students have had a chance to research and learn about synthetic biology a class debate on a specific advancement or on the issue in general would be very useful.

<u>Discussion Points you could use for class discussion or debates</u>

- Why do humans change their environment?
- What is the difference between the selective breeding in agriculture and genetic modification?
- What are the physical limits of Synthetic Biology?
- What are the ethical limits of Synthetic Biology?
- Which advancement of synthetic biology scares you?

DNA Extraction

Try this very simple, low-tech method to extract DNA from strawberries. It is offered by the US Human Genome Research Institute as a way to reach out to students:
http://www.genome.gov/Pages/Education/Modules/StrawberryExtractionInstructions.pdf

For an accompanying video, search "how to extract DNA from strawberries" in YouTube or try the link http://www.youtube.com/watch?v=hOpu4iN5Bh4.

Glossary

DNA (Deoxyribonucleic Acid)	DNA is a chain of molecules (called a polymer) where each 'link' is one of four types (the four nucleotides or bases, A, C, G and T). When people say DNA 'carries genetic information' they are referring to the specific order of links in the chain. During **replication** of DNA this order is preserved. During expression of DNA, other biological molecules (mRNA and proteins) are made which engage in all the biochemical reactions inside and outside cells. These molecules are also chains, and their biochemical properties depend on the order of their links, which are in turn determined by the order of nucleotides in DNA. Thus, small changes to DNA may affect the properties of cells and organisms.
Sequencing DNA	'Reading' DNA or the automated process of determining the order of nucleotides in a DNA sample.
Synthesizing DNA	'Writing' DNA or the automated process of assembling DNA with a specific order of nucleotides.
Standards	A set of conventions that newly created or characterised genetic parts will adhere to, allowing people to use parts without knowing their history or details. Equivalent to standards in engineering disciplines.
Abstraction	Raw information can be hidden in a hierarchy of interrelated labels such as letters, words, sentences, and chapters, or, DNA, parts, devices and systems.
Gene	A gene is a stretch of DNA that is inherited and is usually associated with a protein and thus a specific biological function.
Human genome	A genome is the complete set of genetic material in an organism. The human genomes sequenced last decade represent genetic material from a few different people.

Virus	Tiny biological entities that consist of DNA and a few proteins. Viruses do not have metabolism, so aren't considered to be 'living'. They self-replicate by hijacking the genetic machinery within cells.
Cell	Life is packaged into small, functional units which can self-replicate, eat, move, 'talk' to each other using chemical cues, and much more. These units are called cells.
Replication	The copying of genetic material.
Cell division	The reproduction of two functional cells from a single cell.
Inheritance	The transmission of genetic material between parents and children. In humans this also involves sexual recombination.