What is Synthetic Biology?

Synthetic biology is a **interdisciplinary area** that applies *engineering concepts* to principles of biology [1].

It aims to **re-design existing** natural biological components and systems to create **new** parts, devices and systems that don’t already exist in the natural world [1].

Synthetic biology uses **a design-build-test-learn pipeline** derived from traditional engineering disciplines [2].

- Aims to systemise processes – a re-occurring loop pipeline is used to obtain a design that satisfies the desired specifications

Concepts in Synthetic Biology

Glossary

- Cellular Mechanism: Occurrences that happen at the level of a cell
- DNA: The building blocks of all life, it carries an organisms’ genetic function that defines what it is
- Gene: A section of a DNA sequence
- Genome: All genetic information contained within an organism
- Gene Expression: When cells reads a genetic sequence causing it to produce an outcome
- Genetic Sequence: The order DNA is placed in creating the genetic information of the organism
- Mutation: Changing the structure of a gene, causing it to potentially express a changed function from the original

DNA Synthesis and Assembly

A foundation to key synthetic biology concepts. It is the concept of using **parts of DNA** to assemble larger DNA molecules.

- **Different methods** of assembly that is carried out may include:
  - Restriction Digest / Ligation
  - BioBricks
  - Gibson Assembly

DNA: The building blocks of all life, it carries an organisms' genetic function that defines what it is

Synthetic Bio-Circuitry

- Exploits an organism’s natural cellular mechanisms to build **biological parts** within the cell that performs **logical functions** [3].

- Designed to **sense molecules** and **produce an output** as a response; for instance, fluorescence [3].

- Three main types:
  - **Transcriptional** – uses environment-responsive promoter to activate transcription [4]
  - **Translational** – uses RNA molecules to control gene expression [5]
  - **Post-translational** – uses protein receptors to trigger signalling cascades [5]

Cellular mechanism: Occurrences that happen at the level of a cell

Synthetic Genomes

Genome: All genetic information of an organisms, provide all the information required for organisms to perform its required function

- Synthetic biology can be used to build artificial genomes using a ‘**bottom-up approach**’
  - This approach includes using single-stranded short DNA molecules as the starting material to assemble larger molecules that carry out our desired function [6]
- The aim of this is to **manipulate genetic material** on the scale of a whole genome [6]
- These **redesigned organisms** have new capabilities allowing them to express an unique feature

Metabolic Engineering

- Increasing the production of useful products by optimising processes within cells, such as genes [7]

For example, this can include introducing enzymes that is able to convert sugar into insulin (a more useful final product) for therapeutic uses

Genes: A section of a DNA sequence

Genome Editing and Engineering

- Introducing mutations into a genome for repair of genetic diseases or to add new functions for study [8]
- Modifications introduced by making breaks in DNA

- Methods:
  - CRISPR-Cas9
  - Zinc Finger Nucleases (ZFNs)
  - Transcription activator-like effector nucleases (TALENs)

Mutation: Changing the structure of a gene, causing it to potentially express a changed function from the original

Genome: All genetic information of an organisms

Applications of Synthetic Biology

Biosensing: E.g. engineered organism that detects heavy metals or toxins and produces a measurable output (usually in the form of fluorescence or bioluminescence) [9]

Therapeutics: E.g. drug delivery

Production of biofuels, pharmaceuticals and biomaterials

- Using genetic and metabolic engineering to optimise biosynthetic pathways [10]
- E.g. expression of enzymes with strong, inducible promoters

Considerations

Ethical considerations

- Releasing GMOs into the environment

Dual-use technology

- Beneficial applications, but can also cause harm
- Potential misuse and consequences e.g., Bioterrorism

Construction of biological systems is complicated

- Whilst each biological part may have a known characteristic, actual functions of combining these parts together are not known – lots of trial and error which can be time consuming and costly
- What works in the lab may not work in the environment

PROTECC CORAL

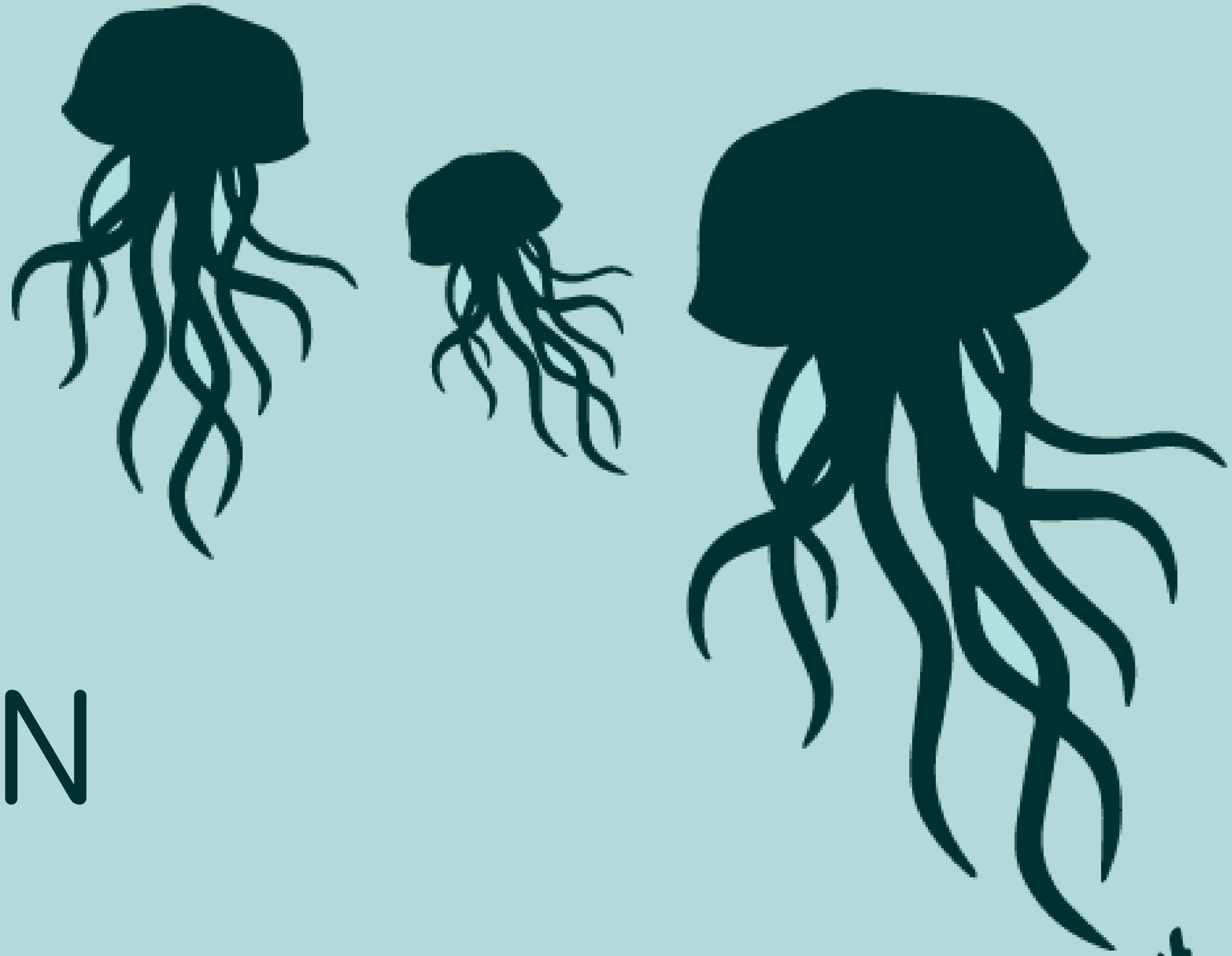
OUR PROJECT

The Coral Bleaching Problem

Climate warming is warming up our seas causing **coral bleaching**. This occurs because the algae in corals that give it food become **stressed** from the heat. This causes the corals to lose their colour and **eventually die** [11]

This occurs as stressed algae increase reactive oxygen species that is toxic in high concentrations to the coral [12]

Reactive Oxygen Species (ROS): A highly reactive molecule that can be both beneficial and detrimental. Theorised to contribute to coral bleaching



OUR SOLUTION

Glossary

- Chaperones: A group of proteins that function in assisting protein formation (folding)
- Proteins: Large molecules that play important roles in maintaining an organism’s health and development. They are required to be ‘folded’ in a specific and unique way to carry out their function.
- Protein Homeostasis: The maintenance of protein concentration, protein shape and location to ensure functionality
- Reactive Oxygen Species (ROS): A highly reactive molecule that can be both beneficial and detrimental. Theorised to contribute to coral bleaching
- Oxidative Stress: An imbalance of the production of ROS
- Glutathione: An antioxidant product that help prevent damage from ROS
- Plasmid: A small molecule that independently carries a small number of genes

Small Heat Shock Proteins (HSP22E)

- Chaperones that help to stop proteins unfolding or aggregating during high stress conditions by maintaining protein homeostasis [13]
- HSP22E from *Chlamydomonas reinhardtii* is stable at 42 degrees Celsius [14]

Goal: We want to understand how HSP22E affects survival and growth at extreme temperatures

Chlamydomonas reinhardtii is a green algae that is used as a model for the algae in corals

Proteins: Large molecules that play important roles in maintaining an organism's health and development. They are required to be 'folded' in a specific and unique way to carry out their function.

Protein Homeostasis: The maintenance of protein concentration, protein shape and location to ensure functionality

Chaperones: A group of proteins that function in assisting protein formation (folding)

Experiments Conducted:

Growth Assay – presence of HSP22E thought to allow better growth at elevated temperatures

Survival Assay – presence of HSP22E thought to increase maximum temperature limits for overall survival

Glutathione System

- Coral bleaching by rising sea temperatures causes an increase of reactive oxygen species (ROS) production [12]
- Increased oxidative stress causes expulsion of algae from coral [12]
- Glutathione antioxidant found to neutralise ROS [12]

Oxidative Stress: An imbalance of the production of ROS

Glutathione: An antioxidant product that help prevent damage from ROS

Reactive Oxygen Species (ROS): A highly reactive molecule that can be both beneficial and detrimental. Theorised to contribute to coral bleaching

Proposed solution:

__Plasmid:__ A small molecule that independently carries a small number of genes

To **produce and recycle glutathione**, several enzymes are required – glutathione synthetase, glutathione reductase and glutathione peroxide

Genes for these enzymes inserted into a plasmid and transformed into *E. coli*

Hope of producing a system induced by ROS, capable of **neutralising ROS** during **high oxidative stress conditions**

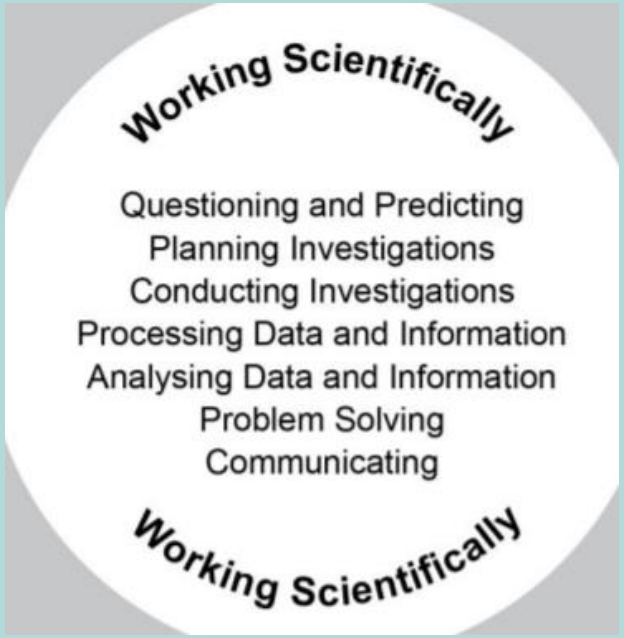
Scientific Method Exercise

The Scientific Method

1. **Question.** *What is the question you are trying to answer? Has it been explored before? Carrying out observations of your environment and asking questions is a good way.*

2. **Investigation.** *What evidence is already available about this topic?*

3. **Hypothesis.** *What do you think the result will be from what you already know*

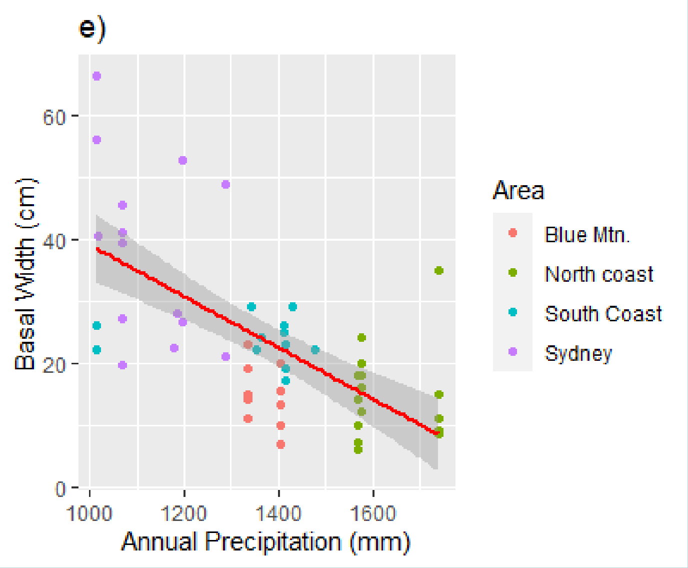


Working Scientifically from NSW ESA Biology Stage 6 Syllabus (2017)

4. **Experimentation.** *Making sure your experiment is valid by only changing one variable at a time.*

5. **Analysis.** *Carrying out statistical analysis if you can, if not do a qualitative comparison. Sometimes a graph can help you visualise your results.*

6. **Results and Communication.** *What did you learn from your experiment?*



Example of qualitative figure

Example: Thought experiment.

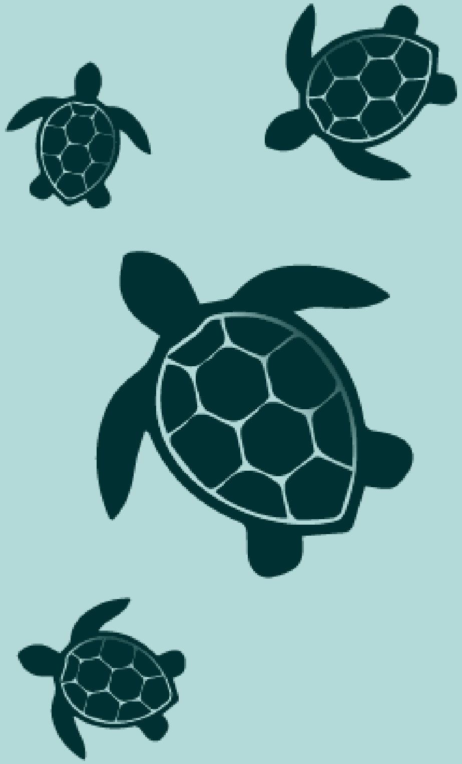
What are your thoughts on using GMO?

1. Question you have on GMO:

2. What background knowledge is available:

3. What are your hypotheses :

4. Think about an experiment you can do to prove it:



Answer these questions on the page over --->

Responses:

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