BIOLOGIX LECTURE

IGEM ST ANDREWS 2021

Introduction

- Welcome to the lecture by the University of St Andrews iGEM team 2021

- **Agenda:**
  - The environment, and how synthetic biology tools can be used to solve different environmental challenges.
  - Life at the University of St Andrews and what it's like to study there.
  - 10 min Q/A.

What is synthetic biology?

Synthetic Biology

Synthetic biology is the design and construction of new biological parts, devices, and systems, and the re-design of existing, natural biological systems for useful purposes.

What are the Sustainable Development Goals ?

- Global goals
- The 2030 Agenda for Sustainable Development:
  - as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity
  - 17 Sustainable development goals (SDG) with 169 targets.
  - No poverty, zero hunger, gender equality and climate action

Sustainable Development definition

- Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
- Brundtland Report, 1987
- It contains within it two key concepts
  - “the concept of 'needs', in particular the essential needs of the world's poor” should be prioritized
  - “the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs”

Sustainable Development Goals

- COP26 – Glasgow, 1-12 Nov
- Related to science as a lot of these goals require scientific solutions and knowledge, in addition to expertise within politics and development
- Thus, SDGs are highly interdisciplinary.

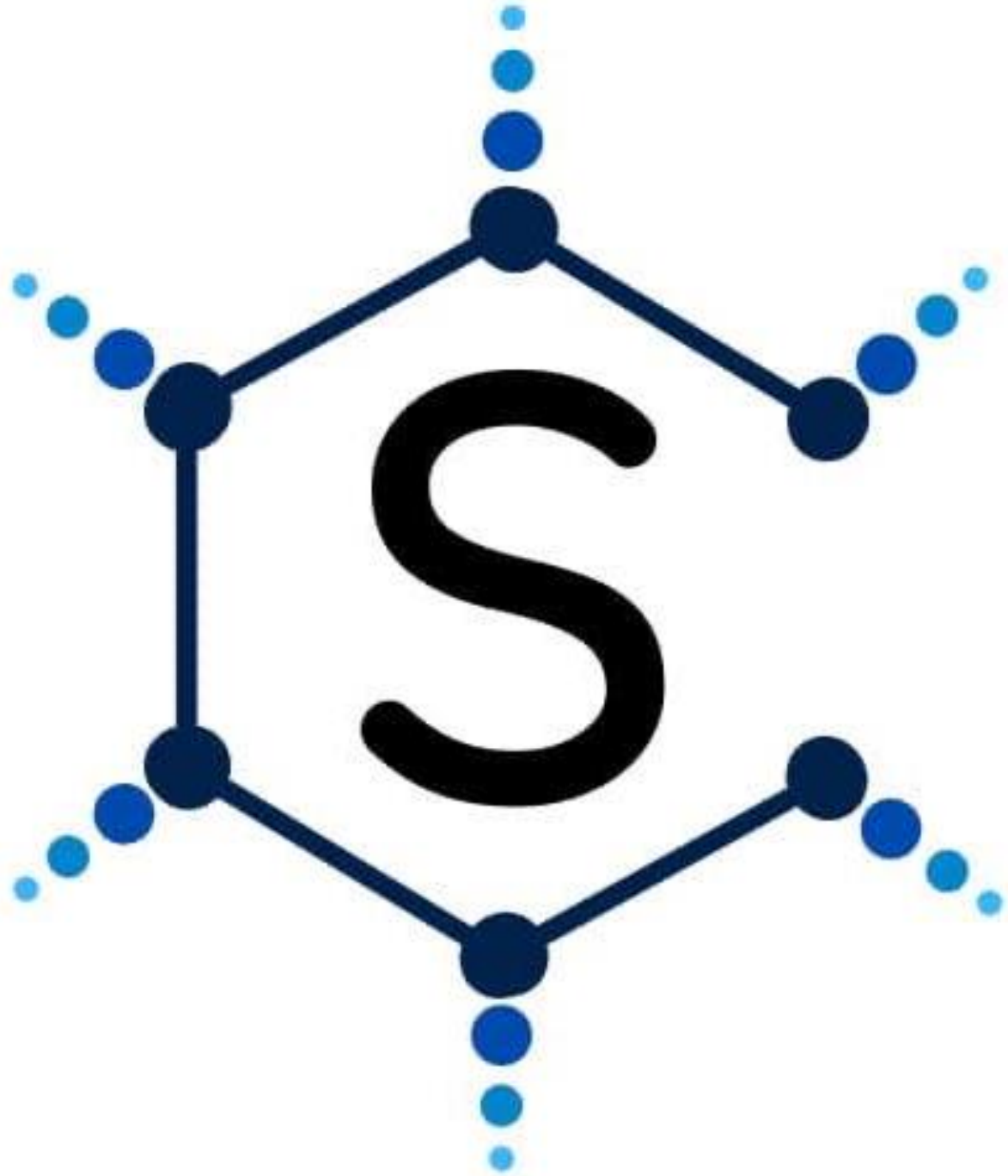
Sustainable Development Goals

- The SDG that our project is based upon is ‘goal 14 - Life Below water’.

SDG14 – Life Below water

- A few of the targets include:
  - By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
  - By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans
  - By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information
- Targets also relate to our iGEM project called Shinescreen.

SHINESCREEN



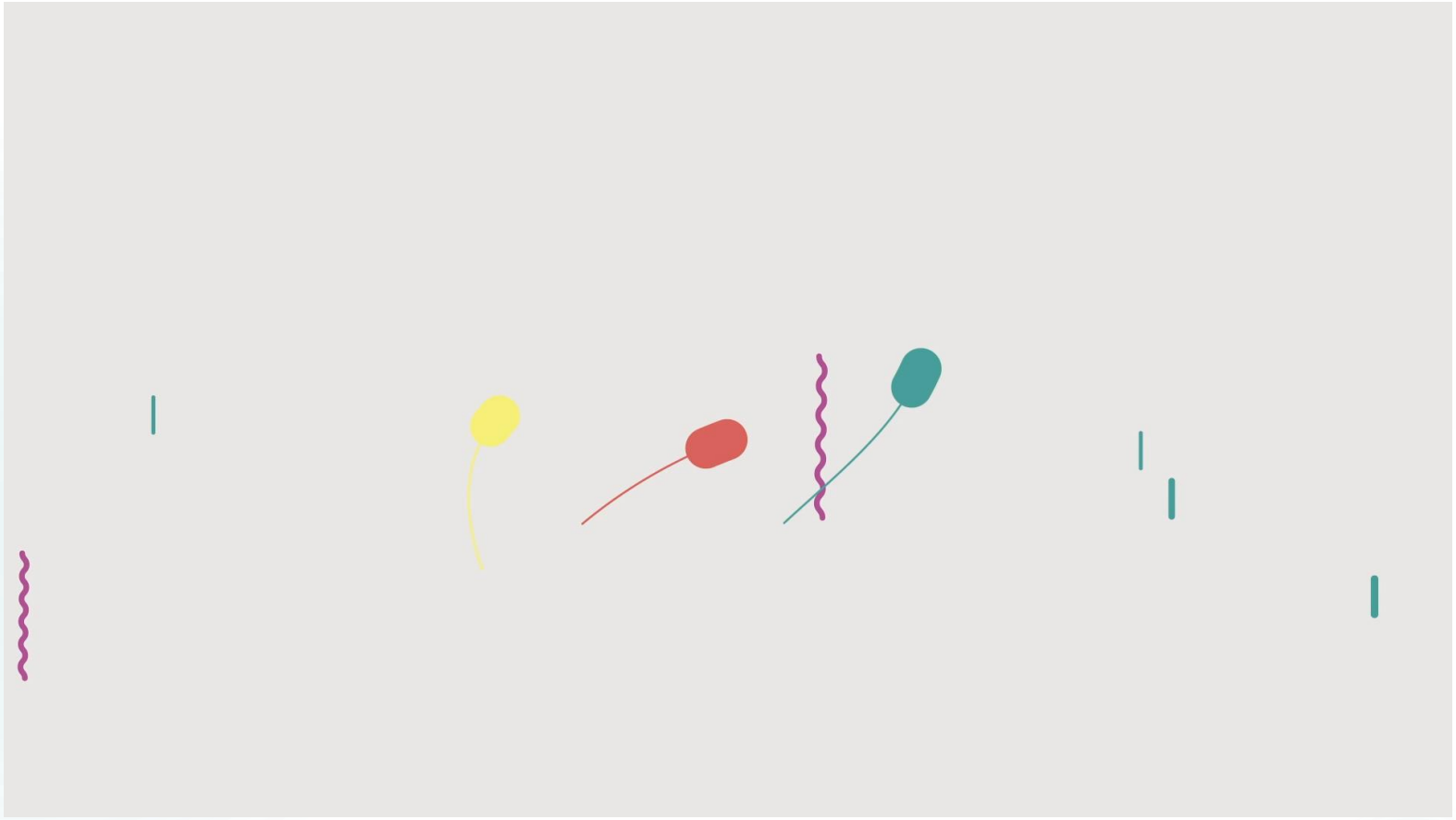
Our project

- Currently, most sunscreens on the market contain ecotoxic chemicals such as oxybenzone and octinoxate.
- Such chemicals cause coral bleaching: a type of marine pollution.
  - Coral bleaching is also caused by changes in temperature, nutrient and light - causing the corals to be stressed and makes them release symbiotic algae called zooxantheallea.
- The release of zooxantheallea leads to the coral turning white.
- The coral is therefore left very vulnerable as the algae is its main source of food. These chemicals also disrupt their reproductive cycles and coral growth.

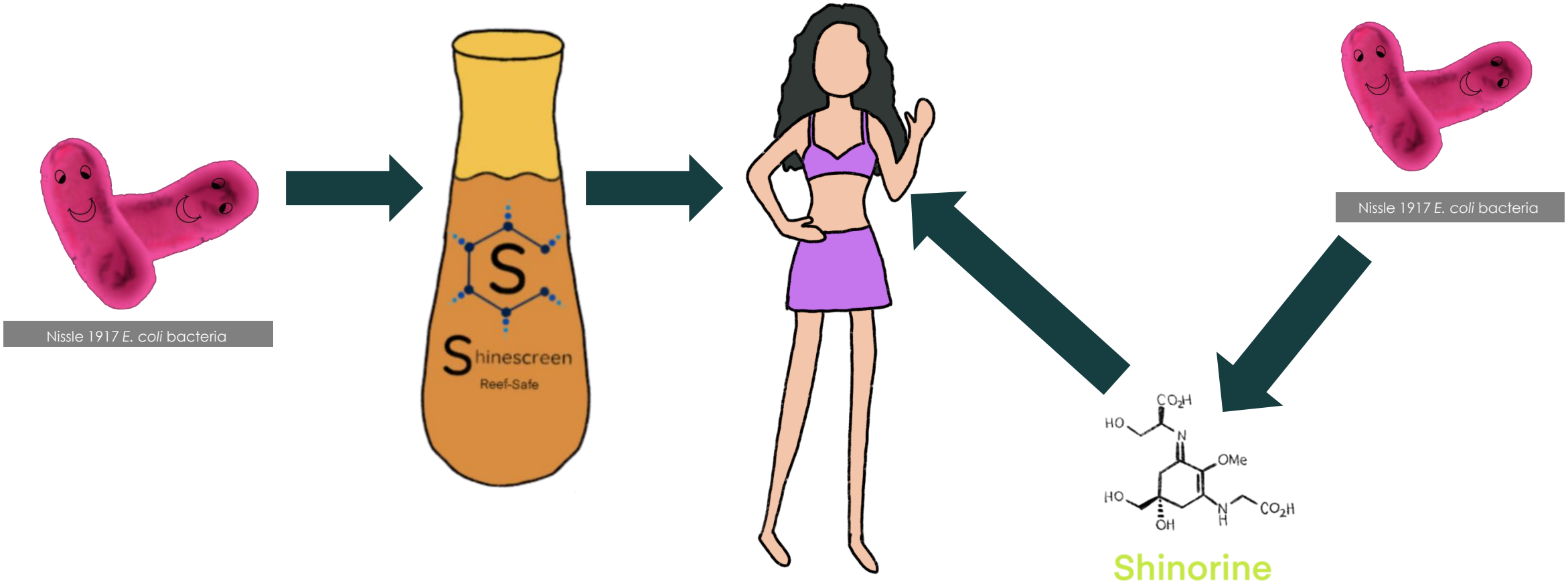
Our project

- Importance of preventing coral bleaching:
  - Coral reefs support half a billion people around the world and a quarter of all marine species.
- For example:
  - The great reef barrier supports 1,500 fish species, 4000 mollusc species and six of the world's seven sea turtle species.
- Coral reefs also provide around 375 billion dollars each year in goods and services. Many people and species are therefore reliant on the coral reefs for their livelihood.

Our Project: Promo Video



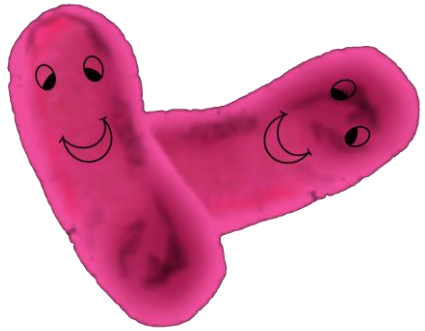
Recap from video:



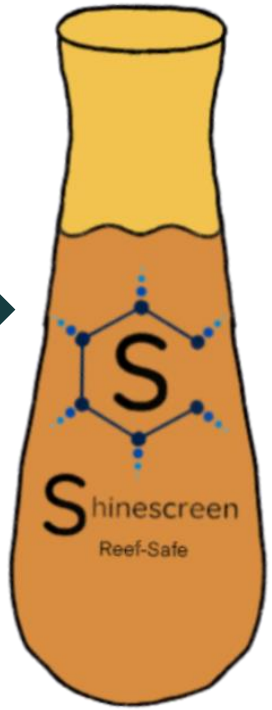
Our Project: Systems

1) Shinogen
(Shinorine–producing component)

2) Thanogen
(Kill-switch component)

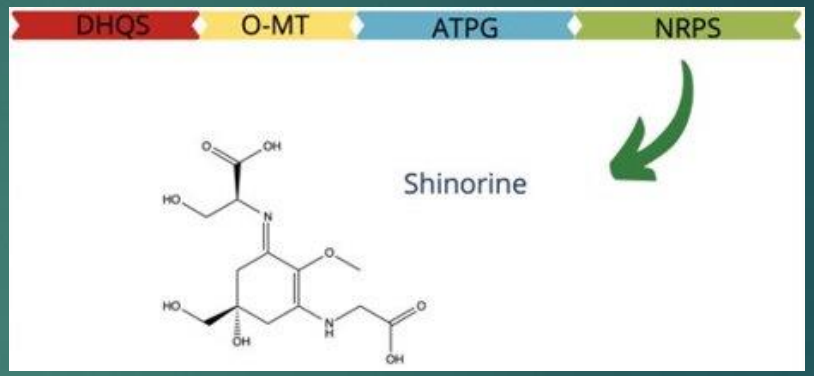


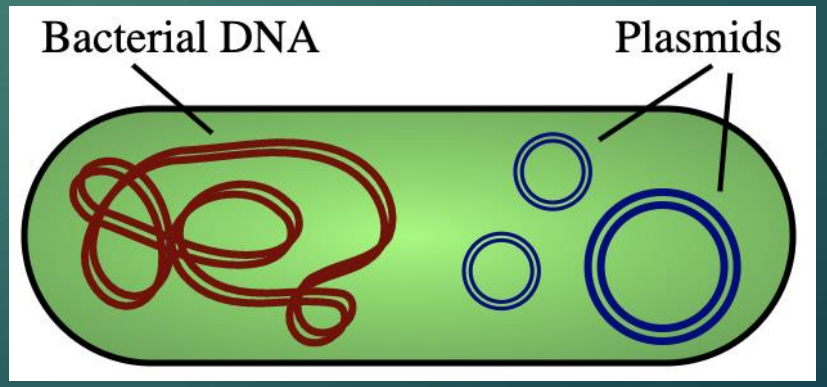
Nissle 1917 *E. coli* bacteria



Shinogen: (shinorine-producing component)

- The genes Ava_3858, Ava_3857, Ava_3856, and Ava_3855 are found in the genome of *A. viriabilis* (a type of cyanobacteria).
- These genes code for the following enzymes: DHQS, O-MT, ATPG, NRPS.
- Together, these four enzymes work together in one pathway to convert one substrate molecule (sedoheptulose-7-phosphate) into Shinorine.
- We want to take these four genes from *A. Viriabilis,* and insert them into plasmids which are subsequently be taken up by Nissle 1917 *E. coli*.
- Hopefully, once the bacteria take up the plasmids, they will be able to produce Shinorine!





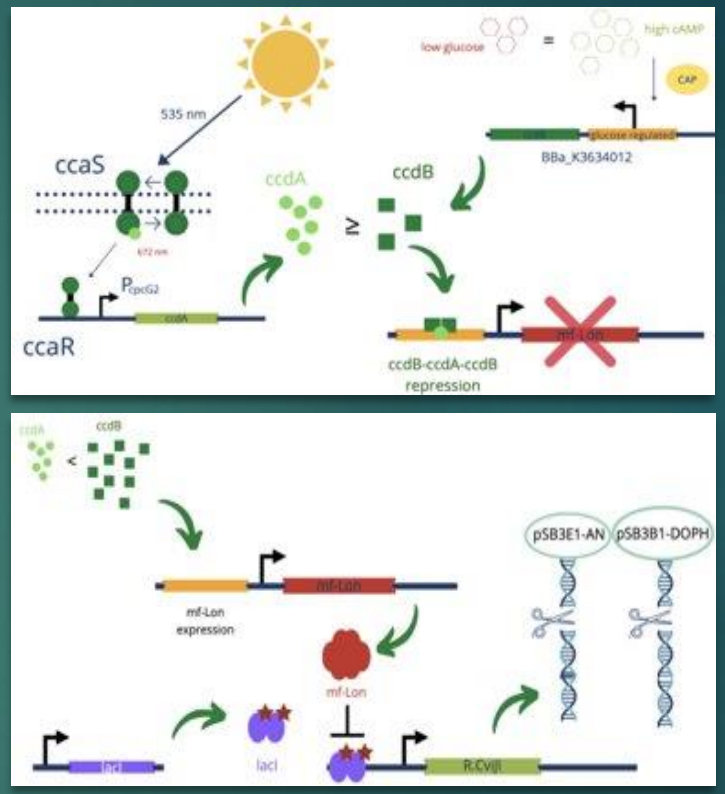
Thanogen: (Kill-switch component)

The Kill-switch safeguards against horizontal gene transfer, as well as the escape of the bacteria into the surrounding environment.

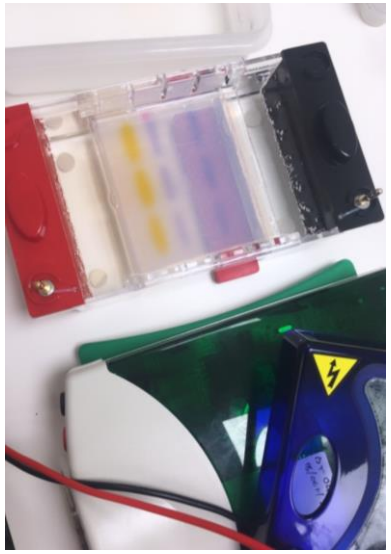
Two factors influence the kill-switch (and therefore the survival of the bacteria) - glucose availability, and sunlight.

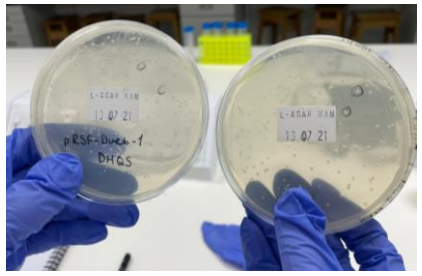
We are engineering this component so that, when BOTH sunlight is present, and the bacteria have a high availability of glucose (their food source), the bacteria survive.

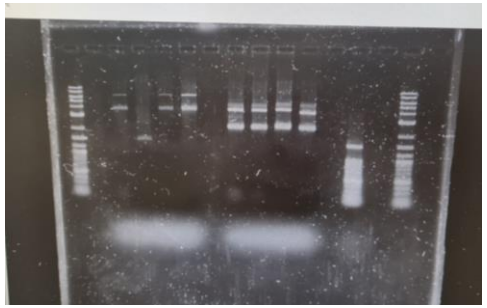
If either the bacteira run out of glucose, or the sun is no longer shining (or they run out of glucose AND the sunlight is no longer present) – then the kill-switch is activated, and the bacteira die.



What we have achieved so far:







How does this relate to SDG14 – Life Below water?

- By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
- By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information
  - Failed, only around 7.5 % conserved
  - Pressure for new target of 30% by 2030

Other Environmental solutions using synthetic biology

Issue: Plastic production

- The global production of plastic has rapidly increased in the past 170 years
- Grows around 8% each year
- Around 14 million tons enter the ocean annually, 40% being single use products such as plastic bottles
- Researchers have for example found plastic in the guts of small creatures on the bottom of the Pacific Ocean
- Some studies have shown that more PET microplastics accumulate on the ocean floor compared to the surface

Solution: Plastic Eating Bacteria

- "Superenzyme"
- Break down plastic bottles made up of PET
- Center for Enzyme Innovation in the UK and National Renewable Energy Laboratory in Colorado
- By combining DNA from two different enzymes PETase, that attacks the surface of plastics, and MHETase, that cuts down the plastic, the super enzyme was produced
- New study published in June, engineered E.coli to break down PET and TA into vanillin

Crop production

- An agriculture company called PivotBio has designed genetically modified microbes to help increase crop yield for farmers.
- These engineered microbes are designed to provide more nitrogen to crops, allowing them to grow better.

Preserving biodiversity

- For example, the organization called revive and restore are trying to rescue the endangered black-footed ferret, due to that it is susceptible to the sylvatic plague
- By taking genes from the domestic ferret, that is not susceptible to the disease, they hope to find the genes that makes it immune
- The genes would then be edited into the black-footed ferret's genome

Preserving biodiversity

- Reduce invasive species
- Gene drives are mechanisms that spread a desired genetic trait through a population to control invasive species
- Golden Mussel in South and Latin America
- Modify reproduction and infertility genes
- Released into the wild
- Gene drives to eliminate Malaria
- Increase coral's resistance to stress factors

Issue: Pollution

- Air pollution, ocean litter and the use of pesticides and fertilizers in agriculture, are examples of different types of pollution
- Prolonged exposure to air pollution has led to the increase in certain diseases in humans, for instance lung cancer and respiratory disease
- Ocean litter is caused by trash washed up from cities, waste from landfills and containers that fall of from ships, leading to that more and more debris is present in the ocean.
- Which either degrade slowly and be in the ocean for years or wash up on beaches
- The use of pesticides and fertilizers that contain toxic ingredients can have devastating consequences if released into water
- It can cause harmful algae blooms, that are blooms of species that produce deadly toxins, sometimes called “red tides” or “brown tides” and can kill fish, seabirds, marine mammals and can harm humans
- When these algae and other organisms eventually die off and decompose, bacteria can suck up the oxygen produced creating “dead-zones” where fish cannot live

Solution: Microbial sensors

- Various synthesized microbial biosensors can target different toxins such as nitrogen, phosphorous and cadium, and respond in different ways. These can be further engineered to create a type of signal when encountering a certain pollutant
- synthetizing certain proteins and insert them into bacteria that naturally decontaminate soil and water, can improve their ability to bind and degrade heavy metals

Solution: Microbial sensors

- For example, Scottish scientists are trying engineer bacteria to convert heavy metals into metallic nanoparticles
- Australian researchers are also trying to create a "synthetic jellyfish", a multicellular structure, that could be released into the water to break down contaminants after a toxic spill

CRISPR-Cas9

- CRISPR are specialized stretches of DNA and the Cas9 is the name of a protein that work as a molecular scissor that can cut DNA strands.
- The technique was taken from the natural defence mechanism of bacteria and archaea.
- Bacteria uses CRISPR-derived RNA and various CAS proteins, such as Cas9 to prevent attacks by viruses and DNA of other invaders by chopping up and destroying the DNA of the invader.
- If these components would then be transferred into a more complex organism, it allows for manipulation of genes, also referred to as gene editing.

CRISPR-Cas9 – Ethical concerns

- Using CRISPR-Cas9 for gene drives can reduce genetic diversity of target population
- Introduced trait could spread beyond target group -> crossbreeding
  - For example, with the Golden Mussel, making other mussels infertile
- If we change human embryos other questions arise:
  - What is the limit to change? How much and what would we be allowed to change
  - Changes will affect generations down the line, making changes that could affect future generations without their consent?

RECAP

- What the sustainable development goals are
- Real life applications of synthetic biology
- Synthetic biology techniques

Life at St Andrews

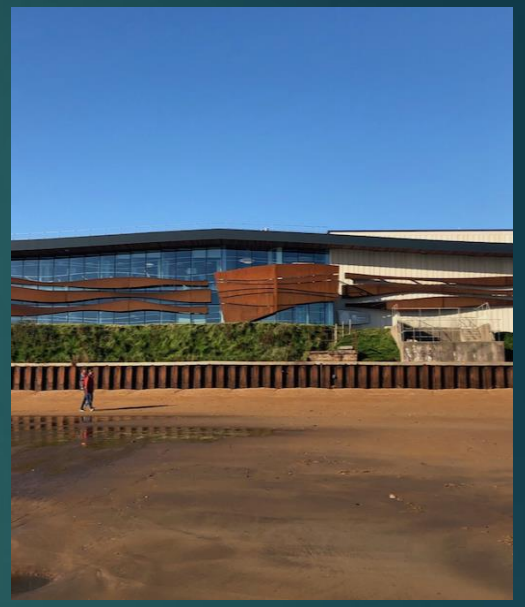
Life at St Andrews

- "Home of Golf"
- Oldest University in Scotland, founded in 1413
- Ranked 2nd/3rd overall in the UK
- First in Scotland

Studying at the University of St Andrews

Studying at the University of St Andrews

- If you want to study biology or the natural sciences, this is a great place to attend for university!
- There is the Biomedical Sciences Research Complex (BSRC) and the Scottish Oceans Institute (SOI)
- Scottish Oceans Institute (SOI), which is located right on the shores of the North Sea.



Traditions

Traditions

- May Dip
  - May Dip occurs right before May exams, and it is when students wake up at dawn and run into the sea
  - Clean of any academic sin
- Raisin and Academic Families
  - 3rd years adopt freshers and make them do challenges
  - Ends with foam fight
- Pier Walks

Thank you for joining us for this lecture!

- Follow our project on:

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Links

More plastic pollution is swirling in the deep ocean than in the Great Pacific Garbage Patch. It's even showing up in the intestines of sea creatures.

- https://www.businessinsider.com/plastic-pollution-microplastics-pervade-surface-deep-ocean-2019-6?r=US&IR=T

Plastic eating enzyme,

- https://www.businessinsider.com/plastic-eating-super-enzyme-recycles-plastic-bottles-2020-10?r=US&IR=T
- Black-footed ferret
- How Synthetic Biology Can Help the Environment | Lamont-Doherty Earth Observatory (columbia.edu)
- Crop production
- Pivot Bio

Turn into vanilla flavouring

- Plastic Waste Can Be Transformed Into Vanilla Flavoring | Smart News | Smithsonian Magazine

Sponsors and supervisors

University of St Andrews

Promega

sea-changers

Benchling

SnapGene

BBSRC

wellcome

TWIST BIOSCIENCE

IDT

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PI: Dr. Chris Hooley