Name:
Class:

Synthetic biology

Towards a critical perspective

Colophon

Universiteit Utrecht

Freudenthal Instituut
voor Didactiek van Wiskunde en Natuurwetenschappen

synenergene
Responsible Research and Innovation in Synthetic Biology

v1.0

This teaching module was developed by the Freudenthal Institute for Science and Mathematics Education, within the framework of the European SYNENERGENE project.

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Parts of this module are based on and inspired by the first lesson module "*Synthetic Biology: What is possible and advisable?* " http://www.fi.uu.nl/toepassingen/28400/

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This teaching module was developed with a grant from the 'European Union's Seventh Framework Program for research, technological development and demonstration' (grant agreement number: 321488).

Content

PART 1
Synthetic biology:
Feelings, moral issues and questions

Video

You will be shown a video about a fictional future scenario where plants can emit light. First read the following assignment, and complete it after watching the video.

https://www.youtube.com/watch?v=xGQ6Cp1dC4c

Assignment 1

Please write down your feelings, identified moral issues[1] and/or dilemmas[2], and questions raised from the video.

Feelings	Moral Issues and Dilemmas	Questions

It is possible to check again the video content by reading the text version on the next page.

[1] **Moral issue:** any matter (question, topic) with the potential to be right or wrong.
[2] **Dilemma:** any situation requiring a choice between equally difficult alternatives.

Bioluminescent street lamps

Her husband thought these shining trees were spooky. Awful Christmas days now seemed to last the whole summer and it was only a matter of time until they would teach the damned trees to sing Jingle Bells too. And where was the off-button on these things, he would complain. What did a man have to do nowadays to get some descent darkness in this world of light?

But she herself thought them beautiful as she gazed up to the intricately fingered web of soft bluish light that waved silently above her head in the gentle breeze. Oh, if only it could always be summer, so that the trees were shining. She had come to hate the harsh, unforgiving mechanical light of the old-fashioned street lamps, which of course still had to be used during winter when the trees didn't work. Especially ugly was spring-time, when the still hesitant glow of the trees had to compete with the street lights that were still on. Well, her husband was just being grumpy and old-fashioned. Bioluminescent plants had become all the rage, and now each day some creative do-it-yourself synthetic biologist would proudly present a new home-grown bioluminescent garden-variety. There were contests, where juries would visit the beautifully luminating gardens. Of course, during grey seasons you had to 'feed' light into your plants using enormous electric lamps, but then the result was so much better.

To be honest, if you wanted to see 'lumis', you were no longer restricted to streets or gardens. More and more wild varieties were popping up in woods and meadows. Well, what could you expect? It is simply impossible to have all those enthusiastic amateur breeders stick to industrial safety regulations. Never mind! No one has been poisoned yet, and that some species of nocturnal animals had moved on to darker areas of the world….well, who cares. It is hard to shed a tear for animals that you never see anyway.

Assignment 2

In pair, explain your answers from assignment 1 to your classmate – and vice versa. Make notes of your classmate answers and explanations in the space bellow.

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PART 2
Already a reality:
Bioluminescent plants and DIY biohacker

Article

Read below an article about an actual scenario where plants are literally being created to emit light and anyone is allowed to buy a DIY (do-it-yourself) biohacking kit.

When bioluminescent plants and DIY biohackers is already a reality: real threats to life?[3]

Synthetic biology techniques are literally hitting the streets, with DIY (do-it-yourself) biohacking kits going on sale. Anyone will have the ability to make at home yeast turn red, for example. While synthetic biologist entrepreneurs are planning to post synbio glow-in-the-dark plants to enthusiasts throughout the US.
Although these biohacking artifices may sound perfectly harmless, they are potentially dangerous, unregulated and presumably self-replicating.

"The ODIN" project aims to make new gene-editing techniques accessible to anyone that can afford the $130 or the $160 kit. These kits contain everything necessary for gene-editing, no extra equipment is required. Each kit comes with all sequence and cloning detail so every customer can perform their own custom genome engineering.

"Glowing Plants: Natural Lighting with no Electricity" pledged almost half a million dollars via Kickstarter to produce a number of strains of glowing plants. People can already preorder a grown plant or a pack of 50-100 fertile seeds of Glowing Plant. They advise customers to "use the plants as a nightlight or show them off to your friends".
Meanwhile, US director of national intelligence, James Clapper, told the Senate he considers gene editing to be one of the six potential weapons of mass destruction and that the "deliberate or unintentional misuse" of gene editing technology "might lead to far-reaching economic and national security implications".
There is a total lack of research into the potential environmental consequences of escaped or released gene edited organisms. How is it that whole schooling kits and biohacking DIY-culture are being entirely missed in the debate about the safety of gene-editing?

[3] Article adapted from "Rogue scientists to DIY biohackers: Real threats to ecosystems are not being taken seriously" | SynBioWatch. (n.d.). Retrieved July 25, 2016, from http://www.synbiowatch.org/2016/04/rogue-scientists-to-diy-biohackers/

Assignment 3

Write down your thoughts and questions that may have been raised by this article.

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Please also explain your feelings in relation to the current perspective of bioluminescent plants and DIY (do-it-yourself) biohacking.

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Assignment 4

Write down the moral issues you can identify from the text "When bioluminescent plants and DIY biohackers is already a reality: real threats to life?" and express your personal opinion about each moral issue you identified.

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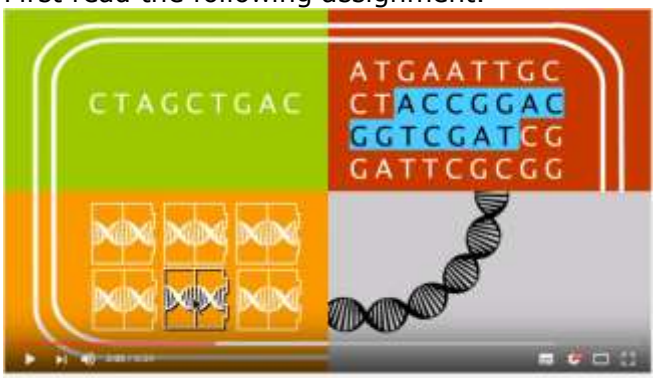
PART 3
Synthetic biology:
What does it actually mean?

Video

You will be shown a video about synthetic biology (i.e. synbio techniques and applications). First read the following assignment.



https://www.youtube.com/watch?v=rD5uNAMbDaQ

Assignment 5

At 2.50, the video will be paused. According to the movie, what is synthetic biology?

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During the second half of the video, techniques and applications of synbio are discussed. Fill in the following table.

Techniques	**Applications**
Cutting and pasting DNA / recombinant DNA technology	*E. chromi*: detects concentrations of a toxin

History

When biologists started working with physicists, chemists and technologists around the start of the twentieth century this led to great developments. For example, the development of biotechnology and of new techniques such as recombinant DNA technology and DNA sequencing. When biologists also began to cooperate with information scientists and engineers, this led to the rise of synthetic biology (see figure 1).

So synthetic biology (synbio) is a scientific field in which various specialisms cooperate. Synbio works on further developing existing techniques such as recombinant DNA technology and DNA sequencing. Researchers can use these improved techniques to design and build new biological systems. They can for instance insert new functions into an existing cell, tissue or organism, or create new cells themselves with synbio.

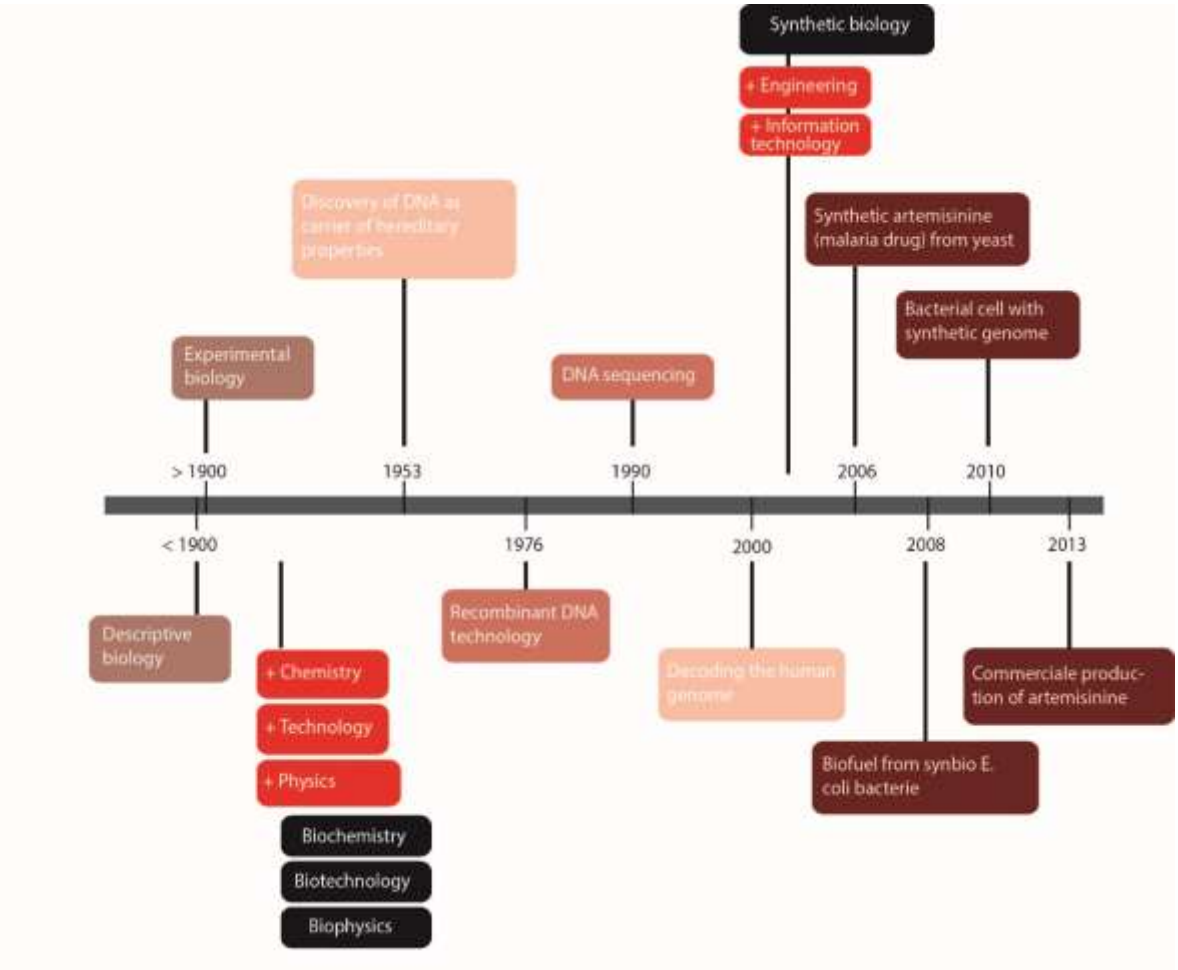


Figure 1: History of synthetic biology

Techniques

Synthetic biology is based on **recombinant DNA technology**. In figure 2 you can take another look at how this works.

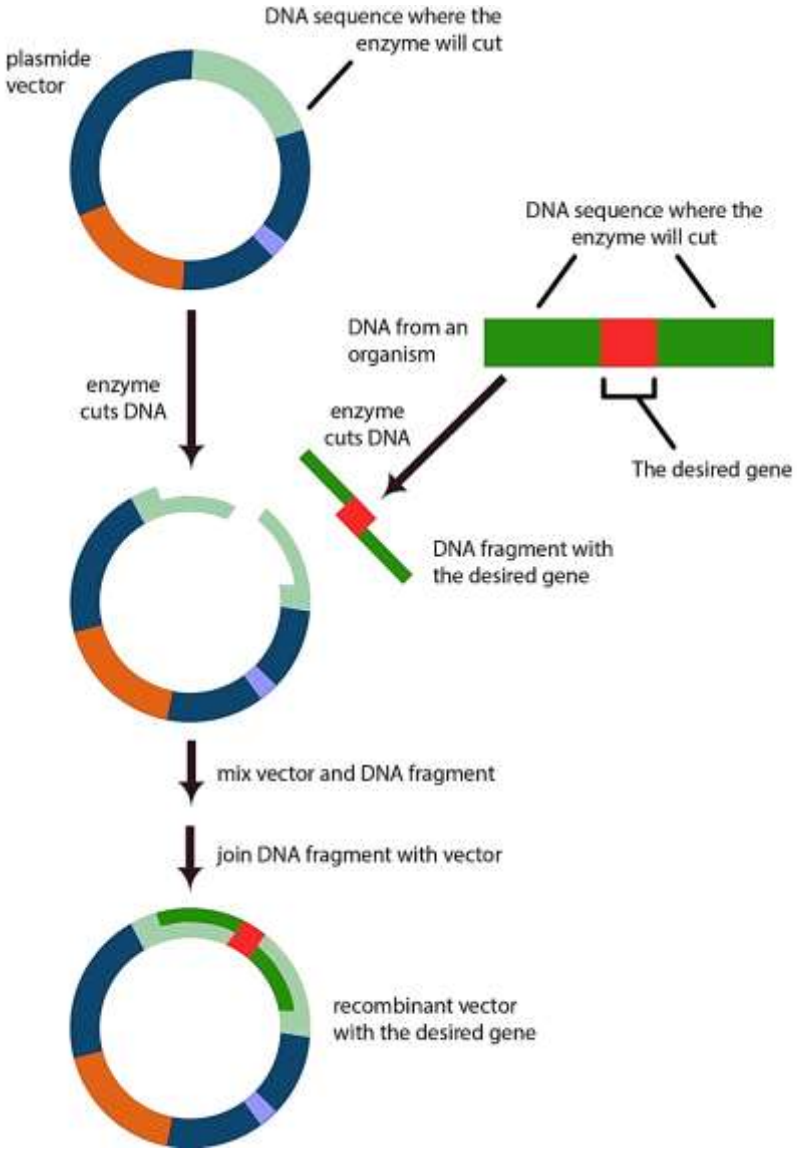


Figure 2: Recombinant DNA technology

In synthetic biology researchers no longer have to cut the desired bits of DNA from existing DNA: they can design the desired DNA themselves and order it online. The DNA is then produced synthetically by a machine, using sugar as a source material. Researchers can also order **BioBricks** from an online database. These are bits of DNA with a specific function (for instance, they code for a particular protein) that have been designed to be combined easily. BioBricks are therefore also called 'plug-and-play DNA'. There are several types of BioBricks, for example:

- BioBricks with only a coding gene or a part of the DNA that can regulate a gene.
- BioBricks that contain the coding gene as well as all parts that regulate this gene.
- BioBricks consisting of multiple genes that together perform a function.

Researchers can use BioBricks to change an existing organism, for example a yeast cell. This works as follows (figure 3):

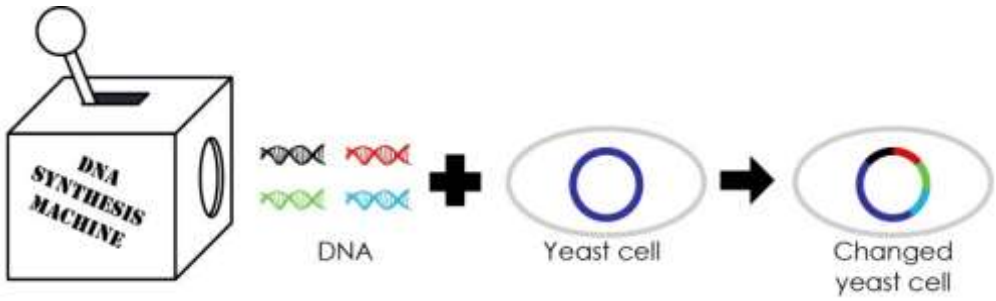


Figure 3: Changing a host with synthetic biology techniques. In this case the host is a yeast cell.

Researchers also try to create **minimal cells**. These are cells that only need the genes that are necessary to survive. In future, researchers might be able to add BioBricks to these minimal cells, to have the cells perform specific functions, such as manufacturing a drug.

Minimal cells can be made in two ways: top-down and bottom-up. **Top-down** means that a researcher adapts an existing cell. To make a minimal cell, a researcher would remove as many genes as possible from the cell, until only the genes that are necessary for the cell to survive and divide are left behind (figure 4). **Bottom-up** means that the researcher builds a cell from scratch. The researcher writes the DNA, or makes use of BioBricks. By only selecting the genes the cell needs to survive and divide, you end up with a minimal cell (figure 5).

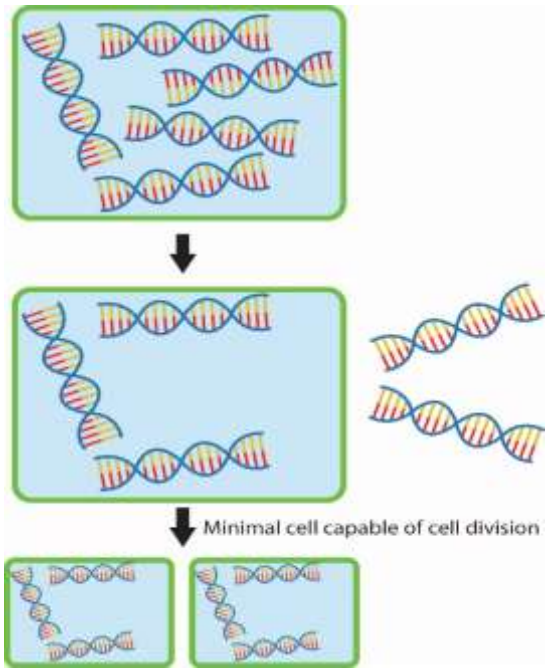


Figure 4: Minimal cell made top-down

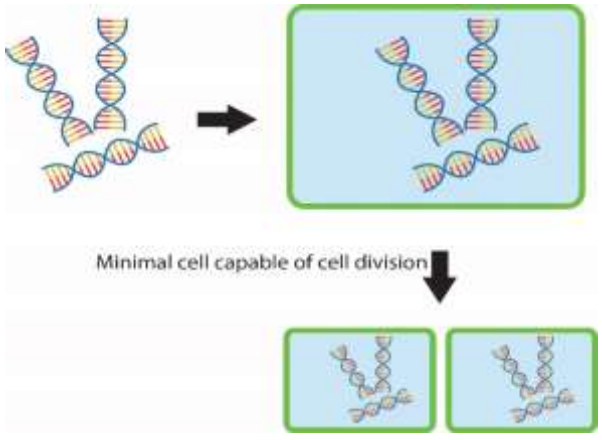


Figure 5: Minimal cell made bottom-up

Applications

Synthetic biology has only been used for about ten years, but already an impressive number of applications has been developed.

Cheap anti-malaria drug

The malaria drug **artemisinin** was originally obtained from a plant, sweet wormwood (*Artemisia annua*). This is expensive and not always enough of the drug was available. By synthesizing the genes for the production of artemisinin with synthetic biology and insert them in yeast (figure 6), yeasts can now produce the drug quickly and cheaply in a reactor vessel. A pharmaceutical company is using this method to produce artemisinin, resulting in about a 100 million malarial treatments a year.

Sweet wormwood

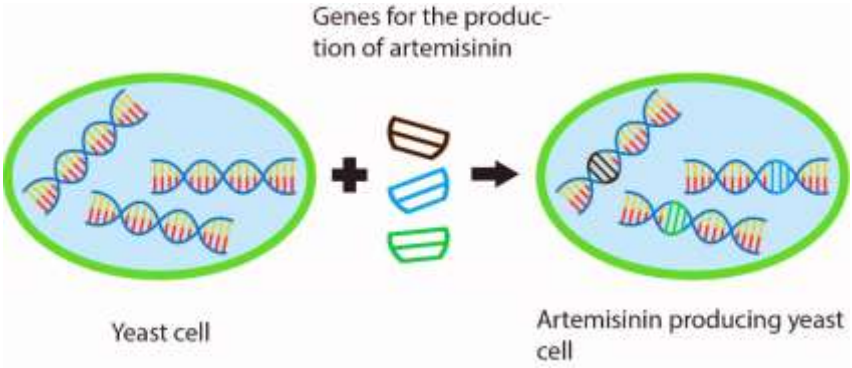
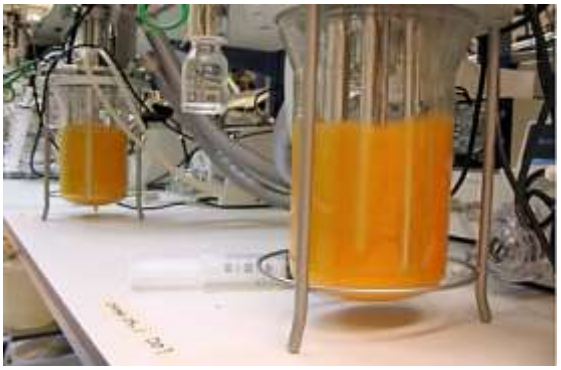


Figure 6: The synthesized genes for the production of artemisinin are inserted in the yeast DNA. The yeast can now produce artemisinin.

Sustainable fuel

Bio-ethanol is an alcohol that can be used as sustainable fuel. Bio-ethanol is made using baking yeast that can convert sugars in corn into bio-ethanol. This can result in corn becoming too expensive as a food crop. Synthetic biology makes it possible to use agricultural waste products such as straw and corn foliage as raw materials for bio-ethanol. This has been realized by adding genes to baking yeast that can convert the sugars in waste products into bio-ethanol.

The first factory producing bio-ethanol in this way opened in 2014.



Lab with yeasts converting waste-sugars into bio-ethanol.

Assignment 6

Write down the definition of synthetic biology and explain how does it differs from traditional recombinant DNA technology.

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Assignment 7

What is your opinion about the creation of the following organisms/products? Please explain your point of view.

a. Cheap anti-malaria drug (bacteria producing artemisinin)

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b. Glowing plants (plants emitting light)

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c. Sustainable fuel (bacteria producing Bio-ethanol)

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d. Synthetic human genome (complete human DNA made by a machine)

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PART 4
The best course of action: An open dialogue

Video

You will be shown a video about a fictional future scenario of a synthetic biology crisis. After watching the video, work with two classmates on the following assignment.

https://www.youtube.com/watch?v=GhjOQCk8E_k

Assignment 8

The video presented an example of a fictional synthetic biology crisis caused by a genetic mutation. It also revealed the following 'groups' which were involved and affected by the crisis:

1. *Farmers*
2. *Synbio industry*
3. *Scientists*
4. *World Health Organization (WHO)*
5. *Population*

*Now reflect with your classmates about each 'group' hypothetical relationships with synthetic biology development **before** the crisis happen. For example:*

1. *Farmers*

- *Farmers may have only been concerned about their great crops and sales.*
- *Farmers knew about the risks but becoming rich was more important.*
- *Farmers did never understand the risks of synthetic biology.*
- *Farmers thought that scientists were ensuring safety.*
- *Only a few farmers did not trust synthetic biology.*

2. *Synbio industry*

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3. *Scientists*

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4. *World Health Organization (WHO)*

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5. *Population*

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Open dialogue

Since the first lesson of this module you learned about the incredible potentials of synthetic biology, but also about its disadvantages, advantages and moral issues. During the whole-class dialogue you will consider the advisability of certain synthetic biology applications and regulations from various perspectives.

Assignment 9

Write below arguments from the open dialogue that you think are important in relation to the advisability of synthetic biology.

	Advisability
Progress What can the synbio produce in terms of progress? Are there any disadvantages to this progress?	
Economy What can synbio produce in terms of economic growth? Could it lead to an unfair distribution of profit? Or will it have a negative economic effect? And who will be affected by that?	

Risks What potential risks are there to synbio? What are the risks to mankind and nature?	
Ethics Is synbio ethically responsible: is this allowed? Do we want this? Where do we draw the line?	

Assignment 10

What is the best course of action to be undertaken for synthetic biology developments?

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