Dominoes

Proposals & process

Anaïs Moisy

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Introduction

The Genetic Constructor Dominoes have been designed as a concept for a tangible interface for biologist to sketch DNA constructs. The interface consists of a series of pieces representing different DNA parts, using Synthetic Biology Open Language (SBOL).
By manipulating these pieces and snapping them together biologists can sketch DNA sequences, which then, could be transferred into Genetic Constructor (Autodesk CAD tool for DNA design) to insert the sequences into the sketch blocks and test the validity of their design.
It could then be send to be assembled by Edinburgh Genome Foundry (EGF), a facility at the University of Edinburgh that offers a unique robotic platform to synthesise DNA.

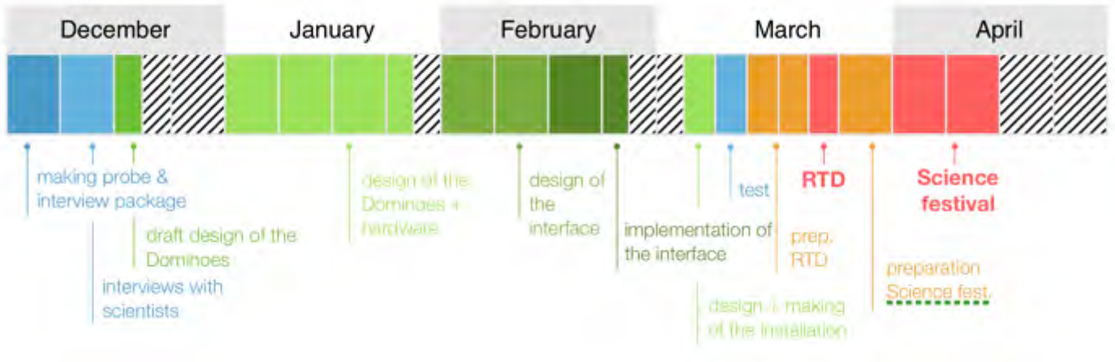
Based on the Genetic Constructor Dominoes, I propose two installations for the 2017 Science Festival in Edinburgh.
The first one is interactive: visitors would have to combine the pieces together and, through visuals and sound, they will experience in real time the principles of DNA design.
Faced with the challenge of designing a microorganism, they would become familiar with the grammar of DNA represented by the different pieces, but also what are the limitations and difficulties of modifying living organisms.

The second one is analogue: I imagined an installation composed of cards that visitors could use to ‘create’ personalised engineered ‘thing’. They first would have to choose an ‘organism’ and then create a sequence in order to modify it; and finally explain the story behind their creation.
Encouraged to reflect on the implications and outcomes (positive and negative) of such creation, it would give both insights of what the general public inspirations for synthetic biology are and a vision of the hopes and fears of the society. Moreover, it would introduce the basic grammar of DNA and its visualisation.

The aim of these exhibitions is not only to inform visitors about the processes of DNA design but also to invite reflection on what it means to design through living organisms.

Interviews planning

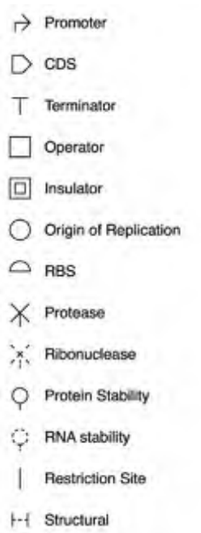
Timeline



Probe package

Dominoes set
The interviewee can use during the session cardboard Dominoes.
All of them can be annotated with felt pen.
Simple laser cut cardboard Dominoes. Some with most used SBOL symbols (Promoter - CDS - Terminator - Restriction site) and blank ones.

SBOL symbols
Card with the list of the symbols and their biological meaning.



Other
Post it
Paper clips (bended, they could be used to show the enzymes cutting site)
Blank A3 papers
Felt pen

A3 printed papers with questions
1. What did you designed ?
Which organism would you modified with this construct ?
Which method or tool kit would you use ?
What would you like to see on a screen when designing this construct ?
2. How would you communicate it to the general public?
Tell us a story

Sequence of events - questions

Duration : 30 min
Location : EGF meeting room

Introducing the project
The Genetic Constructor Dominoes (showing the glass Dominoes) have been designed as a concept for a tangible interface for biologist to sketch DNA constructs.
The initial idea was that biologists could have a kit of dominoes in their lab, allowing them to sketch DNA sequences, which then, could be transferred into Genetic Constructor (Autodesk CAD tool for DNA design).

The goals of this interview / 1 to 1 workshop is to see how this concept could be adapted for an interactive installation for the science festival in April, informing visitors about the processes of DNA design as well as determine if such tool kit could be of any interest for biologists.

Introducing the probe
- Using the pieces, how would you design a new construct ? From what do you start and how do you decide what to replace ?
You can draw and write on the pieces, move them, create a series of different construct.
- If it was generic one, this time try to design one which would relate to a real project, something you are working on currently or have been working on previously.
- Are you missing any symbols or elements to complete your design ?

Introducing the first A3 : about the construct
- What did you designed ?
- Which organism would you modified with this construct ?
- Which method or tool kit would you use ?
- What would you like to see on a screen when designing this construct ?

Introducing the second A3 : about public engagement
- How would you communicate it to the general public ?
Tell us a story
- What aspect is important to convey ?
- Who would you visualise it ?

Introducing feedback / questionnaire
- Would it be useful for you to have a Domino Kit in your lab ?
- When and where would you use the Dominoes ?
- Would you be interested to have it transferred into GC ?

Genome Foundry meets Design Informatics

Science festival - Dominoes project

Consent form

Researchers

Anaïs Moisy (Edinburgh Genome Foundry & Design Informatics, University of Edinburgh)
Larissa Pschetz (Design Informatics, University of Edinburgh)
Hille Tekotte (Edinburgh Genome Foundry, University of Edinburgh)

Description

These interviews aim to investigate DNA design processes and visualisations in order to design an interactive installation for the science festival, where visitors will experience in real time the principles of DNA design.

By signing below you are agreeing to be interviewed as part of the Genome Foundry meets Design Informatics project. Please be advised that the data generated in this study will be kept private and will not be shared with any third party, and all published material will be anonymised.

I give consent to be audio-recorded during this study ( ) Yes ( ) No

I give consent for anonymised excerpts of my interview to be used for publication ( ) Yes ( ) No

Name: _____

Age:
( ) Under 18
( ) 18 - 29
( ) 30 - 39
( ) 40 - 49
( ) 50 - 59
( ) 60 - 69
( ) 70 and over

Nationality: _____ Occupation: _____

Signature: _____ Date: _____

Genome Foundry meets Design Informatics

Science festival - Dominoes project

Questionnaire

1. Would it be useful for you to have a Domino Kit in your lab ? ( ) Yes ( ) No

2. If yes, for which purpose ? If no, why ?

_____

_____

If you have answered Yes to question 1, please answer the following questions :

3. On which support would you use the Dominoes ?

( ) on a white board
( ) directly on a table
( ) other _____

4. When and where would you use the Dominoes ?

( ) alone, working on a project
( ) during planing meetings
( ) during design meetings
( ) informally with a colleague
( ) to demonstrate an idea during a presentation
( ) other _____

5. Do you know Genetic Constructor (GC) ? ( ) Yes ( ) No

If you have answered Yes to question 5, please answer the following questions :

6. If yes, Would you be interested to have it transferred into GC ? ( ) Yes ( ) No

7. Which info would you like to be transferred in GC ?

_____

8. Do you have other suggestions ?

_____

_____

Contact Interviewees

Dear Biologist,

I am a Designer/Researcher working at Edinburgh Genome Foundry and the Design Informatics department in Edinburgh College of Art. I am currently developing the design of a tangible interface for biologist to sketch DNA constructs.
I already designed a set of prototype for this purpose: they are glass Dominoes with SBOL symbols which biologist could manipulate and write on them in order to sketch DNA sequences. I would like to investigate how it could be developed further. Moreover, another goal of this project would be to adapt the concept into an interactive installation for the science festival in April, informing visitors about the processes of DNA design.

For that I would need your help. Getting input from your research and how you work would be really useful. It would only take 30min around a tea or a coffee, where we will discuss how you would use the Dominoes to explain a project involving DNA modification.

Please have a look at the explanation poster for more informations and please get in contact if you have any questions.

If you would like to participate please choose a doodle slot and come at the chosen time in EGF meeting room (2.34) - second floor Michael Swann Building.

http://doodle.com/poll/e4eudb2vefxrz2eg

Thank you in advance,
I am looking forward to meeting you.

Anaïs Moisy

Interviews

Stats

		Age	Nationality	Position	Organism	Sex
Elise		30-39	French	Lecturer	Mamalian	F
Luis		18-29	Mexican	PhD student	Yeast	M
Jamie		18-29	Filipino	PhD student	Yeast	F
Eva		30-39	Spanish	Post-Doc	Yeast	F
Dirk		40-49	Dutch	Post-Doc	Mamalian	M
Emily		18-29	British	Post-Doc	Yeats	F
Chantal		30-39	Chinese	PhD student	Yeats	F
Paulina		18-29	Polish	PhD student	Yeats	F
James		18-29	British	PhD student	Mamalian	M
Roy		18-29	Scottish	PhD student	Yeats	M
Maddy		18-29	British	Post-Doc	Plants	F
Naomi		40-49	Japanese	Lecturer	Plants	F
Matthew		30-39	British	Post-Doc	Bacteria	M

Age

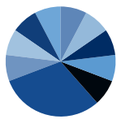
18-29	7
30-39	4
40-49	2

Position

Lecturer	2
PhD student	6
Post-Doc	5

Nationality

French	1
Mexican	1
Filipino	1
Spanish	1
Dutch	1
British	4
Chinese	1
Polish	1
Scottish	1
Japanese	1



Organism

Mamalian	3
Yeast	3
Bacteria	1
Plants	2

Sex

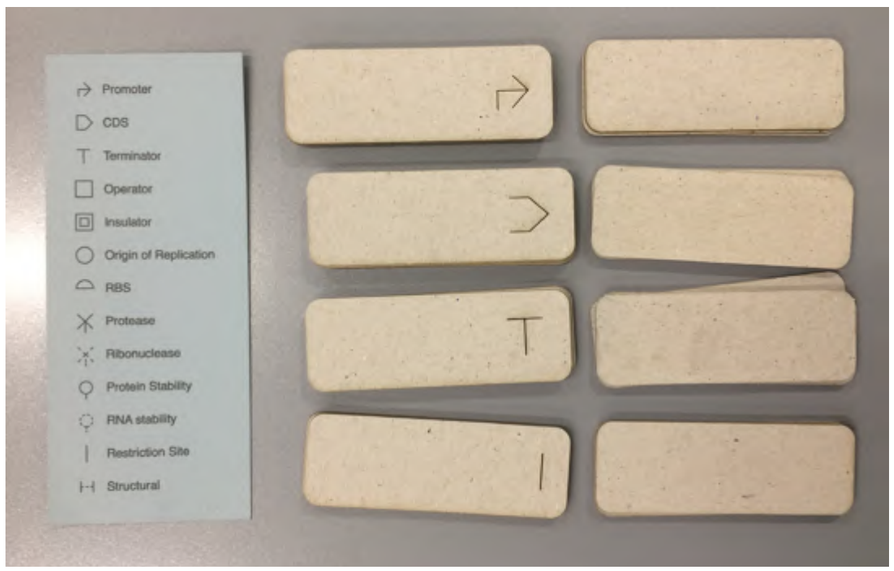
F	8
M	5

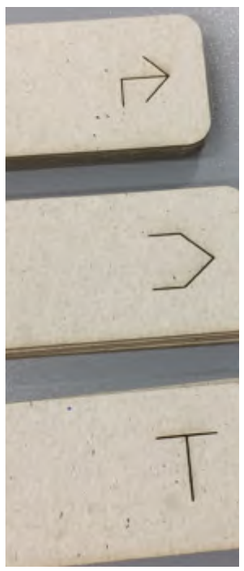
General comments

I did not stick to the frame of questions and activities I prepared. Instead, I let the Interviewee express his/her ideas freely without restrictions. They all came for different reasons: some brought their own material to show me (constructs they printed, note books…), other had specific ideas they wanted to share, and finally other were just curious. It was important to leave open the discussion in order to gather as many information possible. However it was useful to have the cardboard Dominoes, and paper ready to be used if the biologist was willing to use them, as well as being able to propose directions, exercises and questions to revive the discussion.

For the three-first interviews I had the glass dominoes on the table. Instead of using the cardboards one and writing which parts they wanted to use, they used the glass ones as they are more appealing to manipulate. I decided to glue magnets at the back of the glass and installed them on the white board in the meeting room. The Interviewees were able to see them, interact with them if they wanted but were more encouraged to use the cardboard ones.

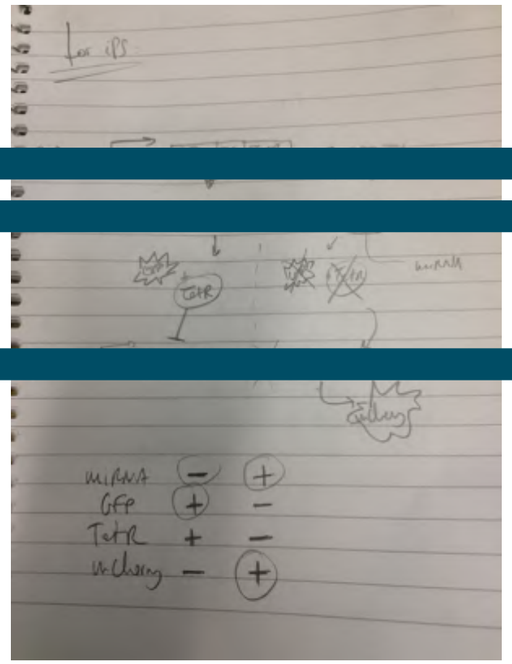
Set up

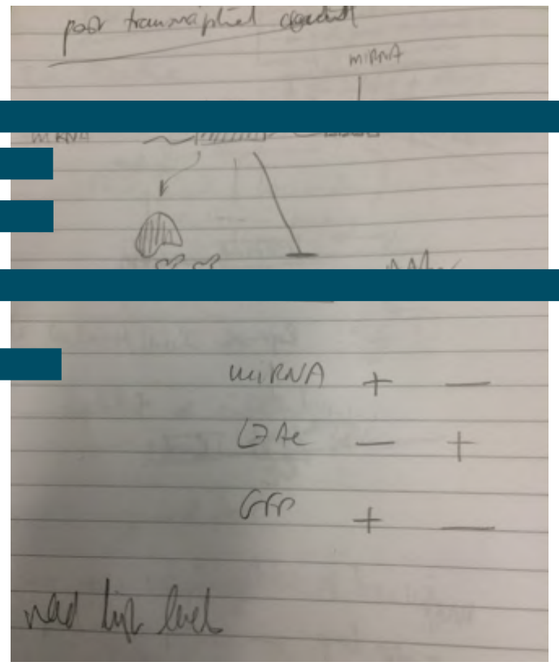




Elise Cachat

- She works on mammalian cells
- It would be great to have a checking in the software when a sequence is uploaded : is it the correct order, the sequence is correctly assemble, it is still in frame…
- For mammalian they would need a different set of symbols, same as in EMMA
- Importance of the logic
- The assembly method is important and the design of the sequence will be different from one methods to the other (number of overhang from one sequence to the other…) being able to tell the software which methods not at the order but at the beginning of the design would be useful to help generating the sequence automatically
- Could be interesting to write on the domino the name of the parts and be able to reuse them (use glass or plastic ones)
- have a kit with Andrea's EMMA kit
- Contact Louise Horsfall group : Cleaning Land for Wealth (CL4W project)
- Naomi Nakayama for plants
- Patrick (CaiLab) for Yeats
- Elise draws and sketch the construct in notebook in group meeting to design new constructs
- it would gain time and it would be practicable to have kit in her lab to communicate and collaborate on the design of new constructs.





Installation

- yeast can change colour or produce different smell by producing different protein (eg: produce vanillin)
- use plants : some can be modified to be bioluminescent
- importance to choose carefully the chassis to convey the correct and accessible message

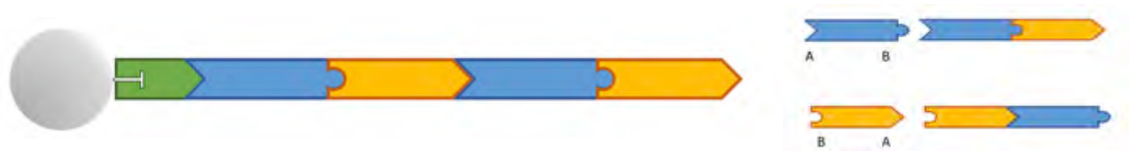
- interesting tool for kids : "Gizmos & gadgets" from little bits
https://littlebits.cc/kits/gizmos-and-gadgets-kit
The Gizmos & Gadgets Kit is the ultimate invention toolbox. Motors, wheels, lights, switches, servos, buzzers even a remote control – snap it all together to spark creativity and fun. Want to invent a remote control racecar? Do it. Create an automatic bubble blowing device? Go for it! Comes with 15 electronic building blocks, detailed instructions for 12 projects, and all the accessories and tools you need to unleash the inventor within.
Each "Bit" is a piece of an electronic circuit. The bits are colour coded and divided into 4 categories: power (blue), input (pink), output (green), and wire (orange). By combining the modules in different ways (by simply "snapping" them together magnetically) you can quickly create any number of interactive electronic projects.

It is relevant as it uses colour coded parts to explain 'the grammar' and snaps with magnet.

- The best way to make the grammar explicit would be to use either symbols to link the blocks together (like picture bellow) or pieces similar to jigsaw's ones.

- keep it simple for beginners (promoter - CDS - terminator)

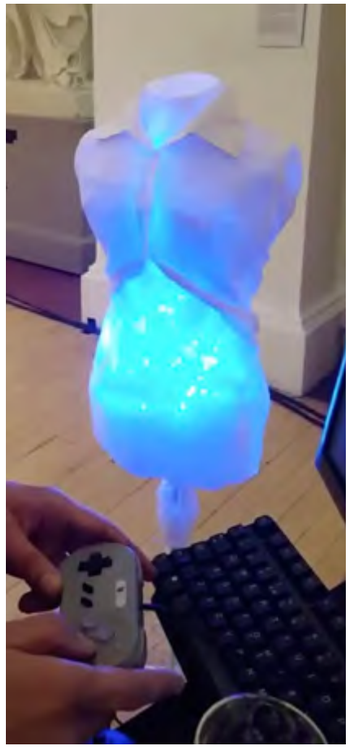
- this year iGem Edinburgh team used dominoes/jigsaw pieces to explain their grammar
http://2016.igem.org/Team:Edinburgh_UG
http://2016.igem.org/Team:Edinburgh_UG/Design



Luis Fernando Montano

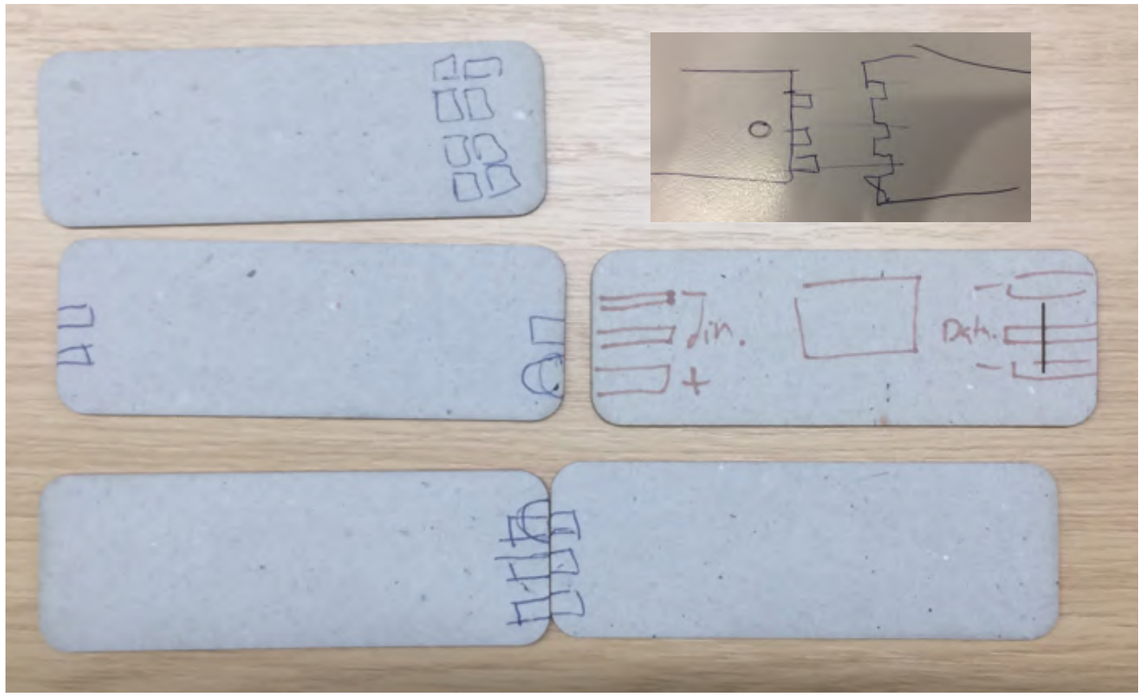
Luis is working with yeast
-
- He did an interactive installation for the DataX exhibition :
“Inside the Black Box”
http://data-x.blogs.edina.ac.uk/2016/11/29/inside-the-black-box-luis-fernando-montano-bohdan-mykhaylyk/
They simulated a bacterial infection controlled by a hidden circuitry of interacting components.
“We challenge the audience to control the growing bacterial infection (red light) by interactively administering treatment (green light). In the process, we will collect time-series data about the behaviour of complex systems and test whether human intuition can outsmart intricate black boxes. If played by enough people as a game, data from high scoring simulations could reveal optimal strategies for diagnosis and treatment of real patients.”

- An operator can be either before or after a promoter
- The DNA (2 strains) is transcribed into RNA (1strain) which will then be translate into a protein
- A ribosome look like a hamburger



Installation

- The dominoes should be an element of a puzzle



- The surface around could conduct electricity
- A wire could represent the plasmid and when physically connected to the pieces it will light up the sequence if it is correct

- Convey the idea of the just right: right amount of production-> if the promoter is too strong the gene might produce too much of one protein which would inhibit another function-> the goal would be to find the right balance between the elements. Same idea with synthetic biology, not all good all bad, but find the just right balance between what will be beneficial and what will have harmful consequences.
- Convey the concept of Traide-off: when a cell is becoming not happy
A trade-off (or tradeoff) is a situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. More colloquially, if one thing increases, some other thing must decrease.
In biology and microbiology, tradeoffs occur when a beneficial change in one trait is linked to a detrimental change in another trait.
- To do that we talked about the idea of developing dominoes with ‘power’ and need to find the right balance to make it viable.

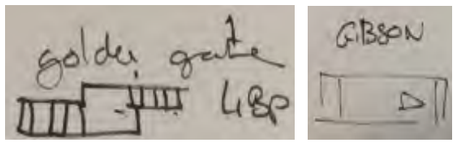
Jamie Auxillos & Eva Garcia-Ruiz

- They both work on yeasts.

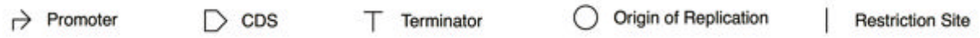
Dominoes

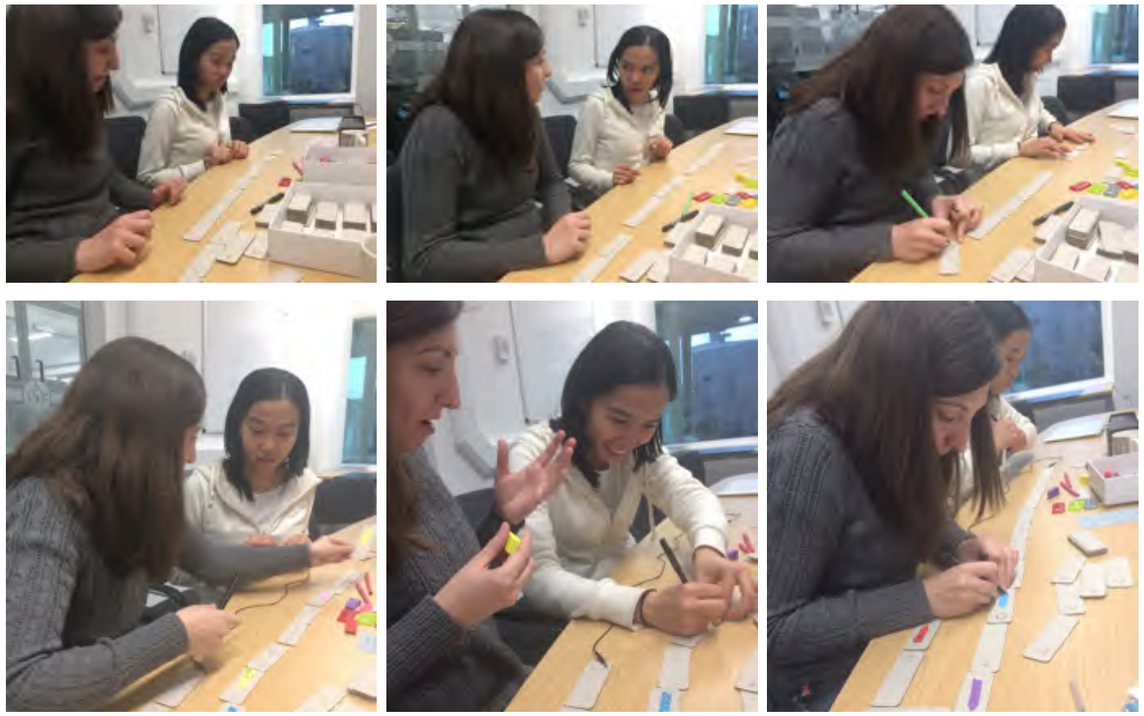
- It was difficult to make them write on the cardboard dominoes : they did not want to damage them, or make mistakes -> they would have been more comfortable to use erasable ones.
- The size of promoters and terminators are important important for them and they were expecting that the size of the blocs would reflect the usual size. For example, Jamie was pointing out that it did not make sense that in the glass set a promoter was longer than a CDS. Promoter and terminator should be small.
- They would like magnets at the back to work on a white board

- They would be interested to have in addition to a 'basic set' of simple blocks a set for Golden Gate assembly and one for Gibson.
For Golden Gate the blocks need 4 bp overlaps on each side (left side : up - right side : down).
For Gibson it is an overlap of the on each side of the sequence. It is represented like this ->



- They would like a library of standard part already written on the dominos (eg: yeastfab)
- The most common signs used are :





What is in the construct they designed (pathway to make a yeast red and green)

CDS
EGFP (green fluorescent protein)
mCherry (red fluorescent protein)
Kanamycin (antibiotic marker)
URA (marker for yeast)

Restriction site
BsAI (x2) (extraction from the plasmid)

Promoter (chosen randomly)
pTDH3
promoter (x2)

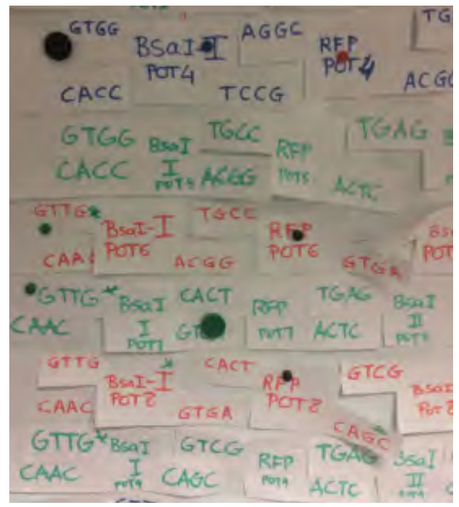
Other
Signal Peptide
p2A
Origine replication

In order

BsAI - pTDH3 - Signal Peptide - EGFP - p2A - mCherry - tcycl - BsAI - Origine replication - promoter - Kanamycin - terminator - promoter - URA - terminator

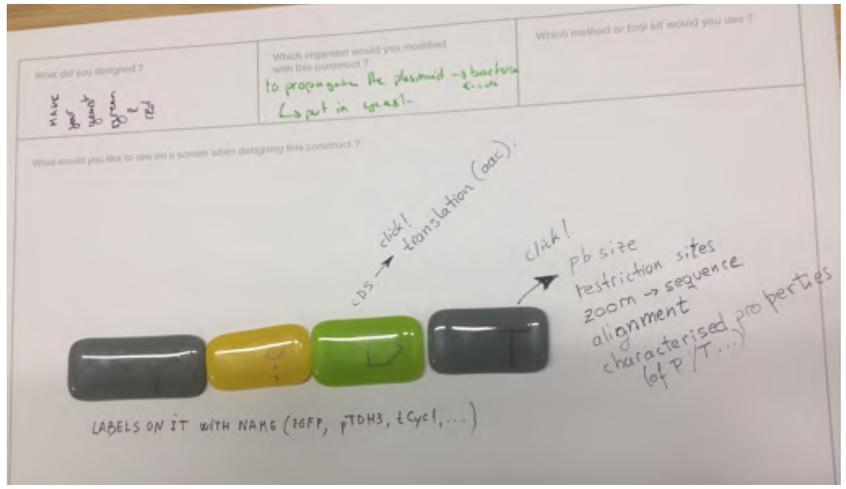
Terminator (chosen randomly)
tcycl
terminator (x2)

- Jamie did handmade parts with papers and magnet on a white board to design her assembly using Golden Gate, in order to determine the 4bps between at the end of the parts.



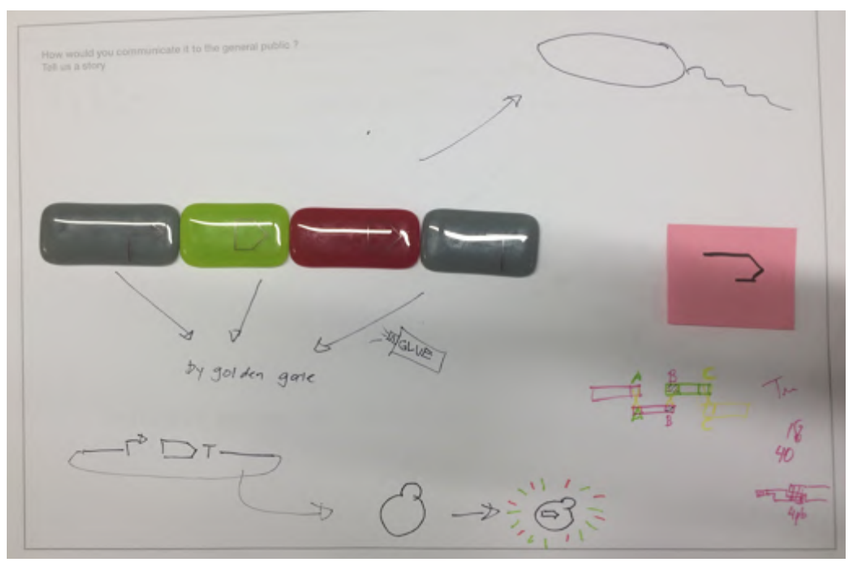
Software

- They would like to be able to get the label they wrote on the parts directly into the software.
- They think it would be useful to get the translation into aminoaide with one click
- The following informations for a part would be useful to get into the software
    - pb size
    - restriction sites
    - zoom into the parts to get the sequence
    - alignment
    - characterised properties



Installation

- keep it simple, essential part : promoter - CDS - terminator
- explain that some methods act like glue to stick the parts together, then they are put in bacteria to be duplicated and then it is extracted to be put inside the host organism, in this case Yeasts.

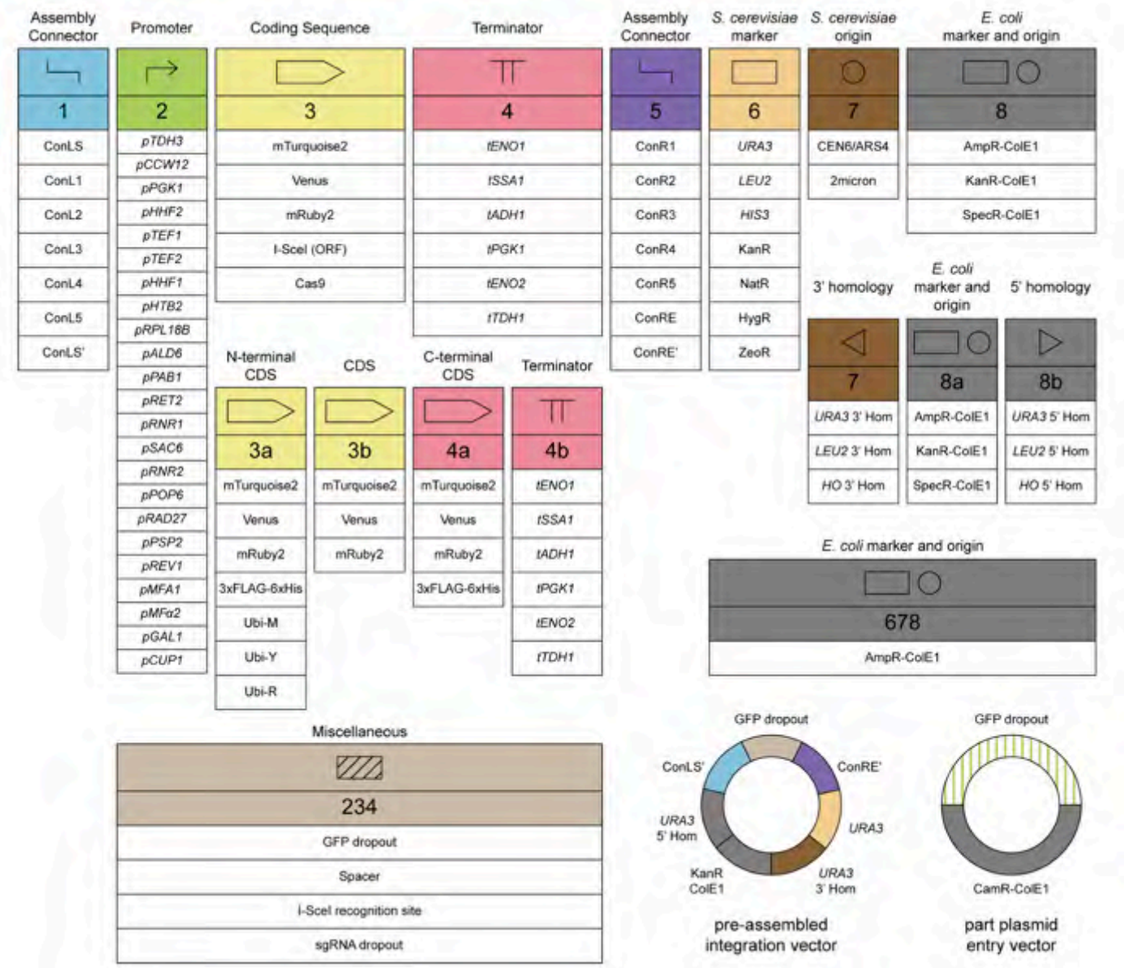


Emily Johnston & Dirk Kleinjan

- Emily work on yeast, Dirk work on Mammalian cells

- They are not very familiar with the SBOL standard in their daily practice, however Emily is tarting to use some of them to design construct on a high level.

- Emily use MoClo toolkit to assemble DNA in yeast. Standard for Golden Gate assembly in yeast
- Similar tool kit are EMMA for mammalian cells and Yeastfab for yeast



Lee, M. E., DeLoache, W. C., Cervantes, B., & Dueber, J. E. (2015). A highly characterized yeast toolkit for modular, multipart assembly. ACS synthetic biology, 4(9), 975-986.

- It would be useful to highlight (a flag is suggested by Dirk) when a similar sequence is in two different (or more) positions in the plasmid.

- It would be useful to have the possibility to see the result of a site specific recombination (see figure on the right) in the sequence.
Olorunniji, F. J., Rosser, S. J., & Stark, W. M. (2016). Site-specific recombinases: molecular machines for the Genetic Revolution. Biochemical Journal, 473(6), 673-684.

- A promoter has a strength : it can be strong, medium, weak…
to get the gene to express 'a lot' you need to have a strong promoter in front, if it is a weak one the gene we not express much.

- Dna is circular in bacteria and yeast (plasmid), however it is linear in human for example.

- The 4 base pairs overlaps are important in the design process.

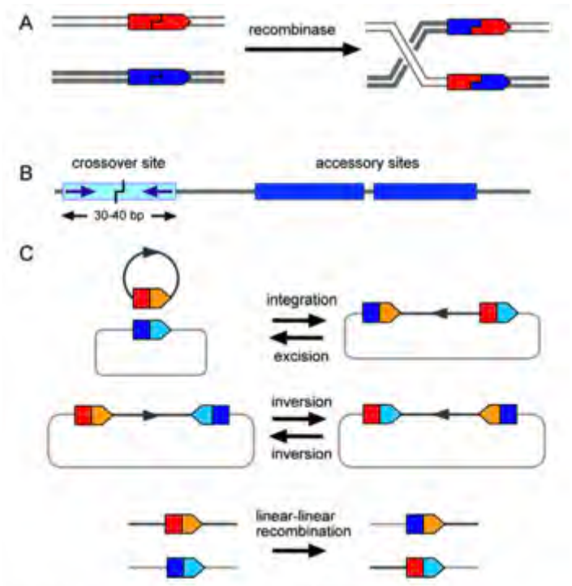
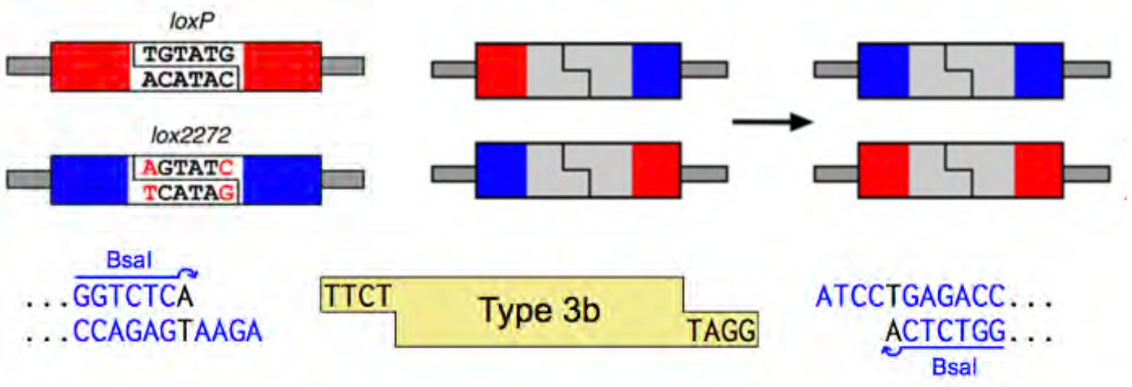
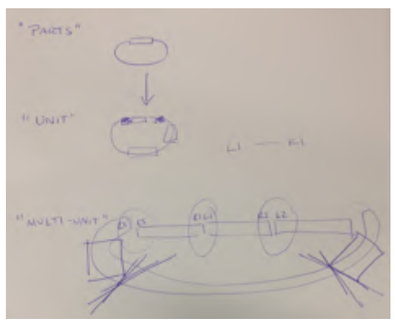
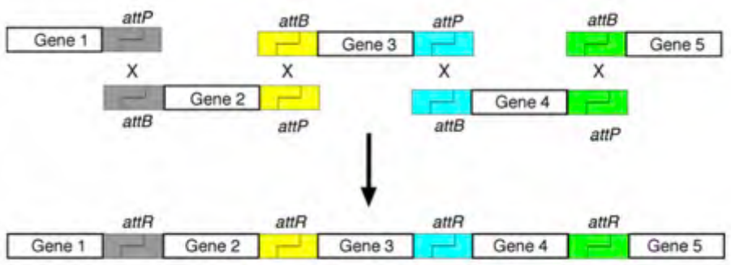


Figure 1 Site-specific recombination: the basics

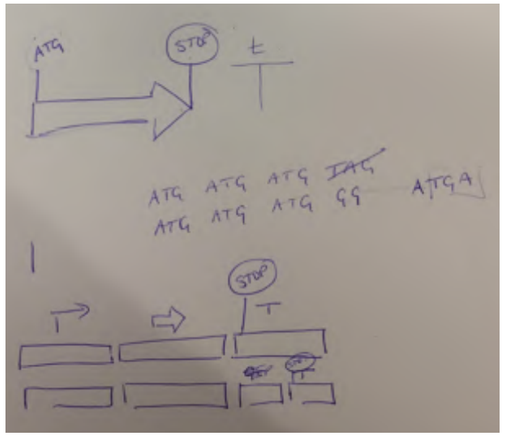
(**A**) SSRs promote cleavage of DNA strands at two sites in the DNA (pointed boxes), rearrange ('swap') the cleaved ends, and rejoin them in the new arrangement. (**B**) A typical recombination site. A crossover site (usually 30–40 bp) (light blue box) with inverted repeat symmetry (indicated by the two arrows) binds an SSR dimer and contains the bonds broken and rejoined by the SSR at its centre. The crossover site may have adjacent accessory sites (darker blue boxes) which bind more subunits of the SSR and/or regulatory proteins. (**C**) Outcomes of site-specific recombination. The events illustrated are discussed in the text.

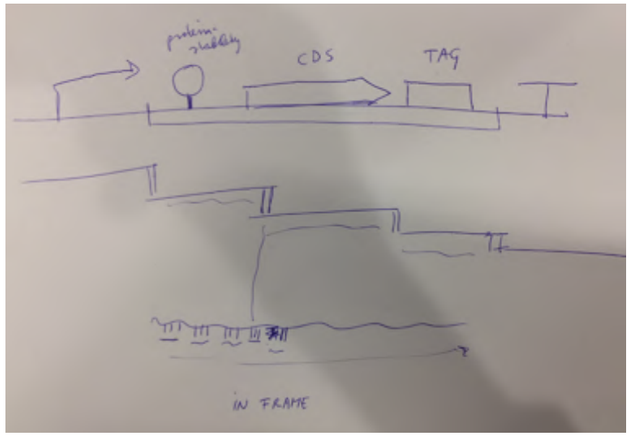






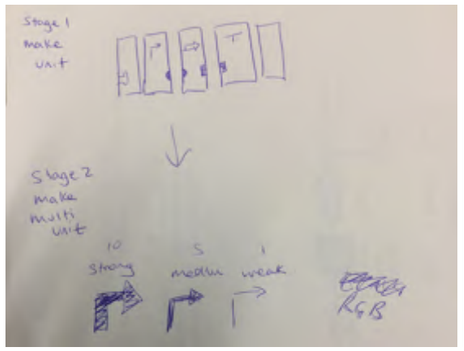
- It would be interesting to see that the sequence is staying in frame when making the assembly in the software. For example that the Stop codon TAG in still in frame when a part is added (ATG is the start Codon)

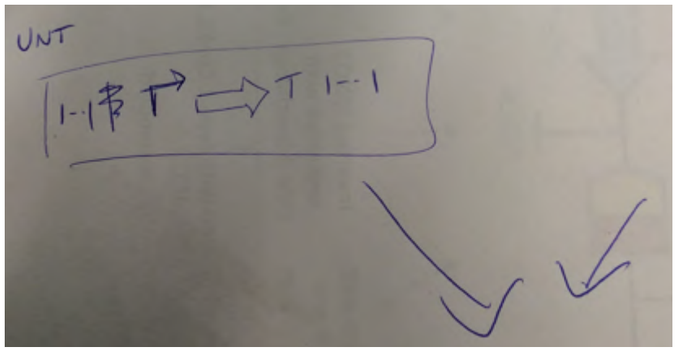




Installation

- Keep it simple : promoter (connector) CDS (connector) Terminator
- We can add the Origins of replication to be duplicated in bacteria + marker such as a drug resistance -> if you add a plasmid into a bacteria, which the bacteria doesn't really need it will not duplicate it: it will abandon it. To be sure it will keep it you need to make sure the plasmid will be necessary for the bacteria. For that, a drug resistance marker is added to the plasmid, and the drug is added into the mix -> the bacteria will not be sensitive to the drug thanks to the plasmid and will keep it and replicate it in the duplication process.
- Need to express the protein
- Idea of a jigsaw
- Using bacteria as an organism to visualise as every biologist use bacteria at some point to duplicate the DNA before introducing into the microorganism of choice.
- Suggestion of emphasising the connectors in the assembly process: the standardisation of assembly method in biology make it similar to the industrial revolution.
- Give instruction to kids : make a turquoise bacteria
the participant will have to make a construct with 2 transcription unit: one with a blue CDS and a strong promoter and one with a yellow CDS and a weaker promoter.
- after checking that the construct is correct (all the LEDs on each blocks are on) use coloured water in different proportion to simulate the creation of turquoise bacteria





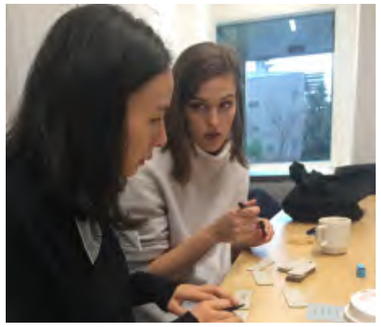
Chantal Shen & Paulina Kanigowska

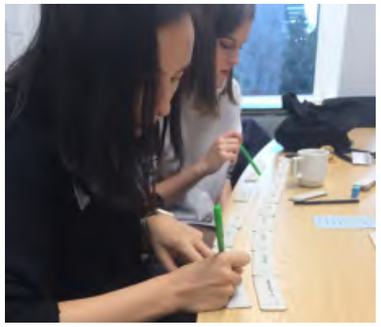
- They both work on yeasts

- Problem with the Sbol: we would not use them alone to explain a construct: we need the names of the parts
- While making the constructs they were talking about what would be the optimal temperature to have a clean cut
- What make the tomato red is the lycopene (bright red carotene and carotenoid pigment and phytochemical found in tomatoes)
- CRTYB & CRTE produce betacarotene
- URA3 : marker to know the plasmid is in the yeast (antibiotic)
- AMP4 : marker for the bacteria (antibiotic)
- Combinatorial assembly allows to get the right balance of the genes with balance of promoters
- Could be good to have 1 bloc = 1 transcription unit (promoter + CDS + terminator)

- They made a construct for a beta carotene pathway. You need multiple CDS to get betacarotene
- In addition to the pathway you need on the plasmid markers to check that the plasmid is in the bacteria as well as ti check if it is in the yeast (it is first add to the bacteria to be duplicated then extracted (miniprep) to be inserted into yeast. So in the plasmid you will have these two bits of construct as markers
- They used a string to make the plasmid backbone
- They made the design evolve, thinking about what they needed to make it viable, moving dominoes around, switching places… which would have been messy or a lot of drawings if it was done in a notebook. Would be interesting to ask to design a construct with pen and paper first and then with the dominoes to see which one is the most efficient as well as if they arrive at the same level of complexity at the end.
- New symbol for Loxpsym Site could be useful

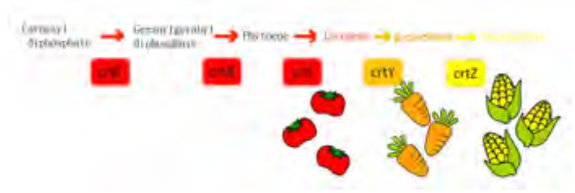




What is in the construct they designed (beta carotene pathway)

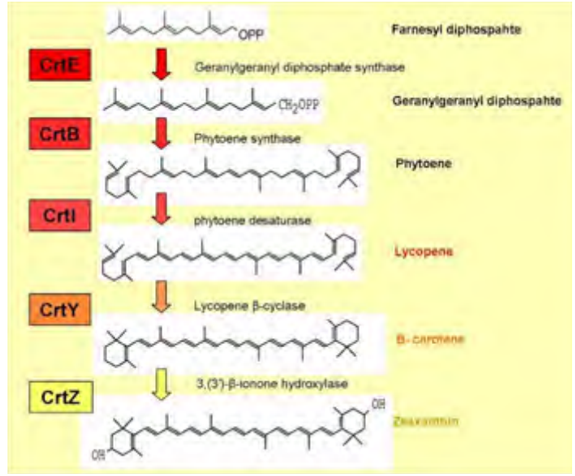
CDS
AMP4 (antibiotique marker)
CRTYB (produce beta carotene)
CRTE (produce beta carotene)
URA3 (antibiotique marker)
CTRI (produce beta carotene)



Restriction site
SmaI (x2) (extraction from the plasmid)

Promoter (chosen randomly)
pURA3
pRNR2
pTEF1
pPGK1
pAmp

Terminator (chosen randomly)
tURA3
tCYC1
tAmp
Terminator 2
Terminator 3



Other
50-100bp Homologous sequence (x2) (yeast integration site)
Loxpsym site (x2) (34bp recombine site induced by Cre)
oriC (propagate in bacteria)
CEN/ARS (propagate in yeast)

In order

SmaI - 50/100bp Homologous sequence - Loxpsym site - pRNR2 - CRTE - Terminator 2 - pTEF1 - CTRI - tCYC1 - pPGK1 - CRTYB - Terminator 3 - Loxpsym site - 50-100bp Homologous sequence - SmaI

pAmp - AMP4 - tAmp

oriC

CEN/ARS

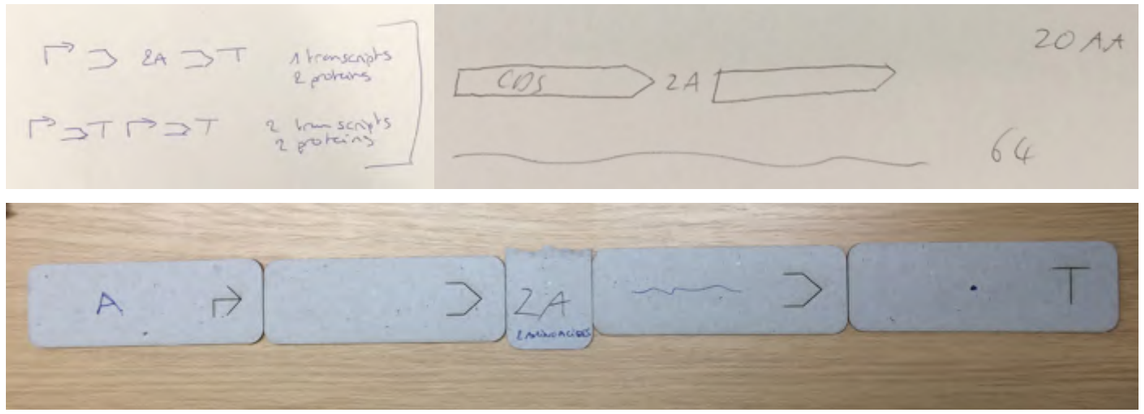
pURA3 - URA3 - tURA3

James Bryson

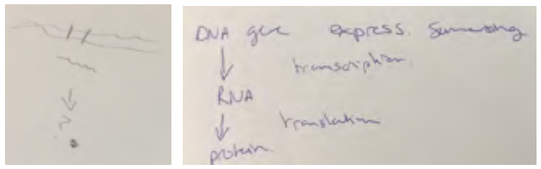
- James works with mammalian cells

- Using LEDs in the coding sequence could be interesting to check if the sequence is correct
- Promoters could be the power source and show the strength : more or less power to show that it is strong, medium, weak…
The weaker it is, the weaker the gene will be expressed.

- 2A -> multicistronique - internal ribosome entry site - it produces :
    - 1 coding sequence
    - 1 single transcript
    - 2 proteins



- The difference between Transcription and Translation are important to explain:
- The DNA is transcribed into RNA
- The RNA is translated into protein



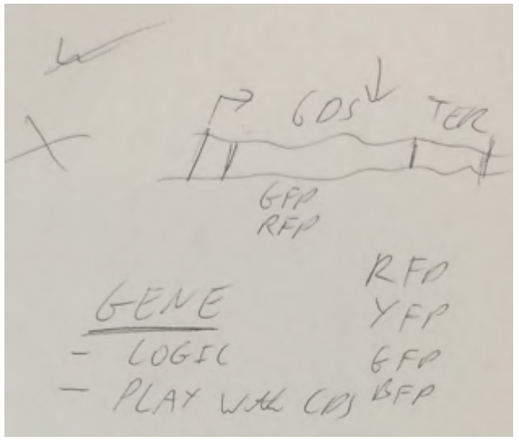
- Concept of the gene : zoom into the gene and explain what is in it:
    - Promoter: start
    - CDS: produce the protein
    - Terminator: stop

- The cards should be magnetised and smaller than the prototypes
- He would be interested to get a library of PNG with the SBOL symbols for his presentations
- Use different colours for -> one per class for the most used ones (promoters, CDS, terminator)

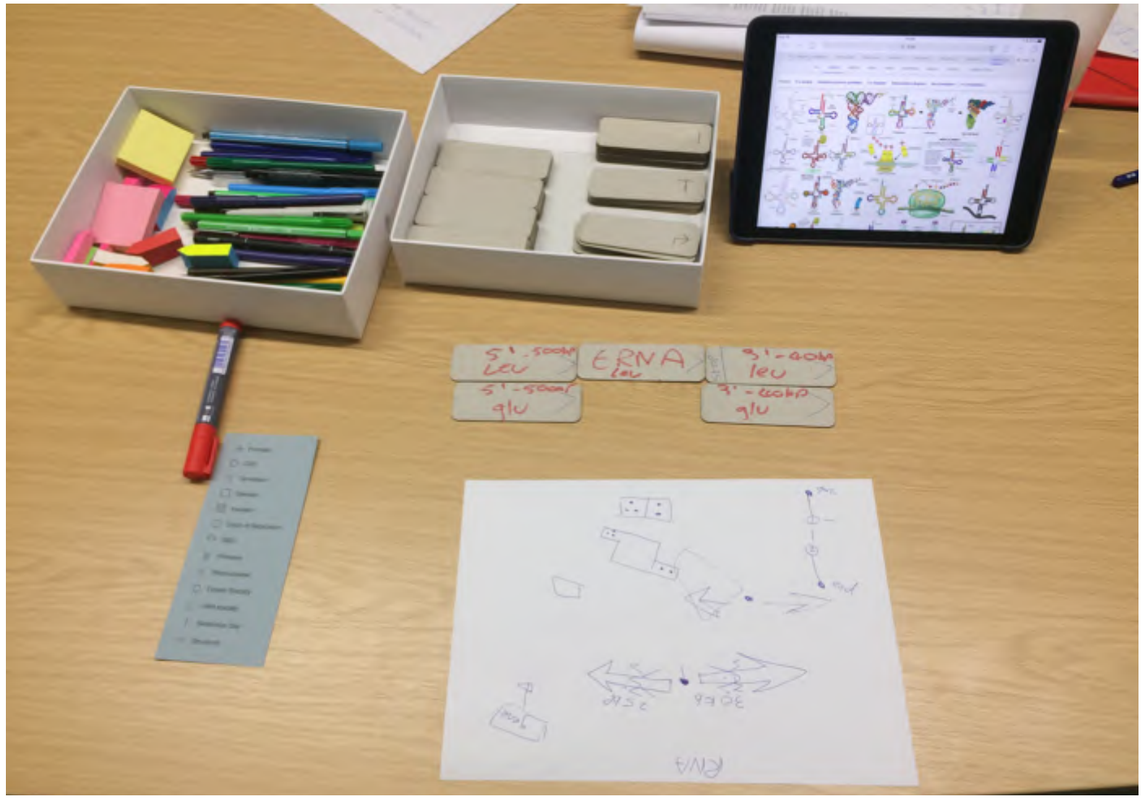
Installation

- It would be interesting to work with people who work with colourful & fluorescent bacterias and yeasts

- possible CDS
    - RFP (red fluorescent proteine)
    - YFP (yellow)
    - GFP (green)
    - BFP (blue)
    - CDS which produce insulin
    - CDS which produce antibodies
    - Artemisinin : antimalarial drug

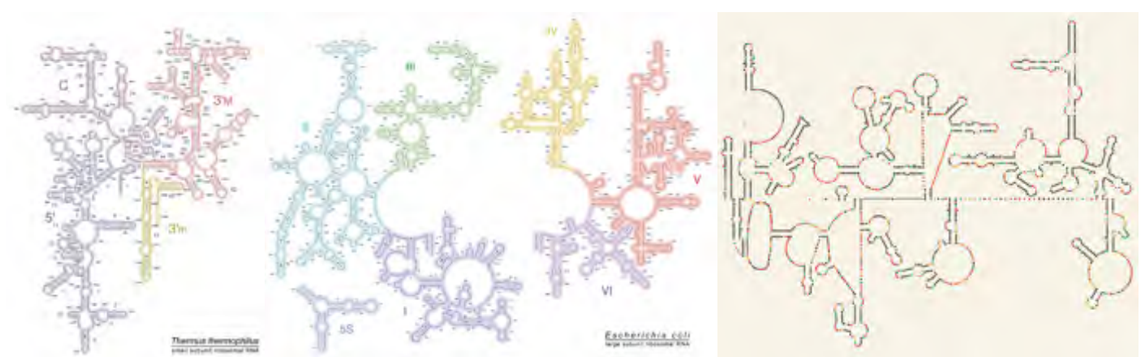


Roy Walker

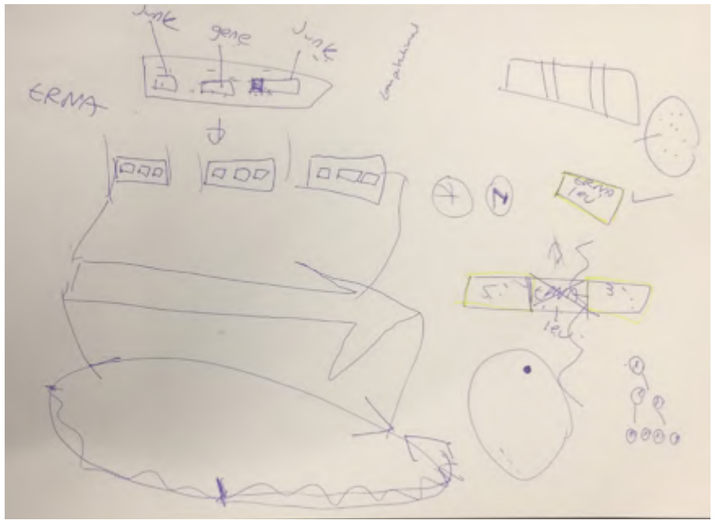


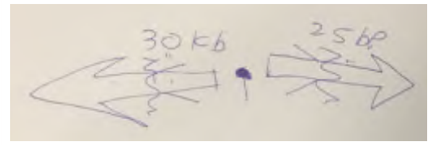
- Roy works with yeasts. He is designing the TRNA chromosome for the synthetic yeast (Sc2.0 project)
- The tRNA gene are doing a work of art in the cells

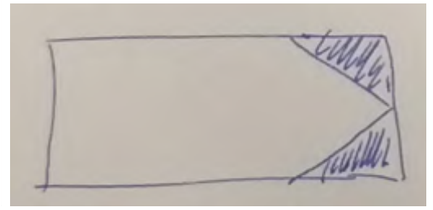
“A transfer RNA (abbreviated tRNA and formerly referred to as sRNA, for soluble RNA) is an adaptor molecule composed of RNA, typically 76 to 90 nucleotides in length, that serves as the physical link between the mRNA and the amino acid sequence of proteins. It does this by carrying an amino acid to the protein synthetic machinery of a cell (ribosome) as directed by a three-nucleotide sequence (codon) in a messenger RNA (mRNA). As such, tRNAs are a necessary component of translation, the biological synthesis of new proteins in accordance with the genetic code.” (Wikipedia)



- Because of the specificity of his project, he would use blank dominoes to sketch his design instead of CDS ones as it is different from the usual : Promoter - CDS - Terminator
In his case the promoter is inside the gene.
- tRNA gene translate tRNA: they are joins - help to join the amino acid into a long chain which form the protein -> they are the workers in a factory.
- a yeast need tRNA to live, however these gene are not very stable, so in the synthetic one they remove all the tRNA from all the chromosomes and one chromosomes with all the tRNA is added, enabling the synthetic yeast to be more stable.
- There is 275 tRNA gene in test which comes in different ‘flavours’: e.g.: tRNA leu -> it might be interesting to determine how many types there is and use different colours for each of them.
- The blocks should be show visually the functions and purpose and designed to be joined togethers
- The bucks need arrows to show the direction : the directions of the gene are very important for this particular project.



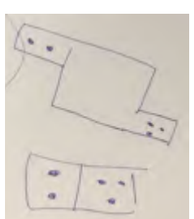


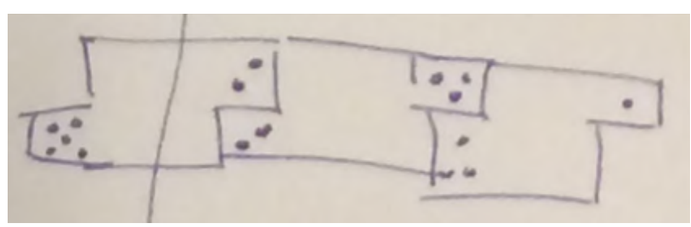


Installation

- possible CDSs
    - orange
    - black / purple
    - change the flavour
    - raspberry flavour

- can be played like a game to explain the grammar : like the common dominoes with dots to join them together



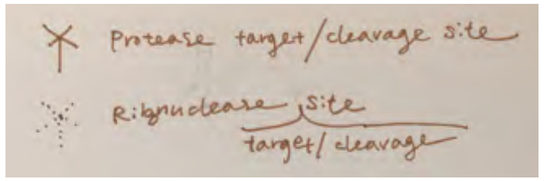


Maddy Seale & Naomi Nakayama

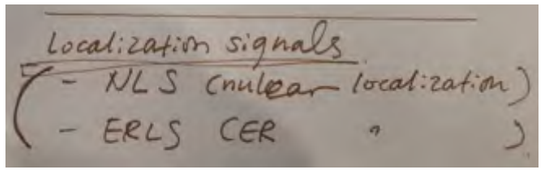
- Maddy and Naomi are working with plants

- They suggested that the colours could correspond to the functionalities in the sequence
- Making blocks with overhangs could be the next steps: the convention is 4 bp, however they suggested that 6 might be better to be sure you stay in frame (codons are made with 3 bp)

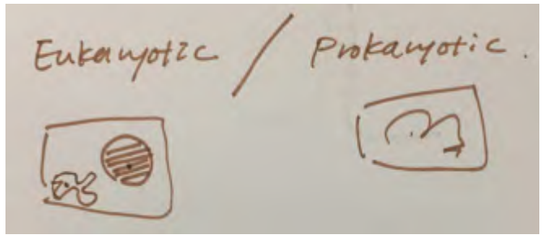
- Protease should be named ‘Protease target site’ and Ribonuclease target site



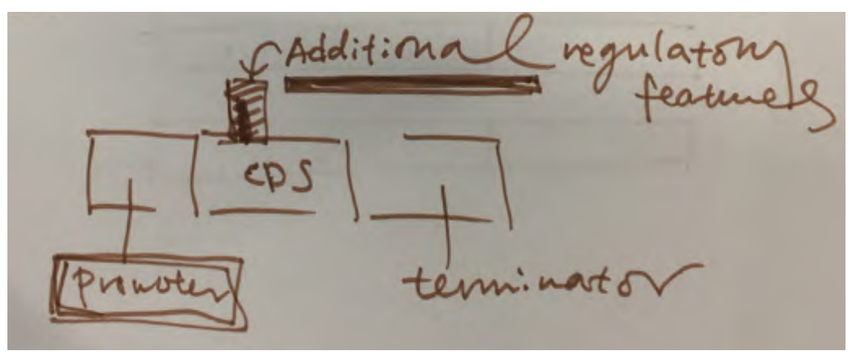
- I could introduce a new symbols
  - ‘Resistance’ : for the antibiotic resistance genes
  - ‘TAG’
  - Localisation signal



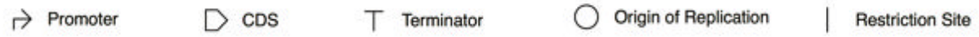
- For plants they would need two different kind of colours depending of the promoters: one for bacteria and one for plants. Some genes in the plasmid will be to be express in the bacteria for the duplication (antibiotic resistance for example) and others will be expressed in the plant. it would be good to make the difference :
  - eukaryotic promoters
  - prokaryotic promoters



- It would be useful to have ‘small’ blocks to visualise part into a part : additional regulatory



feature inside the CDS
- Insulator and Origin of replication are for Bacteria
- It is always tricky to find out how long the promoter should be
- It would be useful to visualise combinatorial using the dominoes (find which promoter for example is the most efficient / appropriate)
- Have a set of disposable cardboard ones could be useful to keep displayed (maybe final version) in the lab
- At first they see it mostly useful for teaching
- For learning the basics need only :



Installation

Some ideas if the organisms to visualise were plants:
- there is a gene in plants that if you remove it the plant become white
- werewolf gene : the roots become very hairy
- a gene to make cauliflower orange
- purple tomatos
- tomatoes and potatoes in the same plant

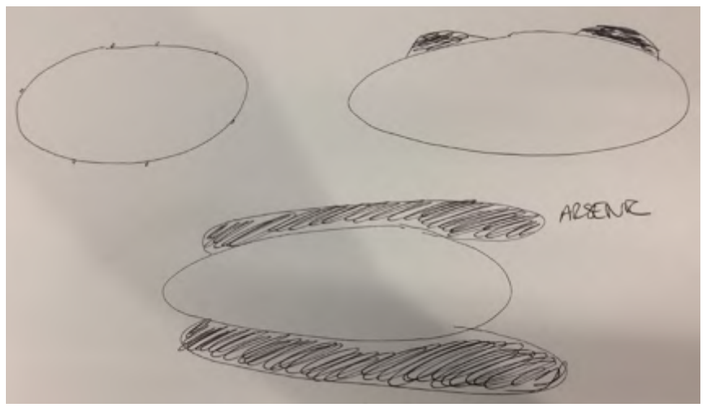
Matthew Edmundson

CL4W project

- Matthew worked on the CL4W project
https://www.youtube.com/watch?v=91ifNd5zonE
CL4W project, engineering bacteria to convert heavy metal waste from contaminated land into industrially and medically useful nanoparticles.
- The aim of the project to use plants as a land remediation technology and to develop an engineered bio-process to produce high value products. This will improve the economic viability of such a clean-up project. So far, the high value products include: metal elements in their nanoparticle forms and organic compounds derived from lingo-cellulose degradation (e.g. DHA). The project is also seeking to convert biomass into a variety of high value products as well as renewable energy.
http://www.core-community.net/partner-projects/cl4w/
- Degrade biomass with the help of fungi and bacteria in order to “unlock” the metals in accumulating plants and at the same time to produce phenol-based chemical building blocks for the pharmaceutical industry and other useful products, like vanillin and ferulic acid.
https://www2.warwick.ac.uk/fac/sci/wmg/research/sustainable_materials_and_manufacturing/projects/cl4w/

Steps of the project (from explanations during the discussion):

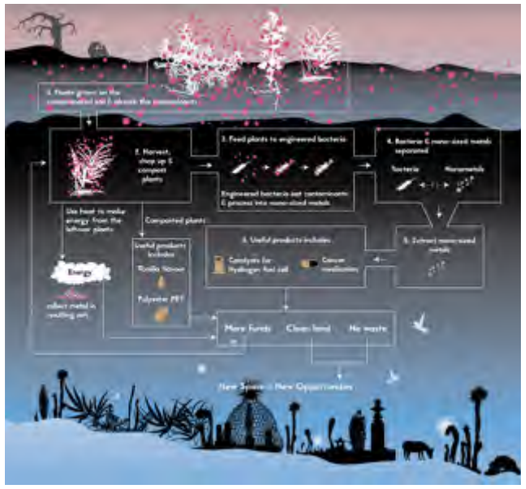
- have a field of non-modified plant growing on a contaminated soil with arsenic (from tin mine)
    - Initial the plants were : Ferns. They can absorb a lot of arsenic, however they are not endemic of UK and grow very slowly
    - Change for sunflower : is should work hypothetically, but have not been done in real. They don’t absorb as much arsenic but grow very fast and are endemic to UK
- Remove the plant and bring them back to the lab
- Degrade the biomass to feed GMO bacteria with will ‘clean’ / get the arsenic
- The design of the bacteria is made by combinatorial design : to find which plasmid and which part is the most efficient to capture the arsenic.



the black ‘bulbs’ around the cell (the bacteria) are arsenic being ‘catch’ by the cell. The more efficient the plasmid introduced into the cell is the more arsenic it will catch: it will look like a ‘hotdog’ (bottom picture).

- an art project “Instruments of the Afterlife” results from the collaboration between scientists from the CL4W project, and art-duo, BurtonNitta.

http://www.core-community.net/partner-projects/cl4w/cl4w-scientists-and-instruments-of-the-afterlife/



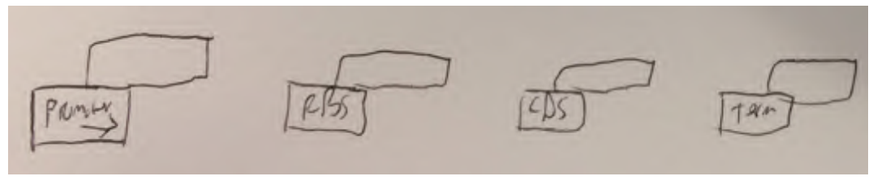
Dominoes

- He said it could be useful to use in the lab to explain things to students, as well as an early design tool (to ‘replace’ or in addition to sketching in the notebook).
- He uses most of the signs in the SBOL apart from

Installation

Matthew did several outreach projects with kid to explain DNA modification / design.
He used lego bricks (see drawing).
The kids had a lot of blocks to play with and had to follow the grammar. He explained it in advance.
When a kid had a functional construct they could SMELL the results. The construct produces where supposed to make the bacteria produced a protein which would have different smell. He had tubes the kids could open to smell the result of their constructs.

- vanilla
- orange
- rose water
- mint
- …



He suggested that to make the modification ‘touchable’ to modify a bacteria to make it ‘slimy’ (make it produce a biofilm).

Other sources

SAM inventor
https://www.samlabs.com/shop/inventor

SAM is the smart construction kit. SAM Blocks connect to the SAM Space app. Each SAM Block has a specific skill : Buzzers, motors, sensors and more. They're wirelessly activated using Bluetooth - to move, illuminate or sound. Program patterns and behaviors using the intuitive SAM Space app.

Radica Cube World Slim & Scoop Interactive Game
https://www.amazon.com/Radica-Cube-World-Scoop-Interactive/dp/B000BFORIK

The world is a cube and its inhabitants are stick people. And these stick people are sticking together in some very fun ways. Single Cube World cubes contain a character and something for that character to play with.
If you prefer being in the game rather than watching from the sidelines, you can choose to interact with each of these characters via built-in motion sensors.
But things get truly interesting when you connect the two cubes together using the magnetic contacts that are on four sides of each cube. The cubes can be placed side by side, or stacked one on top of the other for interactive enjoyment. While both Slim and Scoop have unique animations, once joined together, they will play with, pester, and even protect each other.

DNA double helix
http://www.nobelprize.org/educational/medicine/dna_double_helix/dnahelix.html
http://www.nobelprize.org/educational/medicine/dna_double_helix/help.php?objectname=/educational/medicine/dna_double_helix/

Your job is to first make exact copies of a double-stranded DNA molecule by correctly matching base pairs to each strand, and to then determine which organism the DNA belongs to.
Linkage:

A DNA Card Game
https://boardgamegeek.com/boardgame/157586/linkage-dna-card-game
https://gotgeniusgames.com/linkage/

Linkage is competitive card game that is simple to learn, yet offers lots of depth, forward thinking and replay-ability for 2 to 4 players. But best of all, Linkage was designed and themed around a process normally taught in high school biology, DNA Transcription, (when an RNA copy is made from DNA for protein synthesis or other in a cell) and in this way offers a unique, engaging and tactile experience for someone to familiarise themselves with this fundamental concept of biology.

In Linkage, each player links RNA cards side-by-side to build their own RNA strand, attempting to copy the shared DNA Template (in biology, this process of copying is called DNA Transcription). Players decide whether to Build on their own RNA strand, Repair their RNA strand, or Mutate an opposing strand (or the template itself.) Players earn points based upon how accurately their RNA strands match the DNA Template, and the player with the most points at the end of the game wins!

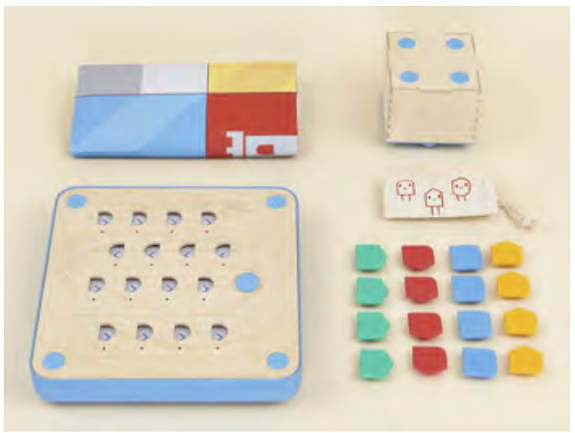
Osmo Creative Game Kit for iPad
http://www.apple.com/shop/product/HK812ZM/A/osmo-creative-game-kit-for-ipad?fnode=a1
http://www.apple.com/shop/product/HJCP2ZM/B/osmo-genius-kit-game-system-for-ipad?fnode=a1
https://www.playosmo.com/en/coding/

Osmo is a unique educational gaming accessory that opens up your iPad to the infinite possibilities of physical play. Crafted with reflective artificial intelligence, Osmo's advanced technology bridges the real and digital realms.



Cubetto
https://www.kickstarter.com/projects/primotoys/cubetto-hands-on-coding-for-girls-and-boys-aged-3
https://www.primotoys.com

A playful programming language you can touch. Montessori approved, and LOGO Turtle inspired. Learn programming away from the screen.
Cubetto Made of tactile and hard-wearing wood he's your child's guide into the world of coding. Coding Blocks A coding language you can touch and manipulate like LEGO®. Each block is an action. Combine them to create programs. Control Board Place the blocks on the board to tell Cubetto where to go. Hit the blue button and Cubetto executes your very first program.



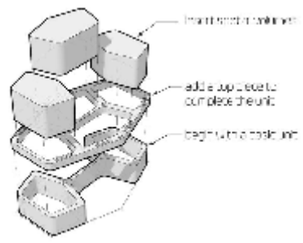

Jungle Speed
https://en.wikipedia.org/wiki/Jungle_Speed

The game revolves around matching cards with identical symbols, and it has some similarities to the game Snap. The similarities between some of the symbols, as well as some of the extra rules, make the game rather challenging. (association by colour and shape)



Conceptual puzzles
http://www.autodesk.com/artist-in-residence/projects/conceptual-puzzles

The Open Source Learning Lab Kit is a conceptual tool for the design of collaborative learning environments. Developed with a renewed sense of craft through digital fabrication, the Open Source Learning Lab Kit is intended to provoke curiosity, desire and delight in making spatial discoveries through a sense of play. How might this play expand our sense of the environment and its influence on learning?




General reports

Kit for the labs

General
- The 4 base pairs overlaps are important in the design process.
- Combinatorial assembly allows to get the right balance of the genes with balance of promoters
- Designs evolve during the ‘workshop’, thinking about what they needed to make it viable, moving dominoes around, switching places…
- Protease should be named ‘Protease target site’ and Ribonuclease target site

Kits
- A ‘basic set’ of simple blocks
- (Promoter - CDS - Terminator - Origin of replication - Restriction site - Blank)
- Could be good to have 1 bloc = 1 transcription unit (promoter + CDS + terminator)
- New symbols for
- Loxpsym Site
- ‘Resistance’ : for the antibiotic resistance genes
- ‘TAG’
- Localisation signal
- A set for Golden Gate assembly (4 bp overlaps on each side (left side : up - right side : down)
- A set for Gibson assembly (an overlap of the on each side of the sequence)
- TOOLKITS (library of standard parts already written on the dominos)
- EMMA
- Yeastfab
- MoClo toolkit

Design
- Could be interesting to write on the domino the name of the parts and be able to reuse them (use glass or plastic ones)
- The size of promoters and terminators are important, they should either be smaller than a CDS to represent the reality or all the pieces should be the same size to avoid confusion (do not reproduce the random length of the glass dominoes)
- For plants or yeasts… they would find useful to have 2 different kind of colours depending of the promoters: one for bacteria and one for plants. Some genes in the plasmid will be to be express in the bacteria for the duplication (antibiotic resistance for example) and others will be expressed in the plant. it would be good to make the difference
- Use magnets at the back to work on a white board
- Show the strength of the promoters has a strength
- The cards should be smaller than the prototypes
- Use different colours for -> one per class for the most used ones (promoters, CDS, terminator)
- For some particular projects, the blocks need arrows to show the direction
- It would be useful to have ‘small’ blocks to visualise part into a part : additional regulatory feature inside the CDS

Purpose
- To communicate and collaborate on the design of new constructs.
- It would be useful to visualise combinatorial using the dominoes (find which promoter for example is the most efficient / appropriate)
- As an early design tool (to ‘replace’ or in addition to sketching in the notebook)
- Useful for teaching

Public installation

General
- Importance of the logic
- Importance to choose carefully the chassis to convey the correct and accessible message
- Keep it simple for beginners (promoter - CDS - terminator)
- Promoter: start
- CDS: produce the protein
- Terminator: stop
- Try to convey the process : The DNA (2 strains) is transcribed into RNA (1strain) which will then be translate into a protein
- The difference between Transcription and Translation are important to explain:
- The DNA is transcribed into RNA
- The RNA is translated into protein
- Explain that some methods act like glue to stick the parts together, then they are put in bacteria to be duplicated and then it is extracted to be inserted inside the host organism (e.g.: yeast, plant…)
- A promoter has a strength : it can be strong, medium, weak… to get the gene to express ‘a lot’ you need to have a strong promoter in front, if it is a weak one the gene we not express much.

- We can add the Origins of replication to be duplicated in bacteria + marker such as a drug resistance -> if you add a plasmid into a bacteria, which the bacteria doesn’t really need it will not duplicate it: it will abandon it. To be sure it will keep it you need to make sure the plasmid will be necessary for the bacteria. For that, a drug resistance marker is added to the plasmid, and the drug is added into the mix -> the bacteria will not be sensitive to the drug thanks to the plasmid and will keep it and replicate it in the duplication process.
- Convey the idea of the just right: right amount of production-> if the promoter is too strong the gene might produce too much of one protein which would inhibit another function-> the goal would be to find the right balance between the elements. (which would recall with the general idea about synthetic biology: not all good all bad, but find the just right balance between what will be beneficial and what will have harmful consequences.) It is linked to the concept of Traide-off: when a cell is becoming not happy
A trade-off (or tradeoff) is a situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. More colloquially, if one thing increases, some other thing must decrease. In biology and microbiology, tradeoffs occur when a beneficial change in one trait is linked to a detrimental change in another trait.

Design
- Uses colour coded parts to explain ‘the grammar’ and snaps with magnet
- The best way to make the grammar explicit would be to use either symbols to link the blocks together or pieces similar to jigsaw’s ones.
- The surface around could conduct electricity
- Using LEDs in the coding sequence could be interesting to check if the sequence is correct
- A wire could represent the plasmid and when physically connected to the pieces it will light up the sequence if it is correct
- Developing dominoes with ‘power’/‘points’ and the player need to find the right balance to make it viable (concept of trade-off).
- Give instruction to kids : make a turquoise bacteria -> the participant will have to make a construct with 2 transcription unit: one with a blue CDS and a strong promoter and one with a yellow CDS and a weaker promoter. After checking that the construct is correct (all the LEDs on each blocks are on) use coloured water in different proportion to simulate the creation of turquoise bacterias

- Promoters could be the power source and show the strength : more or less power to show that it is strong, medium, weak… The weaker it is, the weaker the gene will be expressed.
- When a functional construct is assembled, the user could SMELL the results. The construct produces where supposed to make the bacterias produced a protein which would have different smell: open tubes to smell the result of their constructs.

Grammar
- An operator can be either before or after a promoter
- promoter - CDS - terminator

Chassis and possible CDS

YEASTS
- change colour
- EGFP (green fluorescent protein)
- mCherry (red fluorescent protein)
- CRTYB & CRTE & CTRI produce betacarotene: orange (You need multiple CDS to get betacarotene)
- black / purple
- produce different smell by producing different protein
- vanillin
- raspberry
- organe
- rose water
- mint
- other
- CDS which produce insulin
- CDS which produce antibodies
- Artemisinin : antimalarial drug

BACTERIAS
- make it ‘slimy’ (make it produce a biofilm)
- change colour
- RFP (red fluorescent protein)
- YFP (yellow)
- GFP (green)
- BFP (blue)

PLANTS
- bioluminescent
- the red in tomato is due to the lycopene
- there is a gene in plants that if you remove it the plant become white
- werewolf gene : the roots become very hairy
- a gene to make cauliflower orange
- purple tomatoes
- tomatoes and potatoes in the same plant

Functionalities for Genetic Constructors

- It would be great to have a checking in the software when a sequence is uploaded : is it the correct order, the sequence is correctly assemble, it is still in frame…
- The assembly method is important and the design of the sequence will be different from one methods to the other (number of overhang from one sequence to the other…) being able to tell the software which methods not at the order but at the beginning of the design would be useful to help generating the sequence automatically
- They would like to be able to get the label they wrote on the parts directly into the software.
- They think it would be useful to get the translation into amino acid with one click
- The following informations for a part would be useful to get into the software: pb size, restriction sites, alignment, characterised properties (of promoters, terminators…)
- It would be useful to highlight when a similar sequence is in two different (or more) positions in the plasmid.
- It would be useful to have the possibility to see the result of a site specific recombination in the sequence.
- It would be interesting to see that the sequence is staying in frame when making the assembly in the software. For example that the Stop codon TAG in still in frame when a part is added (ATG is the start Codon)

Tales of Synthetic Biology

Initial proposal - interactive installation

Interactive installation based on the Genetic Constructor Dominoes, visitors could experience in real time the principles of DNA design. They could combine the pieces together implemented with magnets and electronics circuit validating the grammar. If the sequence is correct LED would light up and a visualisation would appear on the screen.
Faced with the challenge of designing a microorganism, they will become familiar with the grammar of DNA represented by the different pieces, but also what are the limitations and difficulties of modifying living organisms.

A wire could represent the plasmid and when physically connected to the pieces it will light up the sequence if it is correct.
OR
Promoters could be the power source and show the strength : more or less power to show that it is strong, medium, weak… The weaker it is, the weaker the gene will be expressed.

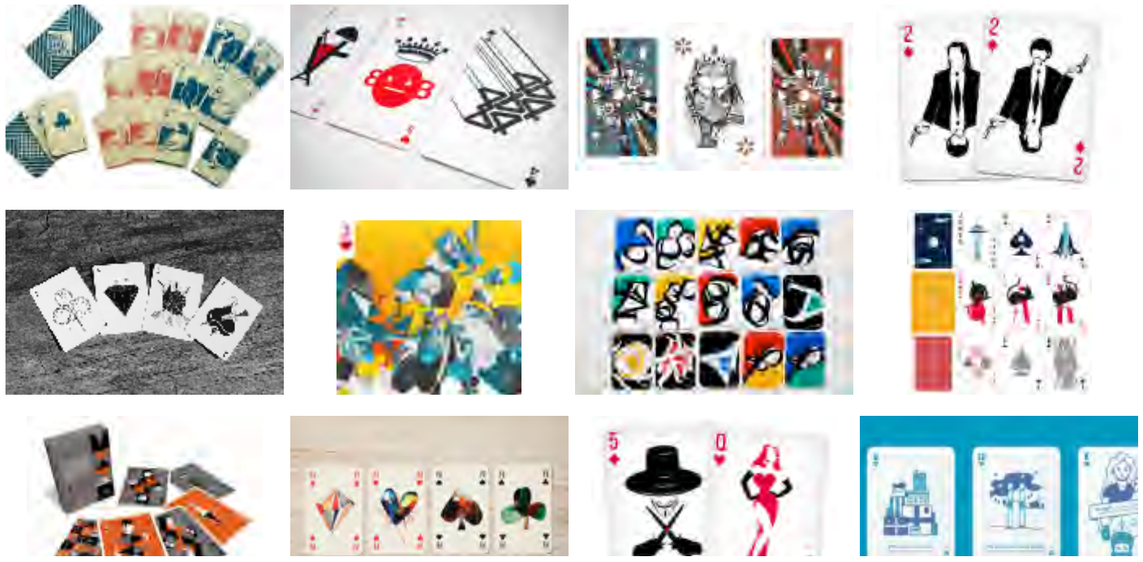
Other possibility of 'visualisation' : when a functional construct is assembled, the user could SMELL the results. The construct produces where supposed to make the bacterias produced a protein which would have different smell: open tubes to smell the result of their constructs.

Low-tech interactive installation - synthetic cards

I imagined an installation composed of cards, inspired by traditional card games, that visitors could use to 'create' personalised engineered 'thing'. They first would have to choose an 'organisms' and then create a sequence with : a promoter - CDS(s) - terminator ; and finally explain the story behind their creation. The result will be displayed on a wall next to the table specially designed to create these personalised GMO, introducing to the DNA grammar.

The blank card asking to tell the story of the designed organism would also encouraged to reflect on the positives and negative sides of such creation and more generally the positives and negatives outcomes of synthetic biology. It would give both insights of what the general public inspirations for synthetic biology are, what are the fantasy ideas and a vision of the hopes and fears of the society.

Inspiration



Using the format and codes of traditional playing cards recall
- the idea of playing with life
- the fact that getting a design / pathway which actually works can be based on luck (similar to winning a game) due to the current limitation of understanding of genomes

Initial extended list of cards

CDS

- blank
- EGFP (green fluorescent protein)
- mCherry (red fluorescent protein)
- CRTYB & CRTE & CTRI produce betacarotene : orange (You need multiple CDS to get betacarotene)
- RFP (red fluorescent protein)
- YFP (yellow)
- GFP (green)
- BFP (blue)
- lycopene (red in tomato)
- orange (in cauliflower)
- violacein (black / purple)
- produce different smell by producing different protein
- smell vanillin
- smell raspberry
- smell orange
- smell rose water
- smell mint
- produce insulin
- produce antibodies
- produce Artemisinin : antimalarial drug
- make it 'slimy' (make it produce a biofilm)
- bioluminescent
- werewolf gene : the roots become very hairy

From iGem parts

Biosafety: Parts and devices improving biological containment.

Biosynthesis: Parts involved in the production or degradation of chemicals and metabolites are listed here.
- produce plastic
- produce B-carotene

Cell-cell signalling and quorum sensing: Parts involved in intercellular signalling and quorum sensing between bacteria.

Cell death*:* Parts involved in killing cells. Lysis refers to the breaking down of the membrane of a cell, often by viral, enzymic, or osmotic) mechanisms that compromise its integrity.
- Lambda phage lysis device
- Lactose inducible lysis cassette expression
- S.aureus killing device.

Coliroid*:* Parts involved in taking a bacterial photograph.
The system consists of a synthetic sensor kinase that allows a lawn of bacteria to function as a biological film, such that the projection of a pattern of light onto the bacteria produces a high-definition (about 100 megapixels per square inch), two-dimensional chemical image.
- Red light biosensor
- Light responsive system

Conjugation: Parts involved in DNA conjugation between bacteria.

Motility and chemotaxis: Parts involved in motility or chemotaxis of cells.
- Speed control device (pLacI-rbs-TetR-terminator-ptet-rbs-chez_his-double terminators)
- Biofilm formation device
- Motility protein B also known as MotB is a bacterial protein that is encoded by the motB gene. It's a component of the flagellar motor

Odour production and sensing: Parts the produce or sense odorants.
- SAM:salicylic acid carboxyl methyltransferase; converts salicylic acid to methyl salicylate (Wintergreen, group of aromatic plants)
- SAM:benzoic acid carboxyl methyltransferase; converts benzoic acid to methyl benzoate (floral odor)
- SAM:jasmonic acid carboxyl methyltransferase; converts jasmonic acid to jasmine odor
- alcohol acetyltransferase I; converts isoamyl alcohol to isoamyl acetate (banana odor)
- Synthetic periplasmic binding protein that docks a vanillin molecule

HISTORY

- blank card to tell the story
- implications
- + sides and - sides

PROMOTER

- weak
- medium
- strong

TERMINATOR

- terminator

ORGANISMS

- blank

Human
- your tongue
- your feet
- your hands
- your eyes
- your ears
- your heart
- your brain
- your lungs
- your bones
- your blood
- your hairs

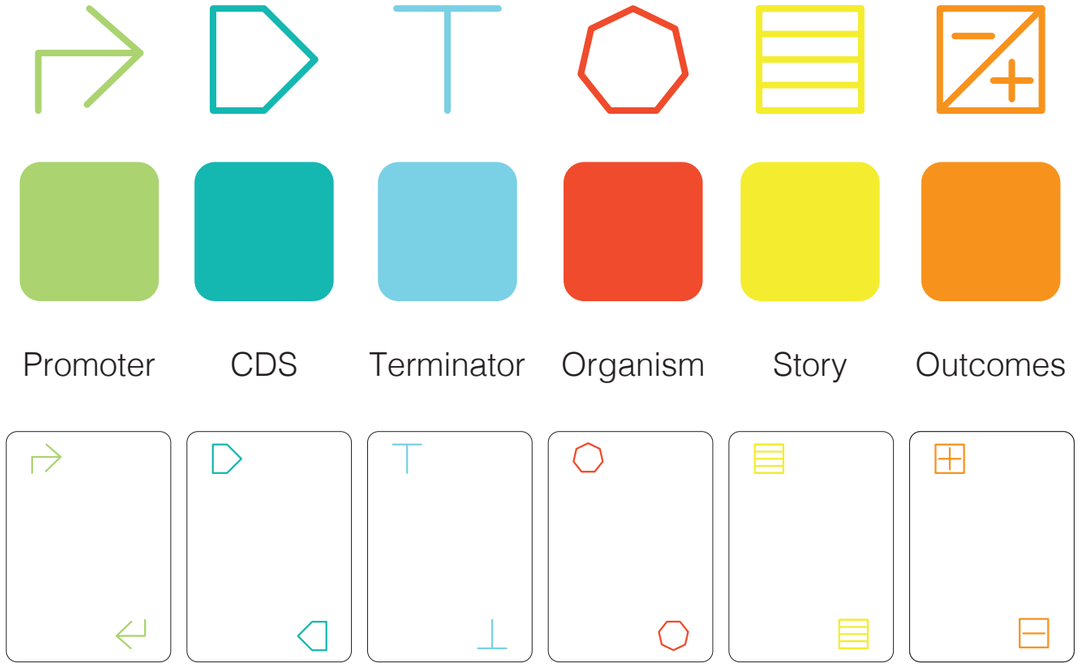
Plants / trees
- olive tree
- bamboo
- birch
- coffee plant
- cotton plant
- daisy
- eucalyptus
- ferns
- ivy
- lilac
- maple
- oak tree
- parsley
- mint
- thistle
- violet
- walnut tree
- wheat
- rose
- cactus

Food
- beef
- pork
- chicken
- corn
- rice
- pasta
- apple
- carote
- banana
- lemon
- potato
- cauliflower
- cabbage
- onion
- raisin
- orange
- tomato
- avocado
- garlic
- mushroom
- nuts
- milk
- cheddar
- mozzarella
- eggs
- prawn
- smoked salmon
- sardine
- chocolat
- sugar
- pepper
- curry

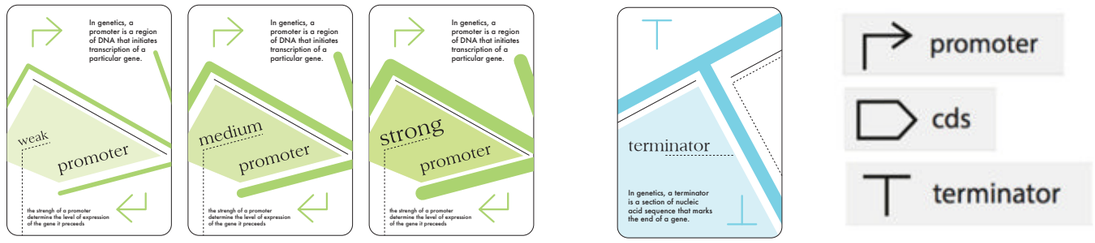
Microorganisms
- yeast
- Ecoli
- fungi
- algae

Animals
- fly
- dog
- cat
- cow
- pony / horse
- monkey
- elephant
- pigeon
- earthworm
- penguin
- frog
- ant
- fox
- butterfly
- dolphin
- duck
- giraffe
- mouse
- snake
- honey bee
- hamster
- lion
- tiger
- koala
- panda
- octopus
- prawn
- pig
- peacock
- rabbit
- snail
- zebra
- turtle
- eagle
- seagull
- salmon
- whale
- dear
- jellyfish

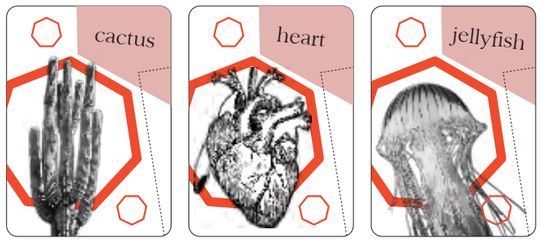
Design of the cards - version 1



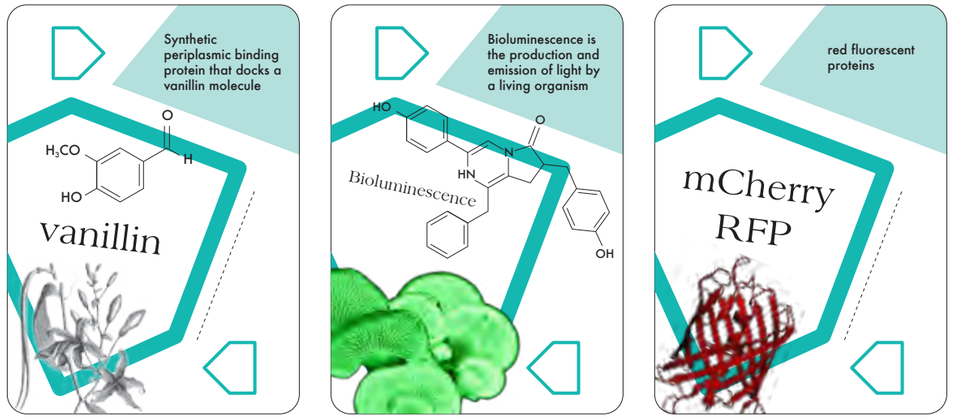
The pictograms for the Promoter - CDS - Terminator are based on the Sbol symbols



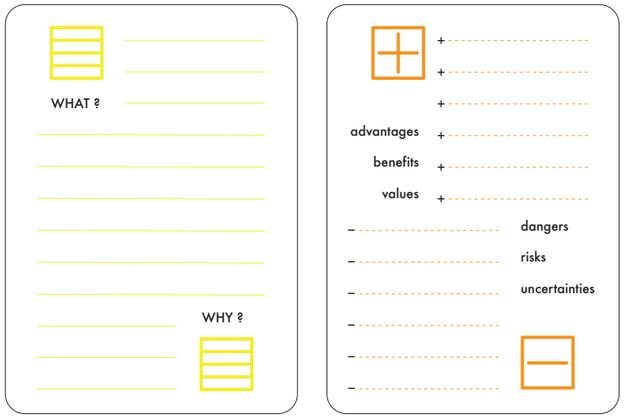
The organism symbol represents the 7 model organisms used in scientific research.



The CDS are presented with there scientific name, definition and coloured illustration.



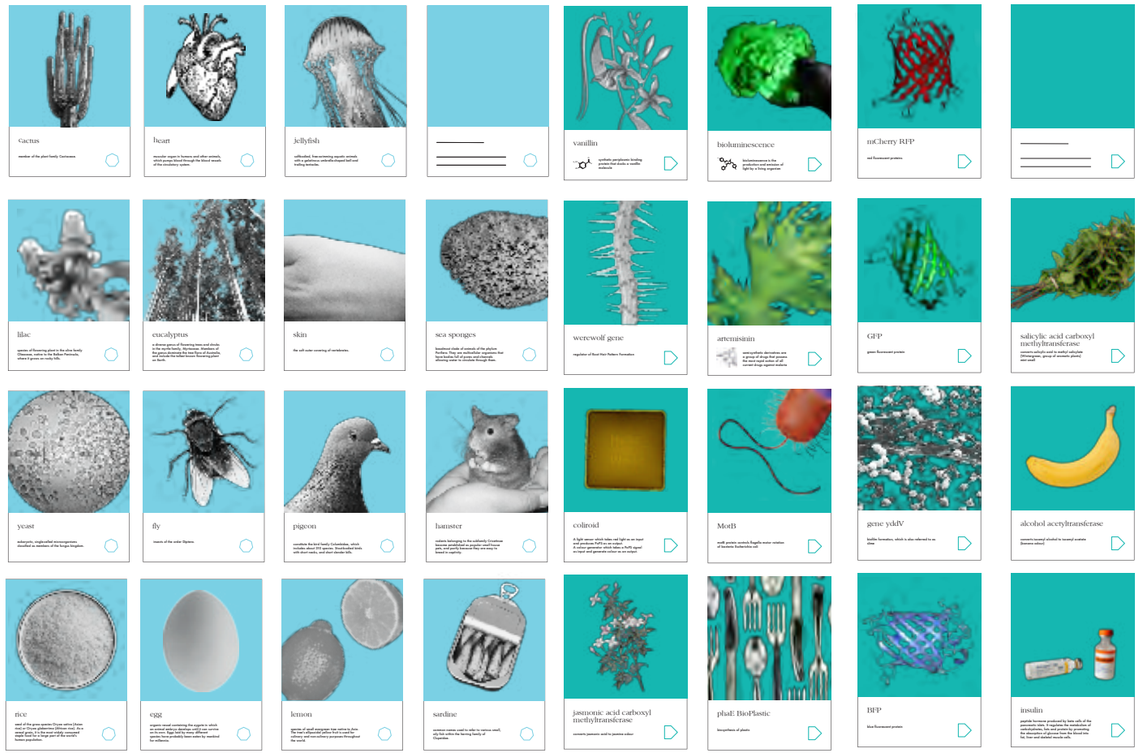
The Story symbol represents a notebook & the Outcomes the negative and positive sides.



Design of the cards - version 2

The previous design was not adapted for an installation : the cards were too small to be readable from far and to include all the information necessary to make it informative and understandable. I redesigned them with a postcard format, the picture occupying most of the space, making it very visual.

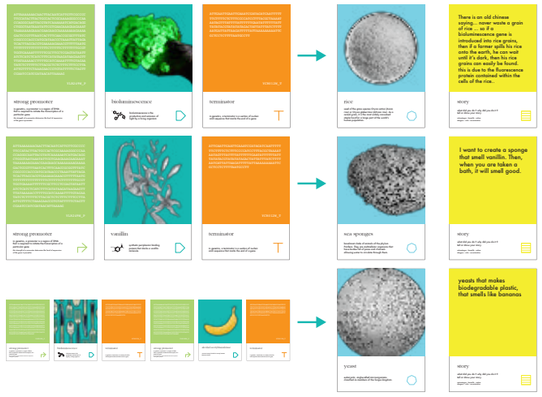
The promoters and terminators are real ones, with their respective sequences, recalling the reality behind the fictional exercise. The organisms are in B&W, in order to foster imagination on the colours, smell, or even form. However the CDSs are in colours, to give visual clues of the nature of the function (change of colour, movement, smell...)



Test of the paper prototype

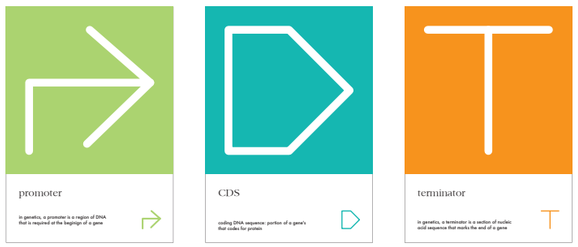
I have tested the prototype on 20 people from designers, artists, biologists, engineers, technicians... It has been well received and generally people spend more than 5 min to choose their cards, going through them and thinking about their design. In few cases they designed more than one construct (3 people). Easily, they get caught up in the spirit of the activity.

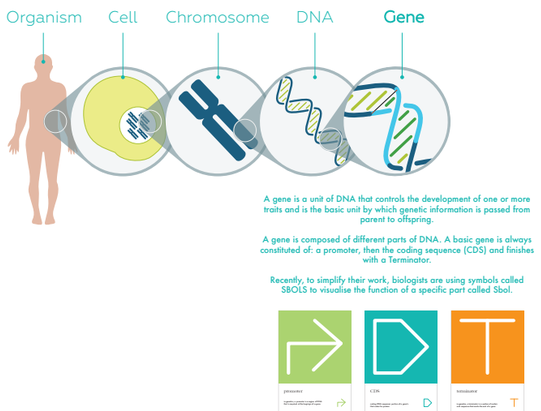
Trying it with scientists allowed me to test the accuracy of the cards, and gave me ideas to create new ones. On the other hand, trying it with non-scientists made me realise some of the complexity of the concept and the fact that I will have to adapt my explanations, but also the design of the cards to make them more accessible. After having one of the participant struggled with the concept, I designed some boards to give instructions, some examples and explain basic biology for the rest of the experience.



1 - CHOOSE AN ORGANISM

2 - CREATE A GENE YOU WOULD LIKE TO IMPLEMENT IN YOUR ORGANISM TO MODIFY IT





2 - TELL YOUR STORY

General feedback and comments

Explanations / design / interactions

- multiple TU (transcription unit) to make more complex organisms: give examples of constructs with one TU and some with multiple one to foster imagination and show the wide range of possibilities
- even if the template has been printed it happen few times that the cards were not positioned on the correct order, or they were choosing only the organism and the CDS without making the complete sequence.
- few participants suggested that the scientific name of the CDS were too complex and not meaningful. Same with some of the definitions: the world gene, transcription, GMO...
These concepts have to be explained with simple words.
- need to explain to non-biologists that the sequence created would be introduced into the cell of the organism of their choice in order to modify it. Contrary of some assumption, it was not trivial and biology principles had to be clarify few times.
A very clear / easy explanation about the sequence was necessary, such as : you have a sequence of DNA which code for a particular aspect or function of your chosen organism. A gene is composed of different parts: promoter - CDS - terminator. It needs them all in this particular order to express in the cell. This sequence of DNA you have created is introduced into your organism, which will modify it. What would you like to create and why ? Tell me your story. Then ask about the possible consequences (positive or negative) of such creation.
- possibility to inhibit a gene : suggestion to represent it by returning the CDS card upside down
- explanation of the cards bigger

***Different* approach to the activity:**
- random choice of cards then invent a story from it
- choice because of the aesthetics then invent a story from it
- examining all the cards, pre selection along the process, then make association to build a thoughtful story (did not have an idea before looking at the cards)
- have an idea in mind and create the cards necessary for it
- have a vague idea and try to find the cards which are related to the idea and develop the story from that
- write a story without making a sequence

***General* comment about the activity**
- “this is the kind of world I would like to live in” talking about the modularity of synthetic biology
- “it was a fun game”
- “I didn’t think it through before choosing the cards”
- “it was cool, what are you looking for doing this kind of activity ?”
- “it is not easy, I don’t have any idea, and I don’t really understand it”
- “ho, I hate the hamster... wait the jellyfish is awesome”

New cards created or suggested
- find CDS of coconut smell
- create CDS inspired by the properties of the organisms cards (or find a way to suggest it to the participants so they create their own CDSs.
- cration of a laser cell using GFP

Promoters
- inducible promoter -> induces the transcription of a gene in the presence of a particular compound

Organisms
- nuts
- dino
- face microbiota

CDS
- oudorless
- cactus needle
- cod flavour (to replace sardine one)
- dracula gene
- onion smell

***Categorise* the stories by:**
- bring something to society
- bring something to individual
- for pleasure
- because it could be pleasant
- new treatment / treat disease
- new way of administrating treatment
- just because it is fun
- something dangerous / harmful
- because it would be beautiful
- because it would be useful
- pure fantasy . science fiction

Who *would* be the user
- European
- American
- African
- Asian
- South American
- Elite
- Upper class
- Middle class
- Lower class
- Third world

Layers of the activity
- learn about the modularity of synthetic biology
- learn about the grammar genetics
- learning about principles of designing DNA
- foster imagination
- insights on what the general public would find interesting
- insights on what are the needs or desires
- encourage to think about consequences (positive or negative): develop criticality
- encourage about the values affected or developed with the rise of synthetic biology

Design of the installation - version 1

Material for installation

To be completed

- table top
- MDF boards (x6)
- length of wood (for the structure of the panels)
- small length of wood (for holding the cards)
- paint
- 2 stools
- cards printed
- pens
- pens pot
- stickers for explanation
- boxes for the cards

Budget

To be completed

≈ £300 the structure
≈ £200 tab Grabbers
≈ £200 graphics
≈ £250 for 1000 postcards (from moo)

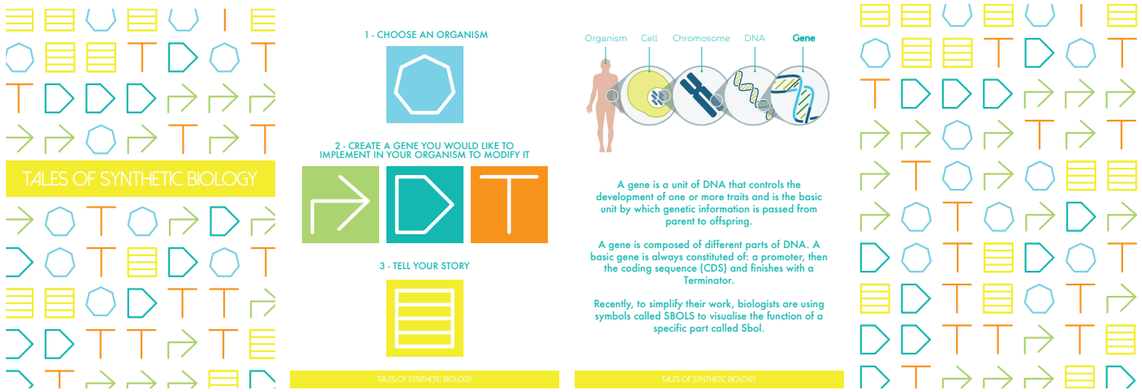
“Tales of synthetic biology” - Results

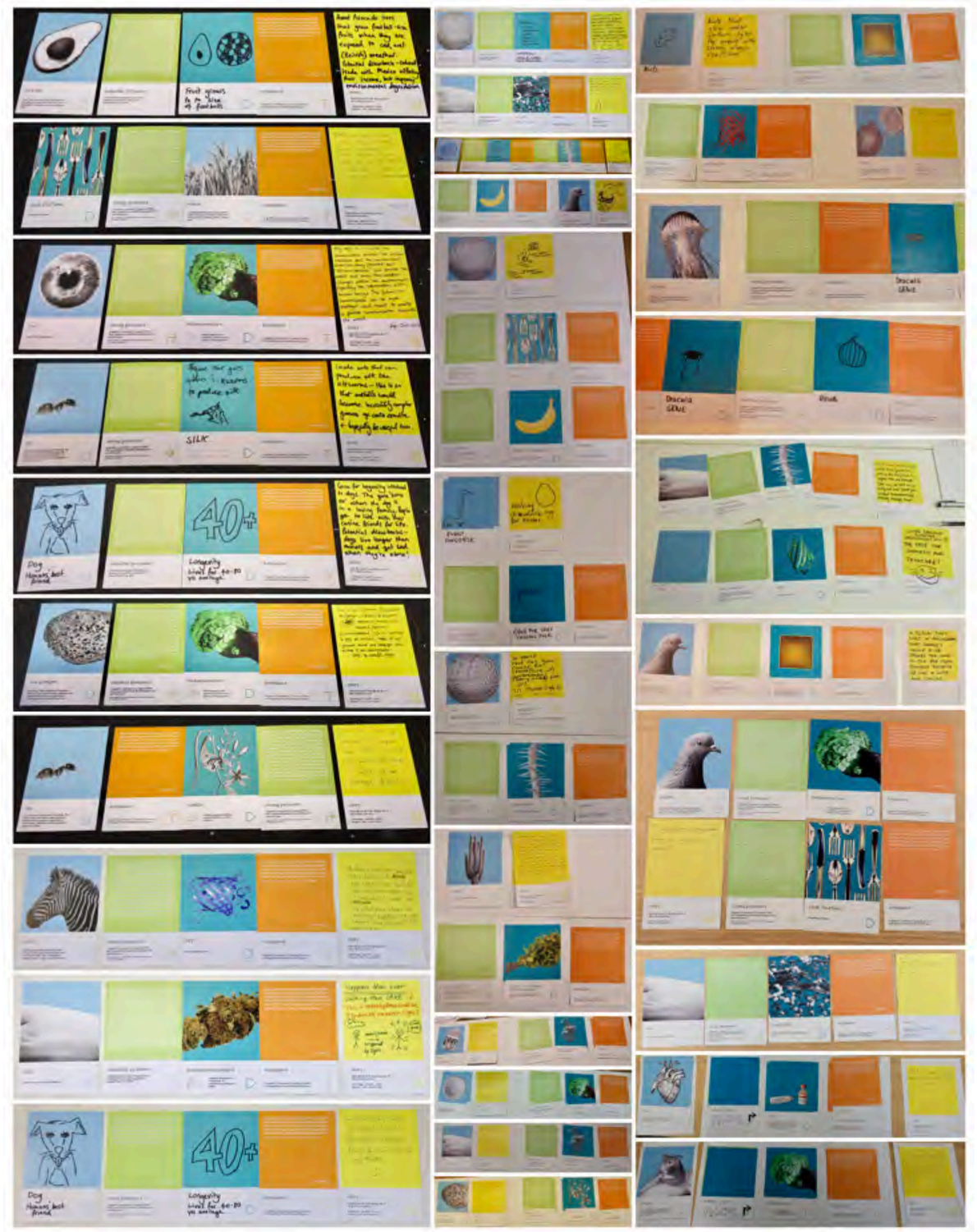
3 packages have been printed
- 1 for Design Informatics
- 1 for SynthSys , School of Biology
- 1 for myself

Each package contain :
- 4 promotions / explanations cards
- 53 blank story cards
- 25 organisms
- 15 blank organisms
- 8 promoters
- 25 CDS
- 15 blank CDS
- 8 terminators

- The paper prototypes have been used during 5 sessions
- The cards have been used twice during Louise Mackenzie ‘Transformation - Thinking Through Making With Life transgenic bio-art’ workshops at ASCUS lab Summerhall as part of Edinburgh International Science Festival 2017.

In total I collected:
36 stories
10 new CDSs
5 new organisms





Grow creates new zones for rapid hair growth on parts of the body close to organs that are diseased. Site can be used as an entry and exit point for useful treatments by passing through hair.

story

A PIGEON THAT LIVES IN AMSTERDAM THAT CHANGES COLOUR IF HE SPENDS TOO LONG IN THE RED LIGHT DISTRICT BECAUSE HE HAS A WIFE AND CHICKS

story

SEA STARFISH THAT PRODUCE INSULIN & GLUCOSES WITH TINY NEEDLES USING THE SPIKES WILL TRANSFORM THE INSULIN THROUGH THE NEEDLES TO THE USER

story

Vitamin B3 in colorful and interesting shapes with good skin we smell - to help you get ok supplement - while playing with the stabbing days human vitamin D deficiency - babies with lighter skin - low in winter / darkened ...

story

I / would like to make scratches smell like jasmin, because scratches smell really bad and I love the smell of jasmin. I just hope these jasmin scratches produce the necessary jasmonic acid precursor

story

I chose to produce histamine in the hamster because I work with CHO (= Hamster cells) 3 light reactants can be really useful for studying gene expression. Mainly through - glowing itself is pretty

story

Produce insulin in the heart when sugar levels in the blood rise to high.

story

RICE IS DULL!
I WANT MINTY, GREENS, GLOW-IN-THE-DARK RICE MUCH MORE FUN!

story

making dinosduck egg for Easter

story

Cuckoos are easy to take care off, they don't need a lot of space and can be left alone for weeks. This makes cuckoos an ideal pick for busy housewives.
However, cuckoos do not give off a pleasant odour. Here we took inspiration from garlic, which contains methylmercaptan to find this cuckoo can give off a nice minty smell.

story

A lemon for valentine's dinner because love is bittersweet!

story

A yeast that can grow roots, EG remove (suck up) contamination (heavy metals) from soil IN Moonlight

story

Glow in an odd direction starting ... Using cells a system of rods, 'd' & 'l' bacteria in colonies expression of mismatched cells into genome - then if a fungal spells the rest you the result - by one point gained it's dark - then the rest genes can apply the found. Then it's due to the bioluminescence protein contained within the cells of the rice.

story

Nuts that glow under certain light for people with strong allergic reactions

story

A banana smelling heart will bring a different fragrance to museum lovings. Blood will then glow in bright colours when exposed to Cobroid

story

The jellyfish has a big stomach with its dracula and it cannot be able to live around it's self because of the smell he produces White Spirit 99

story

I want to create a sponge that smell vanilla. Then, when you are taken in bath, it will smell good.

story

story

They poop everywhere may as well be useful

story

LIVING GROWING GLOWING ORGANISMS ON THE FACE FOR COSMETIC AND SKINCARE!

story

For the professional Summer

story

story

I CAN'T EAT OLIVE FISH SO I'D LIKE A GENETICALLY MODIFIED VERSION WITHOUT THE SMELL & THE FLAVOUR OF A FISH I LIKE

story

Gene for longevity introduced to dogs. The gene 'turns on' when the dog is in a loving family. Dogs get to take with their canine friends for life. Potential drawbacks - dogs live longer than owners and get sad when they're alone!

story

I made ants that can produce silk like silkworms - this is so that eventually would become incredibly complex games of cats cradle + hopefully be useful too.

story

Chefs with taste of vanilla to improve their taste. This will help people eat rockets in periods of food shortage

story

My story is to create the communication between the bacillus megaterium and the environment. With the rising pressure, new "bacillus megaterium" can penetrate the world and know the emotion changes within the environment, especially the interactions with human beings. The fusion bio-illuminescence can be more intelligent and smart, to create a positive communication between the world.

Apr-1st-2017

story

I want to enhance the characteristics of yeast that make it attractive a type it its identity - it is 'yeastiness'. This will require making many different genetic changes and raises questions about the characteristics that make an organism itself.

story

The skin will turn into glow when you as human body needs for the go to something small or enough you body will get starving and you can go crazy running

story

Plant genetically grain such as wheat would be genetically engineered to produce tortoises. In the future we can grow tortoises on the wheat which is sustainable and environmental

11/14/2017

story

Avocado trees that grow football-size fruits when they are exposed to cold, wet (British) weather. Potential drawback - reduced trade with Mexico affecting their income, but improving environmental degradation.

story

Happiest Man ever
Walking Space CAKE
(Skin → tetrahydrocannabinol → Induce like pro water (light))
marijuana → triggered by light

story

I made a dog with a longevity live of 80 years in average. Because dogs are cool and loyal friends. :)

story

I made a luminescence thought tobacco because I ... this black stripes would be look nice in the night. Then I realized that maybe the ... does the black stripes to hide from predators and with luminous they are won't be able to hide.

story

story

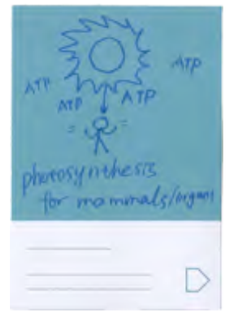
The bright glowing fluorescent sea sponge, a beacon of ... warning of changes in our ocean species.
An environmental icon or message to say be careful, maybe it will genetic sound and language too, to treat it can communicate — Step, be careful, enjoy

story

GENE FOR VERY YELLOW YOLK

Onion

Dracula GENE

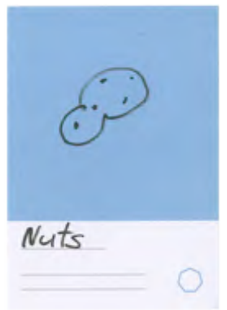


multiple genes induced by nostalgia and/or homesickness

Fruit grows to to size of footballs

SILK

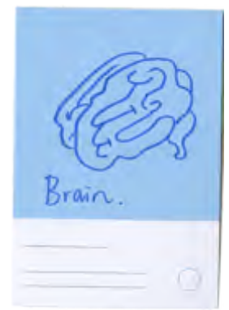
Longevity
Lives for 40-80 yrs average



Nuts

FUNNY DINODUCK

Dog
Humans' best friend



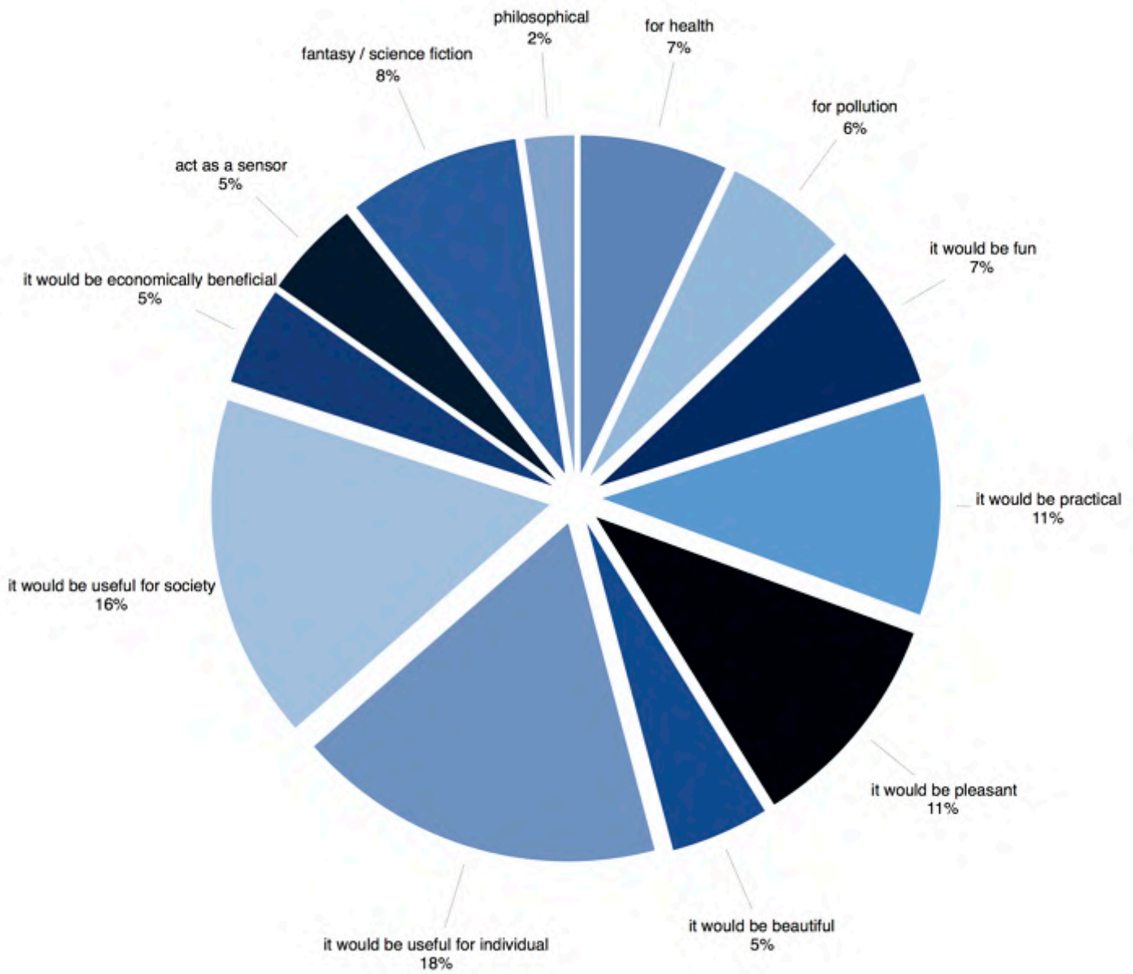
Stuff that lives on the skin

Analysis of the results

There is no clear tendency in the answers, same range of fantasy story (8%) than proposal for health (7%). Being able to gather more data would help to identify a trend (if there is one). I could imagine developing a webapp, where users could create in the same way (with drag and drop) sequences and write stories link to them. Then, they could share them on social media. In addition, it would allow to collect thoughts, reactions from the comments and like section. A very small questionnaire after the activity could also help to gather the data from the type of story produced, allowing live data analysis.

Half of the stories are human-centred, while only one quarter would modify human. It suggests that most of the modification imagined would be beneficial for humans even if an animal or a plant is the target of the modification.

Even though I encouraged to reflect on the consequences (advantages, risks...) on the story card, only 3 stories have a sentence about it. To get more insight on this aspect and encourage broader reflection, designing a longer activity would be necessary.
The sequence and the story would be the first chapter, then the participant of the workshop could have to spot what are the elements part of the ecosystem of this organism and relations with some aspects of human society: cultural effects, group behaviour, social change, social trade-offs, political and economic systems, social conflict, global interdependence... It would be asked to reflect on these connections and establish where could be the potential risks, dangers, uncertainties but also advantages, benefits or values. Each group could analyse the sequence of other groups. From that - chapter 3 - they would come back to their original design and have to change it, taking into consideration the observations from chapter 2. A second iteration of the second chapter and a third iteration of the sequence could be considered. It would help to illustrate that each choice creates new conditions and entanglements with other factors which result in more constrains in the design.
The aim would be to emphasize the interconnectivity of ecosystems and human society, and how synthetic biology could become an important source of disturbance and that each new design should be carefully considered.



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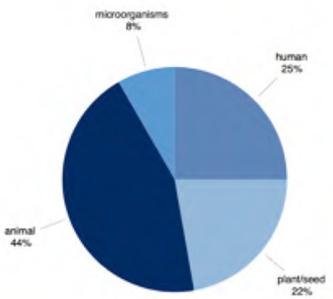
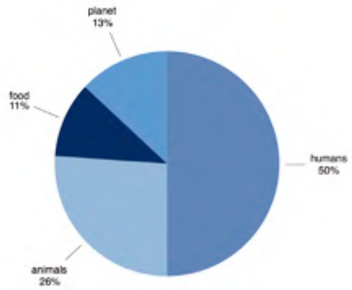
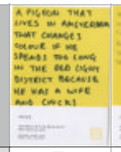
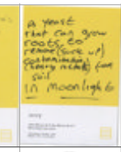
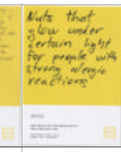
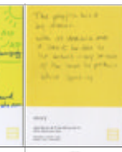
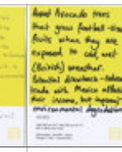
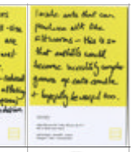


concerned _



thought about impact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new way of administrating treatment	4	☐	☑	☑	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
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it would be practical	9	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☑	☑
it would be pleasant	9	☐	☐	☐	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐
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				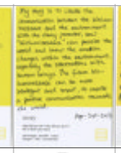	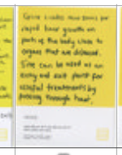												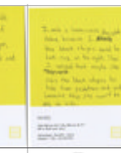	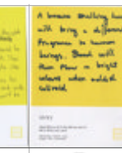	
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new way of administrating treatment	4	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
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it would be dangerous / harmful	0	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
act as a sensor	4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
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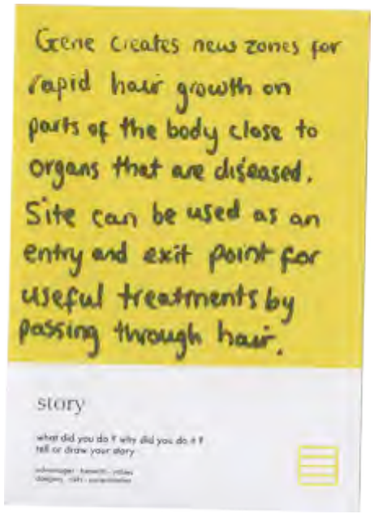
modifying plant/seed	8	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
modifying animal	16	☑	☑	☐	☐	☑	☐	☐	☑	☑	☐	☐	☑	☐	☐	☑	☑	☐	☑
modifying microorganisms	3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☑	☐	☐	☐	☐	☐
thought about impact	3	☑	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐

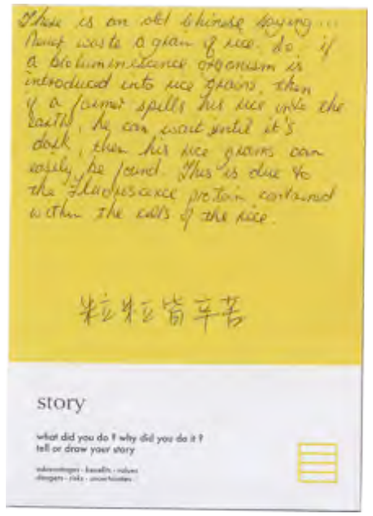
Visualisation of the stories

In order to allow to reflect on some of the stories already created, promote the project and share the ideas, I have decided to illustrate some of the cards. We could imagine a series of ‘postcards from the future’ as a series of illustration, promoted on a dedicated website or in an exhibition during a scientific conference, where these stories could be the starting point to discuss public opinion and ideas on synthetic biology as well as the implications of the discipline in human society and on natural ecosystem.

I choose to illustrate these three as a starting point to illustrate the idea:

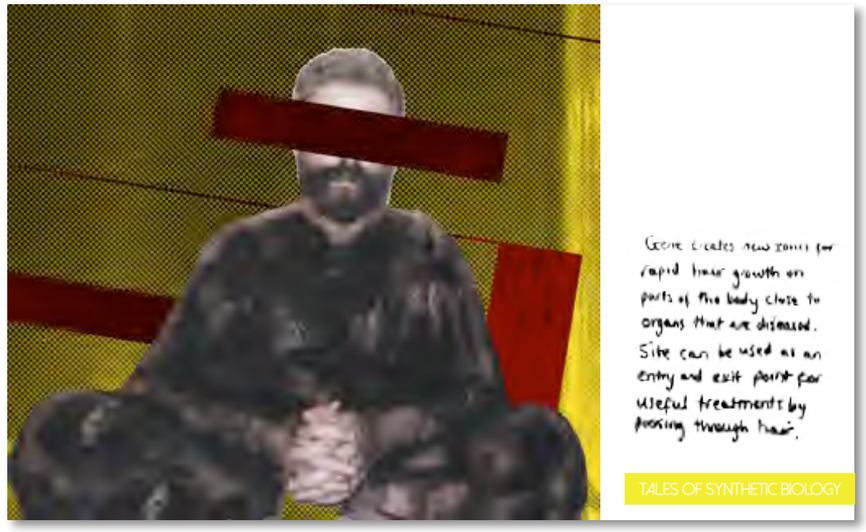


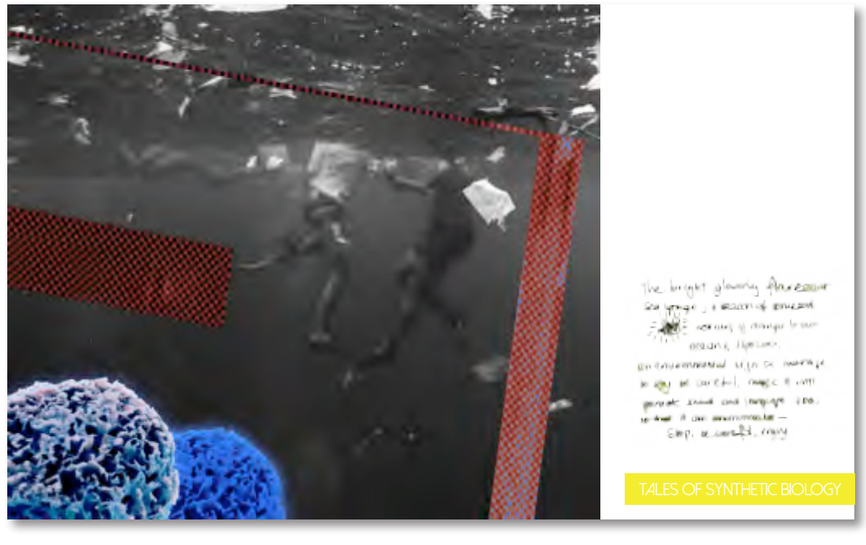
- exploring drug administration
- health topic
- modifying human



- exploring relation between the past and the future in story telling
- old tale, philosophy
- modifying seed/plant

- exploring communication, act as a sensor
- pollution topic
- modifying organism / animal





Thoughts to develop it as a game

The next step in the development of this project would be to redesign the cards and create a game. Some aspects have already been explore with the help of Erika Szymanski, Research Fellow, Science, Technology & Innovation Studies at the University of Edinburgh.
These are initial ideas and they would have to be developed and refined to be tested.

This game should fulfilled these objectives:
1. introduction to the grammar of DNA assembling
2. introduction of the design of biological system
3. introduce the complexity of the process (biology)
4. nurture values and assessment of design
5. foster creativity and critical thinking
6. be fun

New sets of cards might have to be imagined and designed to play around the ideas of being in the scientific process and collaboration: collaboration between the members of the community but also competition to be the first one to publish.

Scientific battle

- each participant have a set of 6 cards in their hand which have been distributed randomly. The rest is the stock where they will be able to pick one if they can not play. They should have 6 cards all the time until they have all have been played.
- in the middle of the table one organism you have to modify
- when a player has a sequence and imagined a story he can play it and have 1 point.
- each player is going to continue to play with the same sequence accumulating point each time he has a new story compatible with the organism in the middle of the table.
- new cards are introduced, which can be played to make more point and help achieve different strategies or played against the other players to destabilize their game and add constrains

Can be played by the player for its own benefice:
joker : can be played to replace a promoter, CDS or terminator
organism : you play it and pick randomly a new organism to replace the actual one, Risk : if a sequence played on the table is not compatible the player need to ‘bin’ it and lose a point

Can be played on the other players sequence
time : the person you give it to had wait a turn to play again: it’s experiment need time to assemble
contamination : the experiment got contaminated, the sequence go to the ‘bin’
value : can be played to replace a promoter, CDS or terminator
assembly failed : the assembly failed and if the other player can not replace the promoter with a more efficient one, it will have to start from scratch
stealing : you steal the idea of an other player but you also loose a point
repressed : you can repress a gene so the other player can not play until the current promoter is replaced by an inducible one

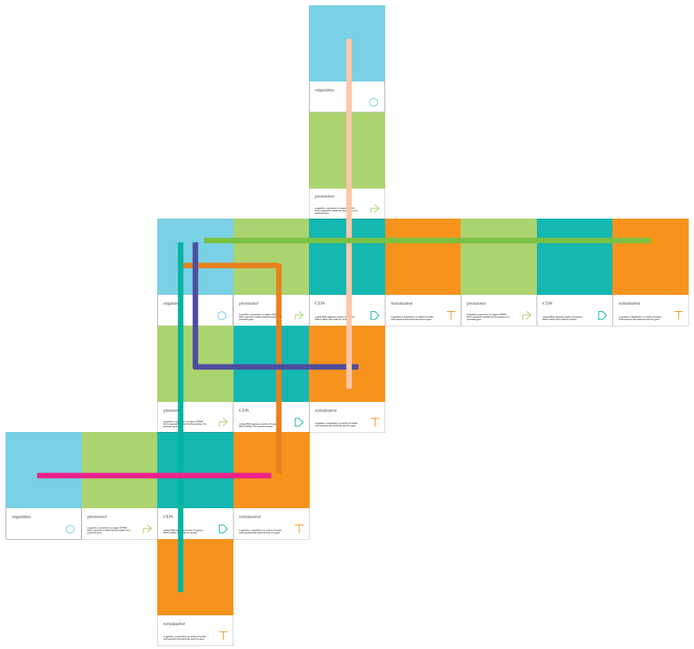
Meet the goal

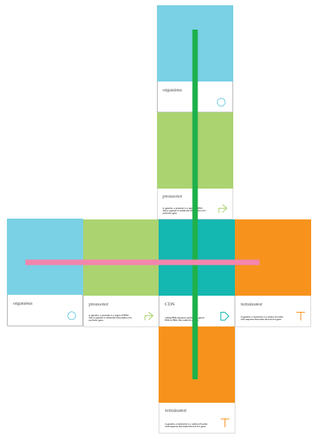
- each participant have a set of 4 cards in their hand which have been distributed randomly. The rest is the stock where they will be able to pick one if they can not play.
- in the middle of the table a set of three cards defining a goal to reach.
- a player can play a sequence if it has all the component, other wise he has to pick a new cards and give away one until he has a organism - promoter - cds - terminator.
- when a player has a sequence and organisms which comply with the condition he can play it and tell the story.

- if some of the other player has a counter story invalidating the initial one : if the modification can go against the goal but the player didn’t see this particular scenario, the point go to all the other players.
- after a sequence and story have been played, the cards of the goal get renewed and the game continue the same way.

DNA scrabble

For this idea each player can add cards and build from the sequence of the other, creating a maze of genetic modification. However you can use a card from another sequence only if your sequence can be the result of a mutation due to the introduction of the other modified organisms you are using the card from. It would emphasise the interconnectivity and repercussions on an ecosystem.





Dominoes for biologists

Design - general blocs

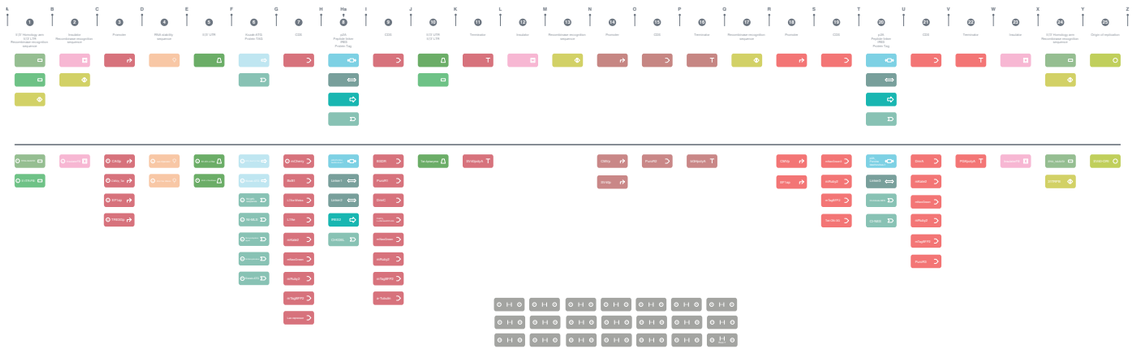
- Use of 5 different colours for the coding sequence (promoter - CDS - terminator) to visualise 1 transcription unit. It will be useful when one transcription unit is will be to be express in the bacteria for the duplication (antibiotic resistance for example) and others will be expressed in the plant/yeast…
- Blank pieces with directional arrow for projects where the direction is crucial at the early design stage.
- Larger pieces for Transcription Unit (containing promoter - CDS - terminator) for high level sketch.
- Small pieces for localisation signal, tag… to annotate some aspect inside a block
- Two different proposals to visualise the strength of a promoter.
- Two special set to design sequences for Golden Gate of Gibson assembly, in-order to determine the ending and connecting sequence of the blocks.
- Each type of block is done with a specific colour + a symbol to give the maximum visual markers, helping to design a sequence.

Design - EMMA kit

Option 1
The colours correspond to type of the blocks.

Option 2
The colours correspond to position of the blocks.

Option 3
The colours correspond to type of the blocks and are numbered for the position.



Material

Solution 1
- laser cut on acrylic
- magnets at the back

Solution 2
- printed vinyl on wood
- magnets at the back

Solution 3
- customised post-it

Software integration into Genetic Constructor

to be continued....

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