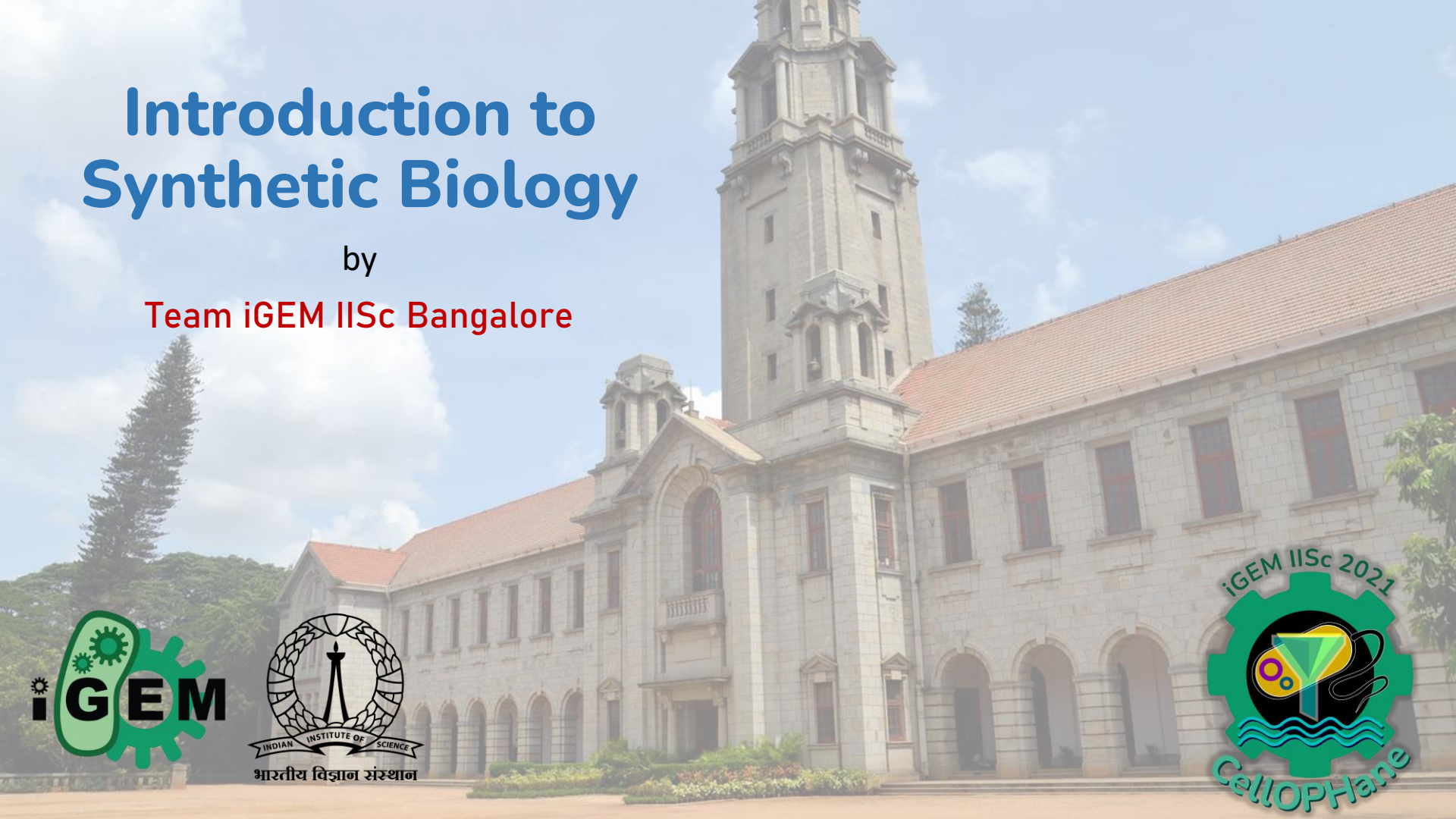
Introduction to Synthetic Biology

by

Team iGEM IISc Bangalore



Modules

What is life? Engineered products vs living organisms

Design Principle behind life

Construction of cells from basic biomolecules

Designing Cells to Obtain Desired Products

Applications of Synthetic Biology in Real Life Problem Solving

Our Project: CellOPHane

Our learning objectives

By the end of these modules, you should have answers to the following questions from the synthetic biology perspective:-

- Can scientists design life and make customized living organism to solve global problems?
- Can a cell be constructed from scratch using just basic biomolecules?
- How can you design cells to make them produce what you want?
- How different is a living organism from an engineered product, like radio?

Living organisms vs. engineered products

Are living organisms special? WHICH OF THE FOLLOWING ARE 'LIVING'?

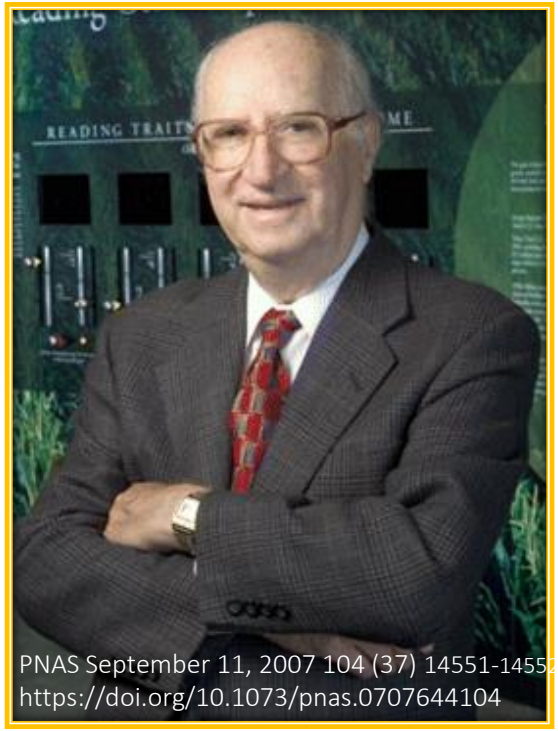
HUMANS	**VIRUSES**
YOUR LIVER	**ENZYMES**
NEURONS	**DNA**
BACTERIA	**WOOD**

NOW THINK ABOUT HOW A RADIO IS DIFFERENT FROM THAT OF A LIVING ORGANISMS?

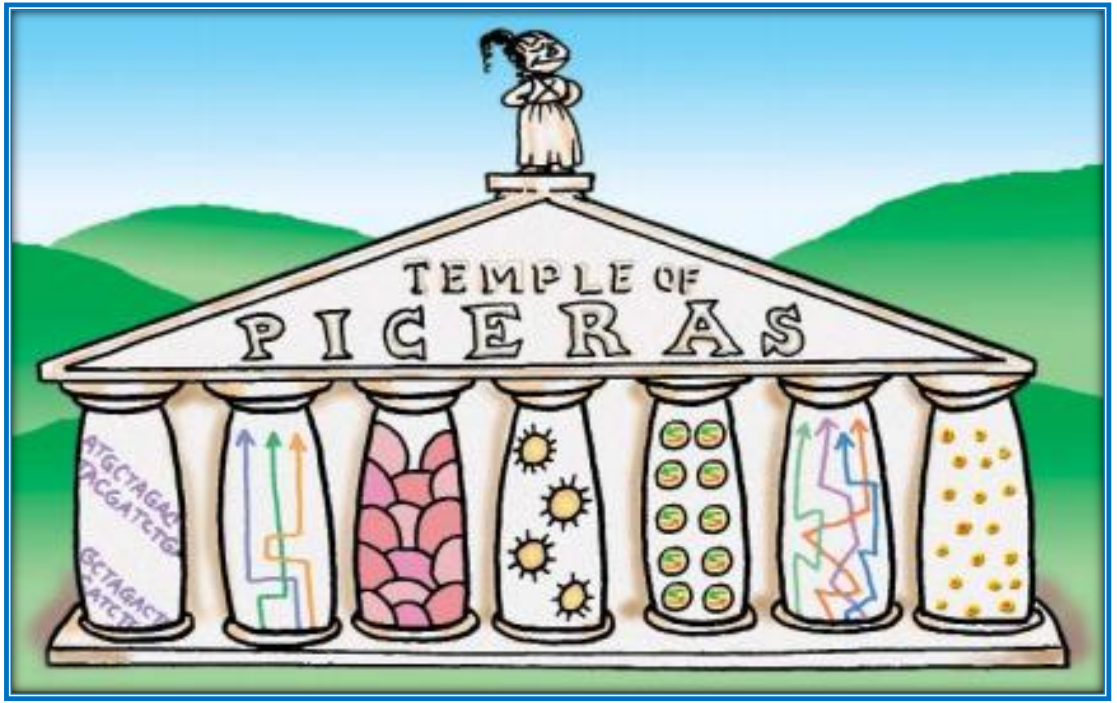
LIFE SCIENCES - BUT **WHAT IS LIFE**?

"The Seven Pillars of Life" – Dr Daniel Koshland defined life in terms of seven principles called the PICERAS

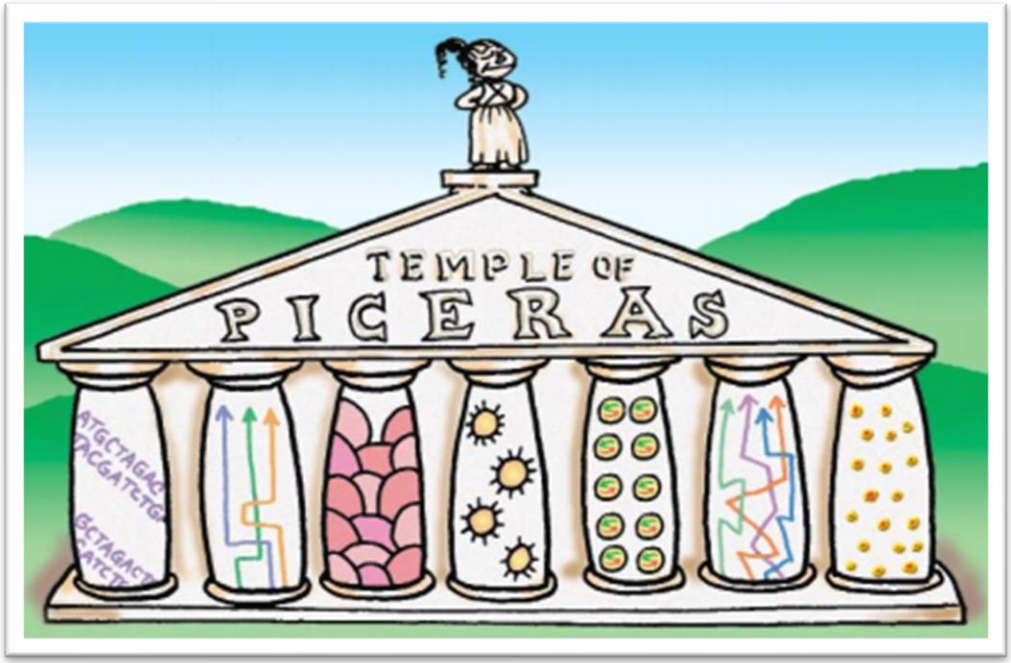
(SCIENCE, VOL 295, 22 MARCH 2002)



PNAS September 11, 2007 104 (37) 14551-1455
https://doi.org/10.1073/pnas.0707644104



PICERAS



P - PROGRAM

I - IMPROVISATION

C - COMPARTMENTALISATION

E - ENERGY

R - REGENERATION

A - ADAPTABILITY

S - SECLUSION

IT IS NOT ALL BLACK AND WHITE

Alternative definitions of life have also been proposed. NASA's definition of life, from an astrobiology perspective, is as follows,

'*Self-sustaining chemical system* capable of *Darwinian evolution*'

… AND HERE WE GO BACK TO THE RADIO

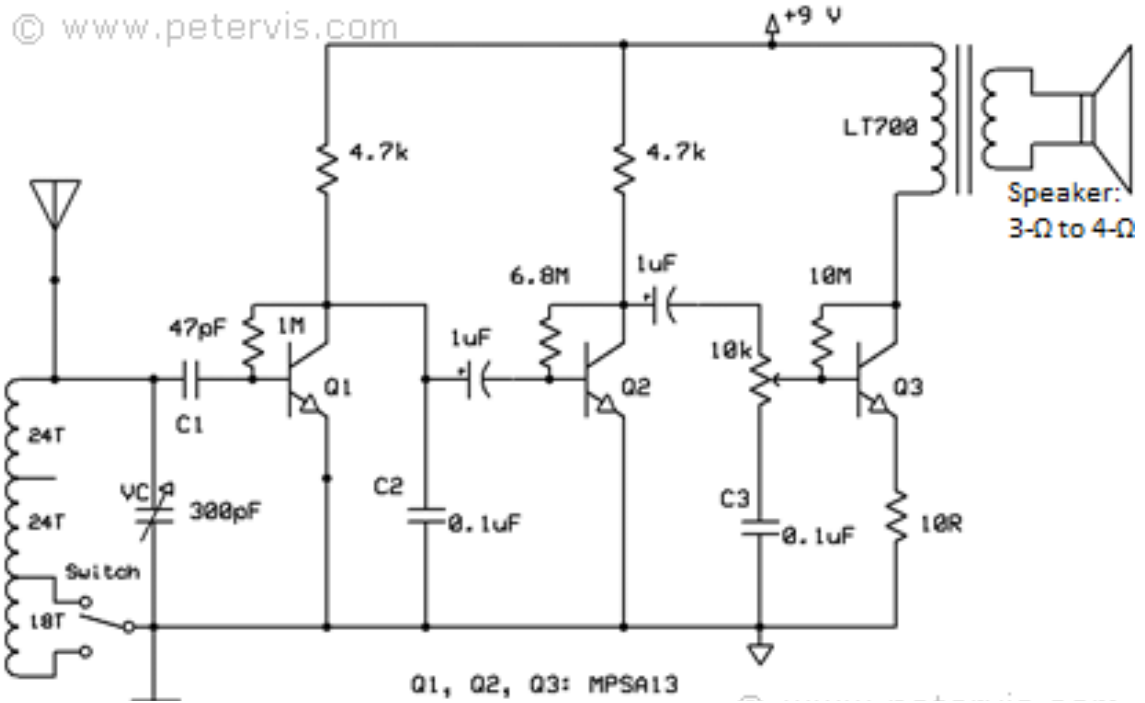
Signals

X

Y

?…

AUDIO OUTPUT



(Lazebnik, Cancer Cell, SEPTEMBER 2002, VOL. 2)

Credits: https://www.petervis.com/Radios/three-transistor-radio/three-transistor-radio-circuit-diagram.html

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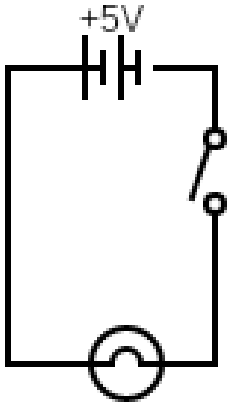
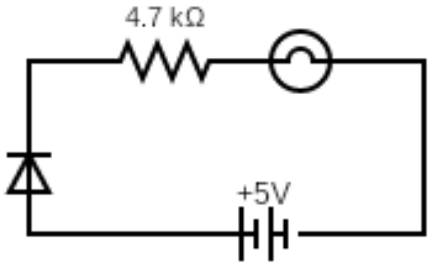
Design? Customise?

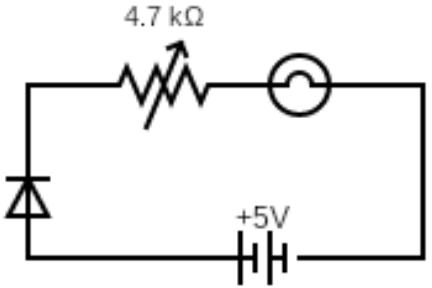
The radio is fundamentally a very complex electric circuit. What is it made of?

Can you think of a simpler system? How would you build one?

- Bulb
- Wire
- Battery
- Switch
- Resistor
- Diode
- Rheostat





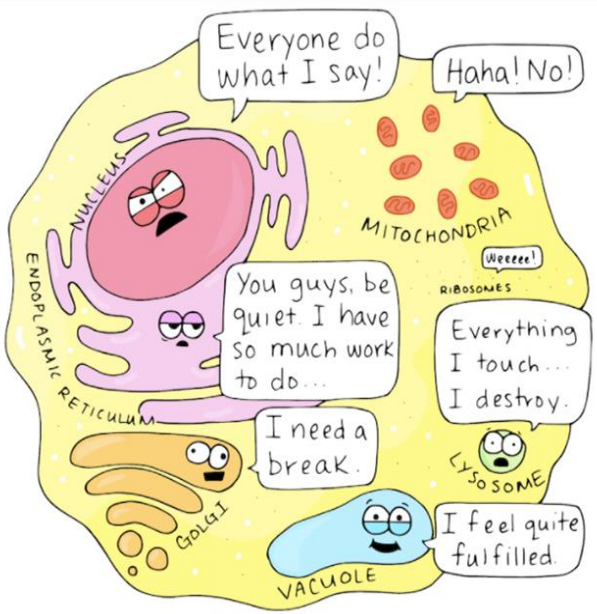


Designing and Customising Cells!

Like a complex circuit can be designed by putting together its components, and customised by Changing them, so can living organisms!

So, what are the components of living systems?

What are the components of cells?



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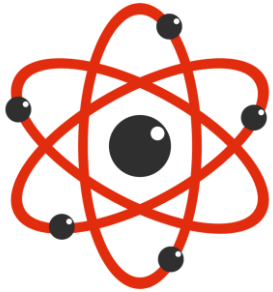
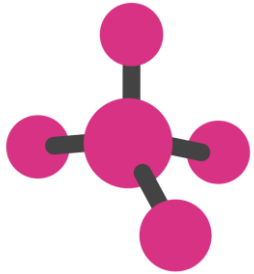
WHAT IS A TYPICAL ("NATURAL") CELL MADE OF?



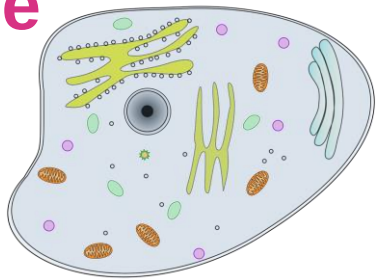
Atom



Small molecule

Large molecule

Cell organelle



Cell

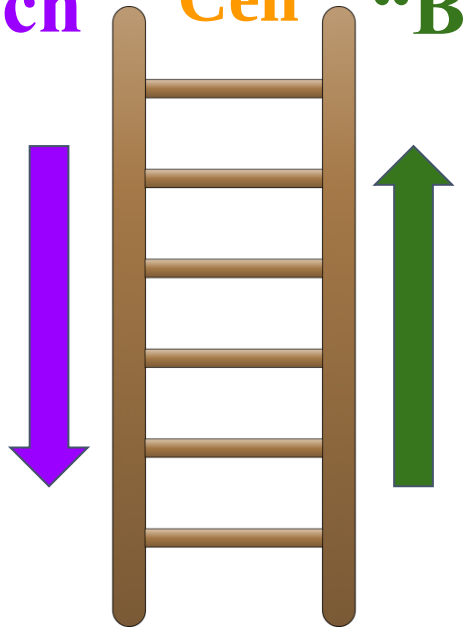
Effectively, the answer is…

BIOMOLECULES!!!

ROADMAPS TO BUILD A CELL WHICH HAS SOME DESIRED PROPERTIES

"Top-down" Approach

- Take a complex system
- Change/modify the component(s) of interest and see how the system responds



"Bottom-up" Approach

- Take the essential components
- Construct a more complex system bit by bit

HOW TO BUILD A SYNTHETIC CELL?

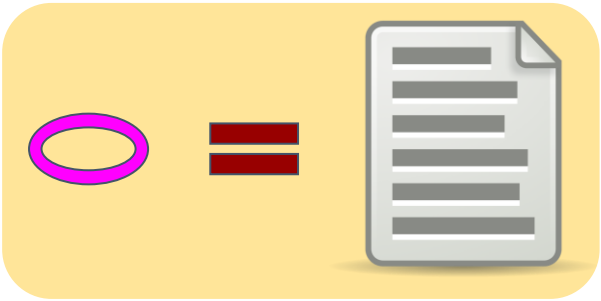
WHAT WOULD YOU NEED TO **BUILD** A SYNTHETIC CELL?

VENTURE YOUR WILDEST GUESSES!

HOW TO BUILD A SYNTHETIC CELL?

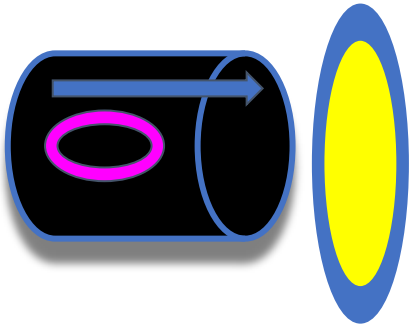
"Liposome" (body made of fat, a biomolecule) like a

Soap Bubble

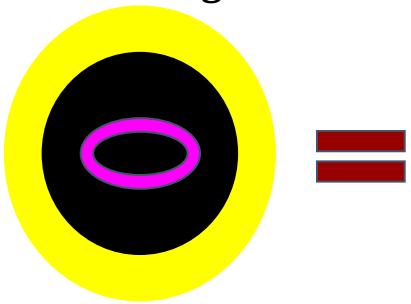


DNA, a wonderful biomolecule, is the blueprint of life!

Nutrient-rich broth



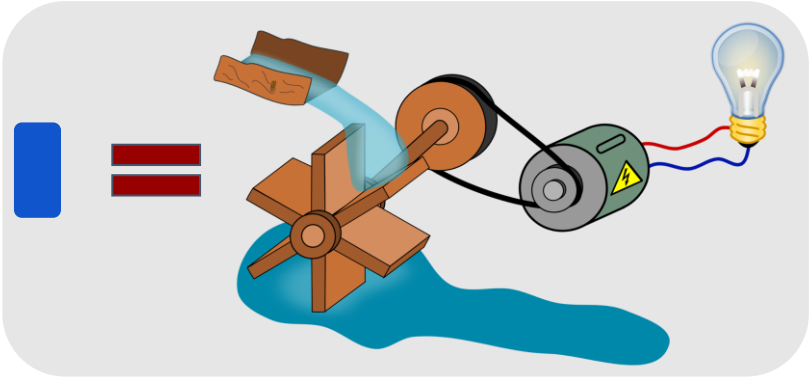
Nutrient rich broth containing DNA

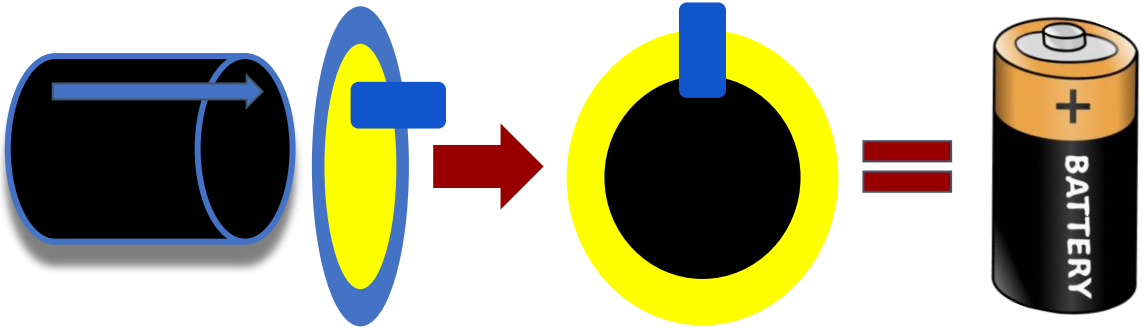


Much like a remote

HOW TO BUILD A SYNTHETIC CELL? (CONTD.)

When the cell is supplied with nutrients, this **propeller-like protein** (another biomolecule) rotates just like a water wheel & generates power to run the cell!





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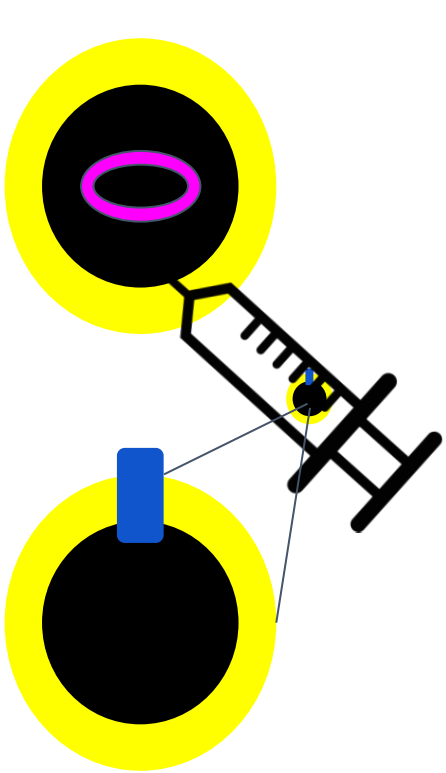
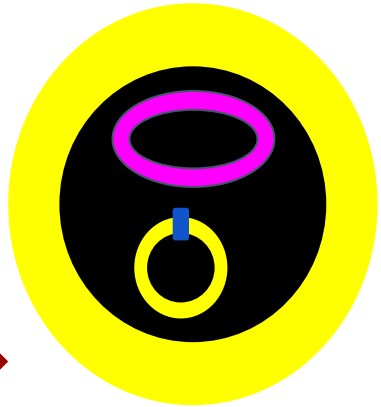
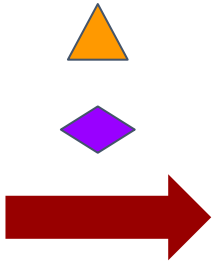
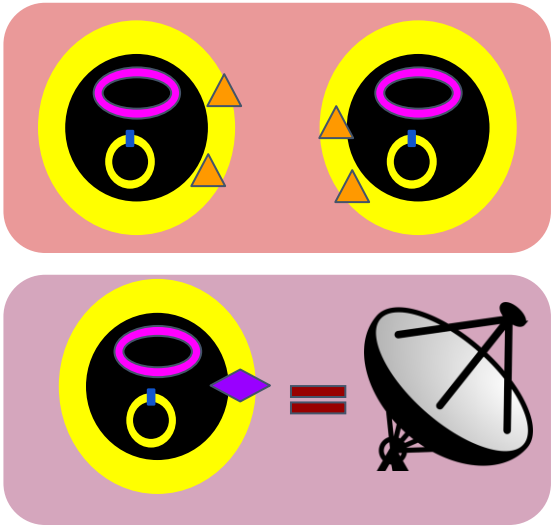




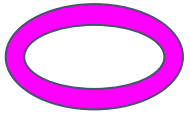
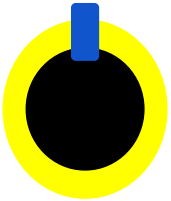




One protein helps in cell division (and thus, in Darwinian evolution); Another protein aids in communication with outside world.

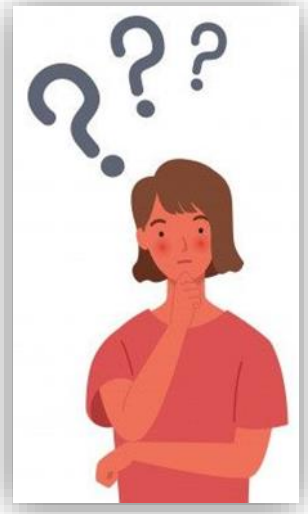
DREAM OF A SYNTHETIC BIOLOGIST!

Combining **only 2-3** of the following bottom-up elements in an artificial cell has been possible:

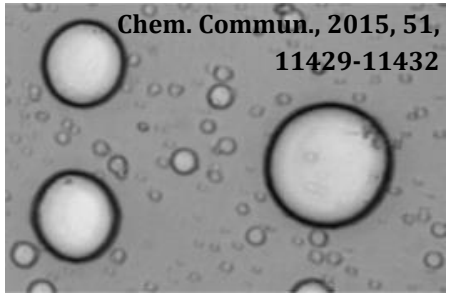
1. Enclosure
2. Broth 
3. Blueprint 
4. Battery 
5. Darwinian evolution 
6. Communication 

WHY BUILD SYNTHETIC CELLS?!

How life might look on other planets

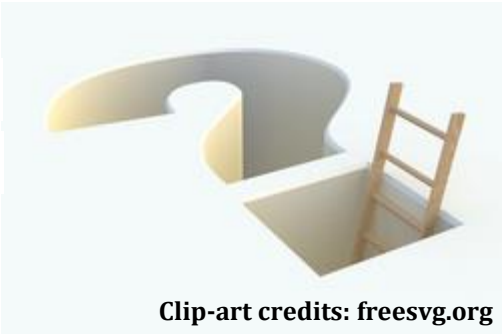


How does a natural cell function properly



How life on Earth originated

Addressing real-life problems



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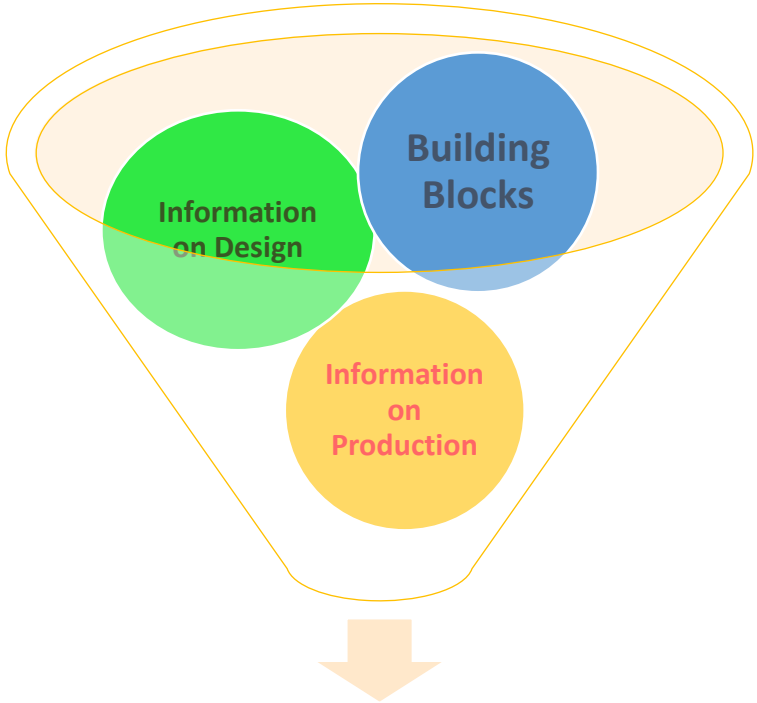
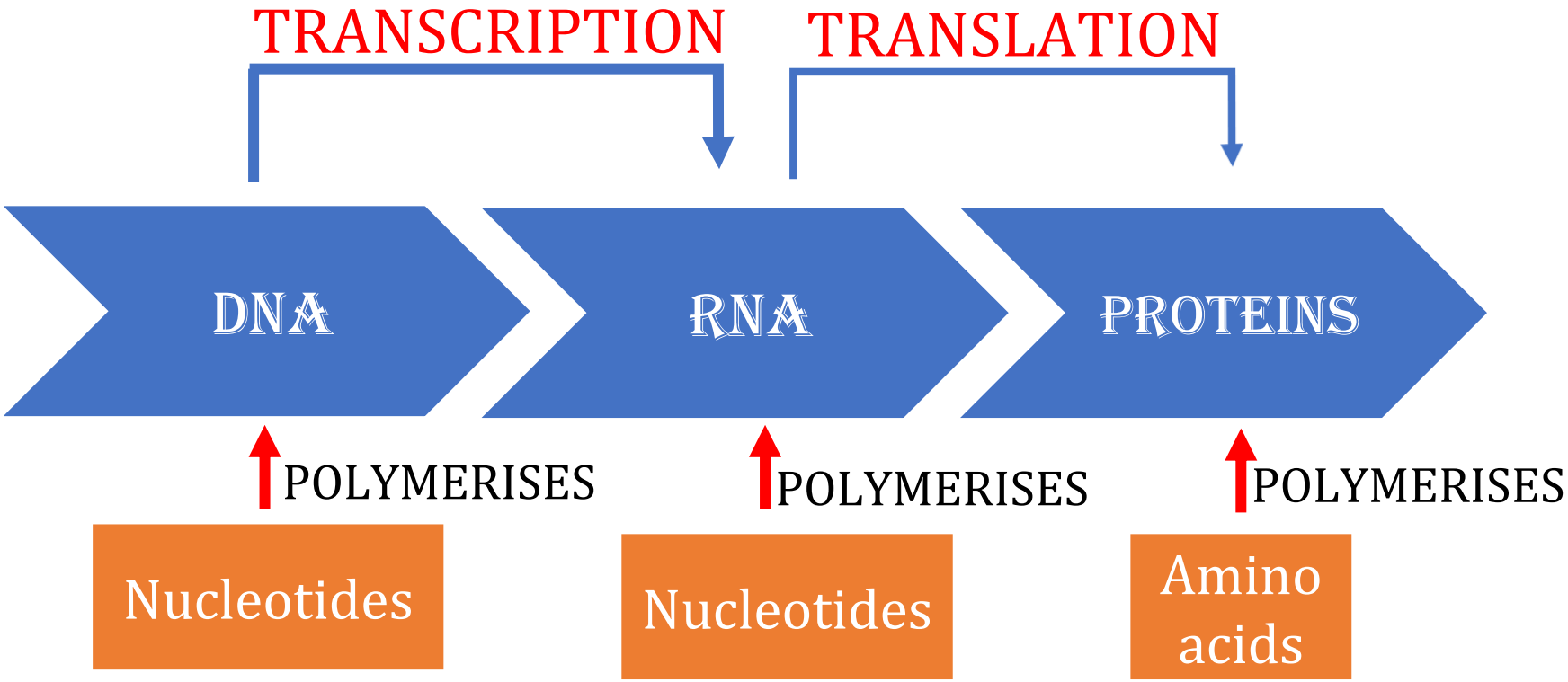
HOW CAN WE DESIGN CELLS FOR OUR PURPOSES?

Nikhita here

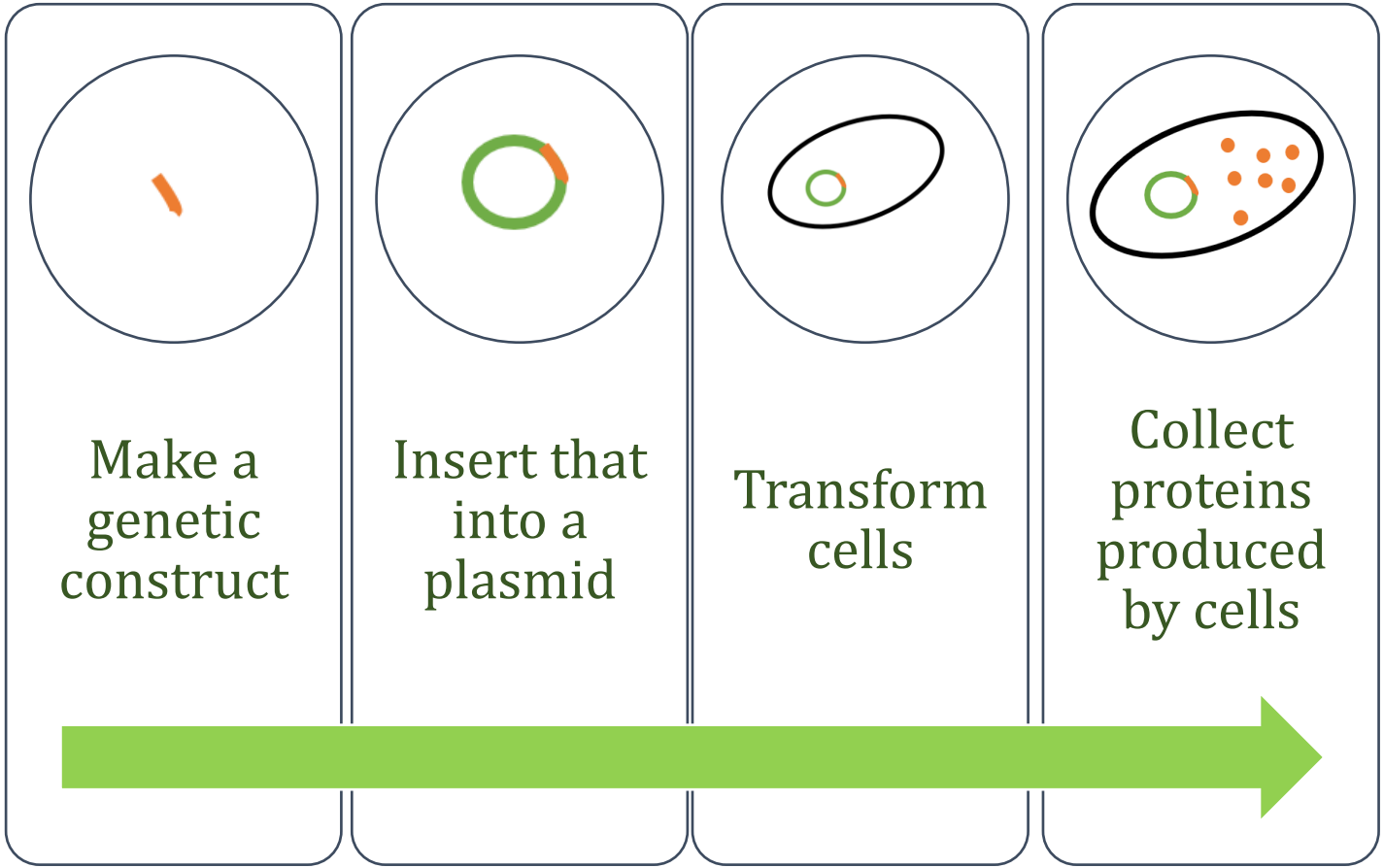


Products of your design produced

Before we design, we must understand how cells produces molecules.



Workflow to produce a designer protein



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The ‘Big’ Problems….

Global Warming

Healthcare

Fuels and Energy

Pollution

Biodiversity

Water

Diagnostics

Waste Management

Food and Nutrition

Covid-19 (pandemics)

Pharmaceuticals

….The Small Solution!

There have been many Awesome developments that have occurred over the past decade with the use of synbio:

- **June Medford, Professor, Colorado State University, and her team engineered plants to purify salt water and secrete fresh water!**
- **Ron Milo, Professor, Weizmann Institute and his team recently developed a strain of *E. coli* that can get all its carbon from CO2!**
- **Bacteria that can remove methane from the atmosphere!**

Source: Wikipedia

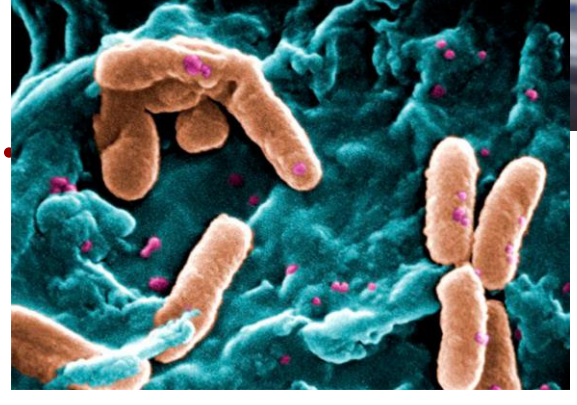
….The ‘Small’ Solution!

- **Personalised Medicine**
- **COVID Vaccines**
- **Restoring Extinct Species**
- **Designer Babies** (ETHICAL CONCERNS INVOLVED!!!)
- **Bioremediation :**
- ***Pseudomonas putida***

And the list is endless....

Source: Infectious Diseases Hub

Source: Economic Times



Credits: Janice Haney Carr

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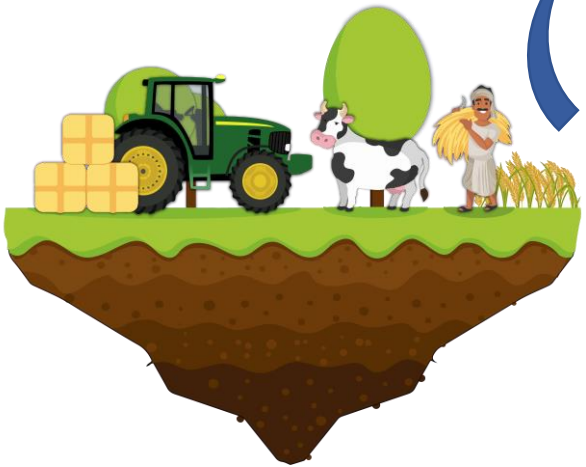
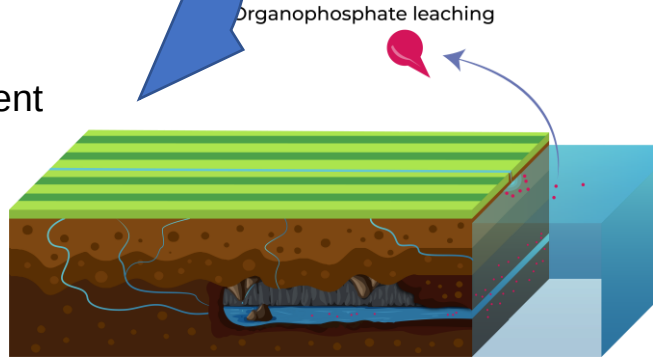
CellOPHane

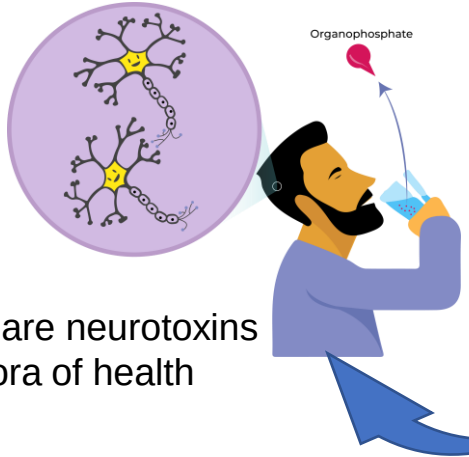


About 50% of Indian population relies on agriculture as a source of livelihood

Farmers spray pesticides to prevent their crops succumbing to pest attacks



Organophosphates pesticides are widely used and these organophosphates can enter the run off water thereby contaminating the water source.



Organophosphate are neurotoxins and cause a plethora of health issues.

Acknowledgement: Aranya Dhibar

CellOPHane

A plug-n-play filter

Degrades organophosphates (used as pesticides) by using a broad-spectrum enzyme

Can be used for other similar bioremediation strategies with minimal modifications

You can replace the organophosphate degrading enzyme to any other enzyme of your choice. The plug-and-play mode also this solution to be implemented in light of other bioremediation problems