Our goal is to help you understand:

What is Engineering?

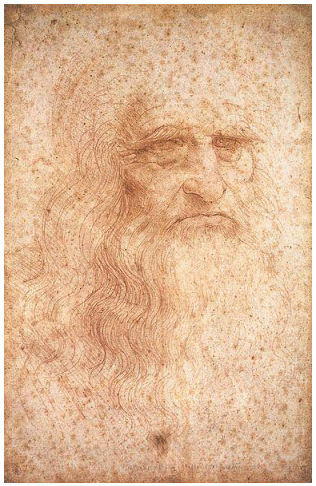
…and how is it different than science?

(Module 1)

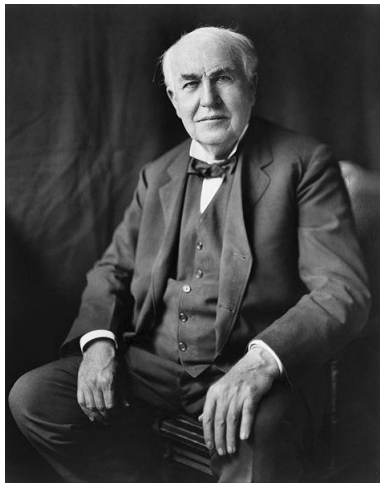
Prof. Nik Nair
Assistant Professor of Chemical & Biological Engineering
Tufts University

What do you think an engineer does?

Can you name any famous engineers?

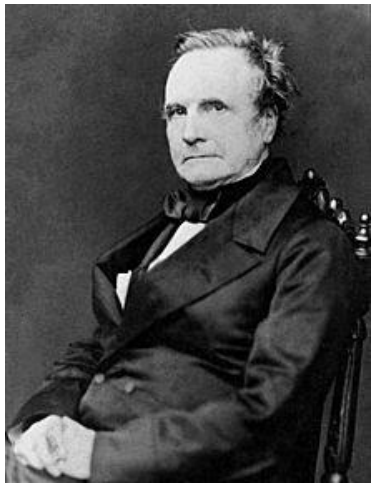


Leonardo Da Vinci



Thomas Edison

Pres. Herbert Hoover



Charles Babbage

Some famous engineers

Marissa Mayer
(CEO of Yahoo!)

Mae Jemison
(Astronaut)

J. Ernest Wilkins
(Manhattan Project)

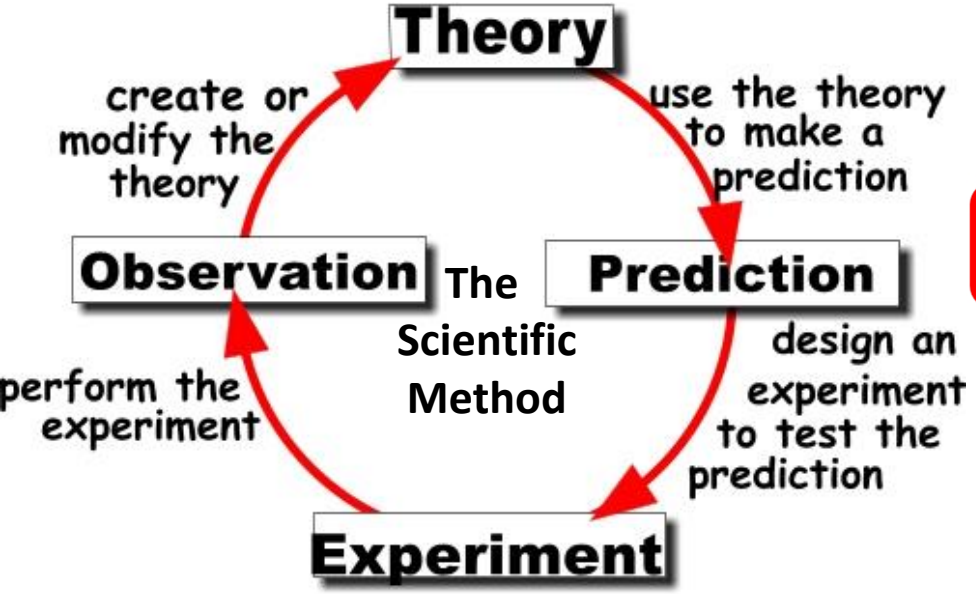
Bill Nye
(The Science Guy)

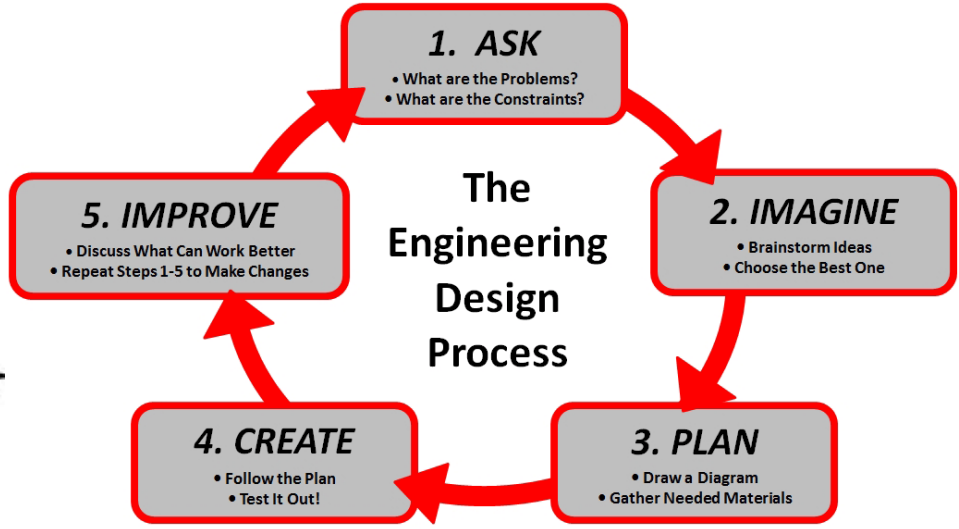
Short Bio of Prof. Nik Nair

1986 – 1994	Sardar Patel Vidhyalaya, New Delhi, India
1994 – 1997	Modern High School, Dubai, UAE
1997 – 1999	Indian High School, Dubai, UAE
1999 – 2003	Cornell University, Ithaca, NY (BS in ChBE)
Fall 2001	Merck, West Point, PA (Intern in Manufacturing Support, Varivax®)
Summ 2002	Merck, West Point, PA (Intern in Process Validation)
2003 – 2004	Bristol-Myers Squibb, Syracuse, NY (Protein Purification Scientist)
2004 – 2010	University of Illinois, Urbana, IL (PhD in ChBE)
2010 – 2013	Harvard Medical School, Boston, MA (Post-doc in Microbiology)
2013 – now	Tufts University, Medford, MA (Asst. Prof. of ChBE)

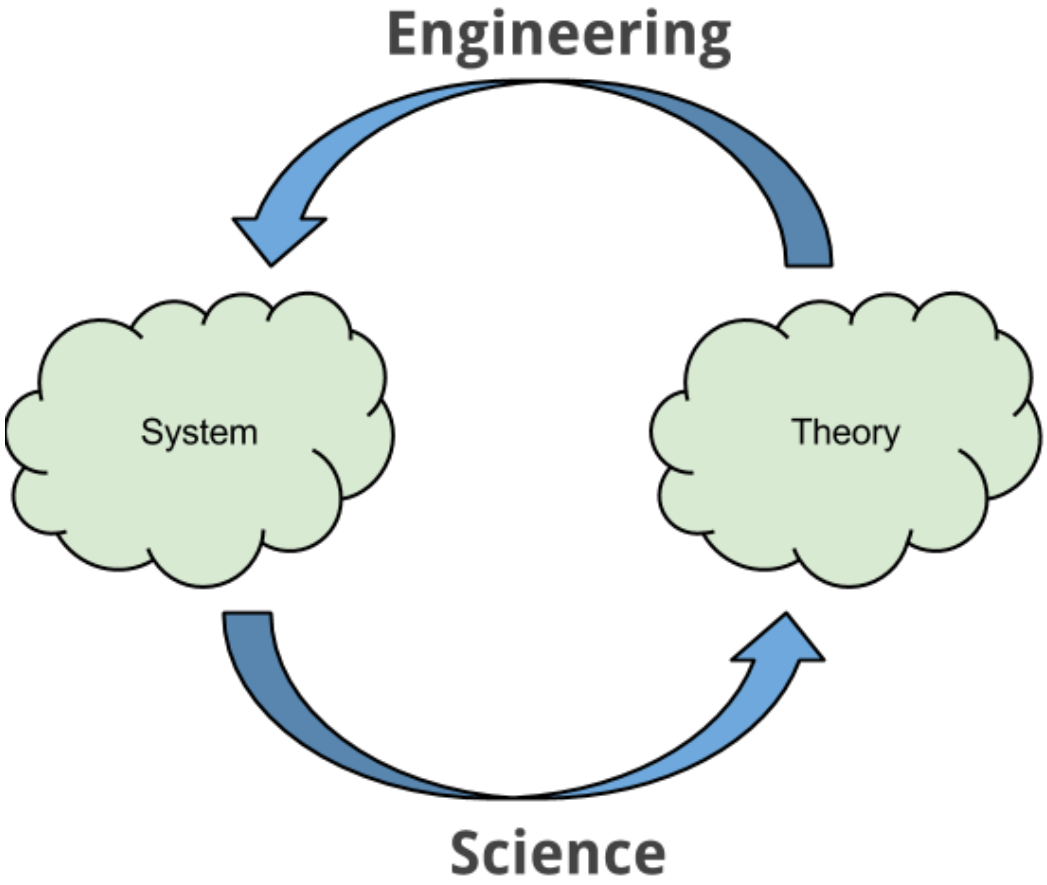
What is Engineering?
…and how is it different than science?

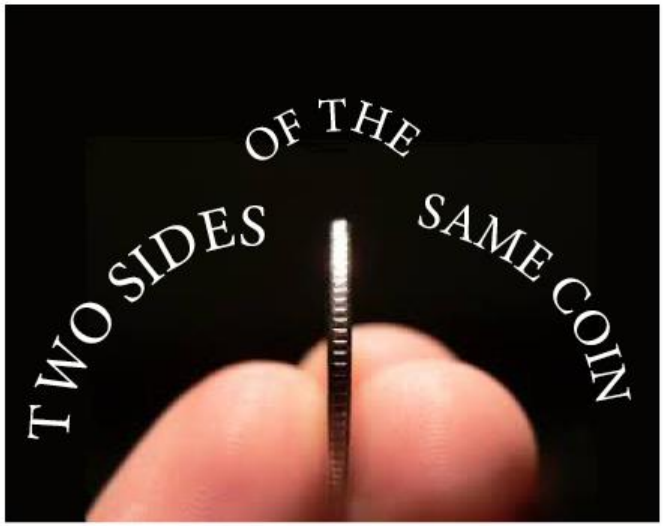
- Science and Engineering
  - – Hypothesis-driven — Design-driven
  - – Discovery-driven — Invention-driven





What is Engineering?
…and how is it different than science?





What is Engineering?

- Not just about building cars, robots, and bridges
- Engineering is involved in any type of invention and optimization

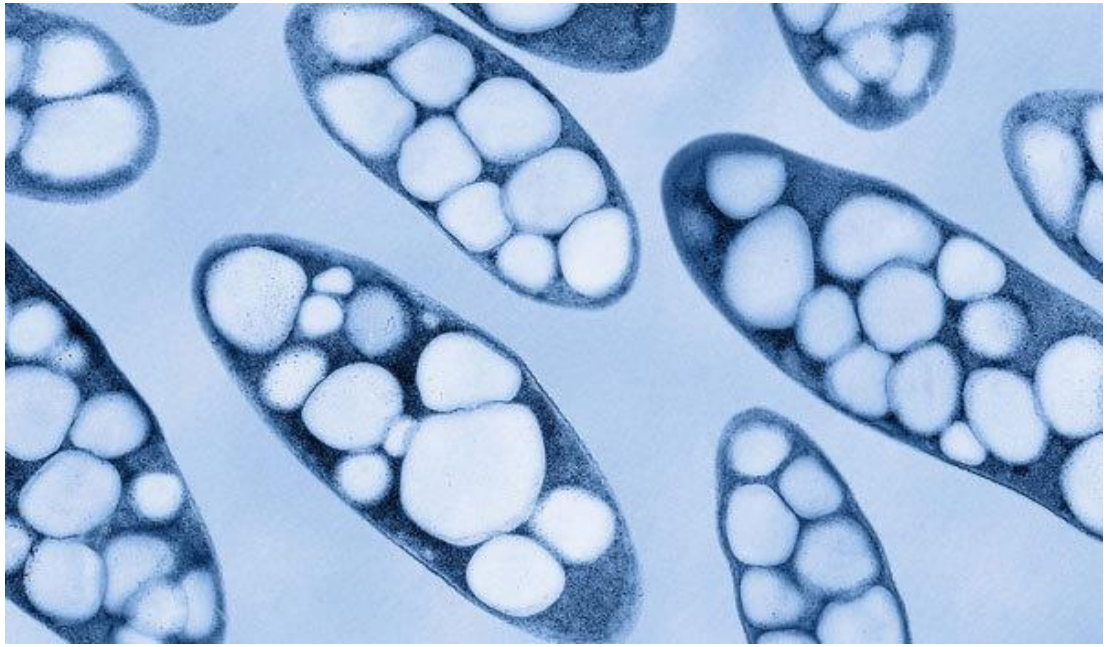
- Synthetic biology is engineering with biology and biochemistry

What is Synthetic Biology?

- Designing and building/modifying organisms for specified needs

What is Synthetic Biology?

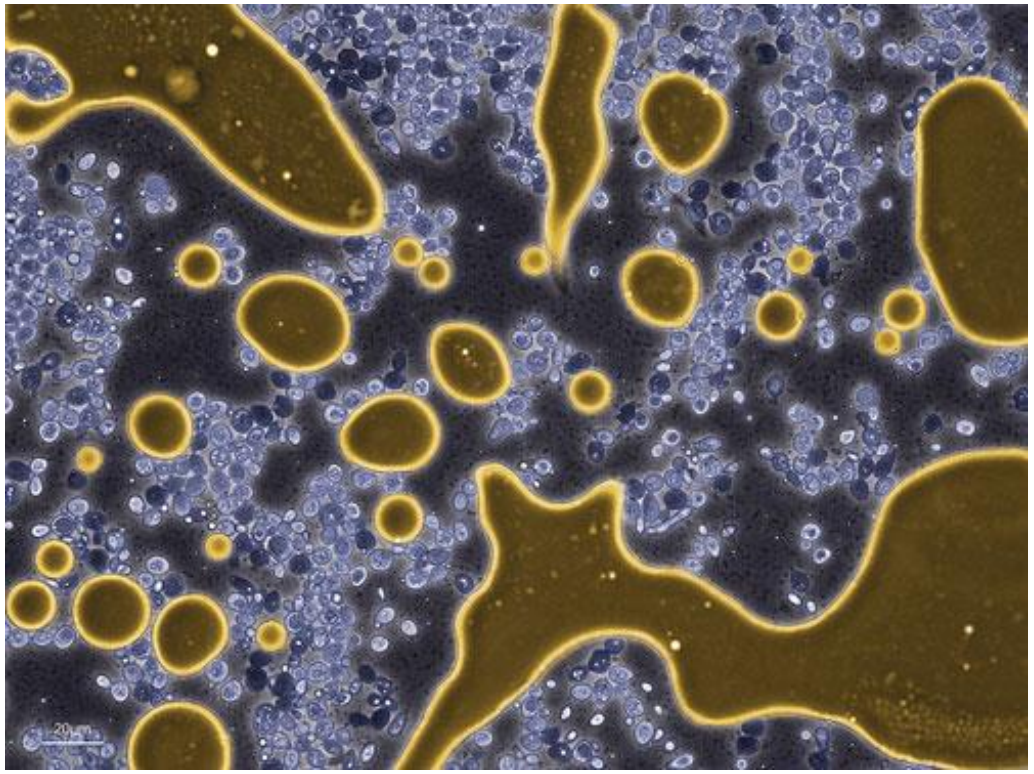
- Needs addressed in various fields
  - Biomedical
  - **Chemical**



Metabolomix

What is Synthetic Biology?

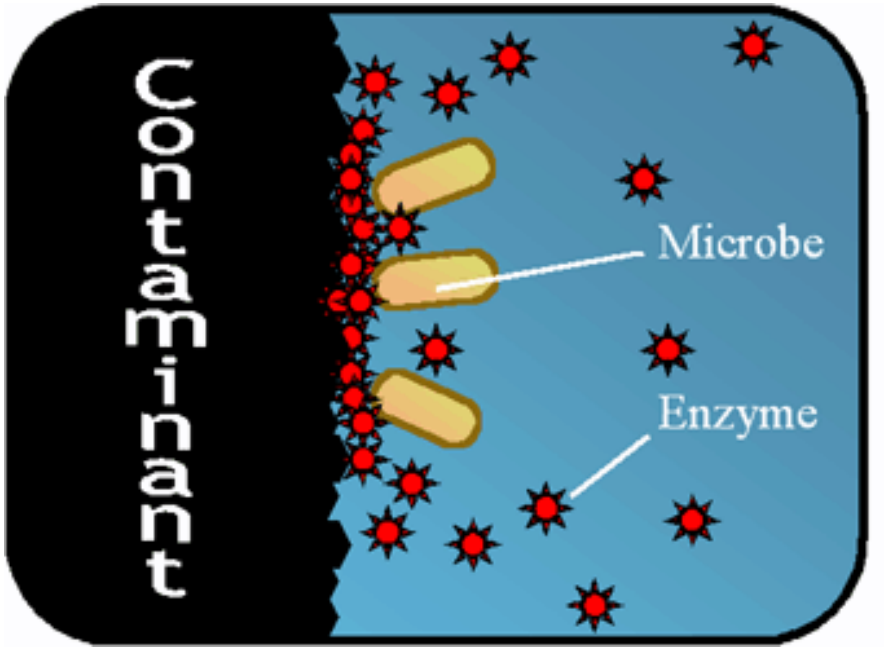
- Needs addressed in various fields
  - Biomedical
  - Chemical
  - **Energy**



Amyris

What is Synthetic Biology?

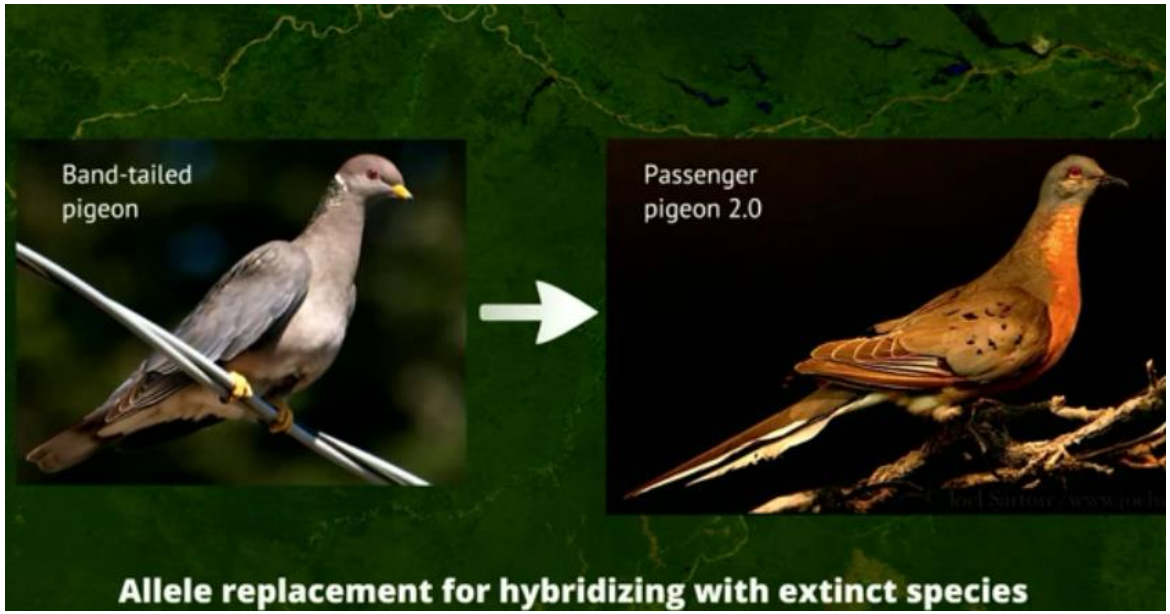
- Needs addressed in various fields
  - Biomedical
  - Chemical
  - Energy
  - Agricultural
  - **Environmental**



http://www.integraenvironmental.com/Images/1contaminant.gif

What is Synthetic Biology?

- Needs addressed in various fields
  - Biomedical
  - Chemical
  - Energy
  - Agricultural
  - Environmental
  - Scientific
  - **“Cool stuff”**
    - **“Jurassic Park”**



What is Synthetic Biology?

- Needs addressed in various fields
  - Biomedical
  - Chemical
  - Energy
  - Agricultural
  - Environmental
  - Scientific
  - **“Cool stuff”**
    - **Fluorescent pets**

BioGlow Avatar™

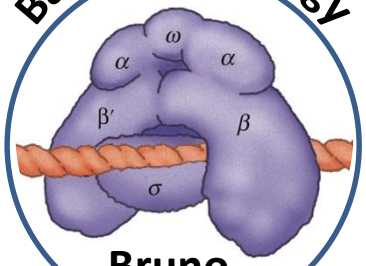
GloFish

Renewable chemicals

Todd
Joe
Venkatesh
Cassidy

S. cerevisiae *E. coli* *B. subtilis*

Basic bacteriology



Bruno

E. coli

Computational tools

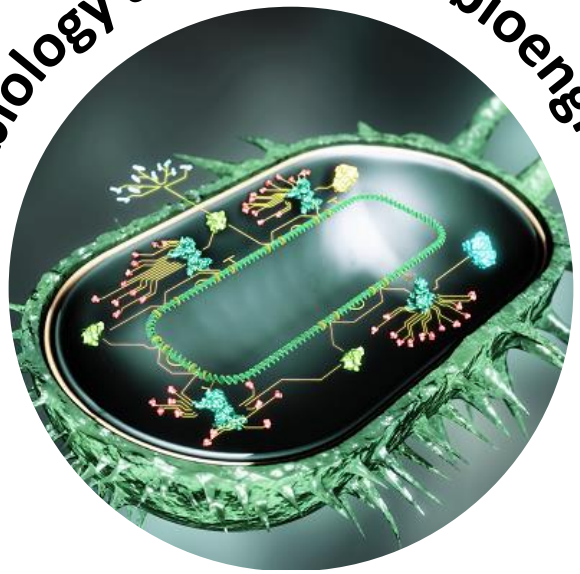
Hassoun
Venkatesh
Sara (CS)
Neda (CS)

Microbiome-ology

Lee
Jayaraman
Van Deventer
Wolfe

various lactic acid bacteria

Synthetic biology and systems bioengineering lab

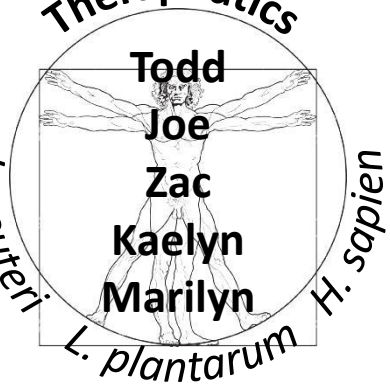


Renewable materials

Bruno

E. coli *B. subtilis*

Therapeutics



Todd
Joe
Zac
Kaelyn
Marilyn

L. reuteri *L. plantarum* *H. sapien*

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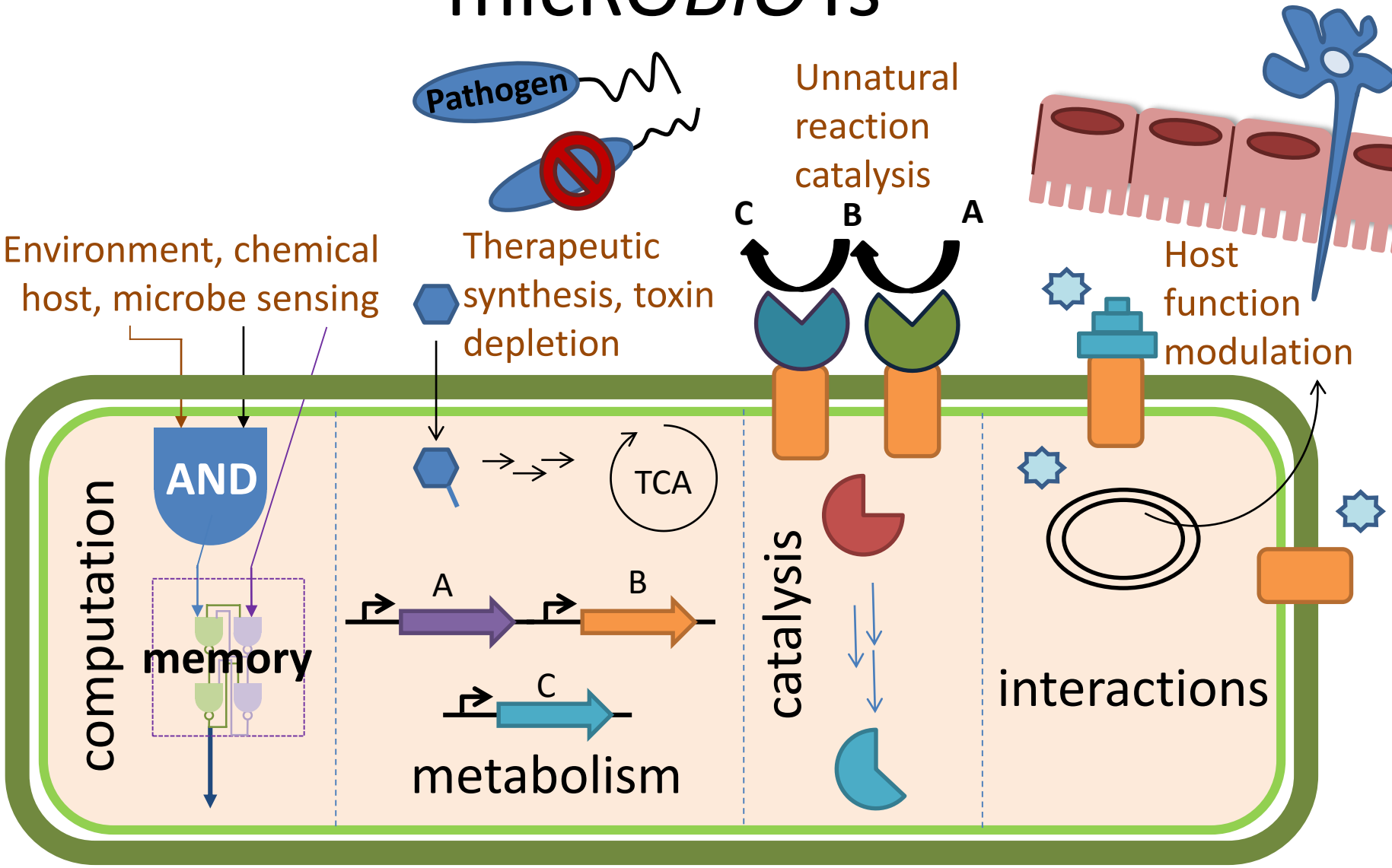
“micRO*BiO*Ts”


Pathogen
Unnatural reaction catalysis
C
B
A
Environment, chemical host, microbe sensing
Therapeutic synthesis, toxin depletion
Host function modulation
AND
TCA
computation
memory
A
B
C
metabolism
catalysis
interactions

The Experiment

Using a micRO*BiO*T sensor in a forensic investigation

Parts of a sensor

Input
(external stimulus)
(eg: movement)

Detector
(recognizes input, creates signal)
(eg: motion detector)

Actuator
(takes input signal and converts it to output)
(eg: switch)

Output
(detectable signal)
(eg: light)

A motion sensor

Biological sensor

Input
(external stimulus)
(eg: movement)

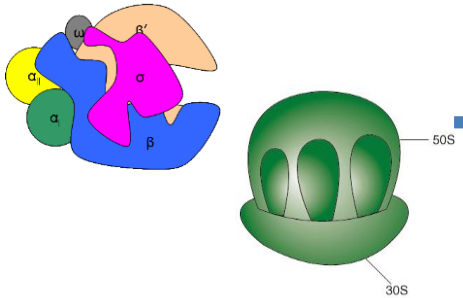
Detector
(recognizes input, creates signal)
(eg: motion detector)

Actuator
(takes input signal and converts it to output)
(eg: switch)

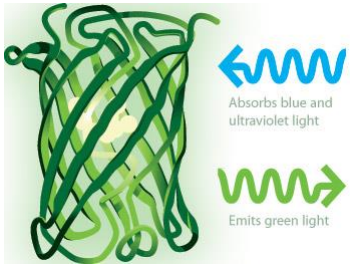
Output
(detectable signal)
(eg: light)

Pathogen metabolite

Binding protein



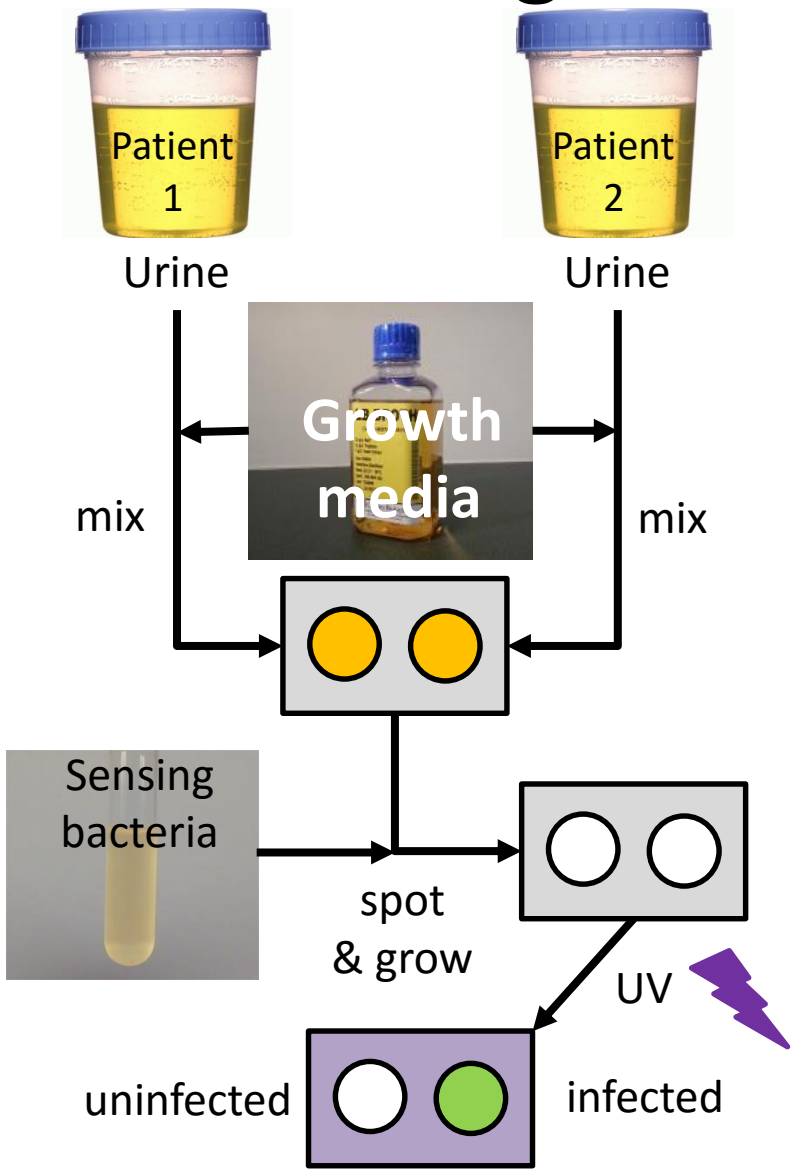
Cellular protein production machinery



Fluorescent protein

Using micRO*BiO*T in forensic investigation

- *Candida albicans* (a fungus) infects the intestines
- Causes a disease called Candidiasis
- Arabinose: metabolite (biological chemical) produced by *Candida* excreted in urine (not in uninfected people)
- Biosensor is responsive to arabinose



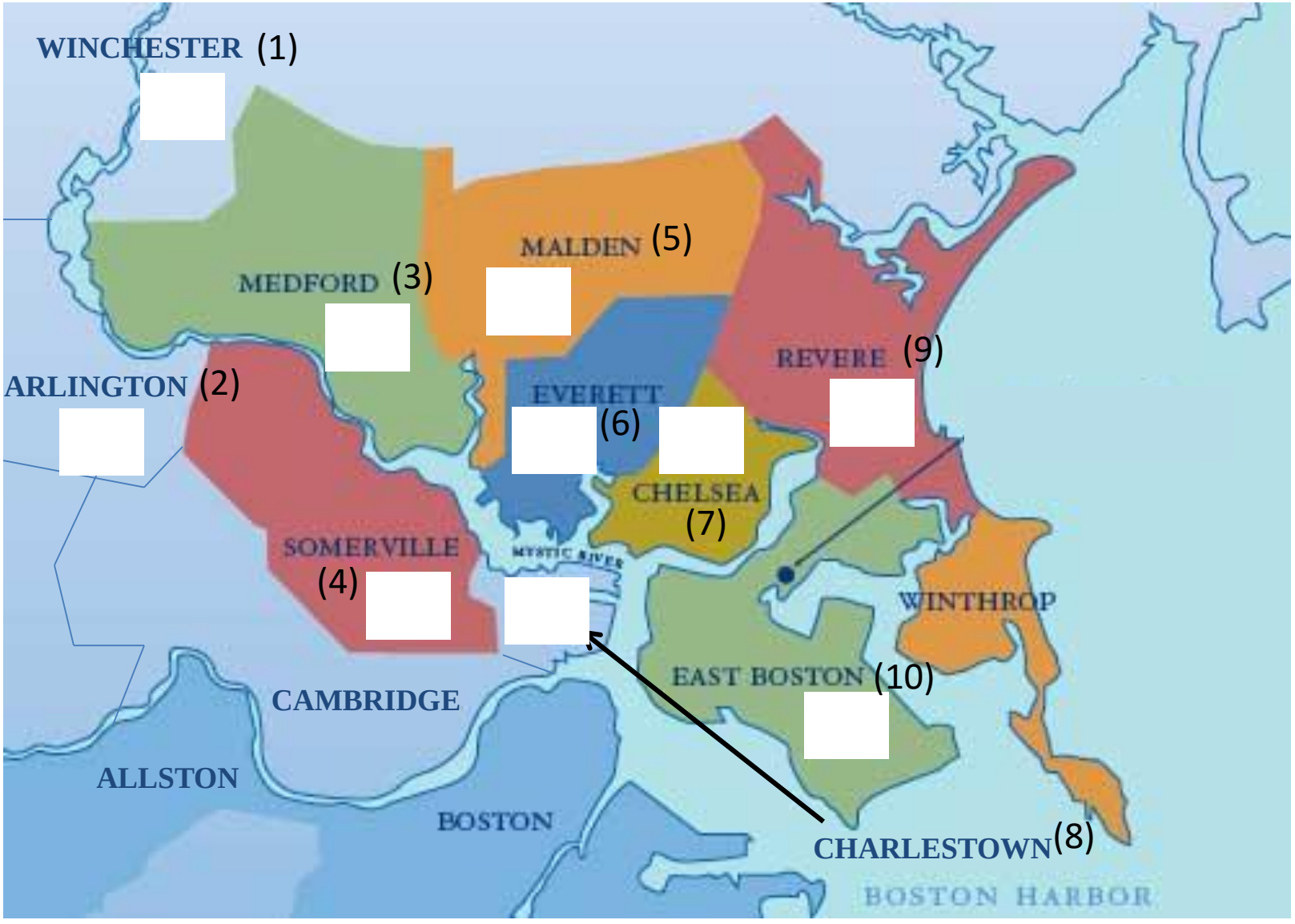
Where is “patient zero” from?

- Patients with symptoms of Candidiasis test for the diagnosed with the biosensor
- # of cases vary with town
- Seem to be clustered in certain towns around Boston

- Hypothesis: infection travels downriver

Find “ground zero”

Find “ground zero”

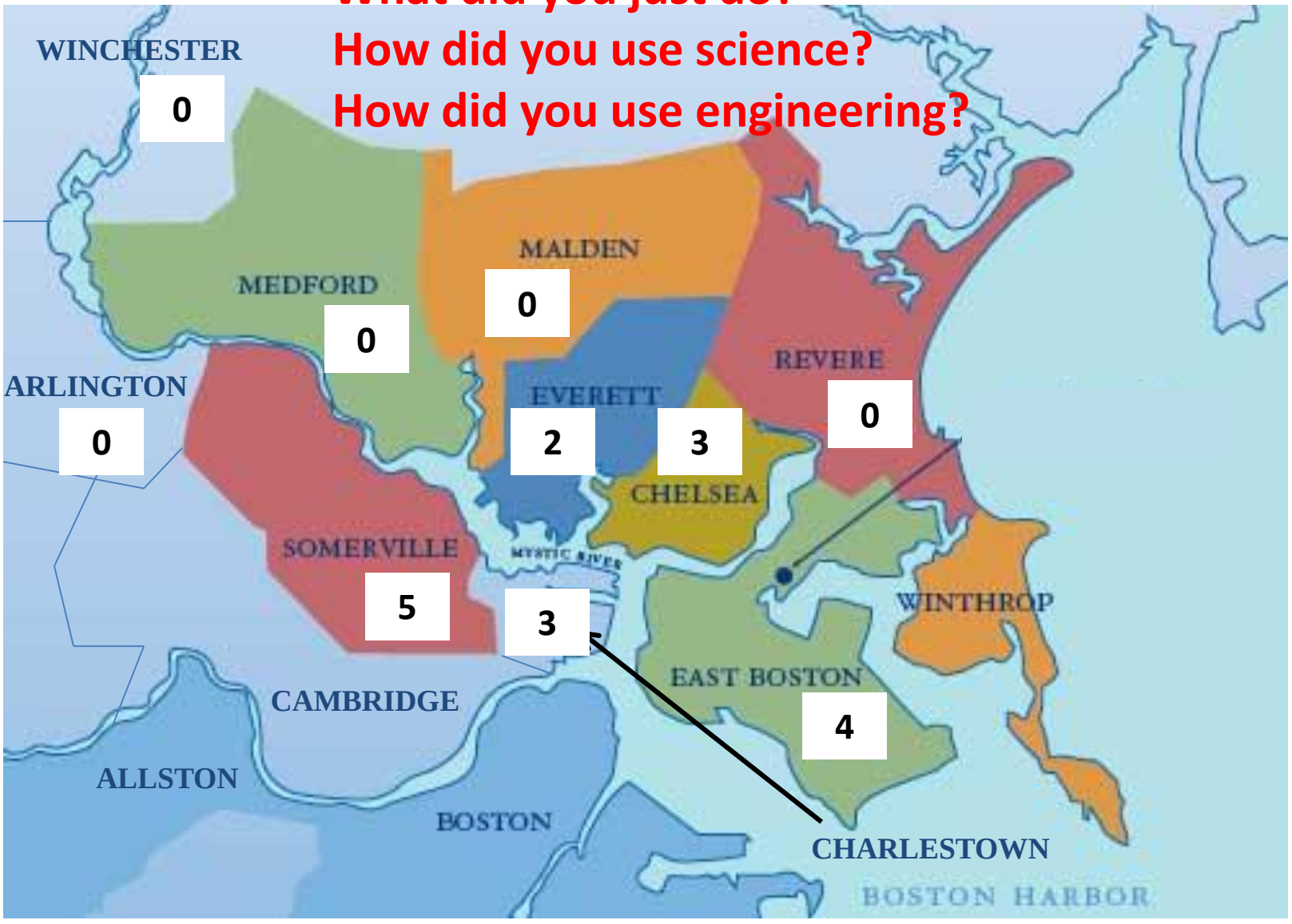


“Ground zero” is Somerville

What did you just do?

How did you use science?

How did you use engineering?



Summary

- Introduction to chemical engineering and synthetic biology
  - Engineering beyond bridges and cars
- Brief intro to the Nair lab
- micRO*BiO*T used to detect pathogen-derived metabolite
- Used it to identify where infection started
  - Used tool developed by engineer to solve a problem to confirm a scientific hypothesis
- Tomorrow: Making the micRO*BiO*T

More questions about engineering?

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- Zac: zachary.mays@tufts.edu
- Venkatesh: venkatesheg@gmail.com
- Cassidy: Cassidy.Hubert@tufts.edu
- Web: sites.tufts.edu/nairlab
- Can also Google “Nair lab Tufts” to find us.

''Engineering ... it is a great profession. There is the fascination of watching a figment of the imagination emerge through the aid of science to a plan on paper. Then it moves to realization in stone or metal or energy. Then it brings jobs and homes to men [and women]. Then it elevates the standards of living and adds to the comforts of life. That is the engineer's high privilege.“ – Pres. Herbert Hoover