Biology

ES131

Unit - 1

Characteristics and purposes of Science and Engineering

What is Biology

Why do we need to know biology?

- First, to find solutions to challenges, that mankind face.
- Sustainability
- Nature is greatest Engineer
- Biological systems evolved to perfection over billions of years
- Applications in Engineering?

1. To find solutions to challenges

Historical: bird flight - airplanes

Sustainability

Biology has already found sustainable methods.
Life forms have evolved, and co-existed in harmony with their surroundings for millions of years.

If we need solutions, we just need to look at how biology does it.

Design through biomimicry: https://www.youtube.com/watch?v=ZODvr_GzNc4
Biomimicry (sustainable) – Janine Benyus: https://www.youtube.com/watch?v=FBUpnG1G4yQ
Biomimicry (Janine Benyus – slightly old, but relevant): https://www.youtube.com/watch?v=k_GFq12w5WU

Sustainability, it's a very big aspect nowadays

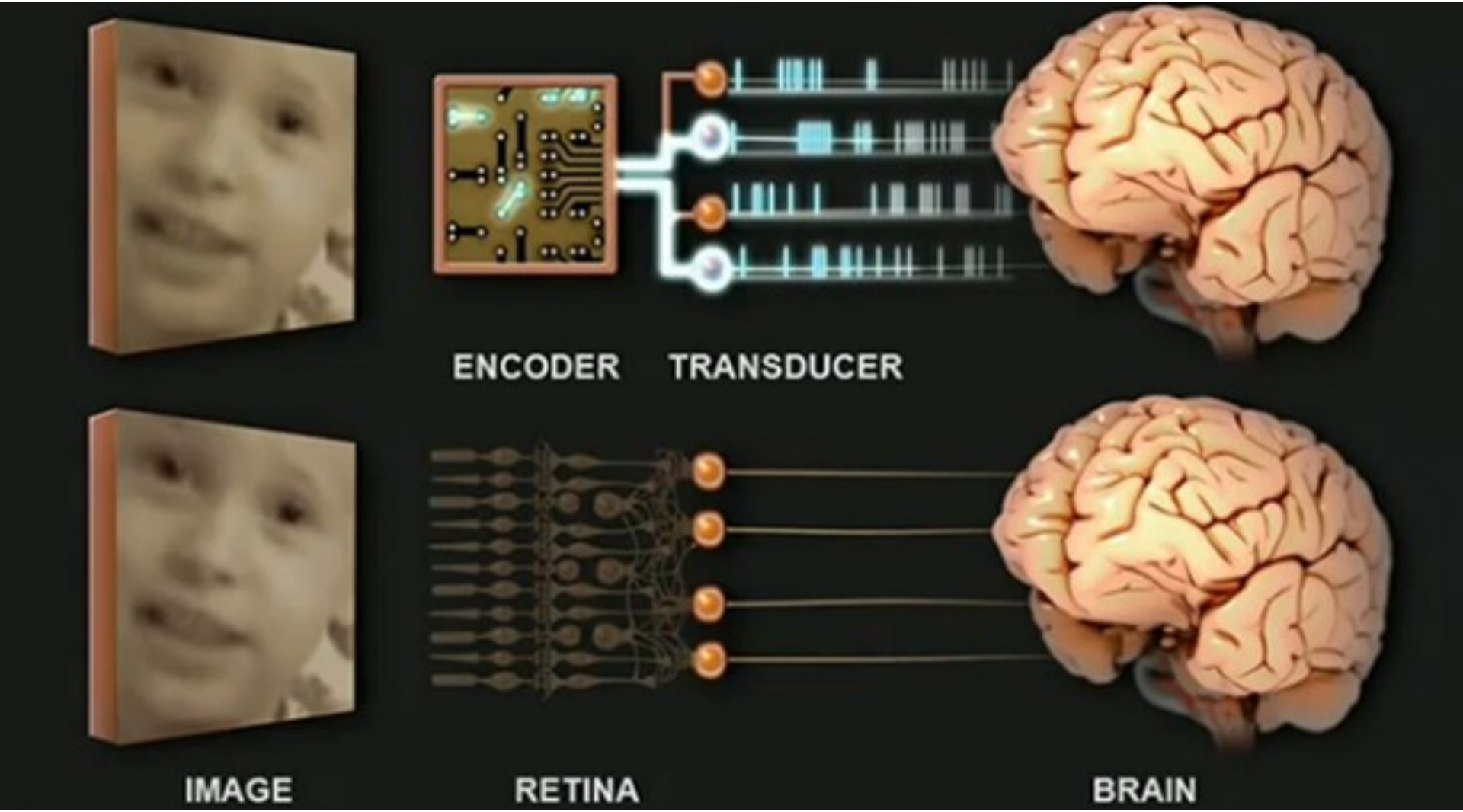
- And, whatever we do, we like to do in a sustainable fashion, so that we don’t spoil the our planet, and leave it for the next generations in the best state that we can.
- Bology has already found sustainable methods.
- This earth is probably 4.5 billion years old, primates developed about 65 million years ago, mankind, humans developed about 40 million years ago, round about that some million years ago.
- And, whereas earth itself has been around for billions of years, so about 4.5 billion years, and life evolved may be some billion years ago.
- And, over time, biology has found methods to do things in a sustainable fashion.
- Life forms have evolved, co-existed in harmony with their surroundings for millions of years atleast, or even billions of years.
- So it's all, all there, we just have to look at it and learn from biology and adopt those practices.

2. Biology is us. Can our wellness, both physical and mental, be better?

Through better understanding – cell, its processes, systems as a whole (e.g. obesity)

Artificial retina – Sheila Nirenberg:
http://www.youtube.com/watch?v=wGDKDjHfhXQ

Brain-computer interface
https://www.youtube.com/watch?v=7t84IGE5TXA


ENCODER
TRANSDUCER
IMAGE
RETINA
BRAIN

The Brain

10^{15} connections (synapses)

10^{11} nodes (neurons)

Driven by external signals

Timescales from milliseconds to years

Stochastic

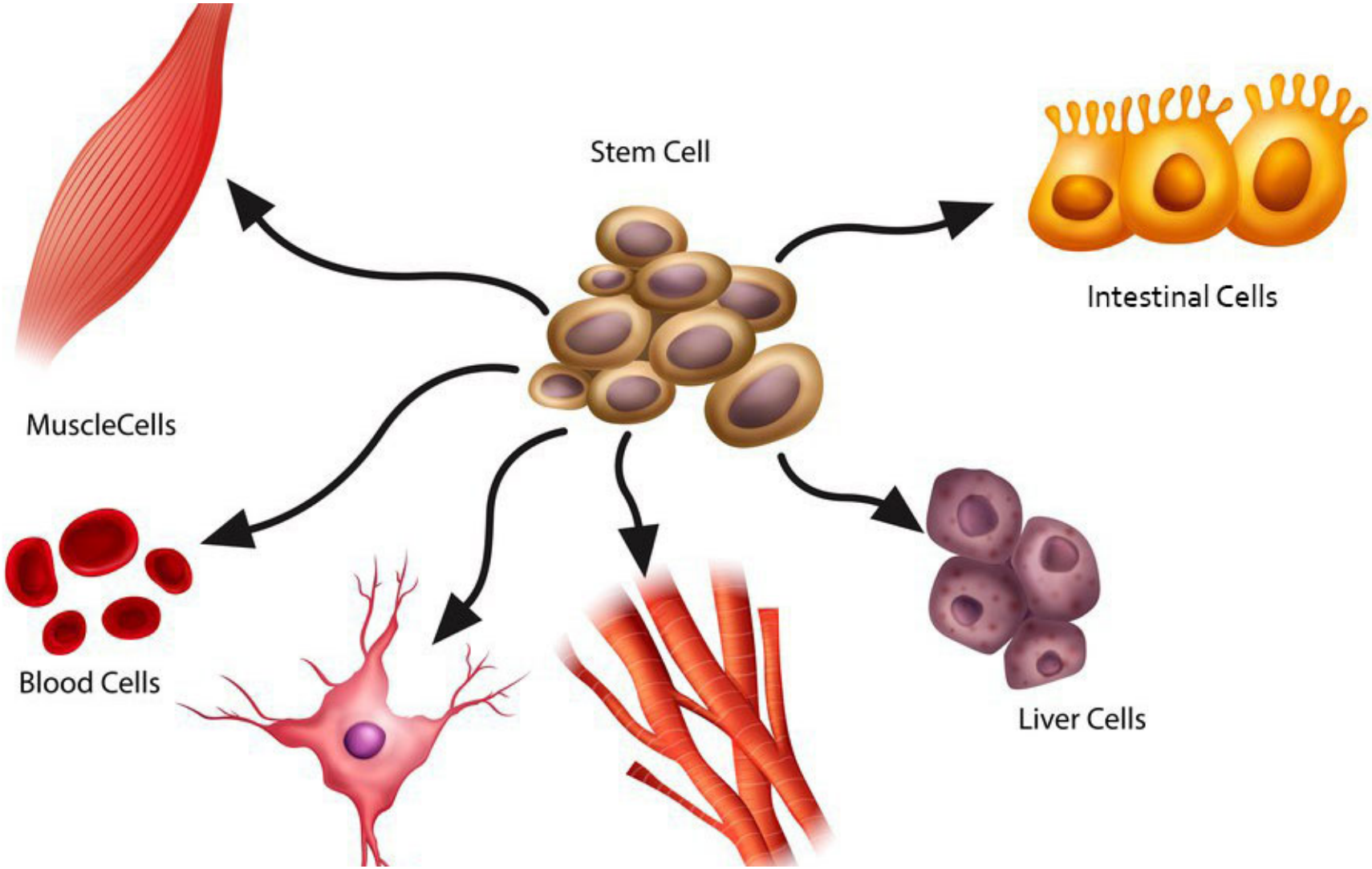
Far from equilibrium

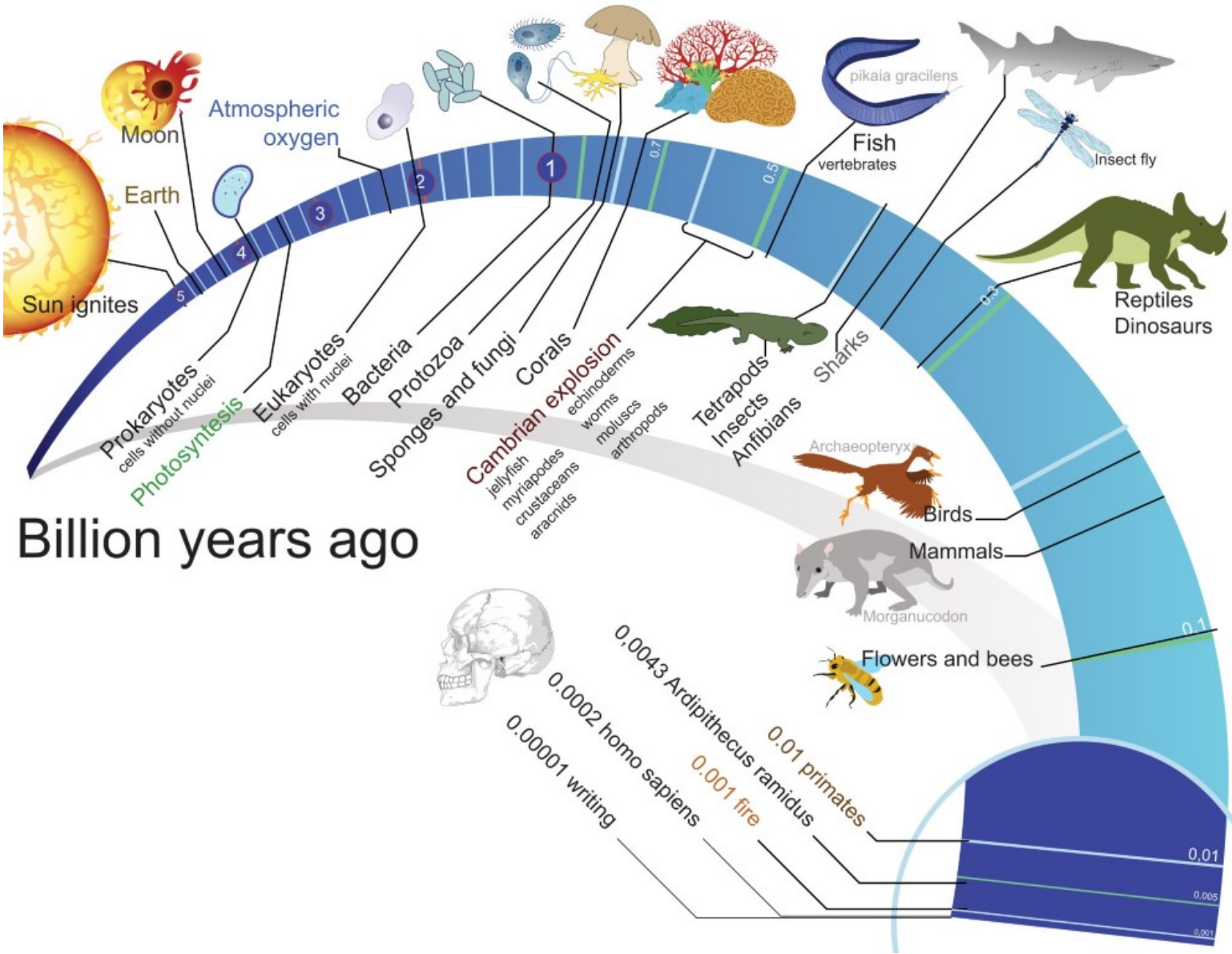
Dynamic long-range and short-range interactions via spikes

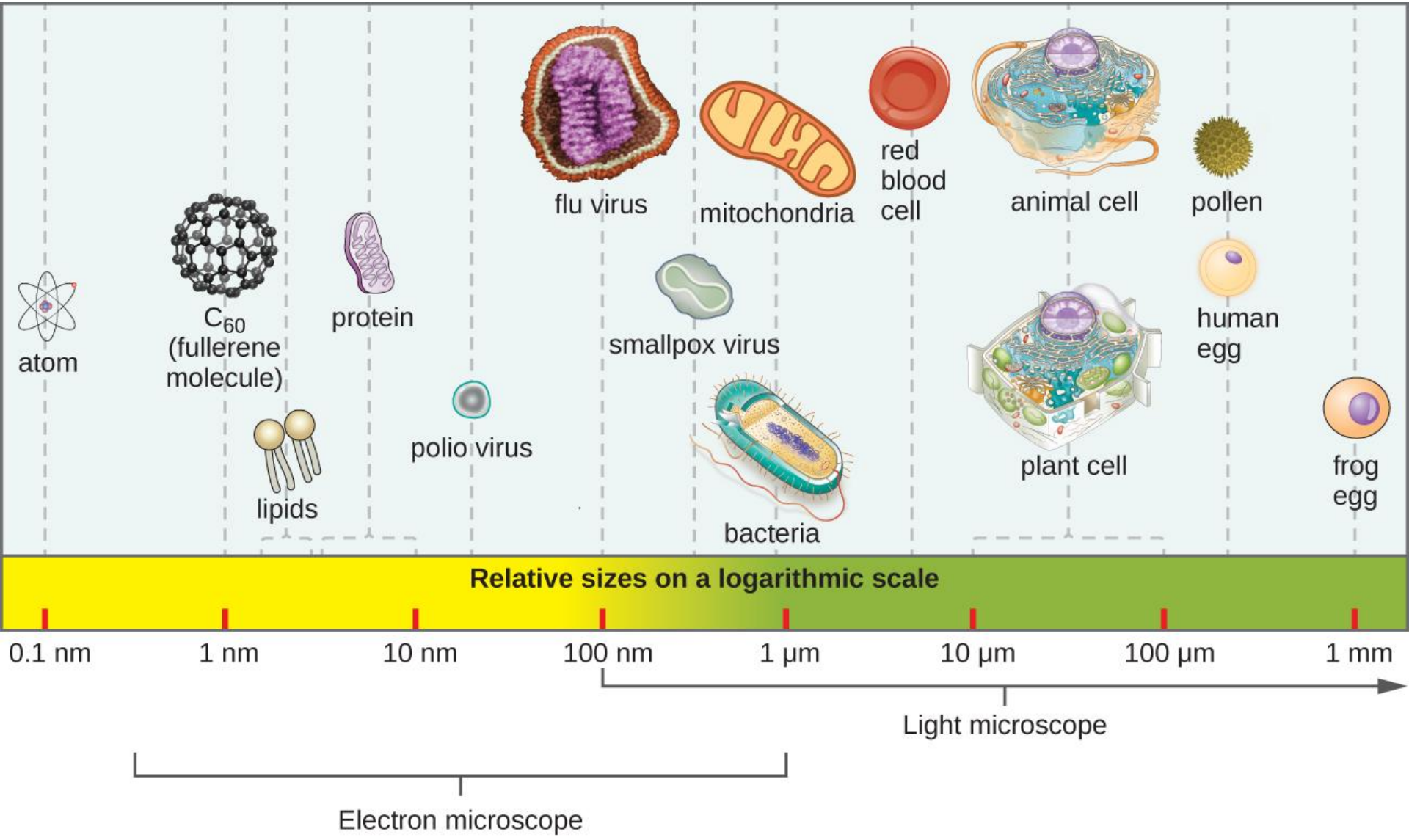
Engineering connection?

Each organ is an optimized machine

Artificial systems?


Stem Cell
Intestinal Cells
MuscleCells
Blood Cells
Liver Cells


Moon
Atmospheric oxygen
Earth
Sun ignites
5
4
3
2
1
0.7
0.5
0.3
0.1
Prokaryotes
cells without nuclei
Photosyntesis
Eukaryotes
cells with nuclei
Bacteria
Protozoa
Sponges and fungi
Corals
Cambrian explosion
echinoderms
worms
molluscs
arthropods
jellyfish
myriapodes
crustaceans
aracnids
pikaia gracilens
Fish
vertebrates
Tetrapods
Insects
Anfibians
Sharks
Insect fly
Reptiles
Dinosaurs
Archaeopteryx
Birds
Mammals
Morganucodon
Flowers and bees
Billion years ago
0,0043 Ardipithecus ramidus
0.01 primates
0.0002 homo sapiens
0.001 fire
0.00001 writing
0,01
0,005
0,001


atom
C_{60} (fullerene molecule)
protein
lipids
polio virus
flu virus
mitochondria
smallpox virus
bacteria
red blood cell
animal cell
pollen
human egg
plant cell
frog egg
Relative sizes on a logarithmic scale
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
Light microscope
Electron microscope

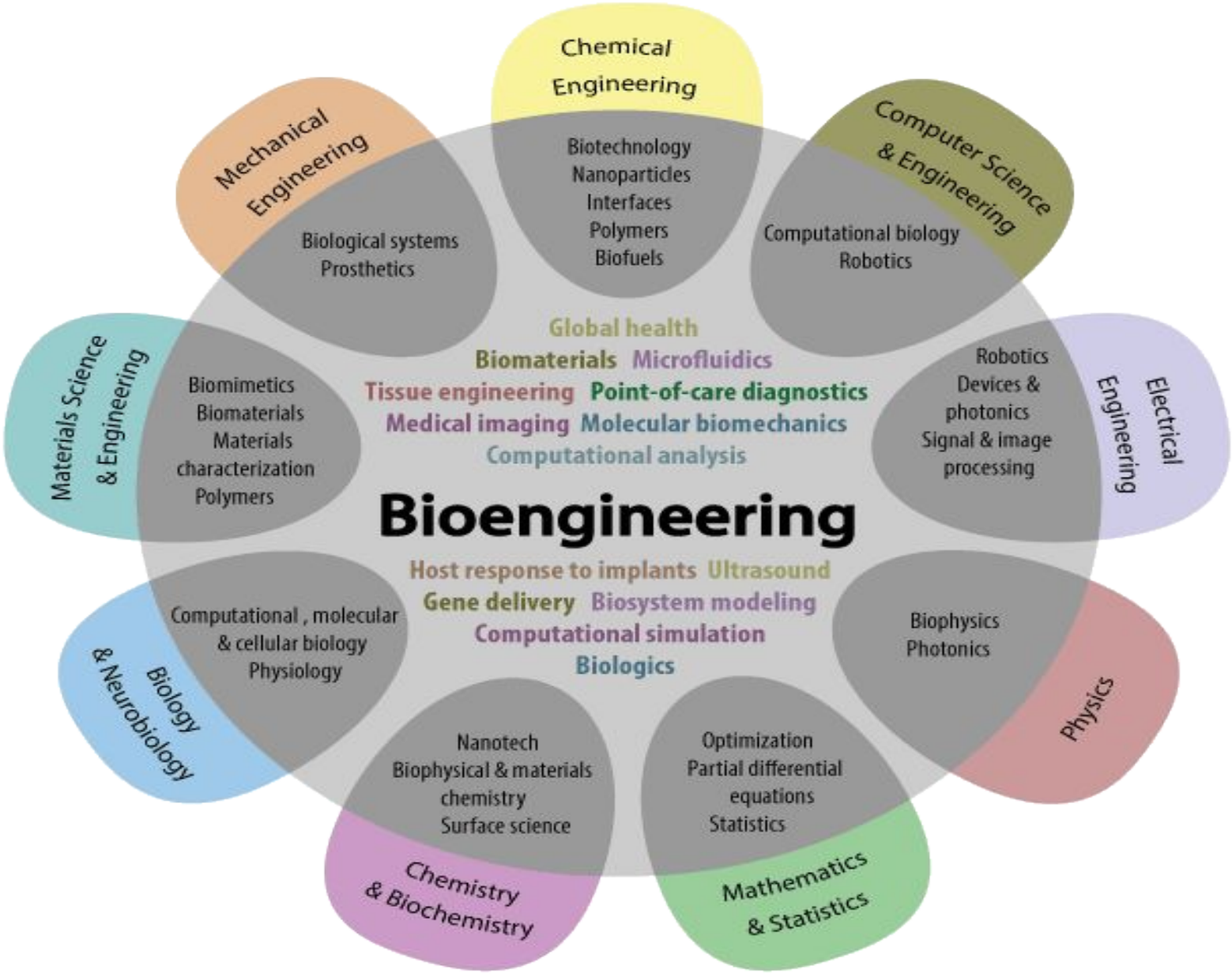
- So what we thought we would do, is pick up some aspects of biology, that, one would need to know as basic information, as to how life formed, how life evolved, they are very interesting aspects which could have a relevance to some of the things that we're dealing with nowadays. And the very fundamentals of biology, the basic biomolecules, how they interact with each other to certain extent may be. Some genetics which are, which is helpful in, predicting diseases and some aspects of DNA, RNA, and so on so forth.

Biological Engineering

The emerging discipline based biological engineering has the potential of using biological materials and living processes in designing systems that are more in harmony with nature.

Knowledge and accepted methods

- The body of knowledge for biological engineering includes fundamentals of engineering practice, including
  - Analysis
  - Computation
  - Design
- Skills, along with a working knowledge of the science of biology including
  - Methods,
  - Principles,
  - Properties
- Applicable to utilization. Biological engineering methods include
  - Systems approach
  - Modeling techniques
  - Black-box viewpoint


Chemical Engineering
Biotechnology
Nanoparticles
Interfaces
Polymers
Biofuels
Mechanical Engineering
Biological systems
Prosthetics
Computer Science & Engineering
Computational biology
Robotics
Materials Science & Engineering
Biomimetics
Biomaterials
Materials characterization
Polymers
Electrical Engineering
Robotics
Devices & photonics
Signal & image processing
Global health
Biomaterials Microfluidics
Tissue engineering Point-of-care diagnostics
Medical imaging Molecular biomechanics
Computational analysis
Bioengineering
Host response to implants Ultrasound
Gene delivery Biosystem modeling
Computational simulation
Biologics
Biology & Neurobiology
Computational , molecular & cellular biology
Physiology
Physics
Biophysics
Photonics
Chemistry & Biochemistry
Nanotech
Biophysical & materials chemistry
Surface science
Mathematics & Statistics
Optimization
Partial differential equations
Statistics

What is Science?

Study of the physical and natural world using theoretical models and data from experiments or observation

Ability to produce solutions in some problem domain

Research into questions posed by scientific theories and hypotheses

Models, Experiments, Observations, Research, Theory, Hypothesis

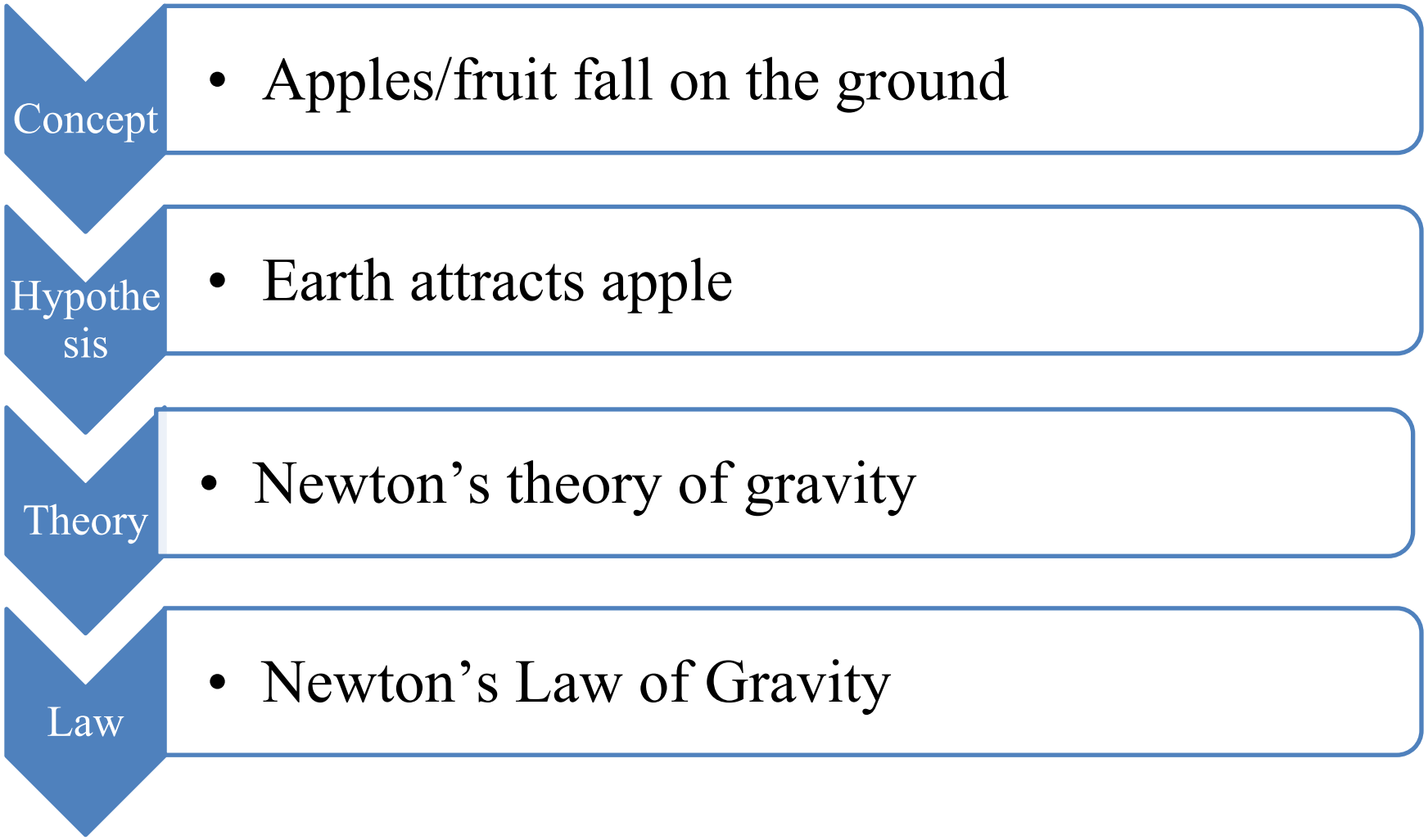
What is Science?

Concept: An abstract or general idea inferred or derived from specific instances

Hypothesis: A concept that is not yet verified but that if true would explain certain facts or phenomena

Theory: An organized system of accepted knowledge that applies in a variety of circumstances to explain a specific set of phenomena

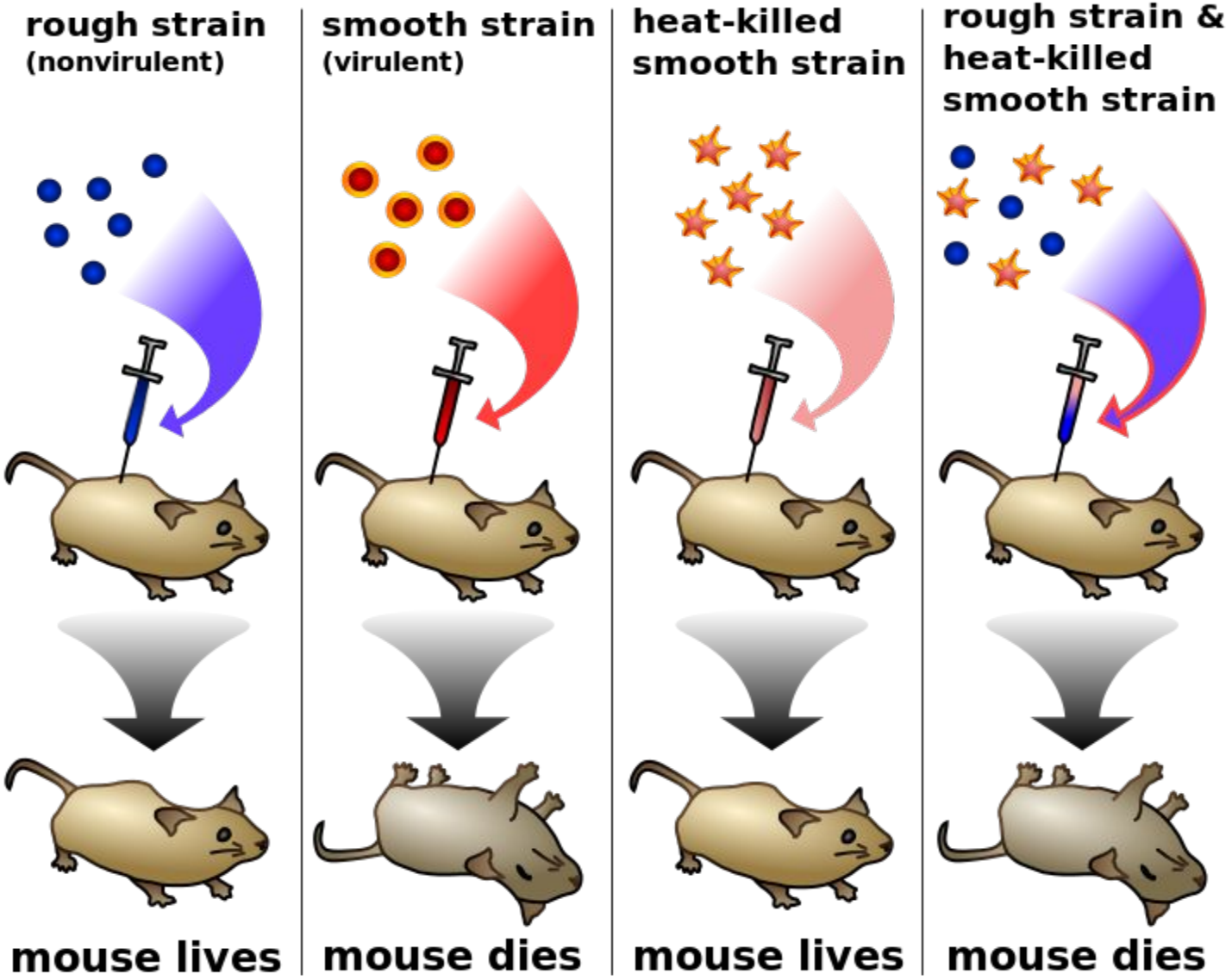
Law: A generalization that describes recurring facts or events in nature

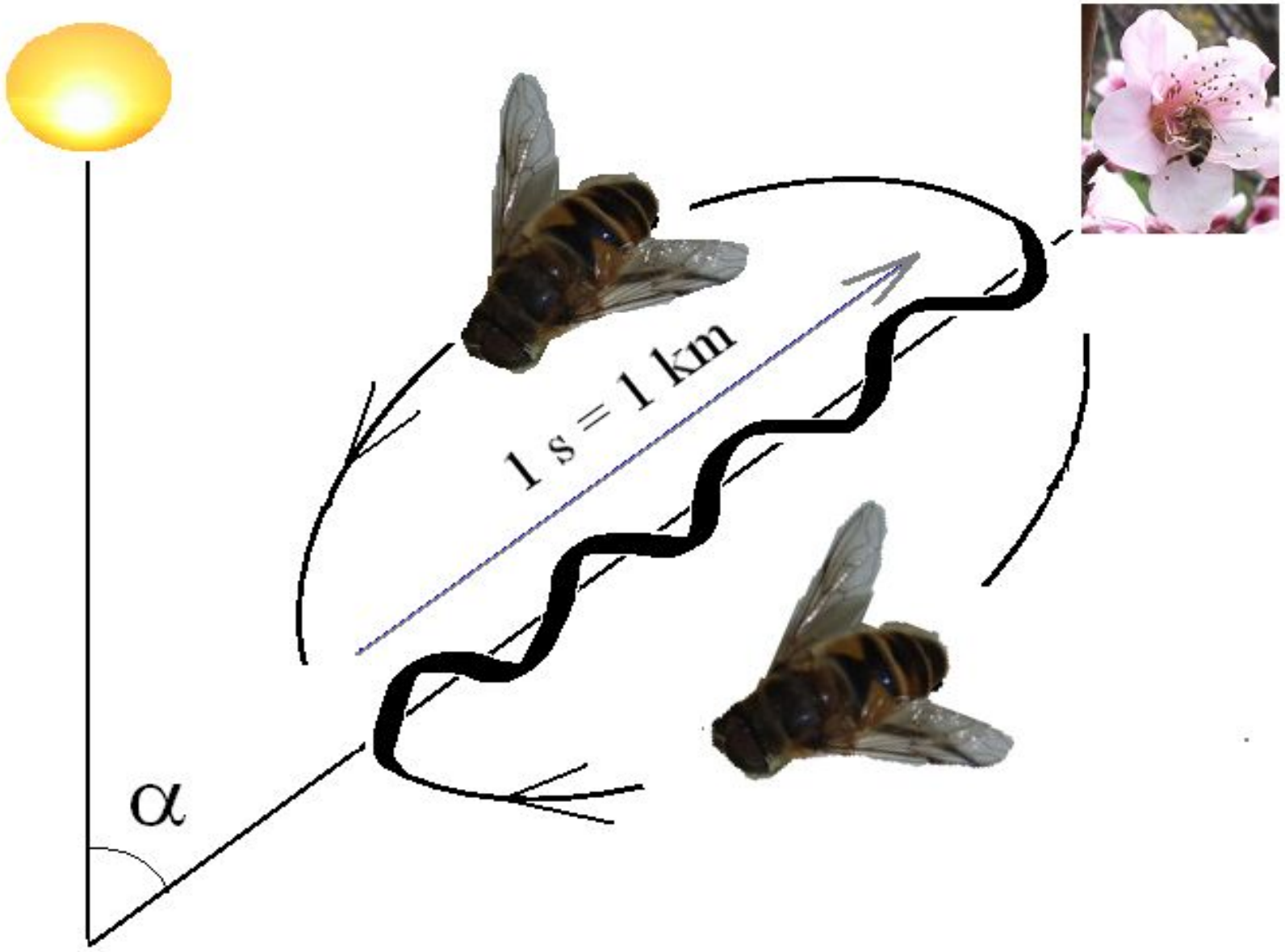

Concept
• Apples/fruit fall on the ground
Hypothesis
• Earth attracts apple
Theory
• Newton's theory of gravity
Law
• Newton's Law of Gravity

Do you do Science?

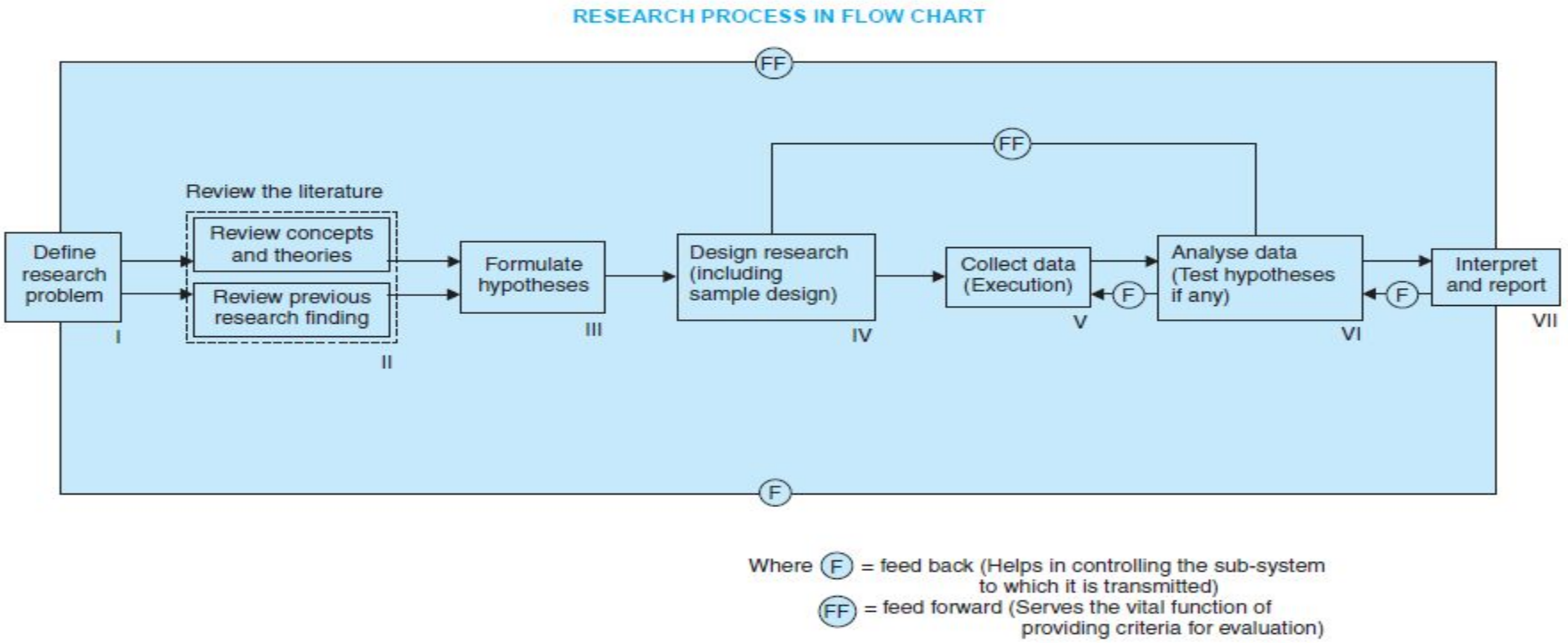
Why do you do Science?

To understand the world better!


rough strain
(nonvirulent)
smooth strain
(virulent)
heat-killed
smooth strain
rough strain &
heat-killed
smooth strain
mouse lives
mouse dies
mouse lives
mouse dies

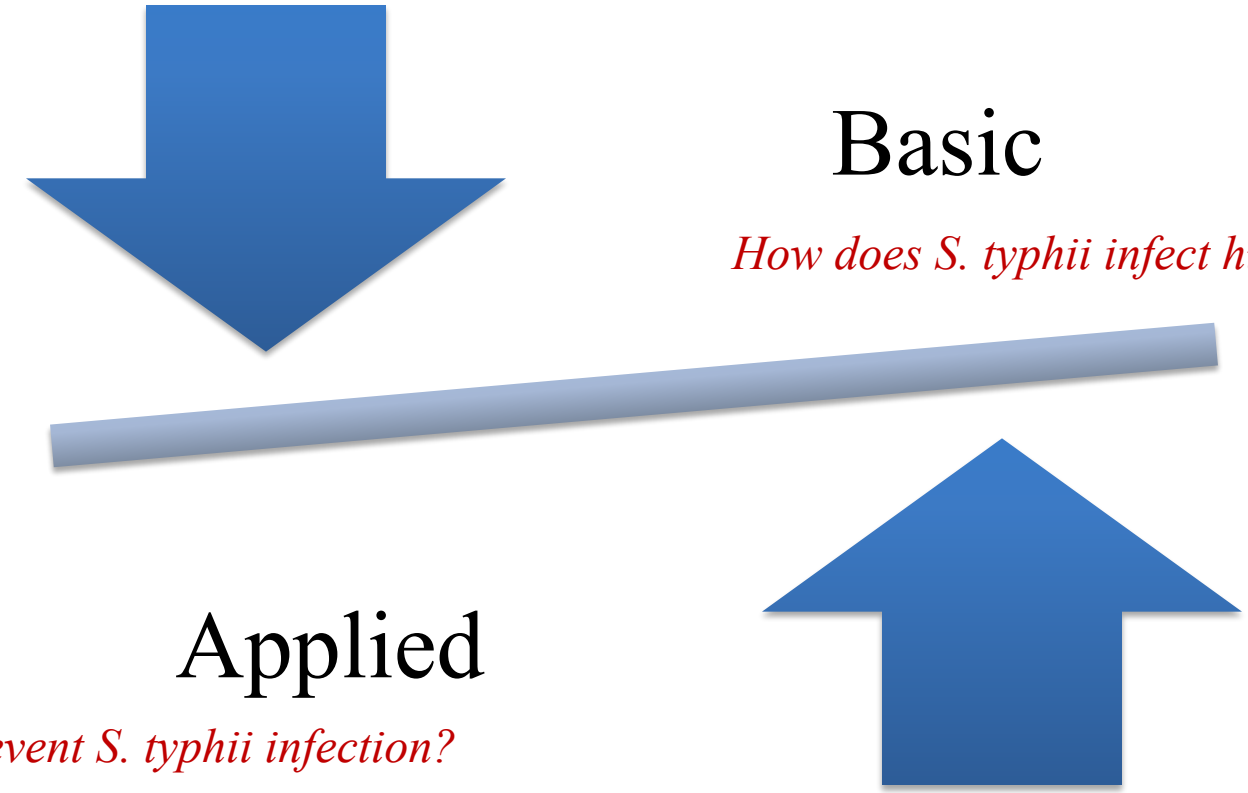

1 s = 1 km
α

Research



Systematized effort to gain new knowledge

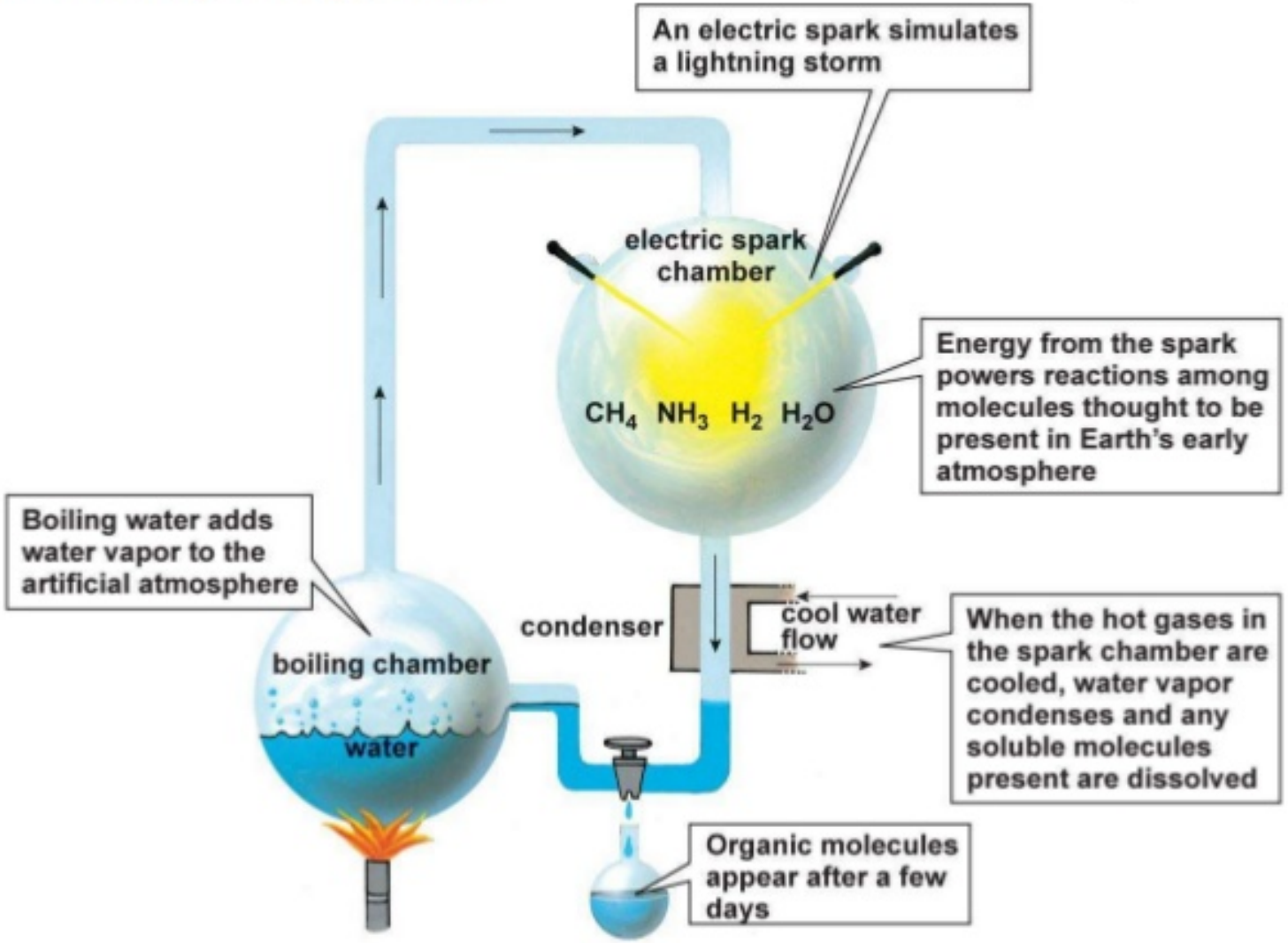
Research


Basic
How does S. typhii infect humans?
Applied
How to prevent S. typhii infection?

Research

1. The beginning of life

Miller's experiment



Phylogeny

4 distinct phases

1. **A random phase:** events occur by chance and observation occurs haphazardly. Electricity – Ben Franklin
    1. Outcome: make the observers aware of the phenomenon being observed.
2. **Descriptive phase:** Genetics – Gregor Mendel,
3. **Quantitative phase:** Mechanics – Aristotle
   Control phase:

TABLE 1.2.1
The Four Phases of Technology

Phase	Description	Physical Example	Biological Example
Random	Phenomena are encountered haphazardly	Heavenly bodies are observed to move	Differences and similarities are noted in animals and plants
Descriptive	Cause-and-effect relationships are established	Apparent heavenly movement appears to be related to seasonal changes	Genetic material is discovered and transgenic organisms are developed
Quantitative	Measurements are refined and dependencies are given numerical values	Kepler's laws describe planetary motion	Optimal microbial growth environments are determined
Control	Modeling and predictive equations lead to knowledge of useful substance amounts, design of systems, and applications to achieve desired ends	Satellites are orbited around the Earth, moon, and other planets	Transgenic microbial production of biochemicals becomes reality

Source: Johnson, A.T. and Davis, D.C., *Eng. Educ.*, 80, 15, January/February 1990. With permission.

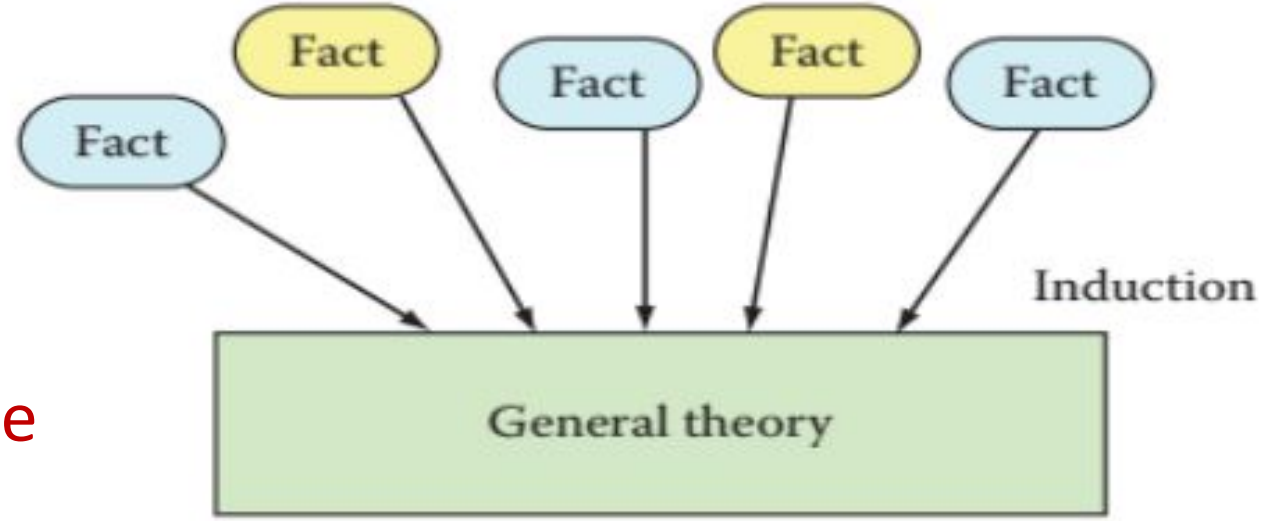
Motivation

- Motivation for Scientists and Engineers

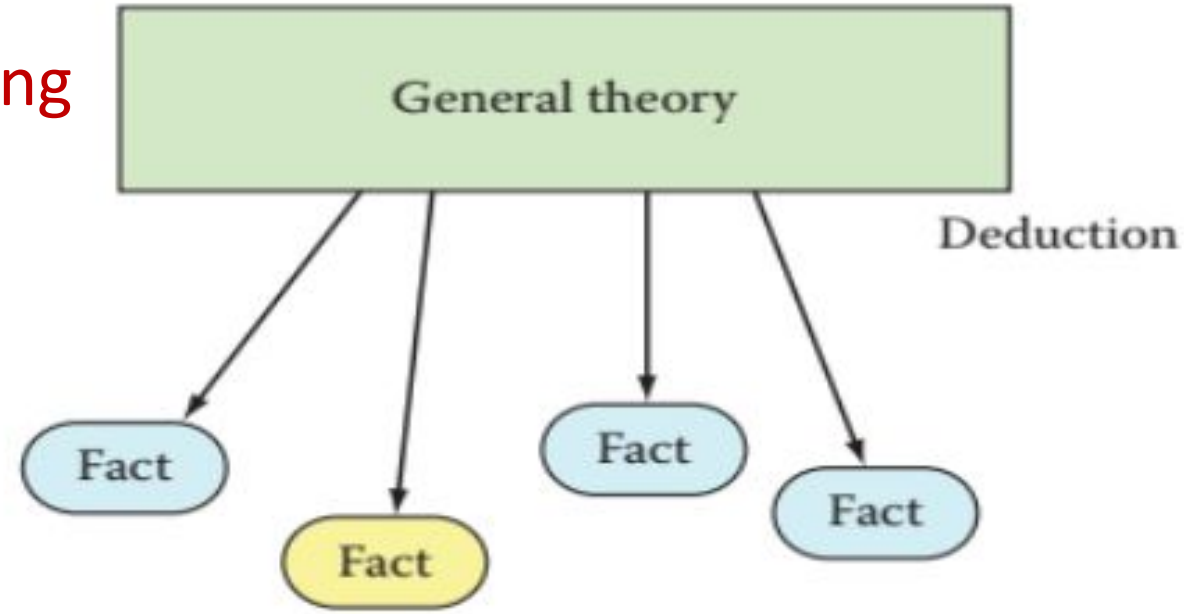
Methods

Scientist	Engineers
Perform experiments to ascertain facts Experiments determined by observed facts	Attempt to predict or control the outcome

Science



Engineering



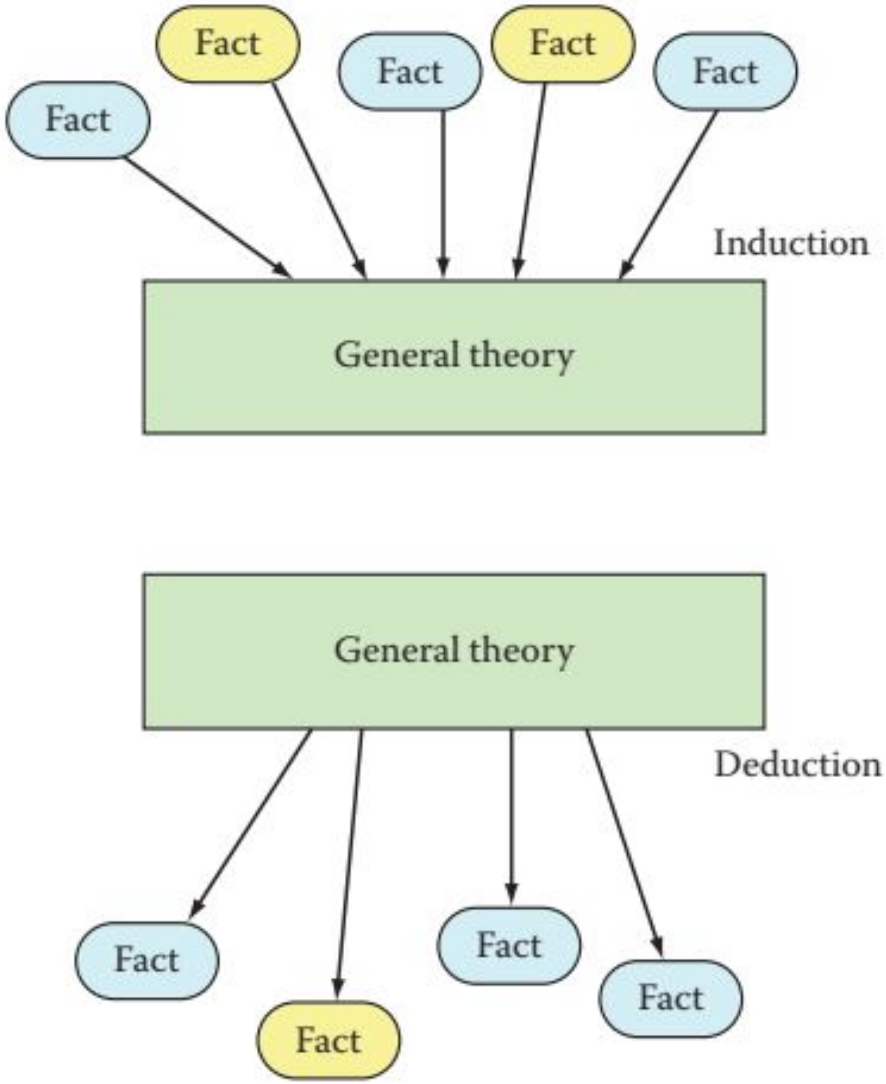
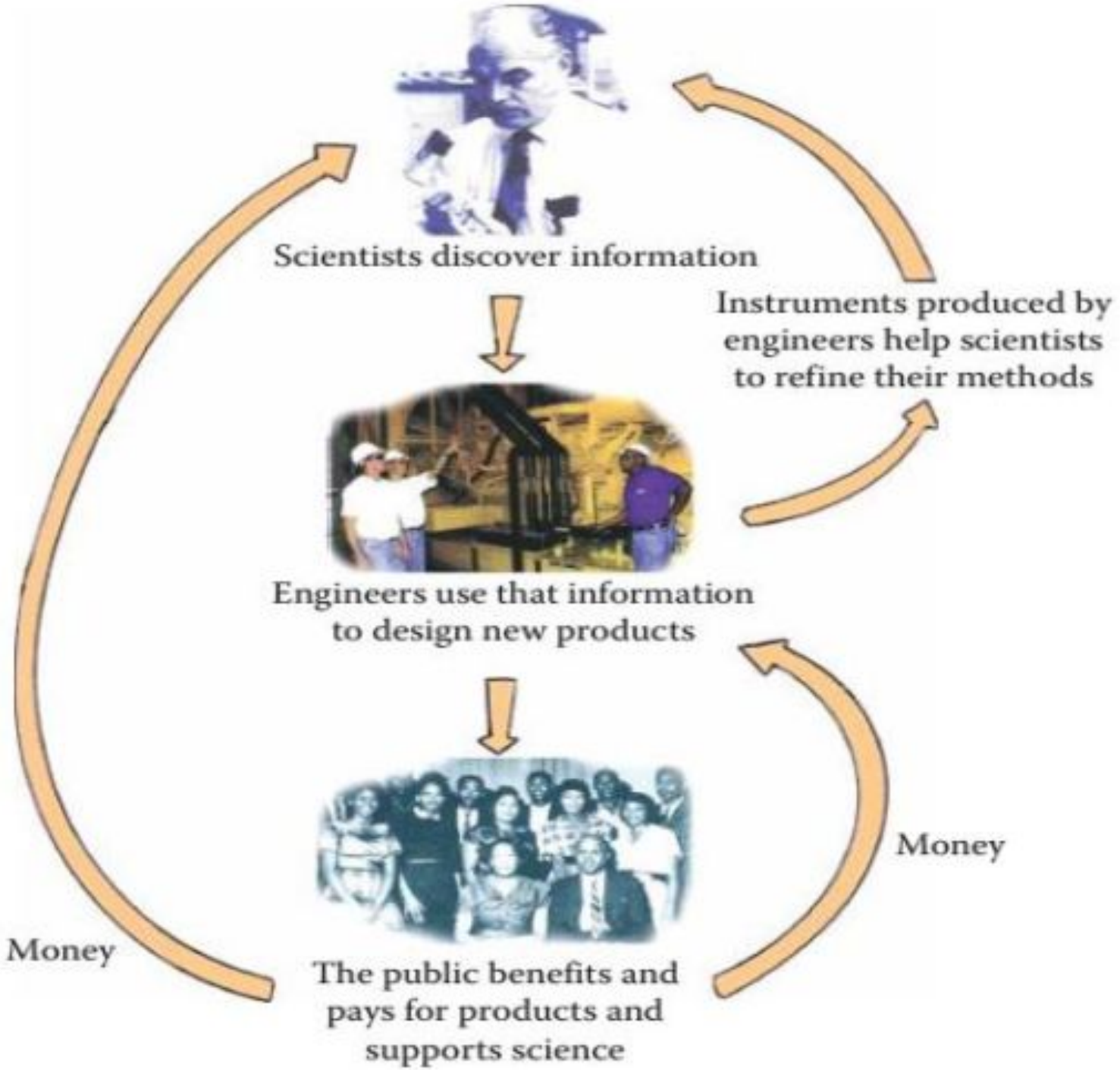


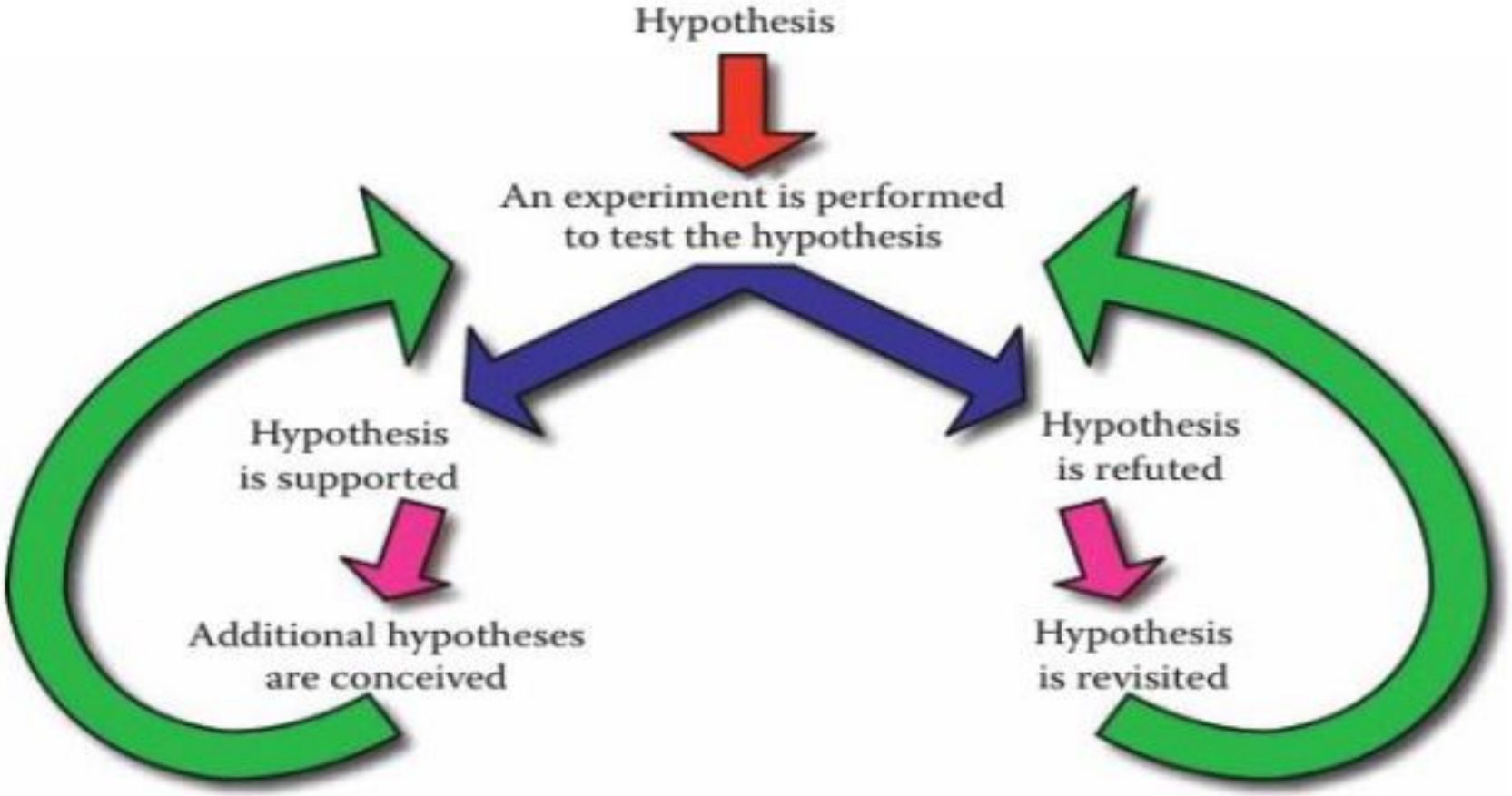
FIGURE 1.2.1 Science (above) is largely inductive, with many accumulated experimental facts contributing to an overall general theory. Engineering (below) is usually deductive, with theory presented first, and predicted facts derived from the theory.

Contrast between Science & Engineering

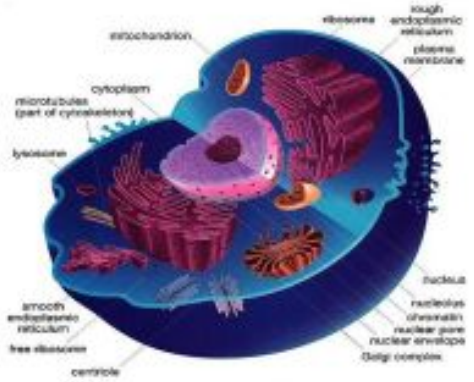
	Science	Engineering
Phylogeny	Random phase through quantitative phase	Quantitative phase and control phase
Motivation	Objects of study	Objects of creativity
Methods	Inductive: large numbers of facts suggest a unifying concept	Deductive: a small set of basic principles leads to specifics
Literature	Incremental	Conceptual
Synthesis	Scientists need engineers to show eventual applications	Engineers need scientists to identify basic facts

Source: Johnson, A.T. and Phillips, W.M., *J. Eng. Educ.*, 84, 311, 1995. With permission.


Scientists discover information
Instruments produced by engineers help scientists to refine their methods
Engineers use that information to design new products
Money
The public benefits and pays for products and supports science
Money

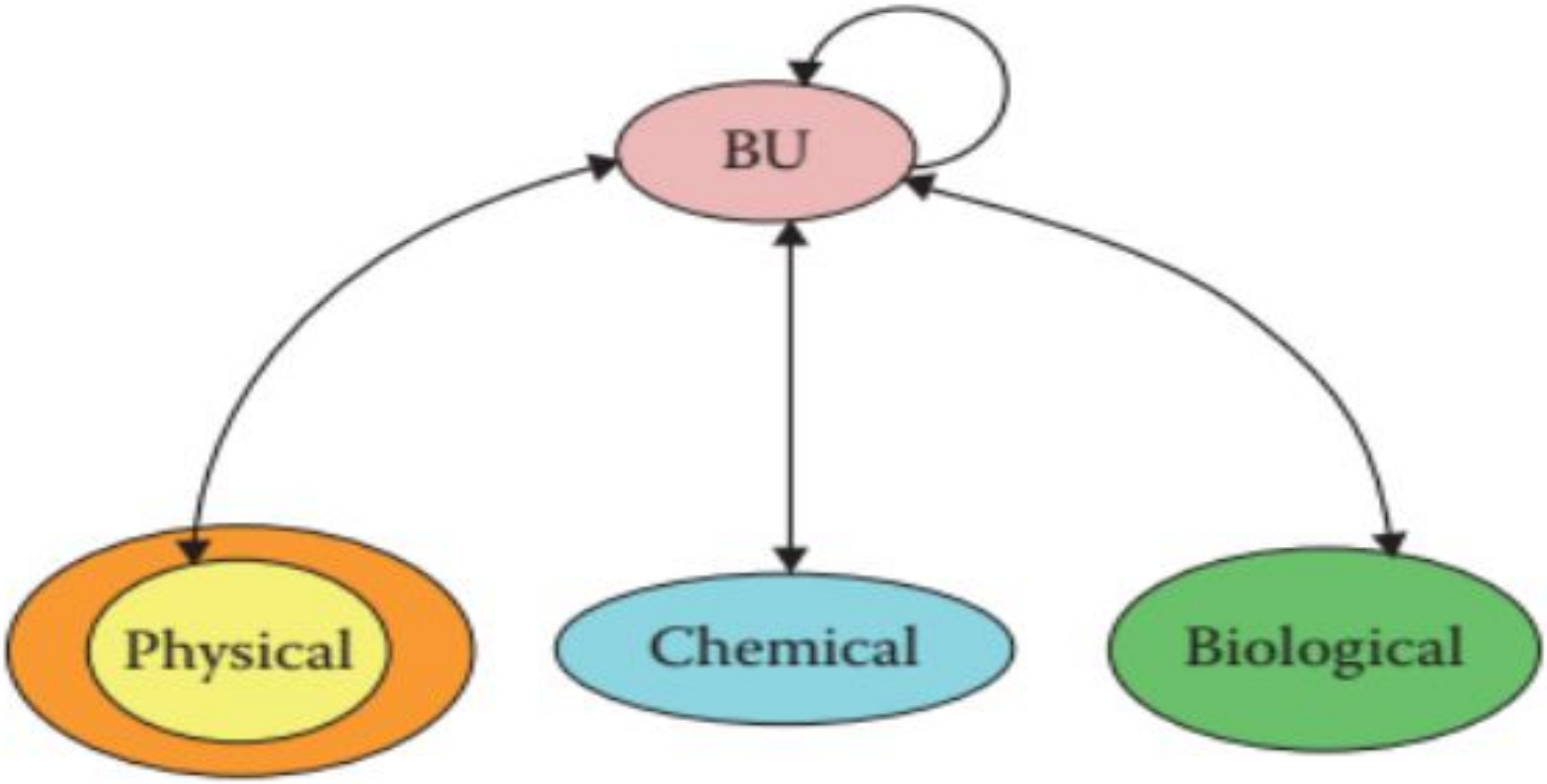

Hypothesis
An experiment is performed to test the hypothesis
Hypothesis is supported
Additional hypotheses are conceived
Hypothesis is refuted
Hypothesis is revisited

What is life?



Unit of life is a *cell*. Processes of living.
(according to F. Harold, "The Way of the Cell," 2001)

- *Flux of matter and energy*
  Chemical activities: absorb nutrients, produce biomass, eliminate waste products
- *Adaptation*
  Structure and function evolve to promote organism survival
- *Organization*
  A bacterial cell consists of 300 million molecules, assembled non-randomly
  DNA → RNA → Protein is strategically planned and executed
- *Self-reproduction*
  Autonomously, not by external forces



How do these principles influence Biology?