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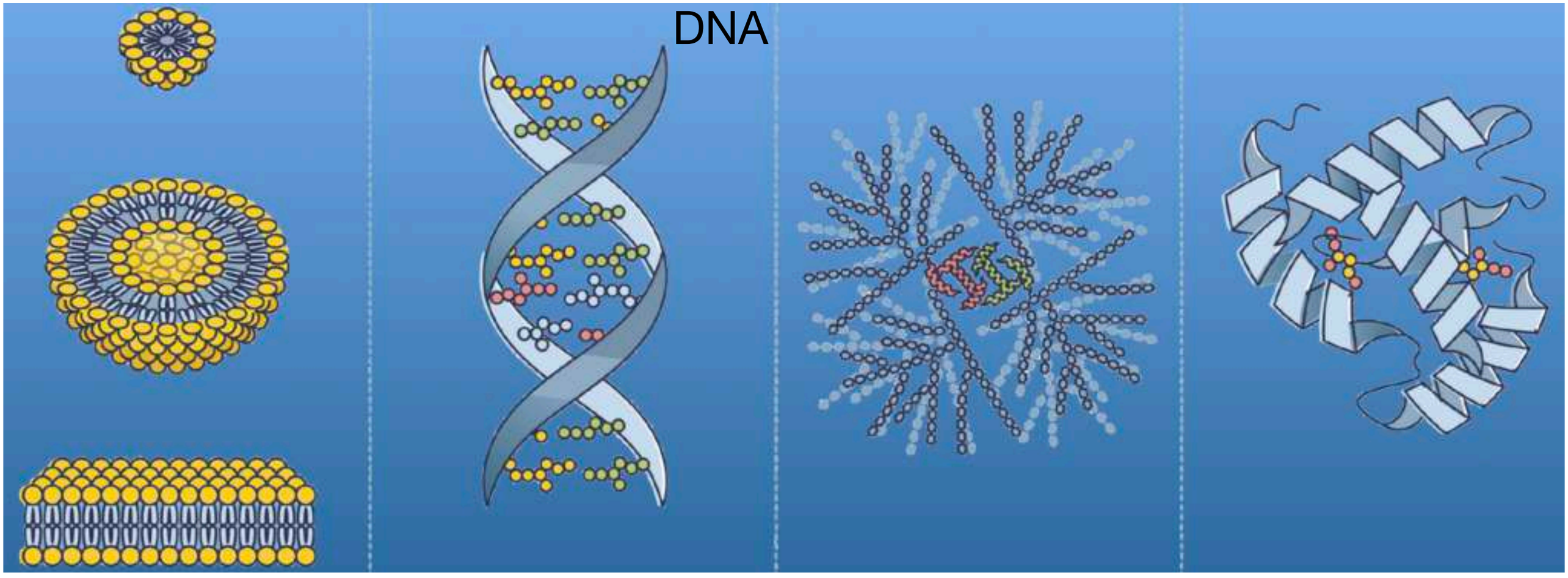
What is Biology?

Study of entities made of biomolecules



Lipids
(Fat)

Nucleic Acids
(DNA or RNA)

Carbohydrates
(Sugars, Starches
and Fibers)

Proteins

What are these entities?

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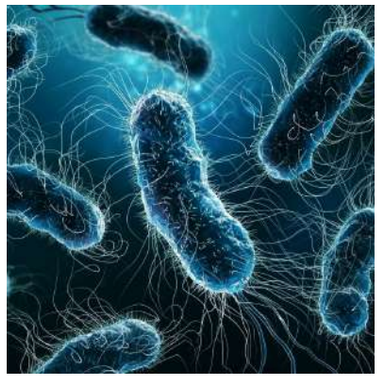
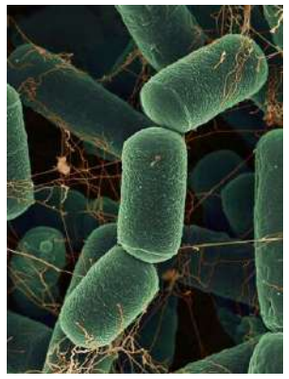
What are the entities made of biomolecules?

few examples..



Bacteria



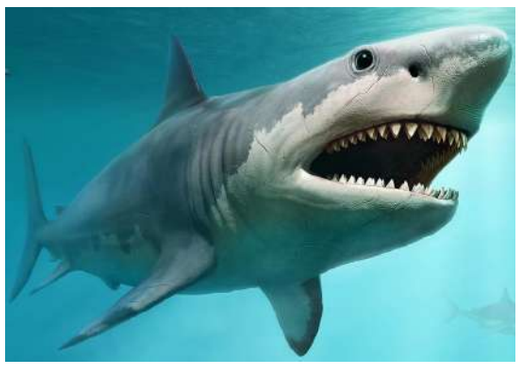
Archaea

Plants

Fungi

Molluscs

Flatworms



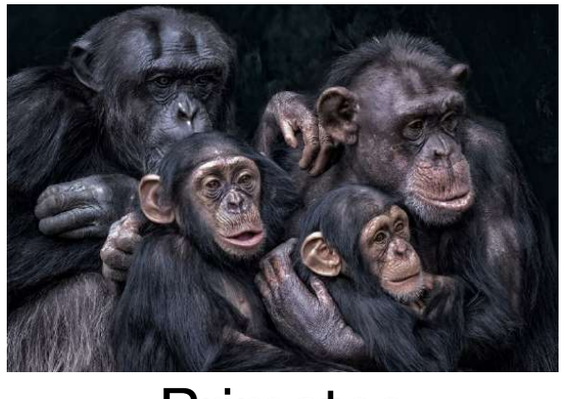
Sharks

Fish

Turtles

Birds

Mammals

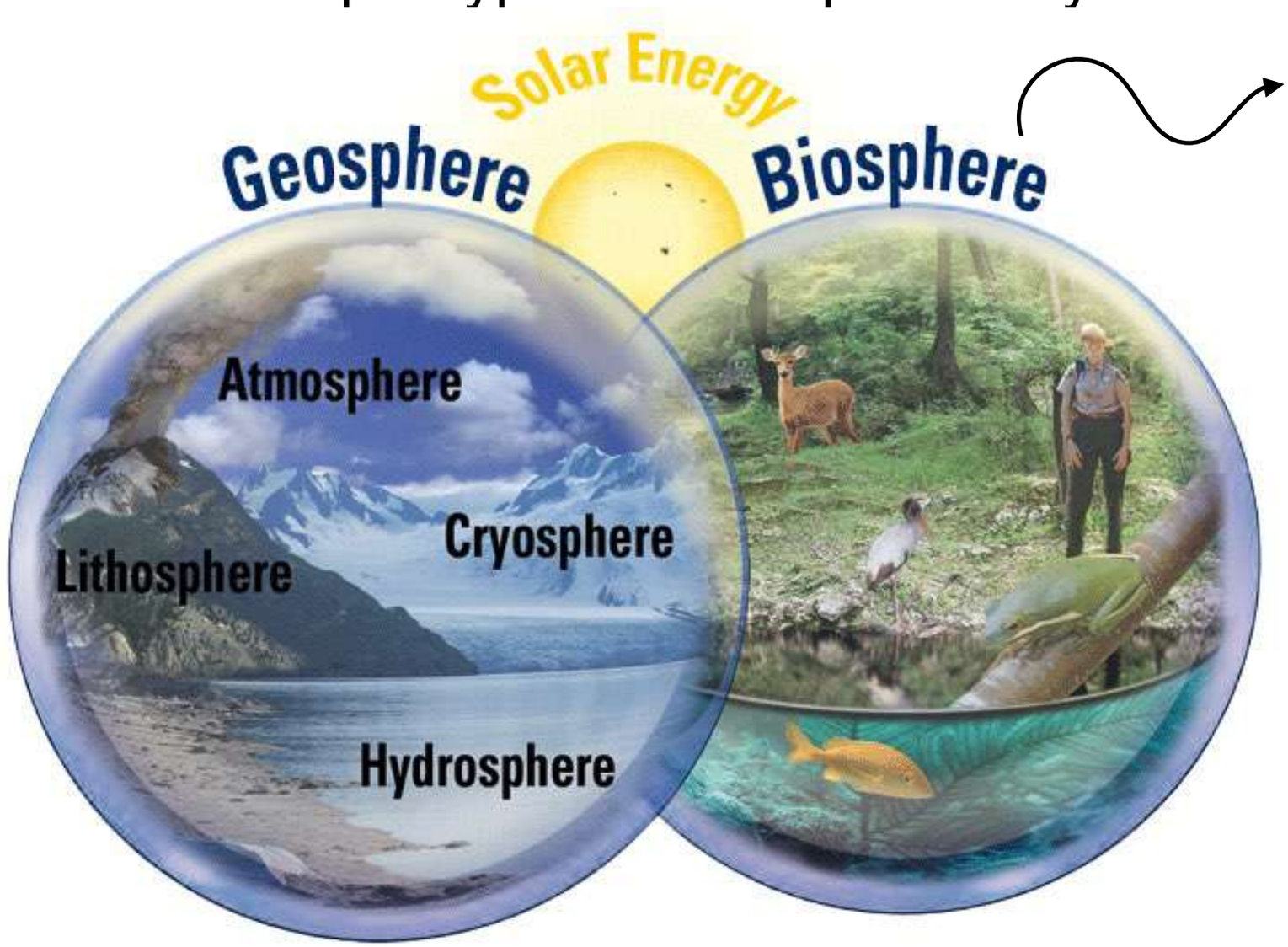


Primates

Entities made of biomolecules do not exist in isolation and are related to each other

Multiple entities of multiple types co-exist = Ecosystem

Multiple entities of multiple types in multiple ecosystems = Biosphere



A part of BB101!

Entities made of biomolecules = living systems

Entities made of biomolecules but not a living system = viruses

Image: James A. Tomberlin, USGS, public domain

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Living vs Engineered systems

Movement
Respiration
Sensitivity

Growth
Reproduction
Excretion
Nutrition

MRS GREN

M-S --EN

Both are intelligent!

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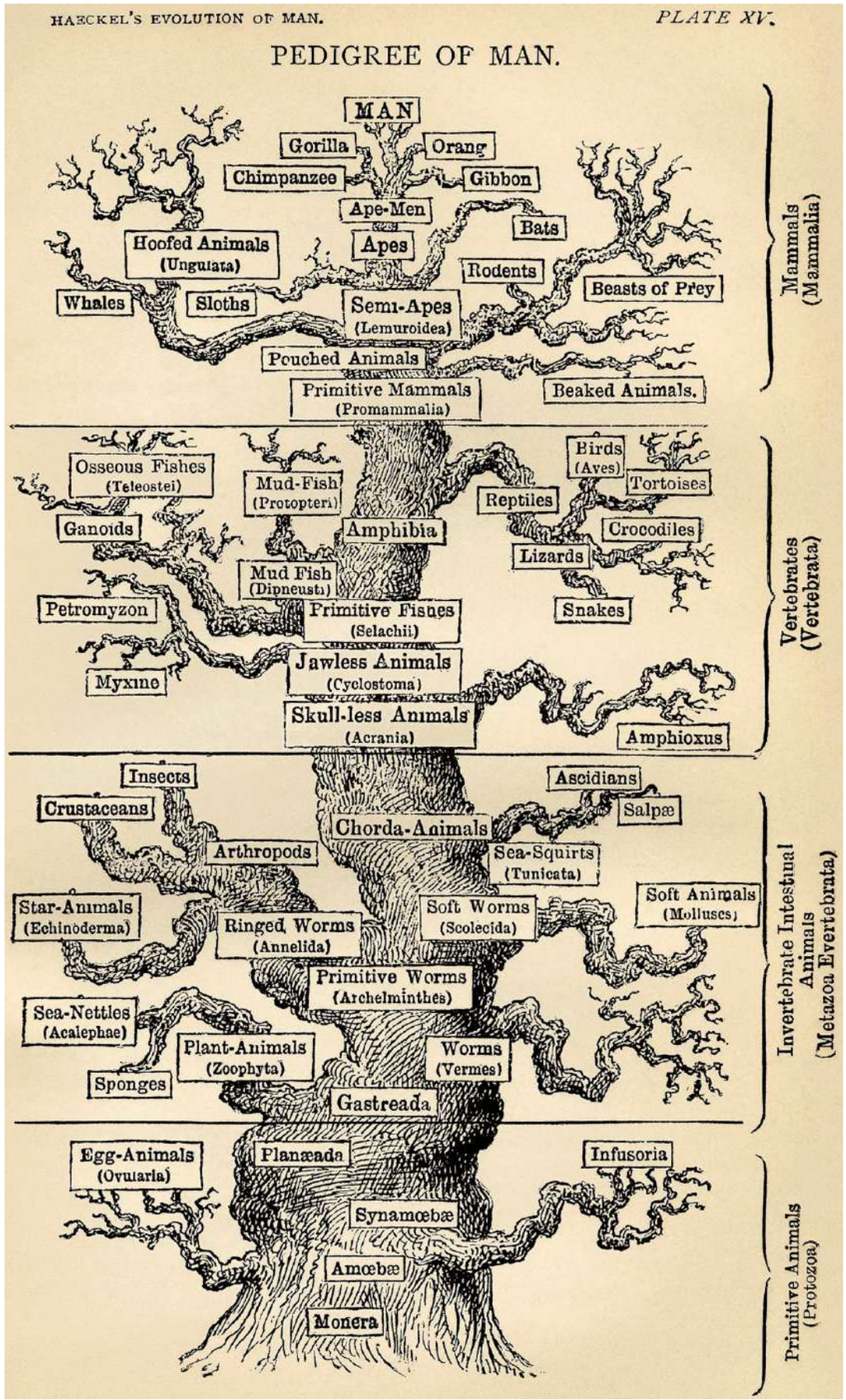
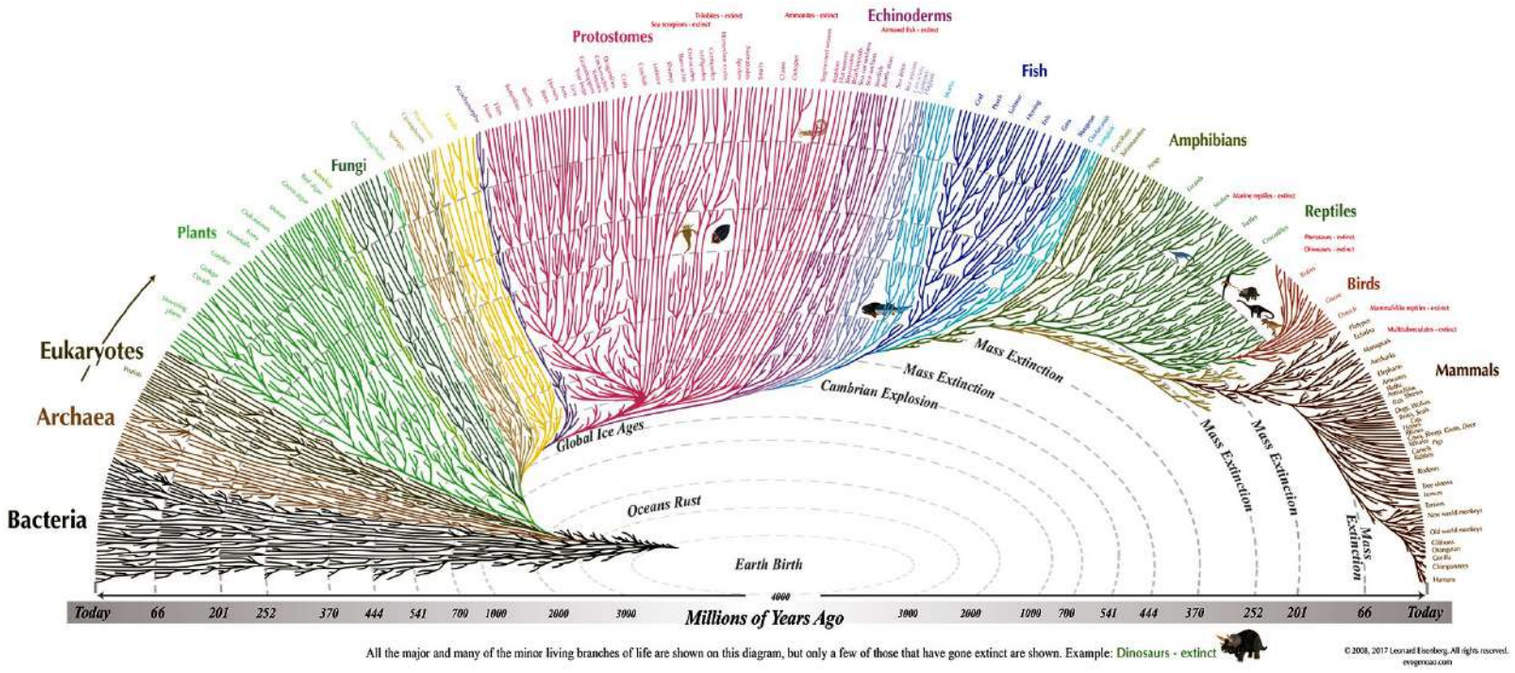
How are living systems related to each other? = evolution



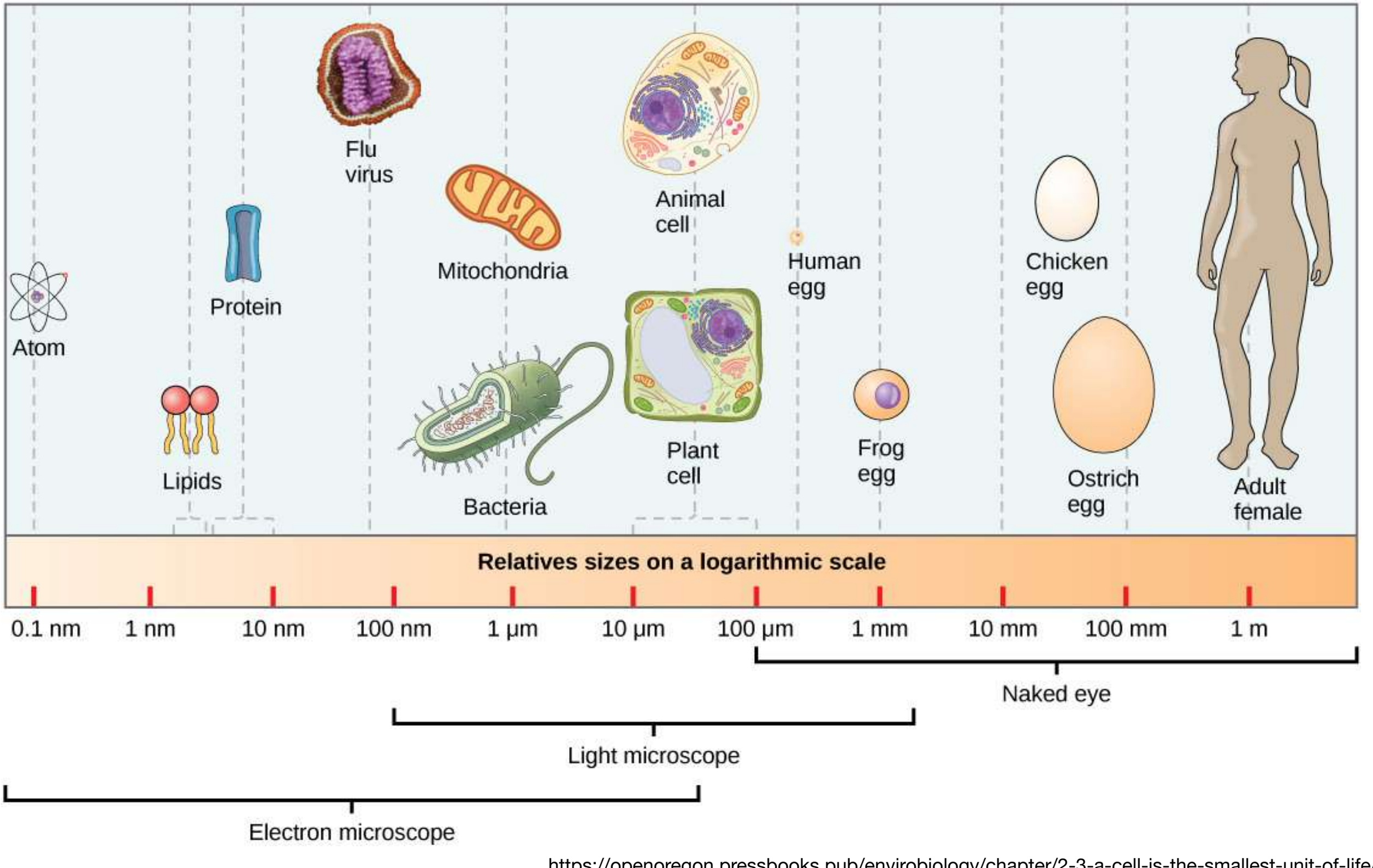


https://www.onezoom.org/

The Evolution of Man, Published in 1879 by Ernest Haeckel

https://wellcomecollection.org/stories/tree-of-life

Biomolecules and living systems span a wide range of length scales



https://openoregon.pressbooks.pub/envirobiology/chapter/2-3-a-cell-is-the-smallest-unit-of-life/

Biomolecules and living systems span a wide range of length scales

https://learn.genetics.utah.edu/content/cells/scale/

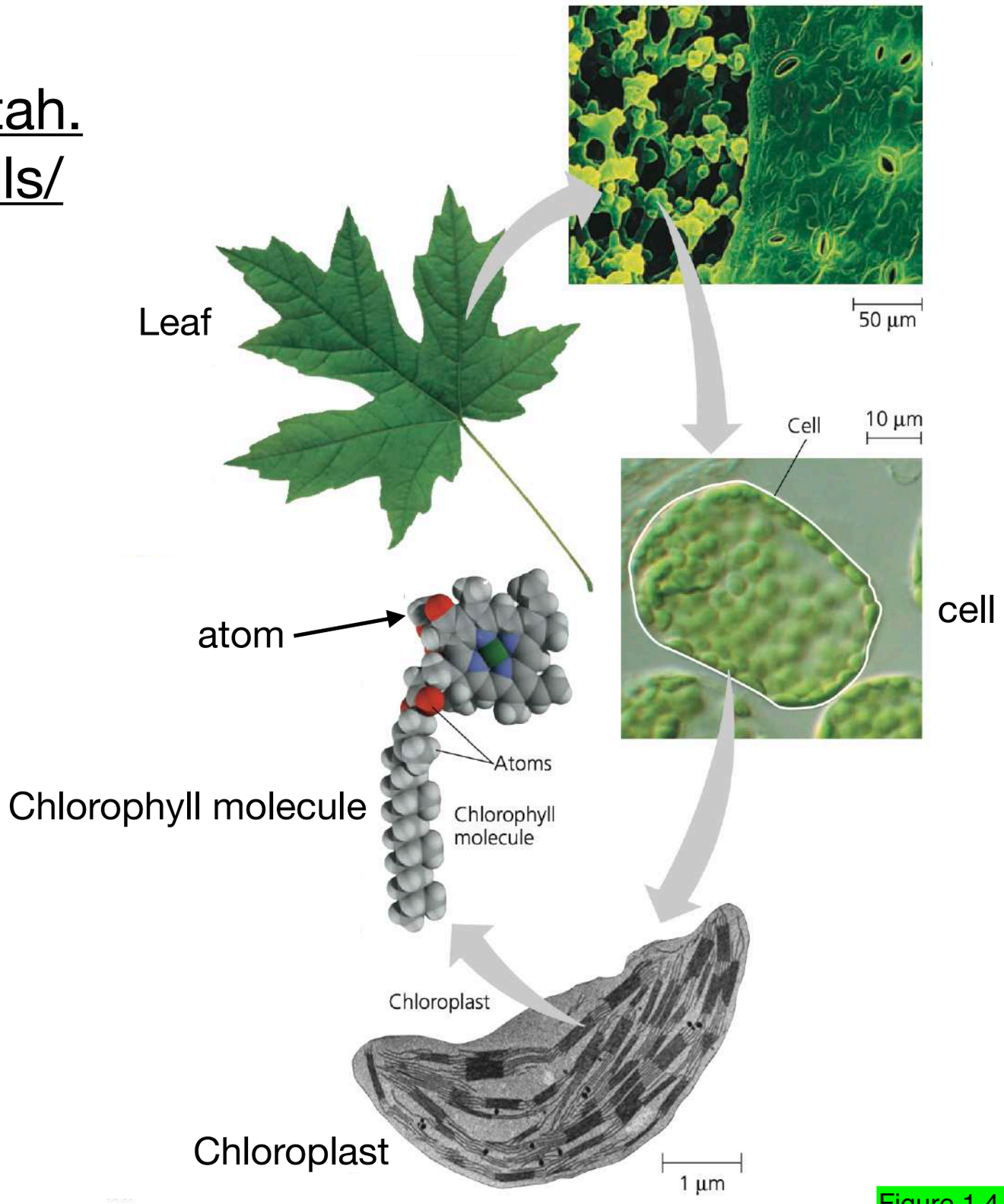


Figure 1.4 of Campbell's Biology: a global approach

Light microscopes capable of imaging at various depth of focus and field of view

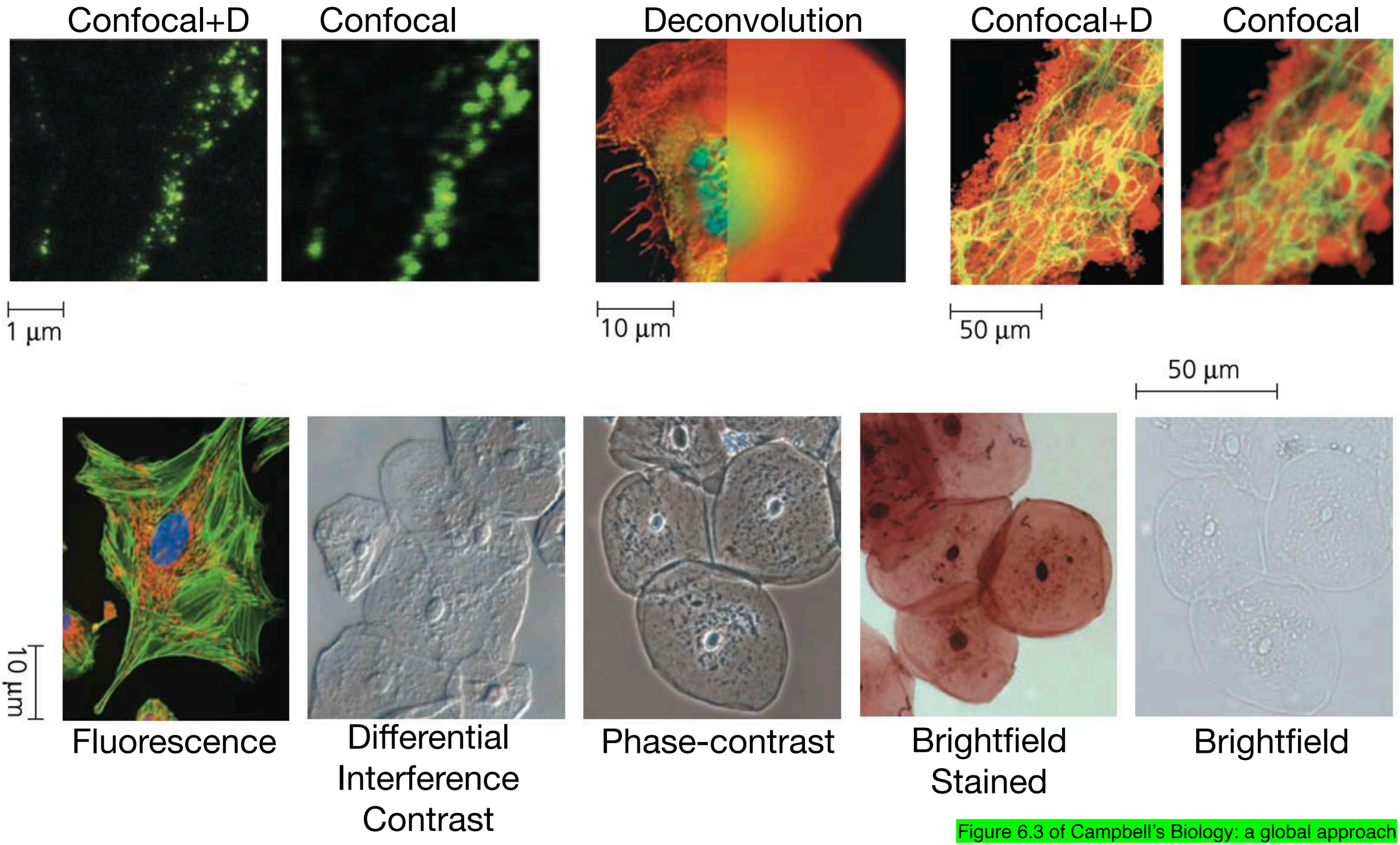
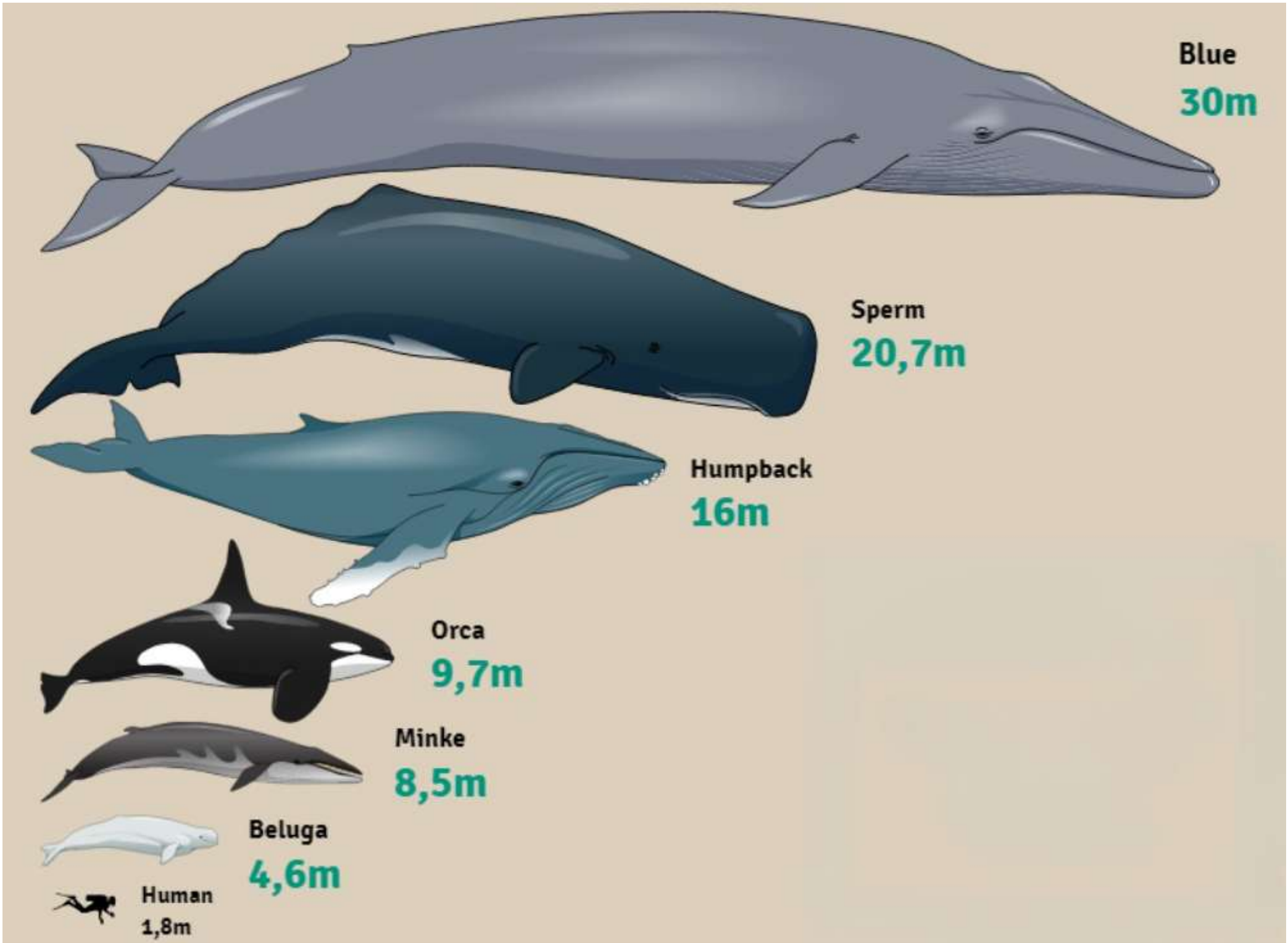


Figure 6.3 of Campbell's Biology: a global approach

Animals show large variations in size
All have same/similar body parts, how do these scale?



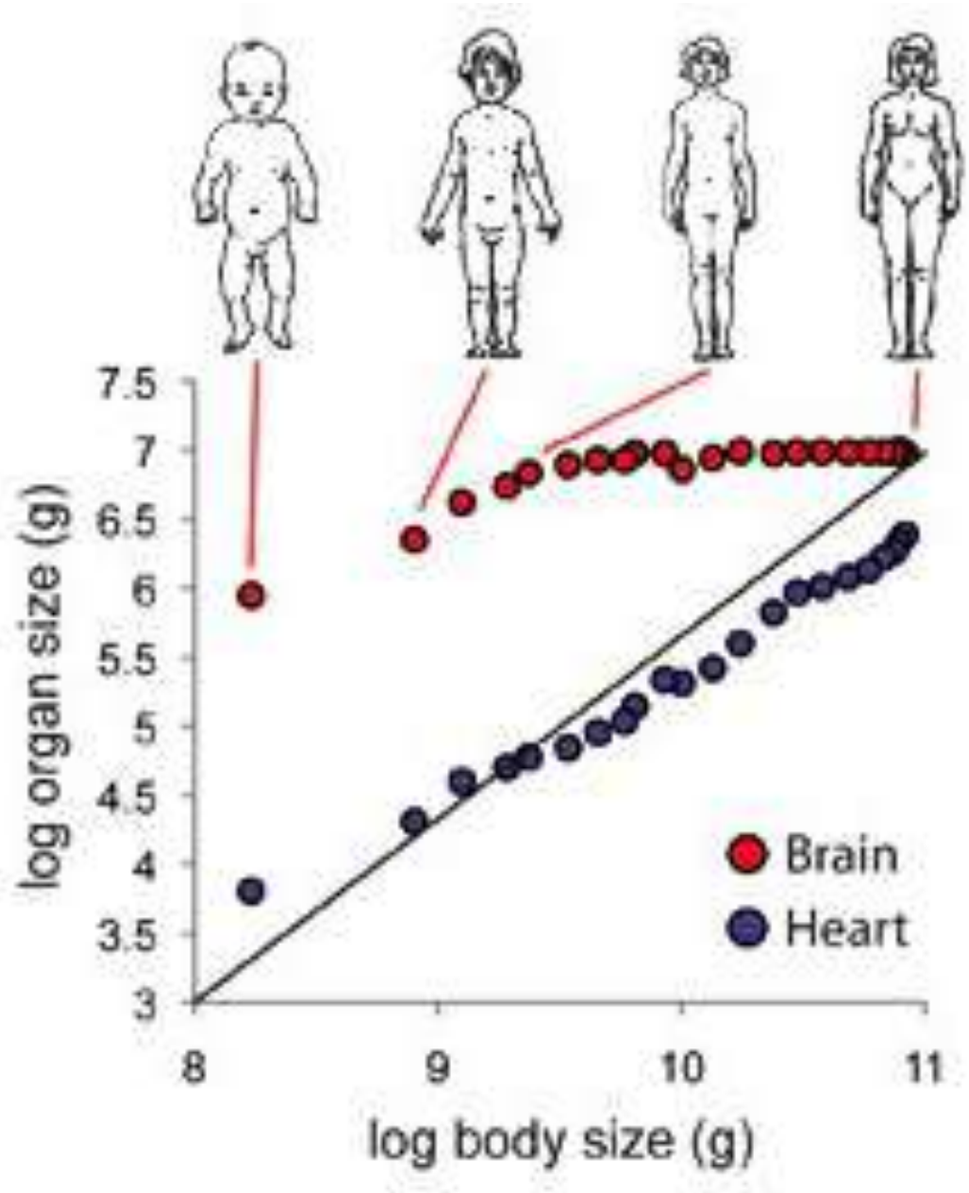
Biological scaling: Isometric vs Allometric

female vs male fiddler crab

Isometric scaling

Allometric scaling

Brain and Heart isometric or allometric scaling with body size?



https://www.nature.com/scitable/knowledge/library/allometry-the-study-of-biological-scaling-13228439/

Biological scaling: Isometric vs Allometric

Direct scaling relationships can be described by $Y = aX^b$

X = body size
Y= organ size (or metabolism) etc
a = initial growth index i.e size of Y when X = 1
b = scaling factor i.e proportional change in Y per unit X

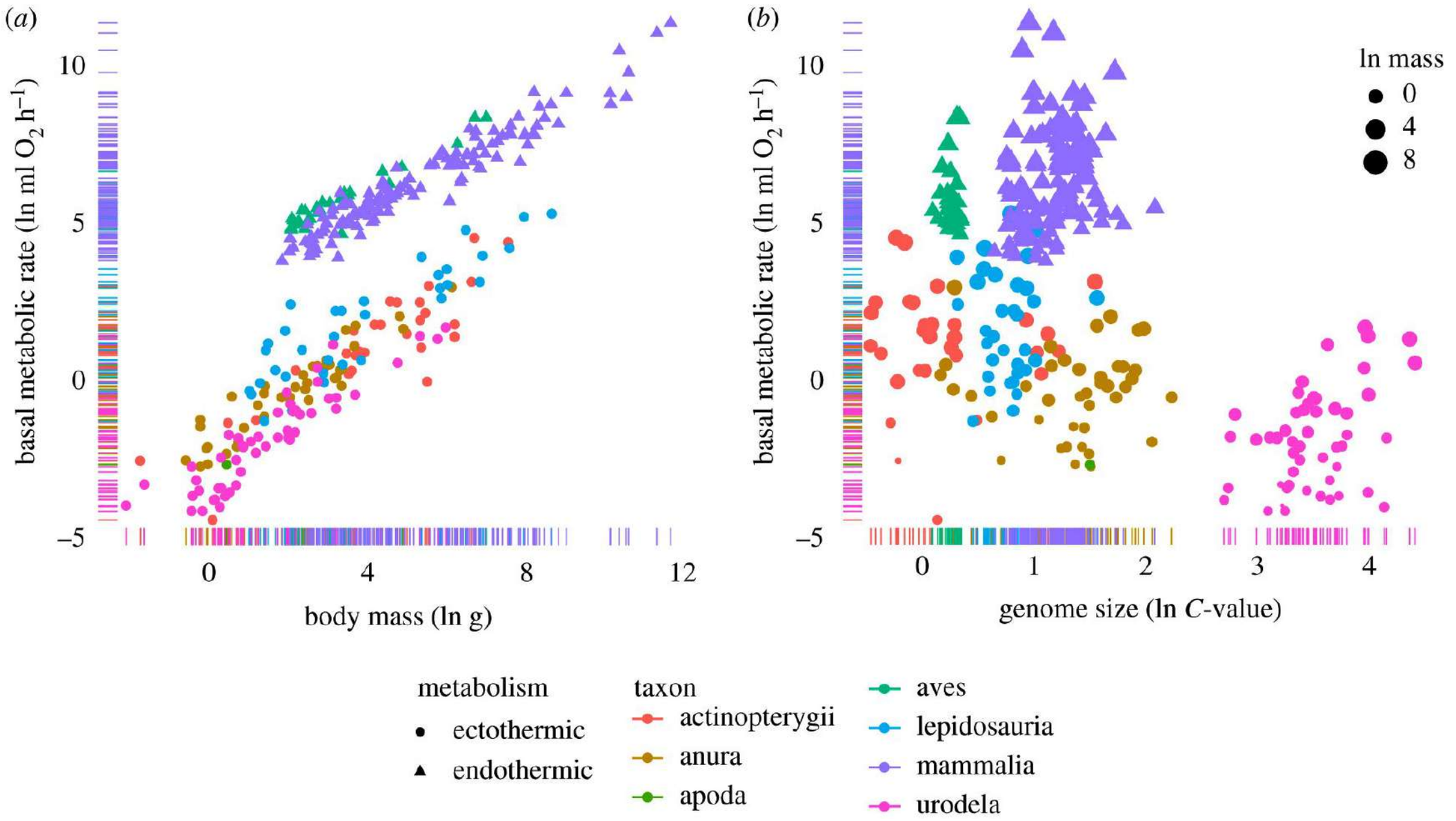
Isometry (organ grows at the same rate as the body): b = 1
Negative allometry/hypoallometry (organ grows slower than the body): b < 1
Positive allometry/hyperallometry (organ grows faster than the body): b > 1

https://www.nature.com/scitable/knowledge/library/allometry-the-study-of-biological-scaling-13228439/

Metabolic rate
isometric or allometric scaling with body size or genome size?

Isometric scaling with body size in both ectotherms and endotherms

No relationship with genome size



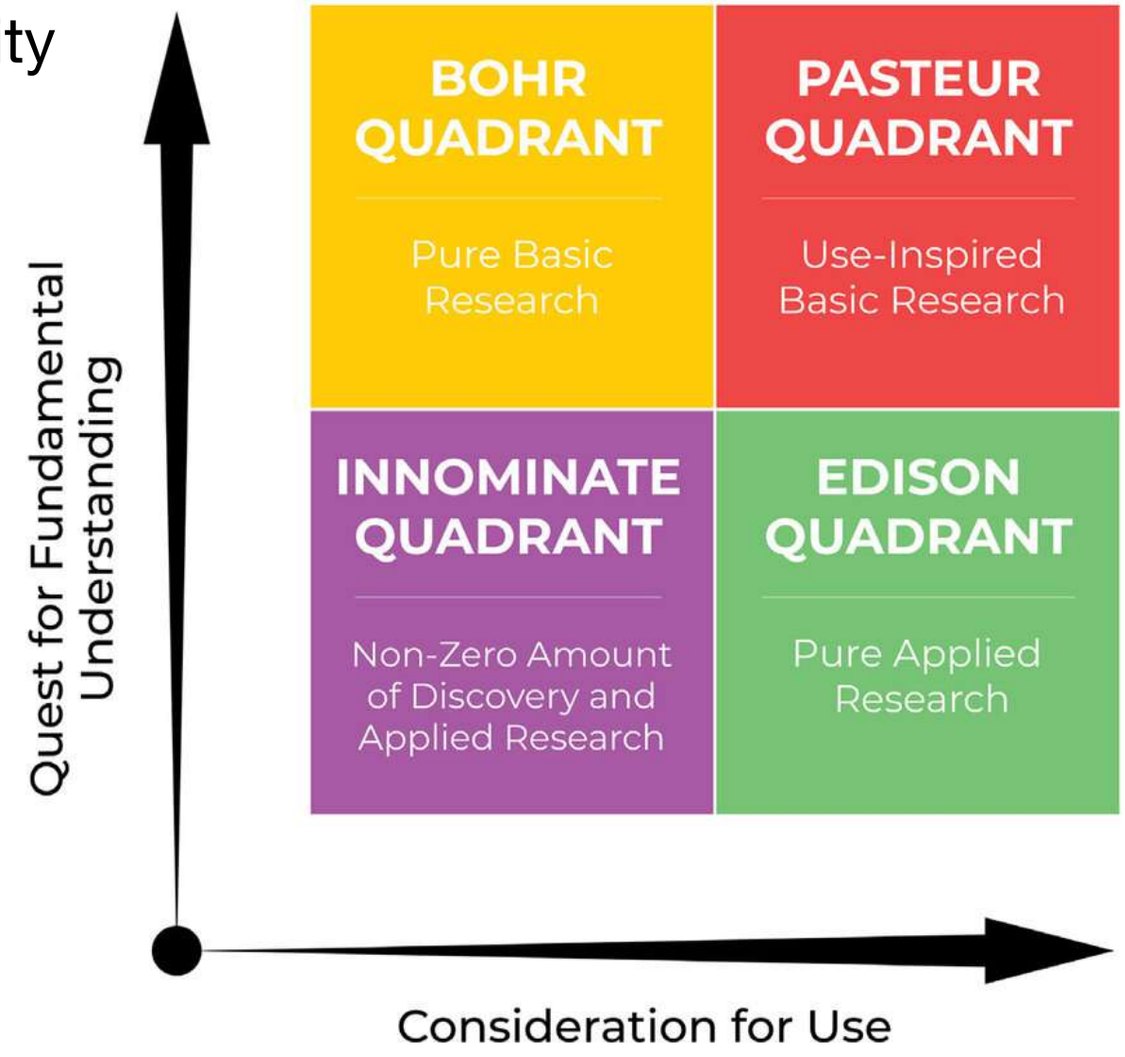
Ectothermic - coldblooded: frogs, fish, snakes, insects etc
Endothermic - warmblooded: humans, birds, dogs etc

J. D. Gardner, M. Laurin, and C. L. Organ, “The relationship between genome size and metabolic rate in extant vertebrates,” Philosophical Transactions of the Royal Society B: Biological Sciences, vol. 375, no. 1793, Mar. 2020.

Discovery vs Invention

Examples

- Newton`s laws of gravity
- Radioactivity
- Circulatory system
- Basic biomolecules

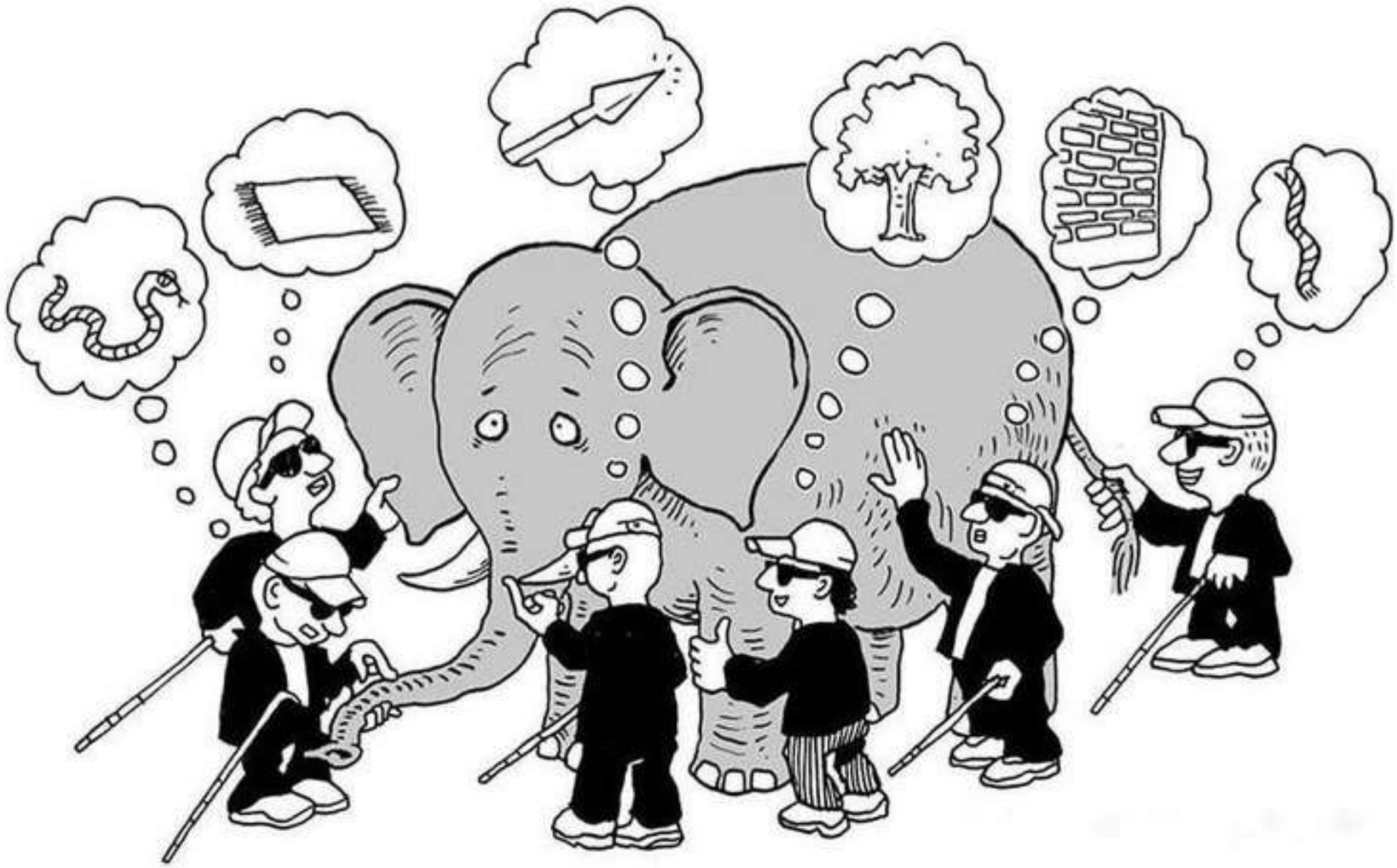


Examples

- Wheel
- Internet
- Electric bulb
- Computers
- Vaccines

How does one study biology (or any other discipline)

Typically, a reductionist approach is taken



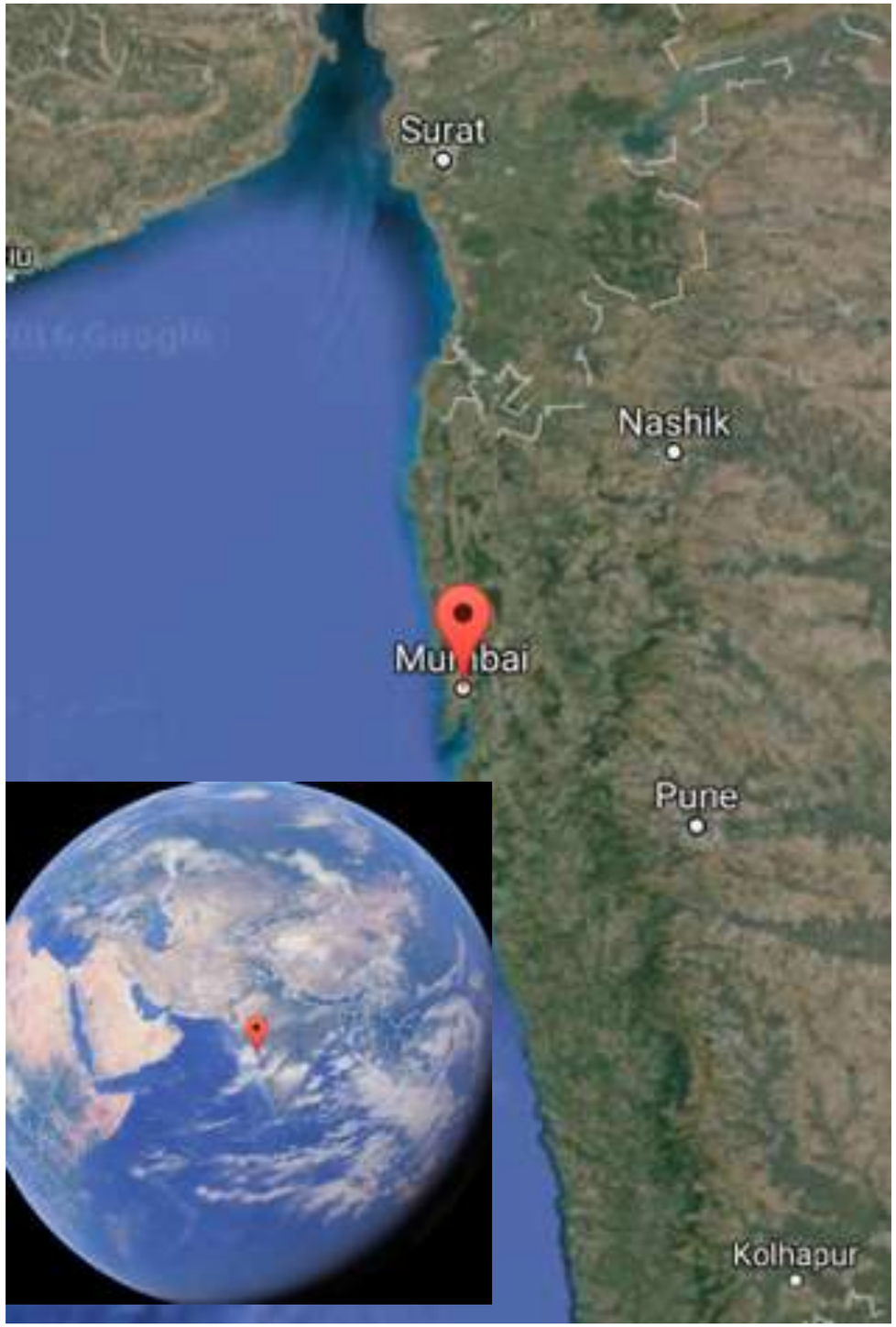
approach has advantages and disadvantages

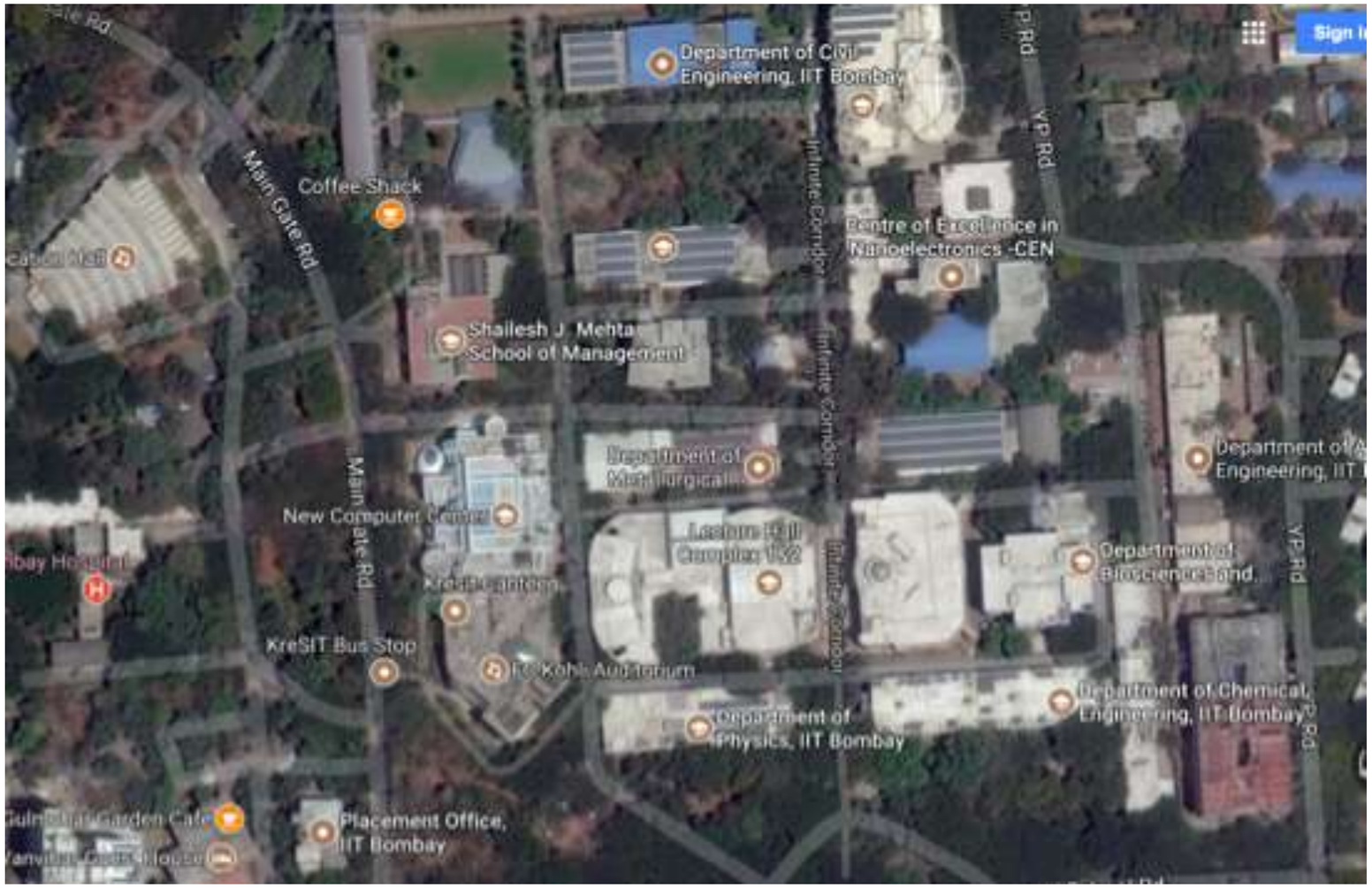
The reductionist approach is not unique to Biology

Biology	Chemistry	Physics
DNA	Atoms	Electrons
Proteins	Elements	Protons
Organelles	Organic	Neutrons
Cells	Inorganic	Leptons
Tissues	Reactions	Bosons
.....	.....	Hadrons
		.....
Living systems	Matter and interactions	Universe

It is the only feasible approach for complex systems
- understand how the parts work and then zoom out to the system

The reductionist approach is not unique to Biology





It is the only feasible approach for complex systems

- understand how the parts work and then zoom out to the system

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The Mega Crib

I thought I was done with all this bio stuff because
I am in a technology institute

Memorization of random facts

Complicated words

No logic!

Requires drawing skills

What I learn for one living system is not exactly the same in another living system - have to re-learn again!!

No Maths

I am a human. Why should I care to know why butterflies have 4 wings?

Too much information

No Physics

No Chemistry

No common concepts to make my life easy

Each complex system has terminologies used to describe and understand it

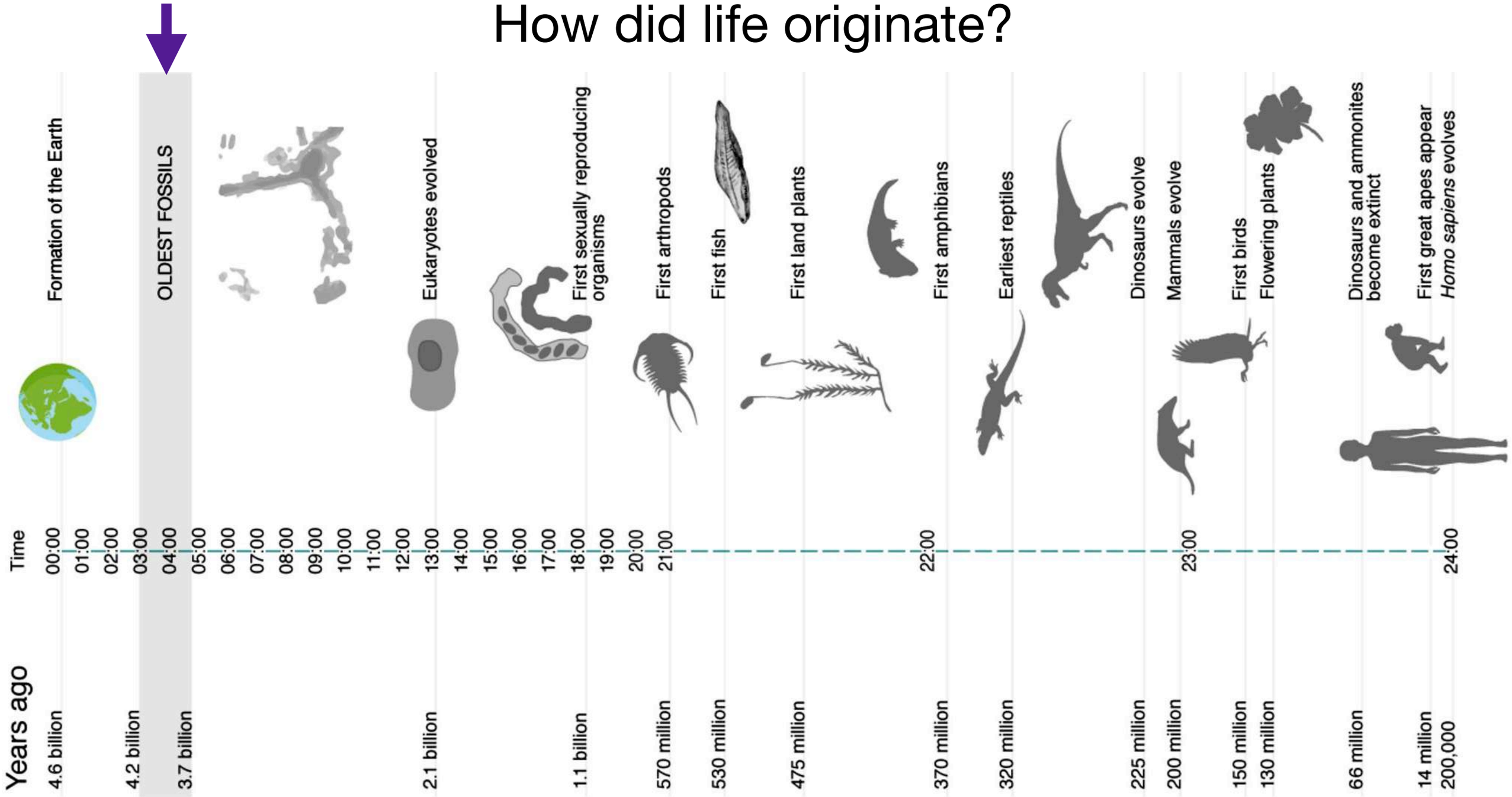
Biology	Chemistry	Physics	Computer Science
Transcription	Exothermic	Alpha particle	Bit
Mutation	pH	Inertia	Byte
Organelles	Alkali	Acceleration	Boolean operators
PCR	Aldehyde	Antimatter	Universal Resource Locator
Allele	Absolute zero	Brownian motion	Firewall
.....	.....	Hadrons	.....
		.....	

Living systems | Matter and interactions | Universe | Technology and communication

- Approaches to understand biology in the 21st century is radically different
- The perception of biology is as it used to be in the 20th century

You can decide whether you wish to remain stuck in the 20th century
or
join us in the 21st century

How did life originate?



4.6 billion years condensed into 24 hours

The general view is that living systems (biotic) originated from non-living things (abiotic)

Lecture 1: Living systems are made of biomolecules

What were conditions like when Earth formed?

Volcanoes, Gas

Electrical discharges

Water

Are these conditions sufficient to trigger emergence of biomolecules?

Miller and Urey

Stanley Miller (1930-2007)

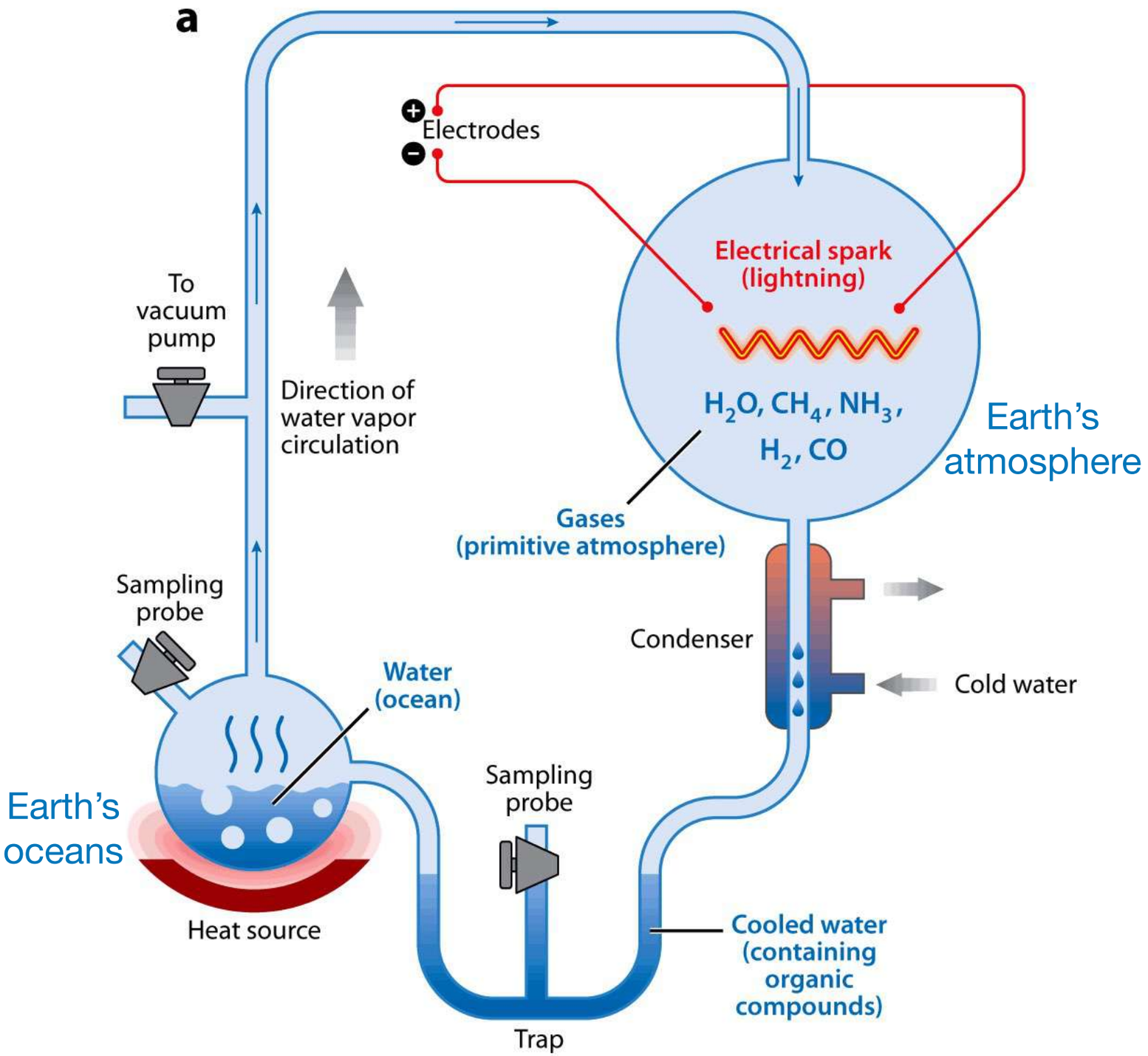
- As a 23 yr old PhD student in the lab of Harold Urey at University of Chicago
- In 1951, provided experimental proof of how interactions amongst abiotic components of early earth could have produced organic compounds
- Such organic compounds included amino acids = building blocks of proteins

Harold Urey (1893-1989)

- 1934 Nobel Prize in chemistry for discovering Deuterium
- During WWII, led the Manhattan Project to make the first atomic bomb
- After the war got interested in understanding how the earth's temperature changed over time

Miller-Urey (Spark discharge) experiment

Recreated in the lab conditions of prehistoric earth and then checked what types of molecules emerged



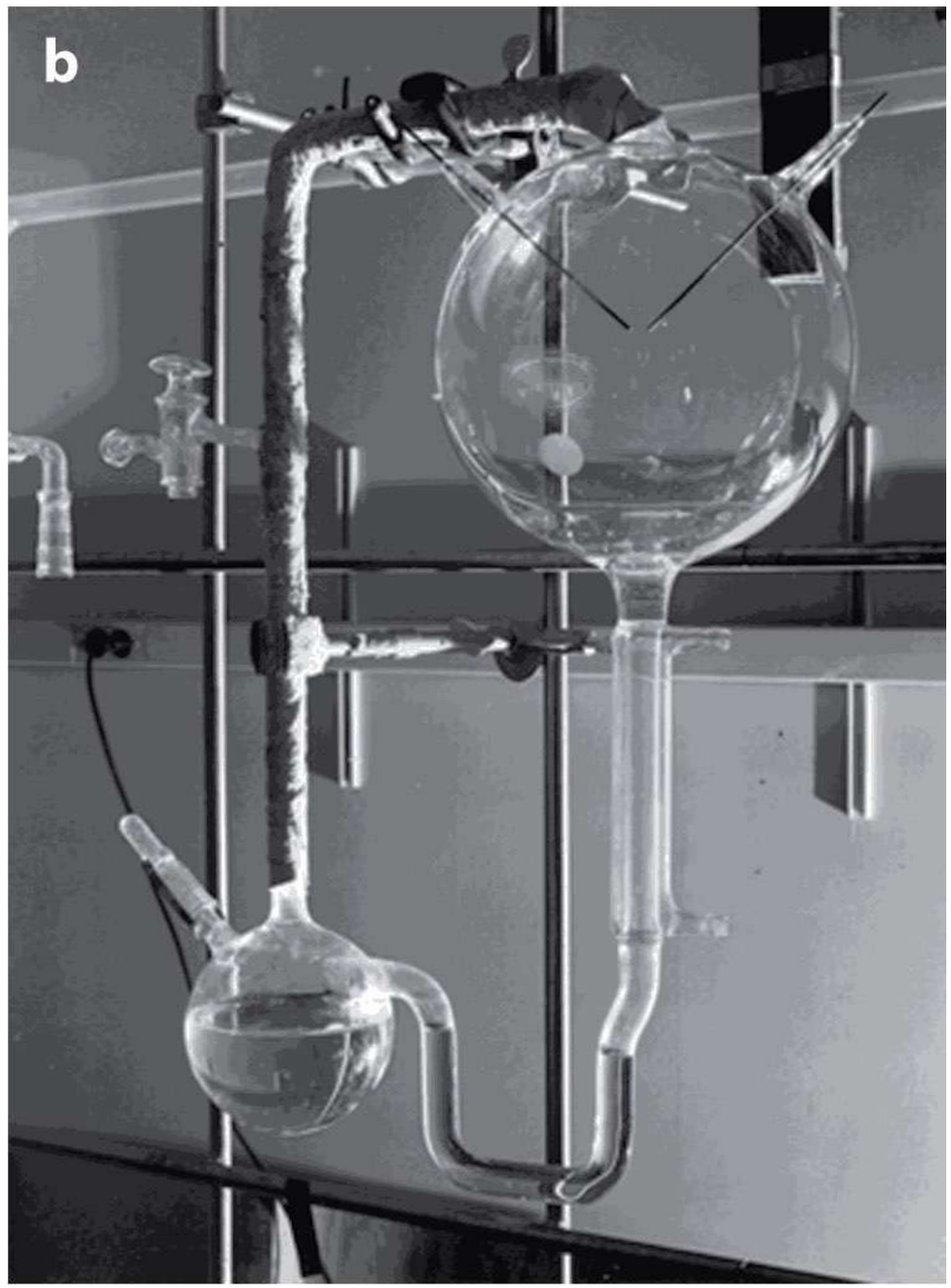


Figure 4.2 of Campbell's Biology: a global approach

Annual Rev of Earth and Planetary Sciences Vol. 41:207-229, 2013

Performing Miller-Urey experiments

Conducting Miller-Urey Experiments

Eric T. Parker[1], James H. Cleaves[2,3], Aaron S. Burton[4], Daniel, P. Glavin[5], Jason P. Dworkin[5], Manshui Zhou[1], Jeffrey L. Bada[6], and Facundo M. Fernández[1]

[1]School of Chemistry and Biochemistry, Georgia Institute of Technology

[2]Earth-Life Science Institute, Tokyo Institute of Technology

[3]Institute for Advanced Study

[4]Astromaterials Research and Exploration Science Directorate, NASA Johnson Space Center

[5]Goddard Center for Astrobiology, NASA Goddard Space Flight Center

[6]Geosciences Research Division, Scripps Institution of Oceanography, University of California at San Diego

https://www.jove.com/v/51039/conducting-miller-urey-experiments

What did the Miller-Urey experiments prove?

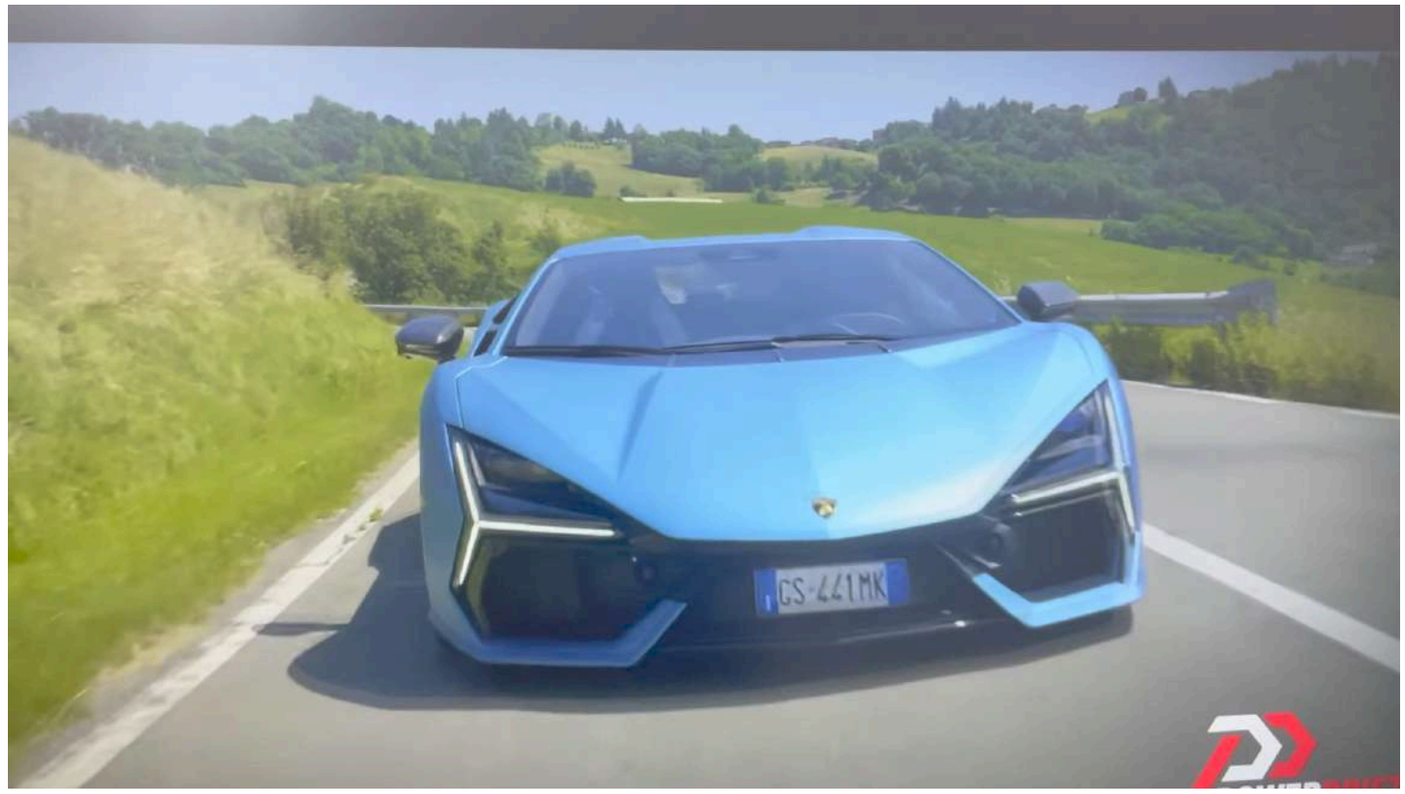
If living systems were self-driven Lamborghinis….

can be proved to emerge spontaneously

Raw materials
Metals
Paint chemicals etc

How?

This exists



No proof

This exists

No proof

No proof

This exists

What did the Miller-Urey experiments prove?

organic matter could arise from inorganic matter - environment interactions

Did the experiment yield biomolecules?

No

The experiment yielded building blocks for some of the biomolecules

Are biomolecules alive?

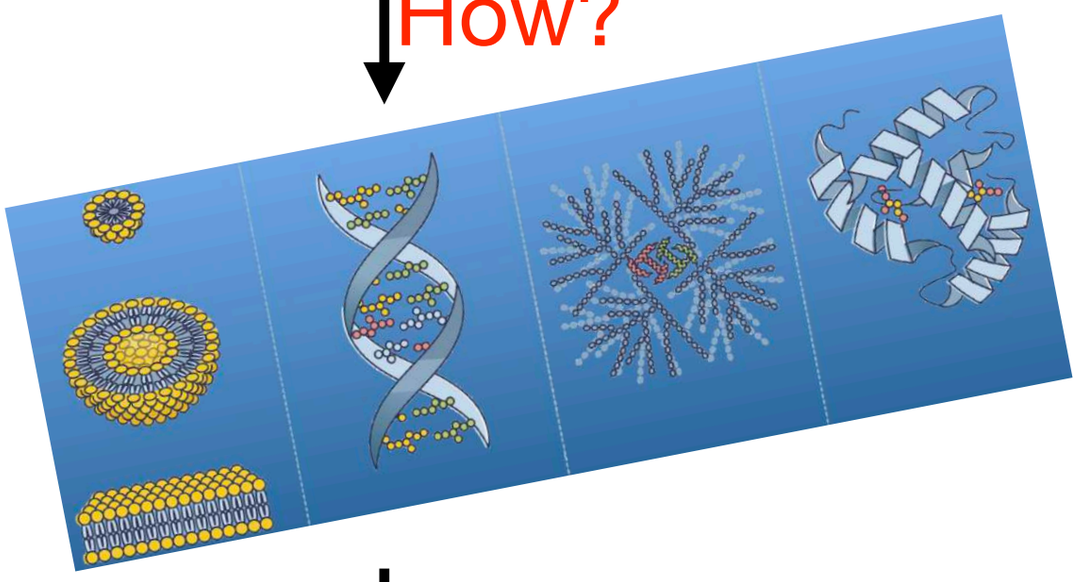
No

Living systems are made of biomolecules, but biomolecules themselves are not alive

What did the Miller-Urey experiments prove?

Raw materials
Amino acids
Etc

How?



How?

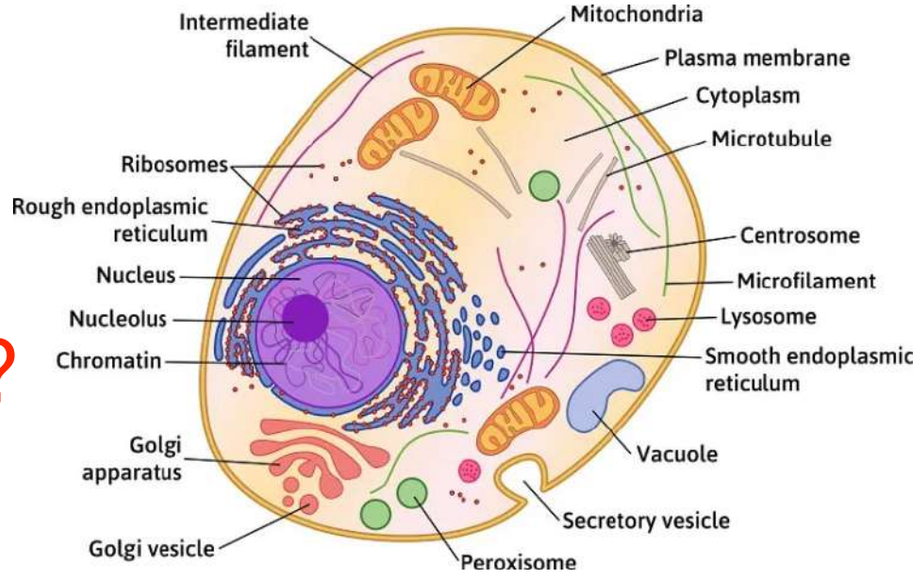
Organelles:
mitochondria,
ER, Nucleus etc

How?

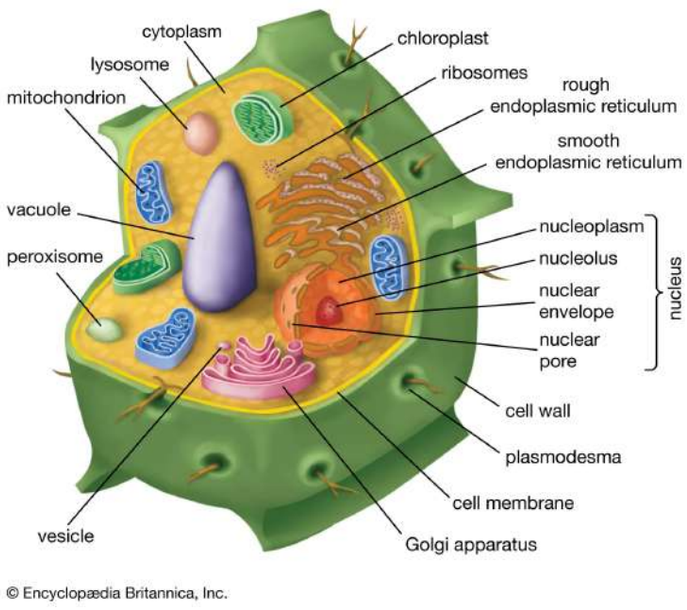
We know biomolecules, organelles, cells and living systems exist and we know a lot about how they work

We don't know how biomolecules emerged from the raw materials that first came into existence on planet Earth and any of the subsequent necessary steps

How?



How?

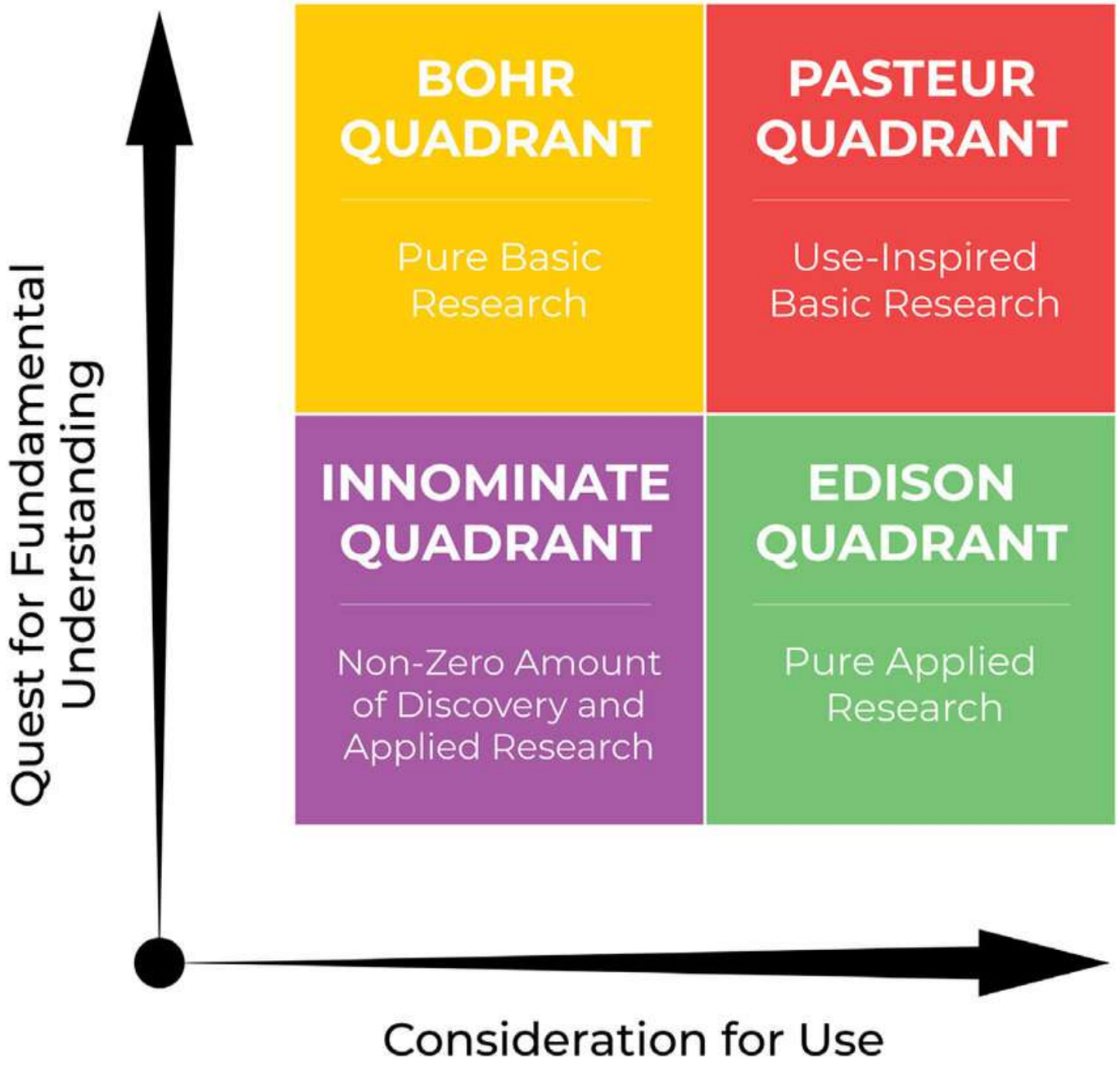


Open Questions

- How did the building blocks of biomolecules assemble into biomolecules?
- How did biomolecules assemble into super assemblies with repeatable structure and function?
- How did biomolecular super assemblies form cells?
- How did cells make more cells?
- How did cells come together to make cell clusters?
- How did cell clusters attain a repeatable ordered structure?
- How did the cellular ordered structure attain function to make a living system?
- How did the first living system make more of itself?

- Why did this entire process occur so successfully on planet Earth?
- Can it happen on other planets also?
- Has it happened on other planets also?

Where would you place the Miller-Urey experiments?



Evolution 2.0 Prize

384,355 Share Follow (2.5K)

Artificial Intelligence + Origin of Life Prize, $10 Million USD

Where did life and the genetic code come from? Can the answer build superior AI? The #1 mystery in science now has a $10 million prize.

Data Science | Engineering | Healthcare | Technology | Powered By HeroX

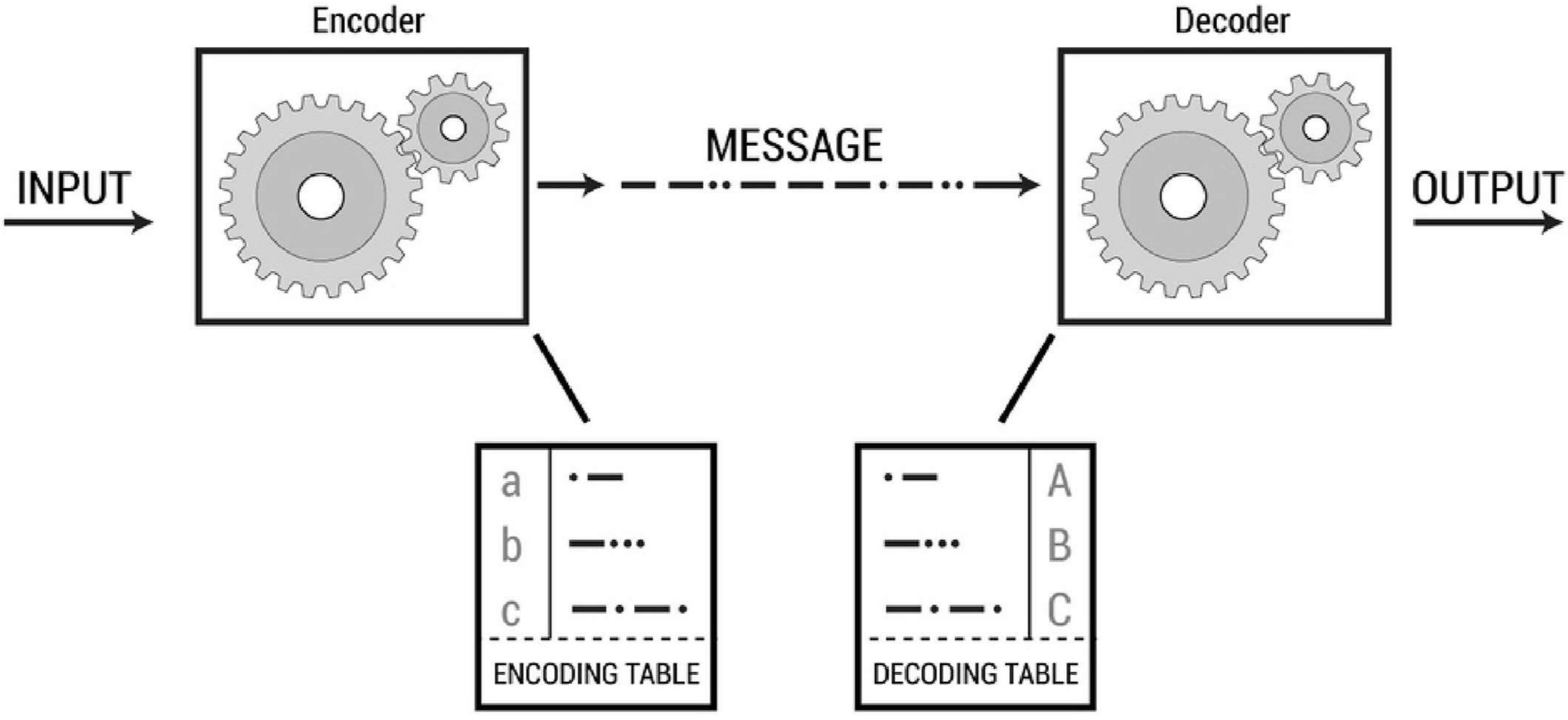
Stage: **Enter**

Prize: **$10,000,000**

SOLVE THIS CHALLENGE

https://www.herox.com/evolution2.0

Information coding, transmission and decoding



(https://www.sciencedirect.com/science/article/pii/S0079610721000365)

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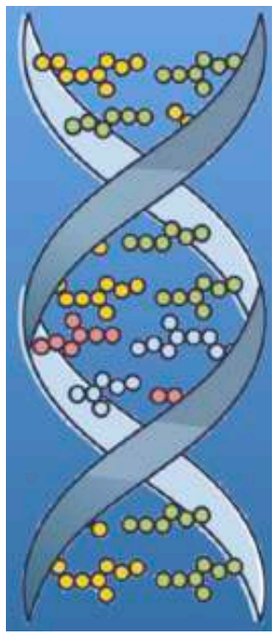
The big unknown for information coding, transmission and decoding in living systems

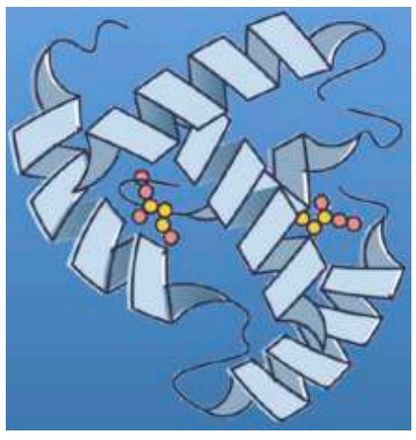
How did the information code of proteins get encoded into DNA to be decoded back as proteins?



Over-simplified view of information transfer in biology

Information in DNA is decoded into proteins

Amino acids are made by biosynthetic pathways inside cells



No proof exists that proteins can encode for DNA and RNA

Early earth atmosphere can make amino acids

amino acids are building blocks of proteins

Proteins therefore must have emerged as the first biomolecules

All living systems now make proteins by decoding information coded in DNA