INTRODUCTION TO CELL SCIENCE
CELL THEORY
MODEL CELLS IN MEDICINE

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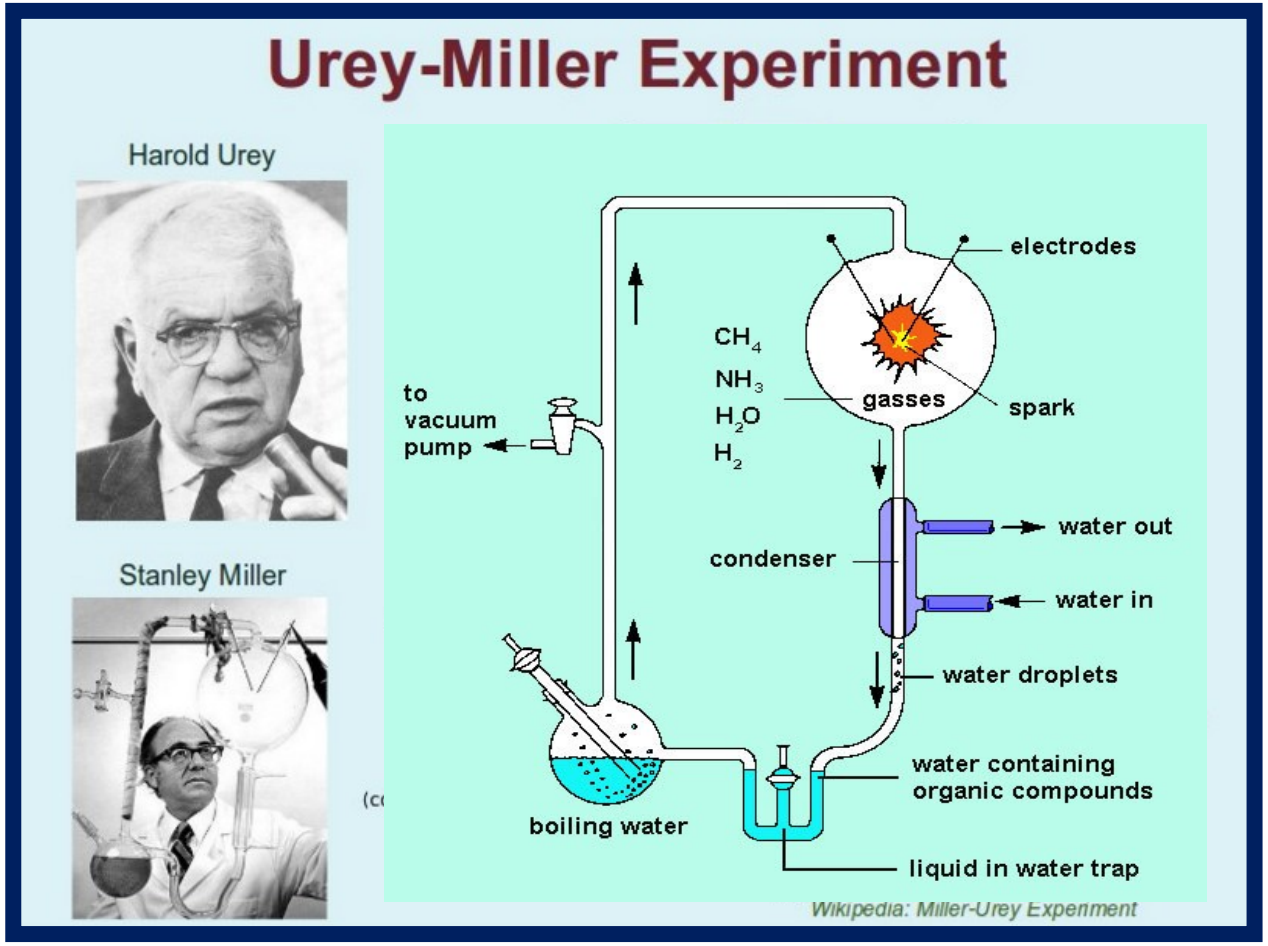
Which are the criteria of terrestrial life?

1. Stable internal environment (homeostasis)
2. Organized structure
3. Metabolism
4. Growth/development
5. Ability to reproduce
6. Ability to adapt to the environment
7. Responsiveness to environmental stimuli
8. Cellular organization

Urey-Miller experiment



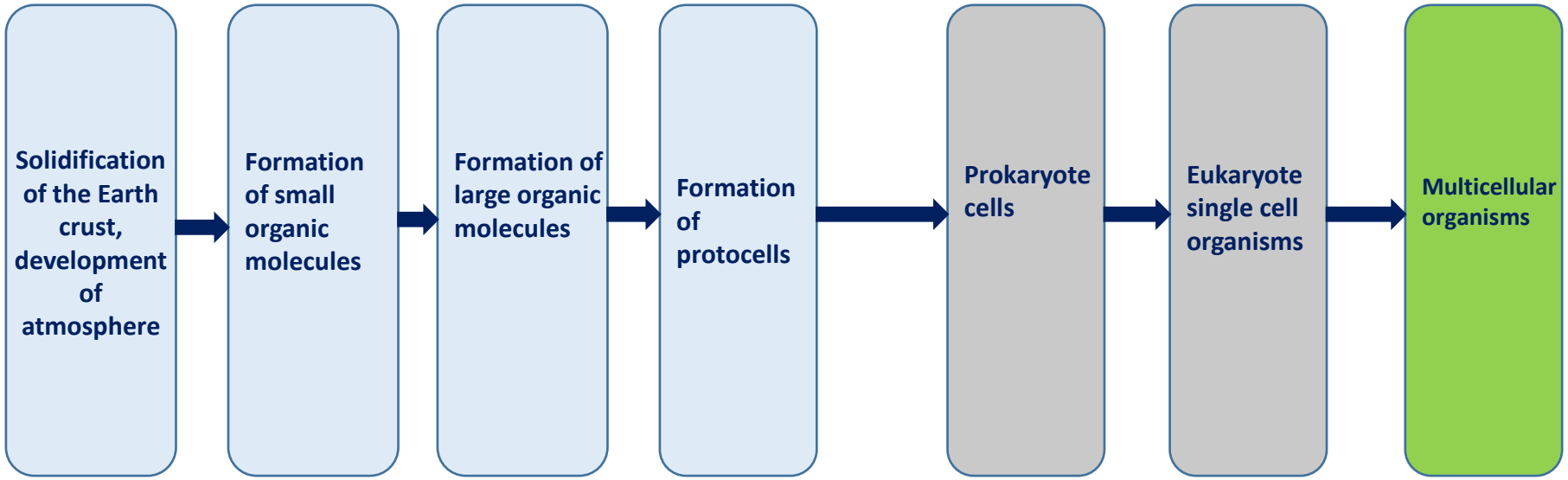
1953, Chicago

- **Amino acids**
- **In later experiments: building blocks of sugars, lipids and nucleic acids**

Chemical → biological evolution

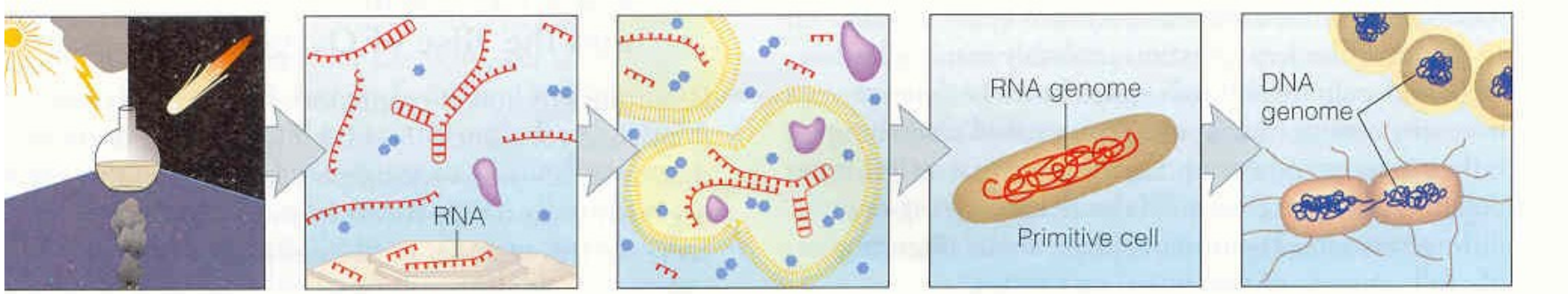
Chemical evolution (~ 1 billion years)

Biological evolution (~ 3.7 billion years)

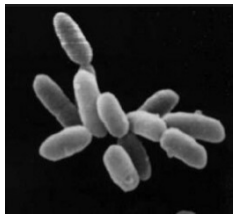


Major steps of the chemical evolution

1. Random polymerization of the nucleotides → formation of ribozymes that are capable of limited self-replication (RNA world).
2. Natural selection rescued ribozymes that catalyzed the synthesis of small proteins. Oligopeptides formed complexes with RNA → first ribosome→ protein synthesis became widespread
3. Proteins proved to be better catalyzers than ribozymes (thus, became dominant biopolymers)
4. Nucleic acids were later used for genome purposes
5. Phospholipids of appropriate lengths formed lipid bilayers spontaneously



Which are the live organisms on Earth?

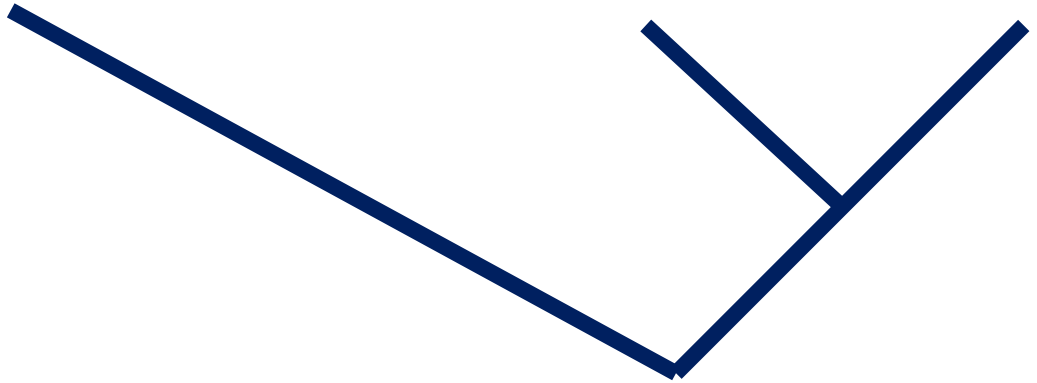


Bacteria

Archea

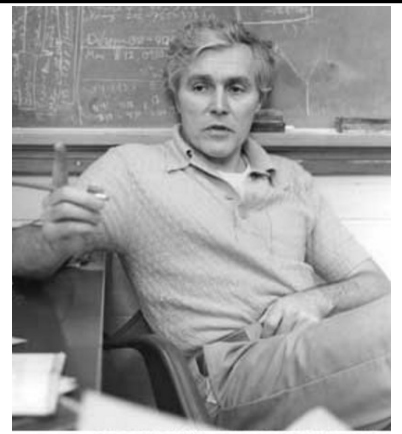
Eukaryotes

fungi
plants
animals



Last universal common ancestor (LUCA)

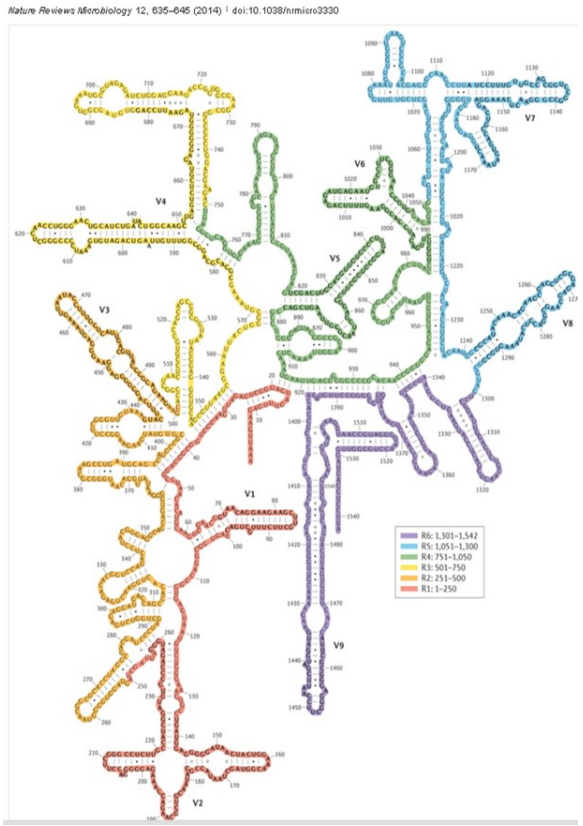
The three domains of cellular life



NARA/U. of Illinois 306-PS-E-77—5743

1990 Carl Woese

Classification based on gene sequencing of the 1980's



The molecule conserved in all cellular life forms: Small subunit of the ribosomal RNA (16S rRNA)

16S rRNA

- Its conserved sequence provides the strongest evidence for Darwin's theory of a common ancestor of life on Earth

- Evidence for the existence of the " Last Universal Common Ancestor (**LUCA**) "

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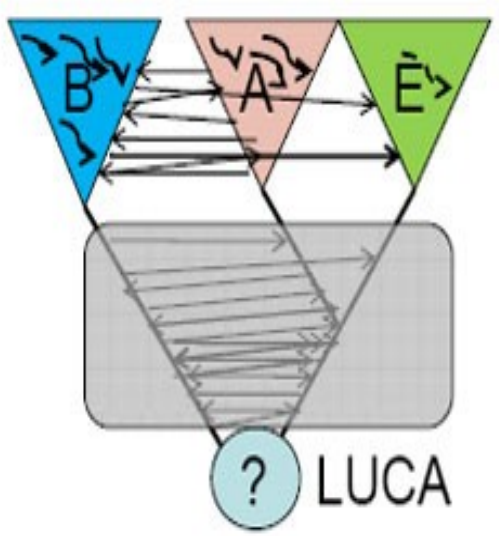
Horizontal gene transfer (HGT)

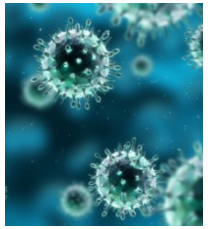
- Gene exchange between species
- HGT is the major evolutionary rout to gain new features in prokaryotes (think of the spread of antibiotic resistance even today)



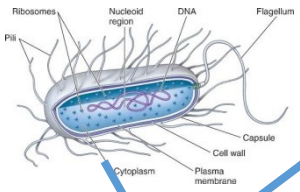
Early intense gene transfer?

Biological systems

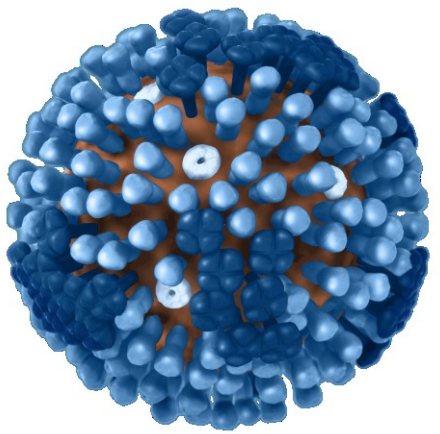
Empire of viruses



Empire of cellular life forms



The empire of viruses



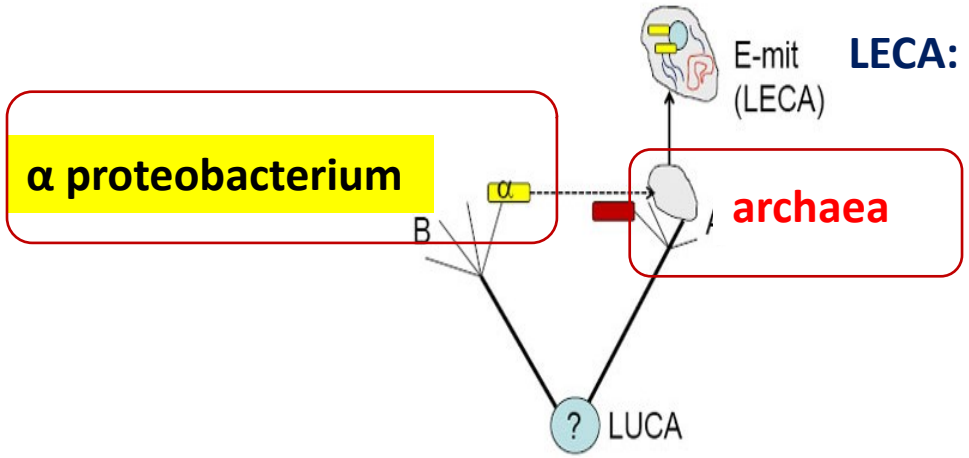
- **The biological empire of viruses is larger and more diverse that the empire of cellular life forms**

Origin of eukaryotic cells

- Lynn Margulis (1970: Eukaryotes are formed by the cooperation of various types of prokaryotes)

Hypothesis of generation of eukaryotes

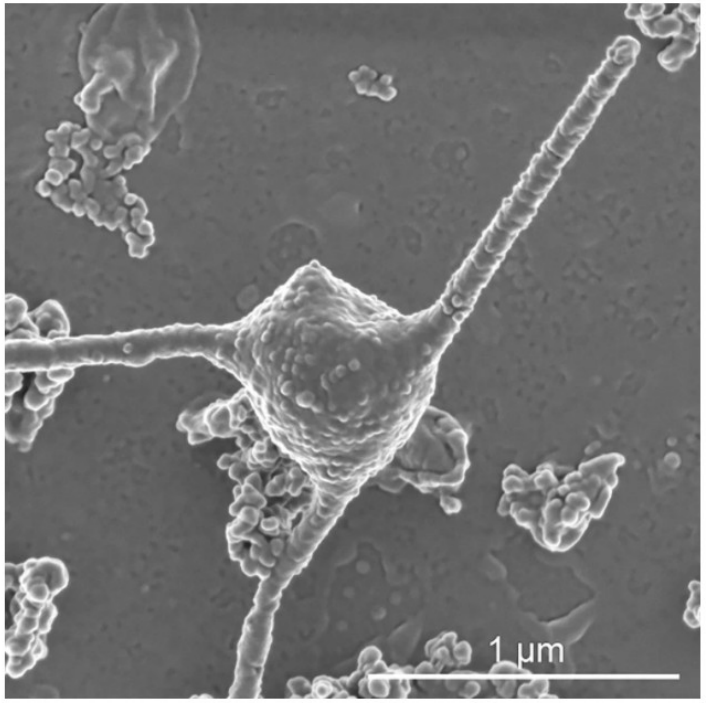
Symbiote hypothesis



LECA: last eukaryotic common ancestor

Eukaryotes are archaebacterial chimeras

Prometheoarcheaum



Prometheoarchaeum begins as a tiny sphere, sprouting long, branching tentacles and releasing membrane-covered bubbles over the course of months. Hiroyuki Imachi, Masaru K. Nobu and JAMSTEC

From deep see sediments researchers succeeded isolate and grow an archea, with Eukaryote proteins but no organelles.
It is hypothesized that these cells could have engulfed bacteria that became their mitochondria.

Isolation of an archaeon at the prokaryote-eukaryote interface.Imachi H et al. Nature. 2020 Jan;577(7791):519-525.

Eukaryotes

- “Bacterial" genes encode for metabolic enzymes and membrane transporters
- “Archaeal" genes in eukaryotes usually encode for proteins of translation, transcription and replication.

The discovery of cells

Robert Hooke (1600s)

- Cell structure of cork

”cells”

What is a cell?

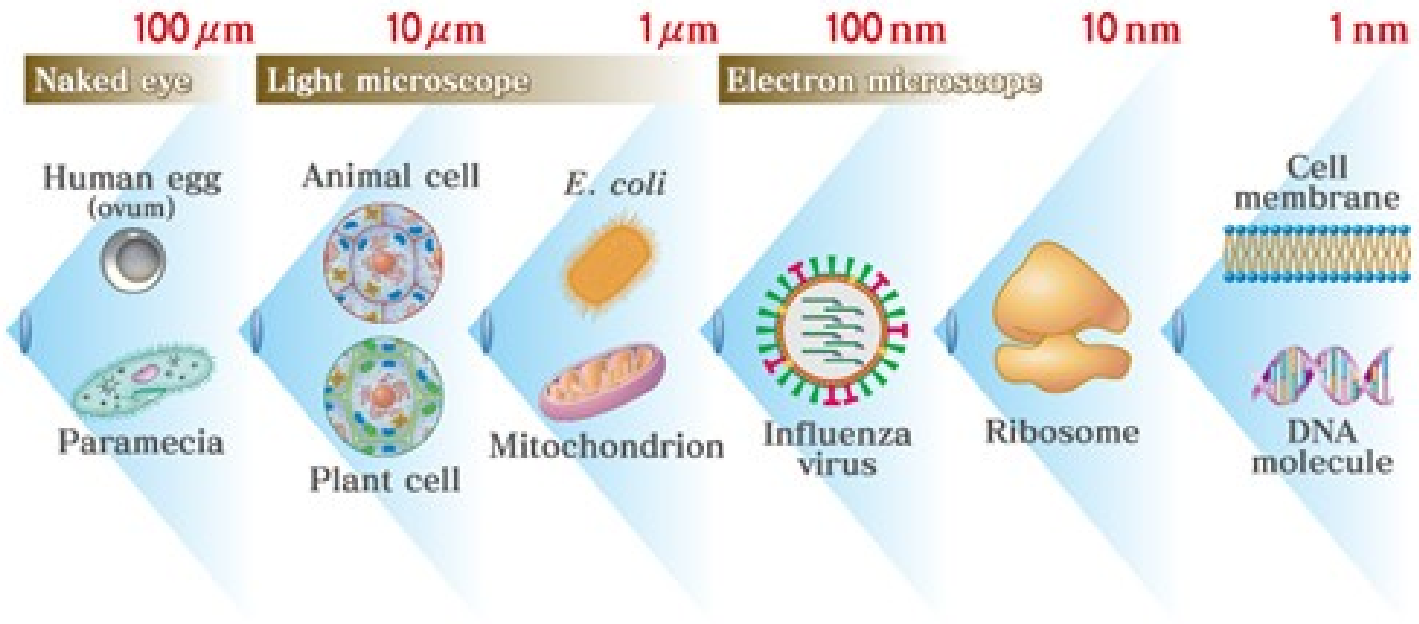
- The cell is a membrane enclosed system capable of maintenance of its structure and capable of reproduction.
- The cell represents the basic and smallest unit of cellular life.
- Known organisms are built of cells.

Cells of our body

- $3x10^{13}$ human cells and 3.8 $x10^{13}$ bacterial cells in our body
- ≥ 200-300 different cell types
- Cellular sizes, shapes and internal structures are different

What is the size of a cell?

- Prokaryote cells 1-10 micron
- Eukaryote cells: 10-100 micron

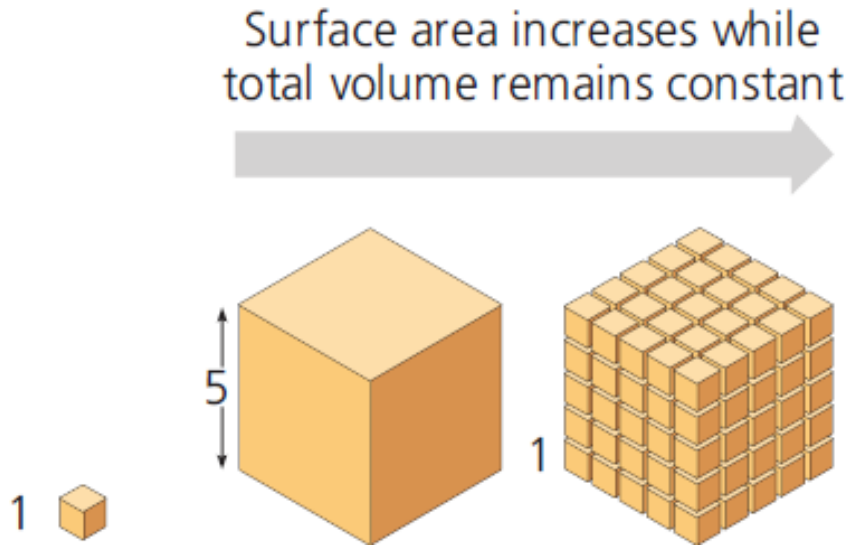


http://www.microscopyu.com/moviegallery/livecellimaging/u2/index.html

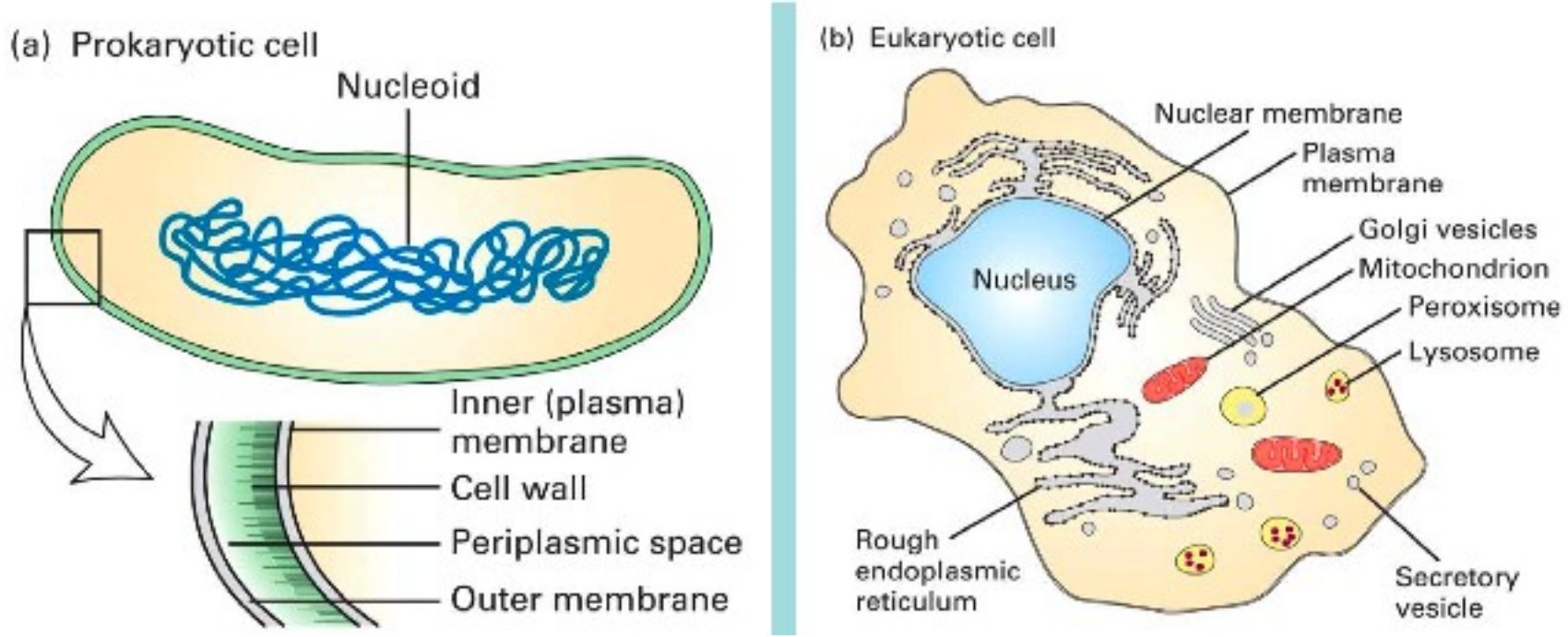
Why cells are so small?

- Cells acquire information and nutrients through their surface membranes

- Cells can only regulate a limited amount of active cytoplasm



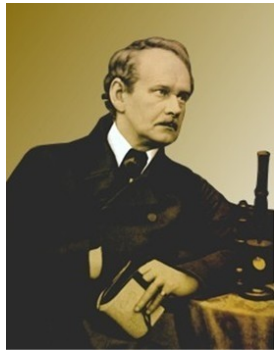
Prokaryote and eukaryote cells



Eukaryotes and prokaryotes

- Prokaryotes
  - Since 3.8-3.6 billion years
  - No nucleus
  - Circular chromosomes
  - Division by fission
- Eukaryotes
  - Individual cells: 2 billion years ago
  - Multicellular organisms: 1 billion years ago
  - Nucleus with pairs of chromosomes
  - Asexual and sexual reproduction

Cell theory



- (1839) Theodor Schwann és Matthias Schleiden

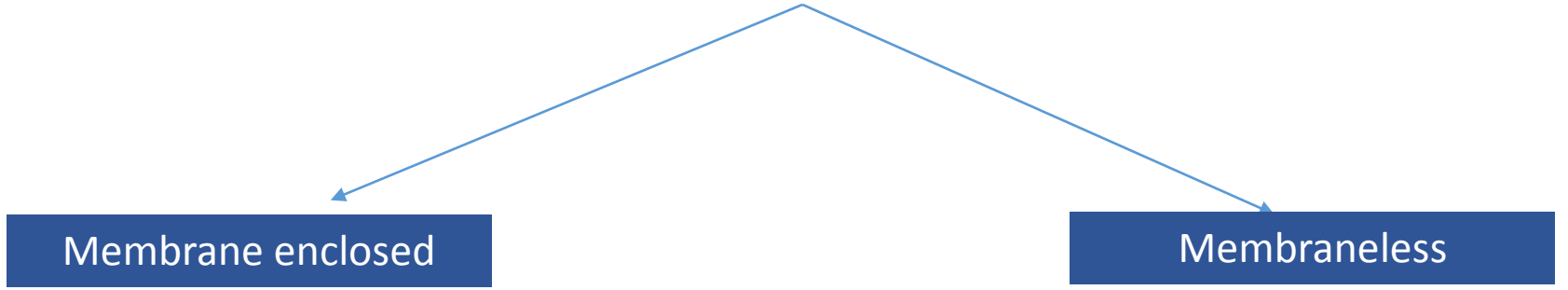
  “ all living organisms consist of cells”

- (~50 years later) Rudolf Virchow

  “All cells from cells”

Organelles

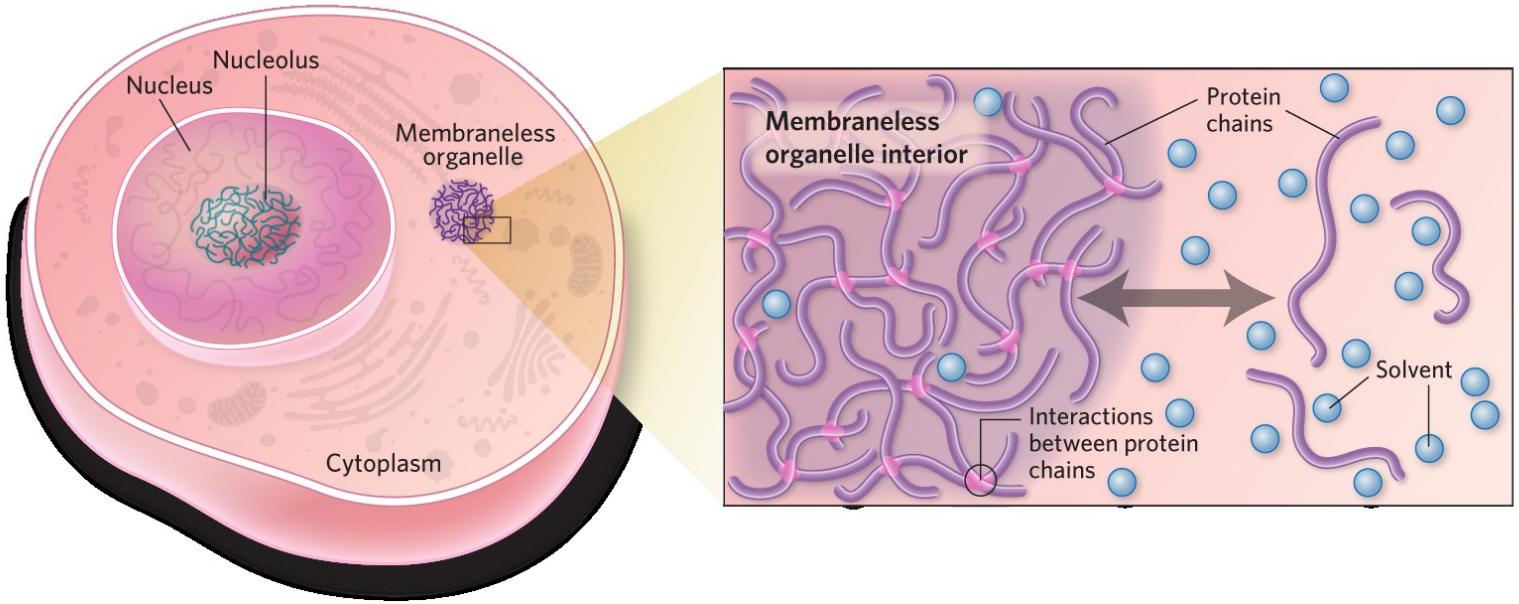
Subunits of cells with specific functions



Nucleus
Mitochondrion
Endoplasmic reticulum
Golgi
Lysosome
Peroxisome
Transport vesicle

Nucleolus
Ribosome
Centrosome
Cytoskeleton
Stress granules

Membraneless organelles



For liquid-liquid phase separation to occur in cells, the polymers that make up membraneless organelles—typically highly flexible proteins and nucleic acids—must exceed their saturation concentration

Plasma membrane and other membranes of the cells

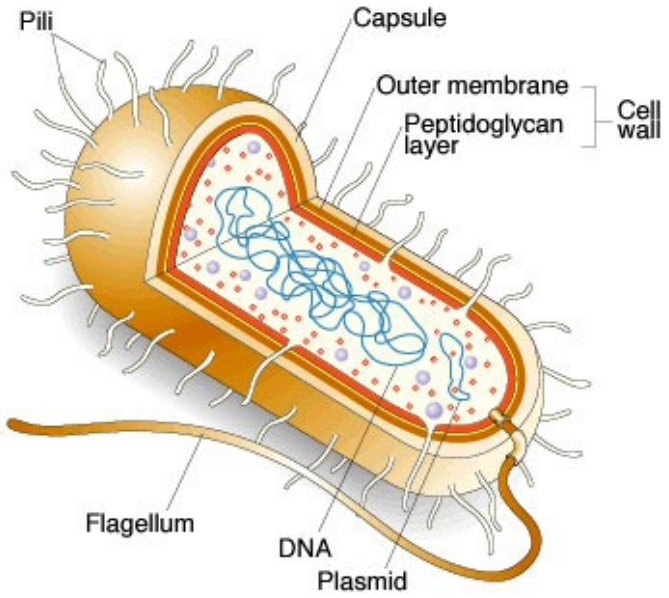
They constitute 80% of the dry weight of eukaryotic cell
Thickness: 6-10 nm
lipids (40-60 %), proteins (60-40 %) and carbohydrates (2-10 %) and water

Functions

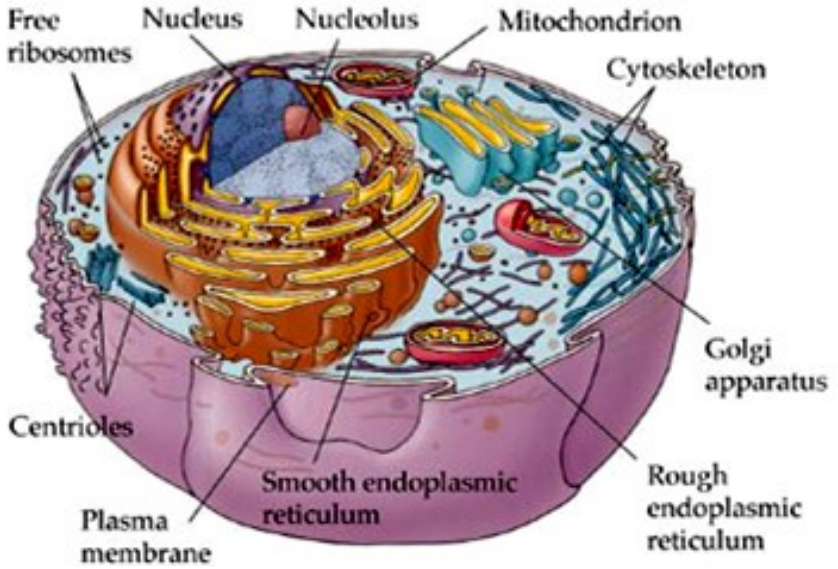
1. **Protection and separation**
2. **Regulated transport**
3. **Regulated information transfer (receptors)**
4. **adhesion**
5. **antigenity (self identity)**

Major difference between pro- and eukaryotic cells

There is no internal membrane



Internal membrane system = compartmentalization = organelles



II. Model cells of biomedicine

II. Model cells of biomedicine

❖ Can serve for the following purposes:

- Basic research
- Clinical diagnostics
- Monitoring therapy
- Drug development

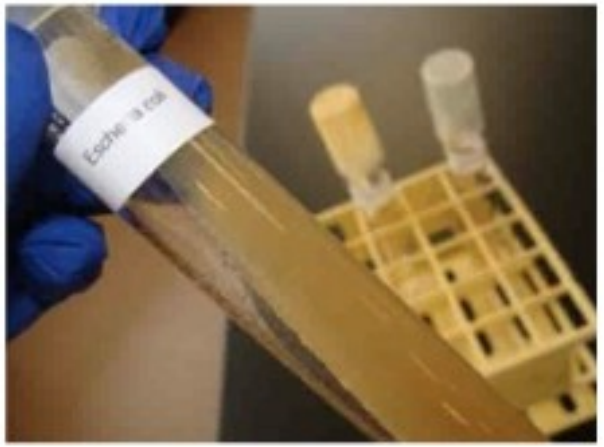
Benefits of using model cells and organisms

- Cells grown in laboratory can represent the functions of tissues/organs
- Physical, chemical or biological parameters can be controlled
- Cells can be grown in large amounts, and the statistical power of their evaluation is stronger
- Cells can often replace experiments with live animals

IN VITRO

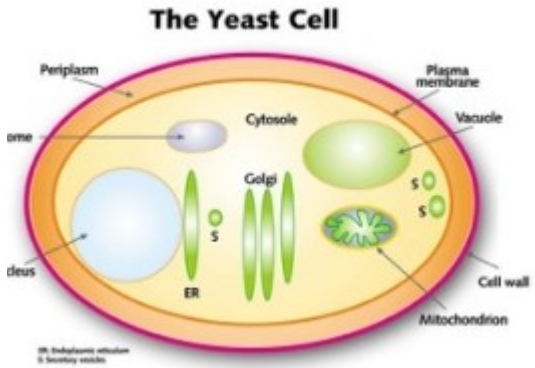
Eserichia Coli (E. Coli)

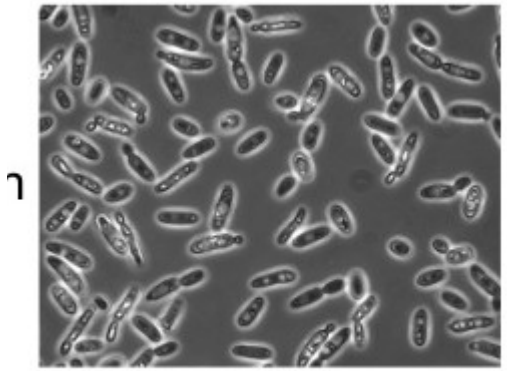
- Easy to grow in the lab
- Several millions of cells can be grown
- Rapid growth
- Easy to modify genetically



Saccharomices cerevisiae (bakers yeast)

Unicellular fungus
5-10 μ diameter

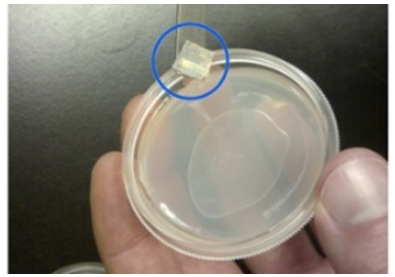


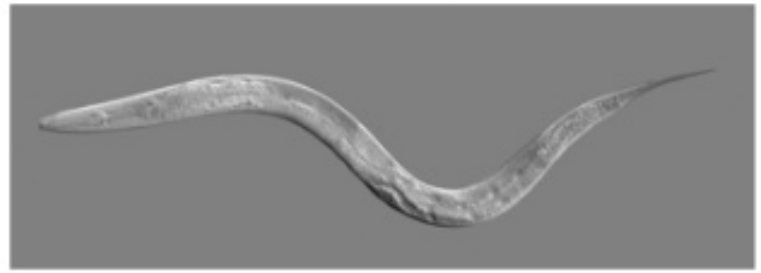


- Easy to grow in the lab
- Can be stored easily
- Easy to modify genetically

Caenorhabditis elegans

- **1mm** long worm
- The male consists of exactly 1031 cells





- Easy to grow in a lab
- Rapid growth
- Short life cycle
- Known cell number

- Easy to modify genetically
- Easy to store its eggs

Drosophila melanogaster (fruitfly)

Insect
2.5 cm long

- Easy to grow in a lab
- Needs small space
- Short life cycle
- Easy to modify genetically

Zebra fish

4-6 cm

- Easy to grow in a lab
- Needs relatively small space
- Fast life cycle
- Good growth model

Cell culture

Culturing and growing cells under laboratory conditions in sterile culture medium.

Petri dishes

flasks

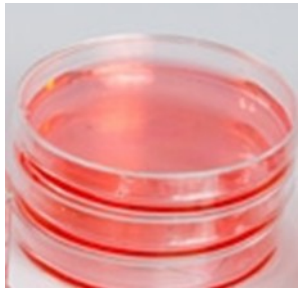
24 well plate

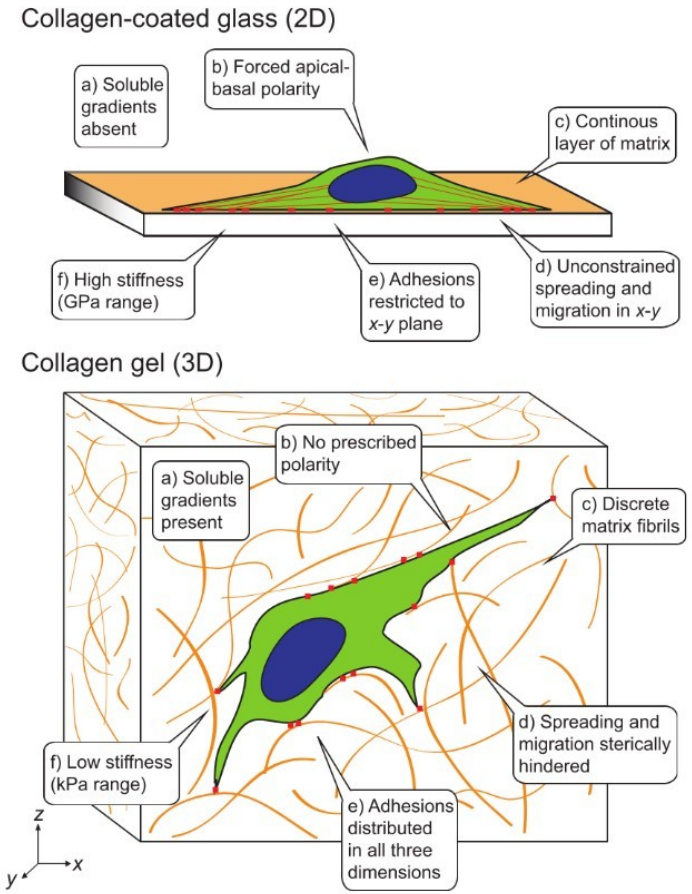
96 well plate

6 well plate

12 well plate

Traditional 2D cultures versus 3D cultures

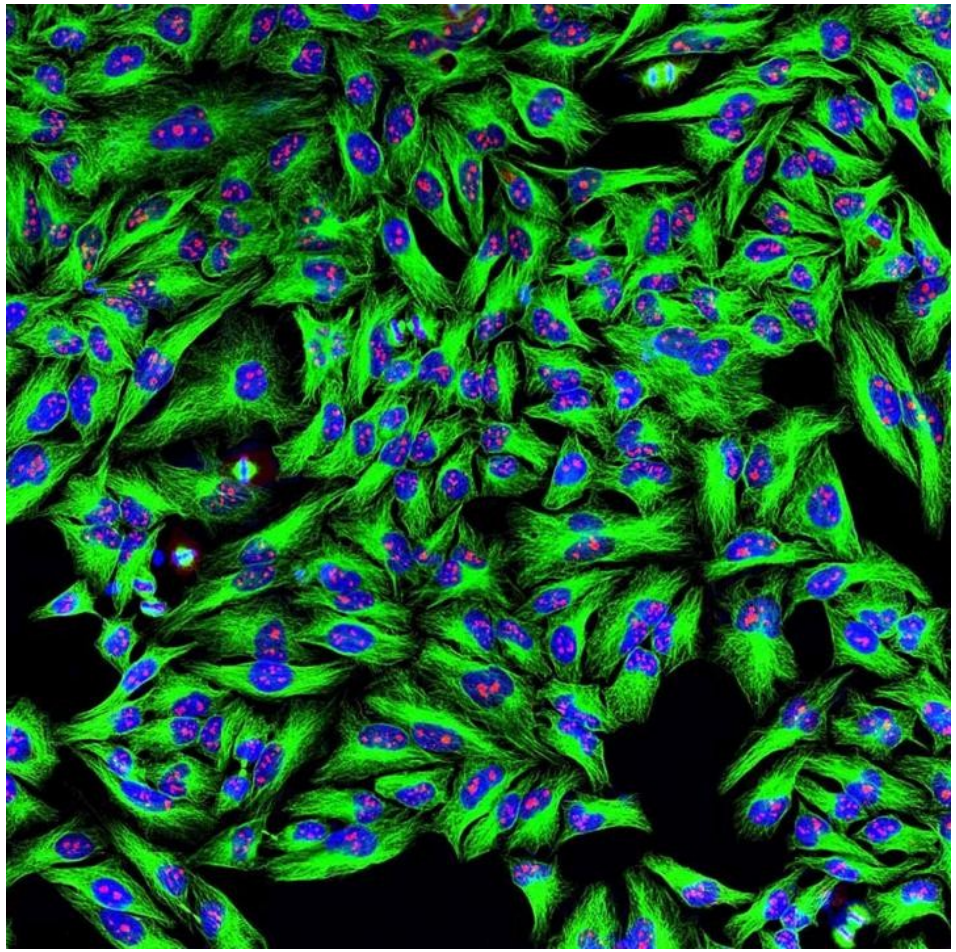


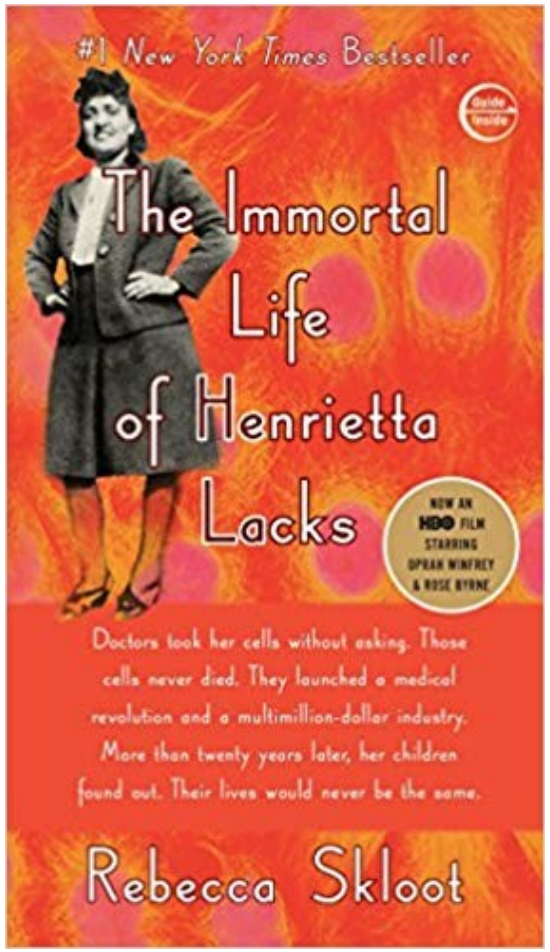


3D organoids: “mini organs”

Tumorous cell lines

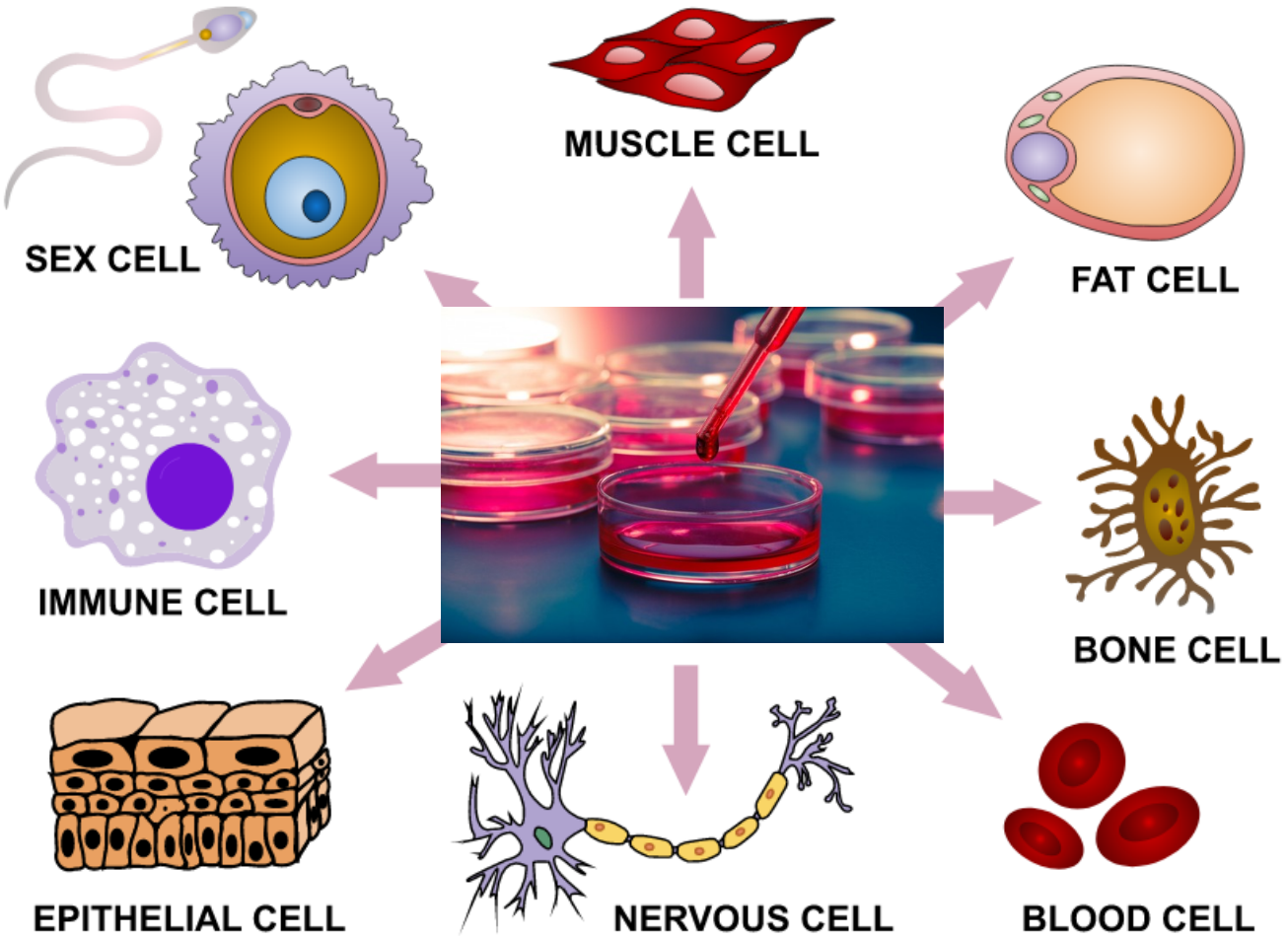
HeLa cell line (1951-)





https://www.tebu-bio.com/blog/2017/11/28/hela-cells-the-first-cell-line/

STEM CELLS



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