Cell Structure

Introduction to Bioinformatics Course

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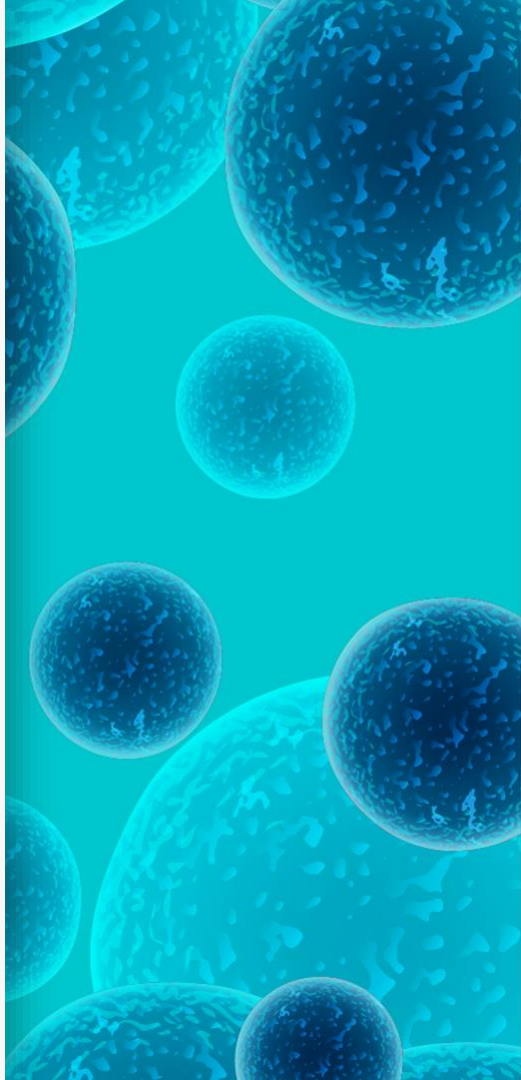


What does it mean to be living?

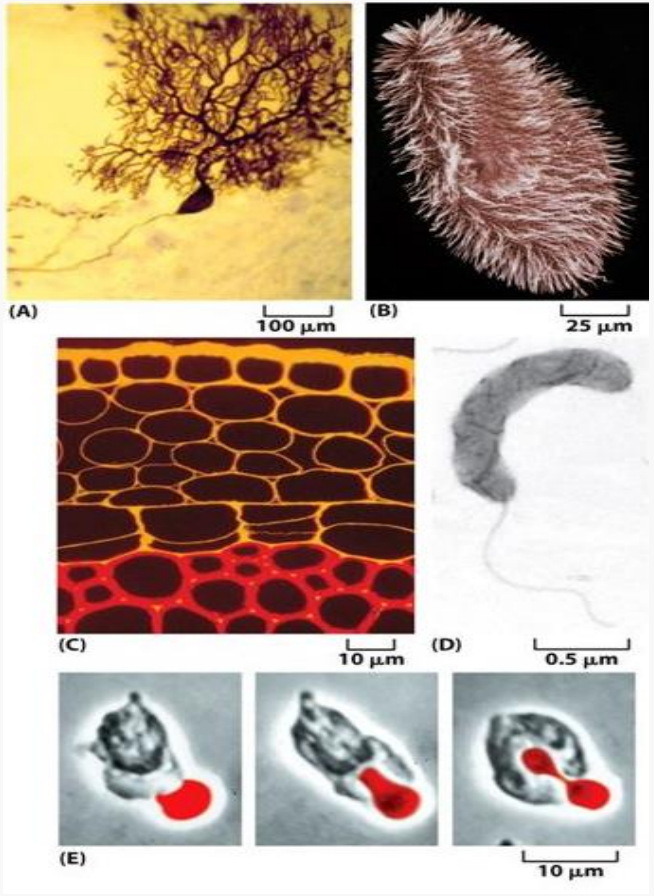
- All living things are made of **cells**: small, membrane-enclosed units filled with a concentrated aqueous solution of chemicals and endowed with the extraordinary ability to create copies of themselves by growing and dividing in two.

- The simplest forms of life are solitary cells. Higher organisms, including ourselves, are communities of cells derived by growth and division from a single founder cell.



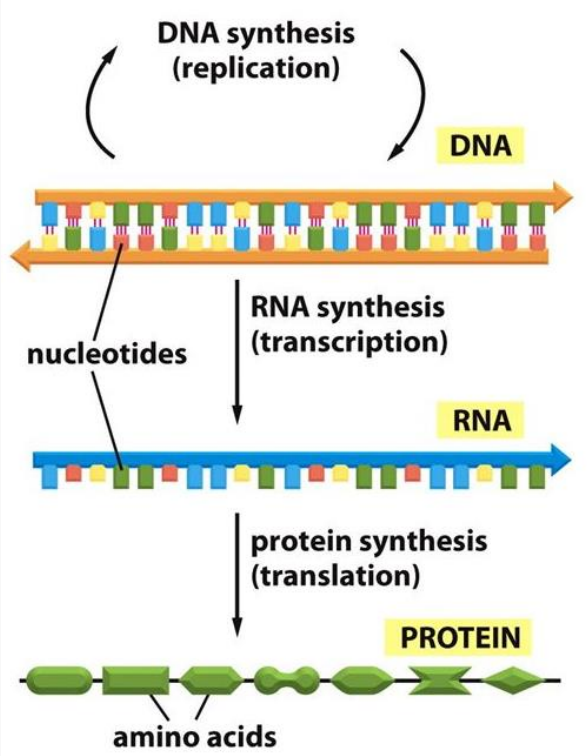

Unity and diversity of Cells

- The dimensions of cells encompass a range spanning from micrometric to mili-metric lengths.
- Cells vary no less widely in their shapes and functions. Some cells are clad only in a flimsy membrane; others augment this delicate cover by cloaking themselves in an outer layer.
- Cells are also enormously diverse in their chemical requirements and activities.



Unity and diversity of Cells

- All cells can grow, reproduce, convert energy from one form into another, control their internal workings, respond to their environment, and so on.
- All cells are composed of the same sorts of molecules that participate in the same types of chemical reactions.
- In all living things, genetic instructions—*genes*—are stored in DNA molecules, written in the same chemical code, constructed out of the same chemical building blocks, interpreted by essentially the same chemical machinery, and duplicated in the same way to allow the organism to reproduce.



Kingdoms of Life

Prokaryotes

Bacteria

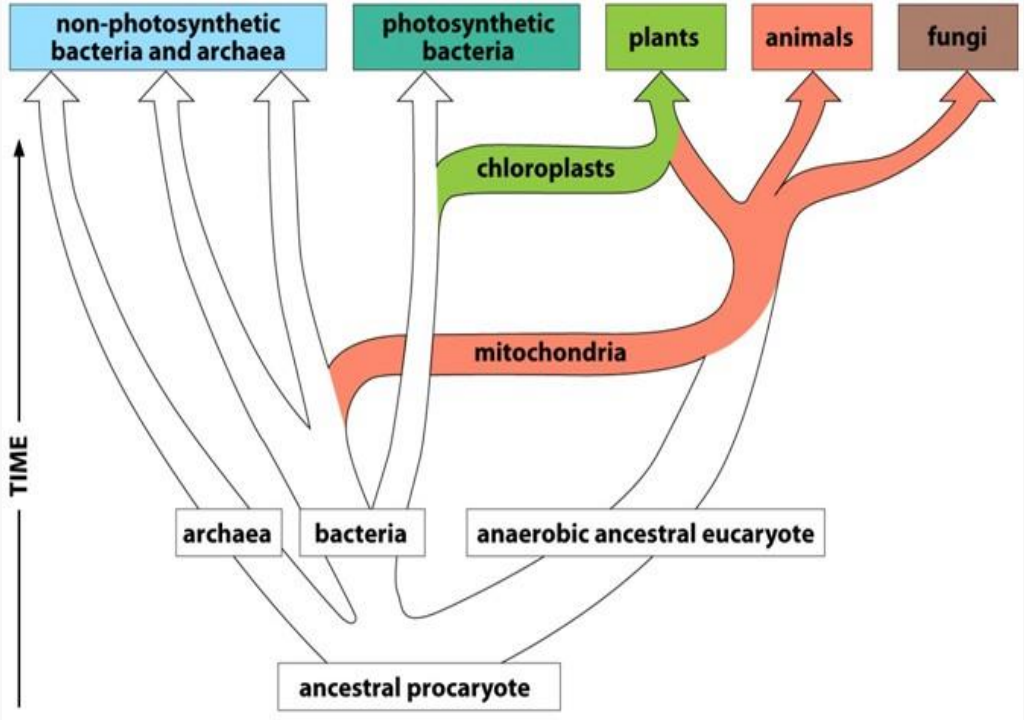
Archaea

Eukaryotes

Animals

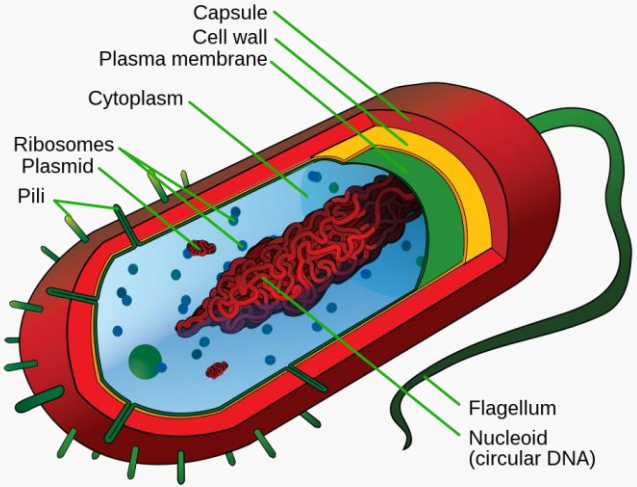
Plants

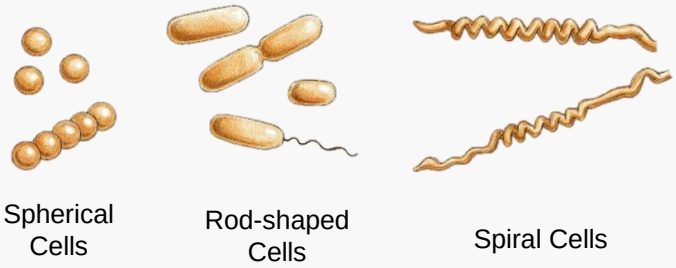
Fungi



Prokaryotic cells

- Single-celled organism that lacks a nucleus and other membrane-bound organelles.
- In shape and structure simple and limited. But In chemistry Most diverse and inventive class.
- Bacteria play a vital role in many stages of the nutrient cycle by recycling nutrients and the fixation of nitrogen from the atmosphere.





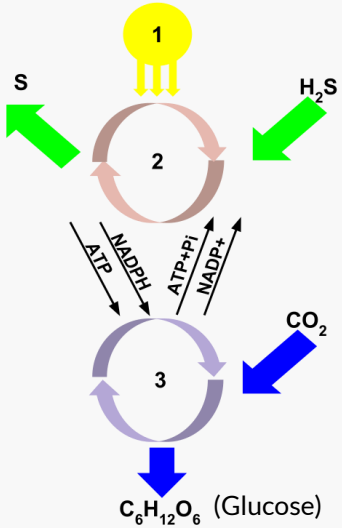
Spherical Cells

Rod-shaped Cells

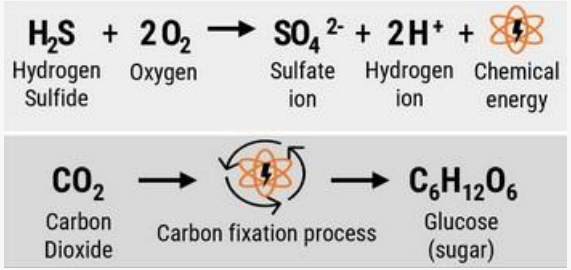
Spiral Cells

Prokaryotic cells

$6CO_2 + 12H_2S + Light \rightarrow C_6H_{12}O_6 + 12S + 6H_2O$

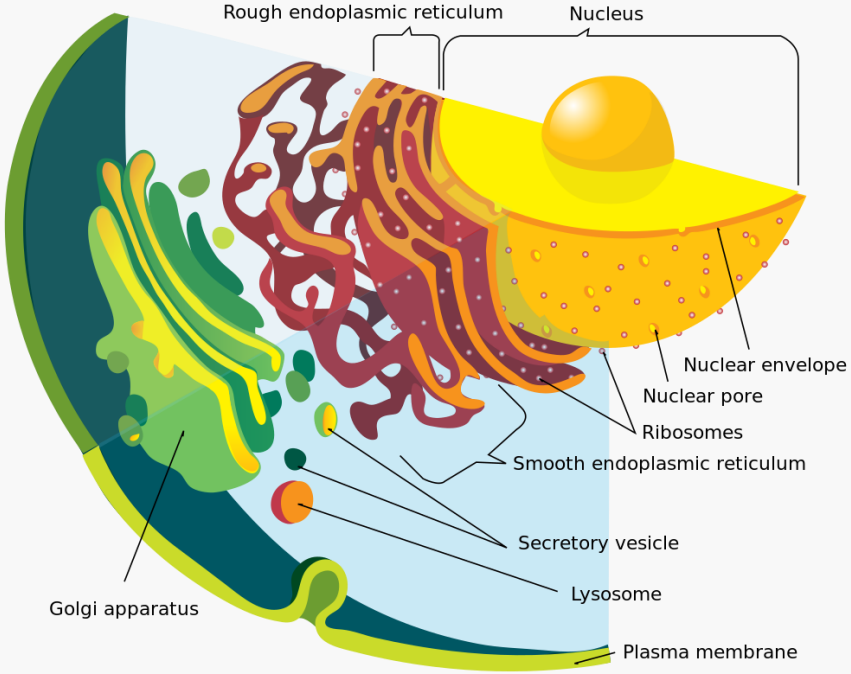


- Some are aerobic, using oxygen to oxidize food molecules; some are strictly anaerobic and are killed by the slightest exposure to oxygen.
- any organic material, from wood to petroleum, can be used as food by bacteria. Some other prokaryotes can live entirely on inorganic substances. CO2, N2, O2, H2, S and P from air, water and inorganic material.
- Some of these prokaryotic cells, perform photosynthesis, getting energy from sunlight; others derive energy from the chemical reactivity of inorganic substances in the environment.



Eukaryotic cells

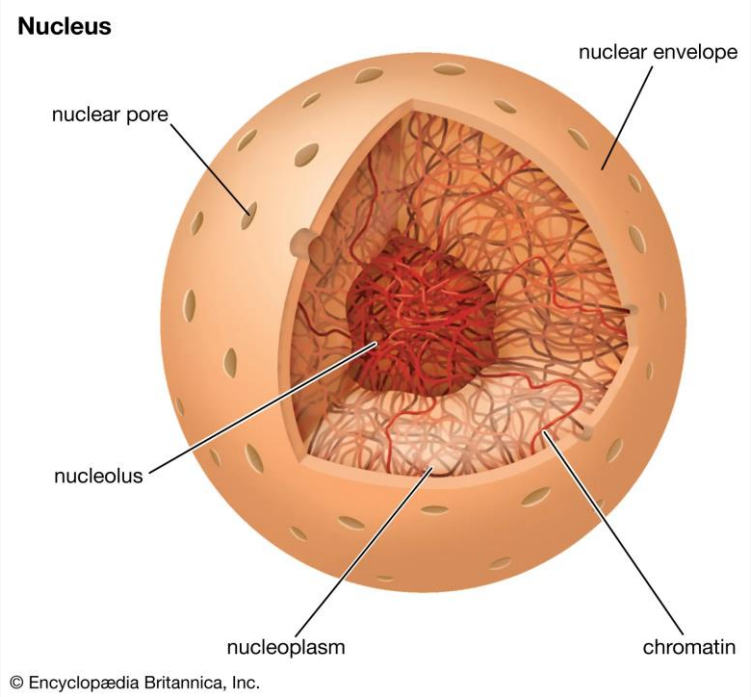
- Eukaryotic cells, in general, are bigger and more elaborate than bacteria and archaea.
- Some live independent lives as single-celled organisms, such as amoebae and yeasts.
- Others live in multicellular assemblies (plants, animals, and fungi)



Nucleus: Command center housing DNA

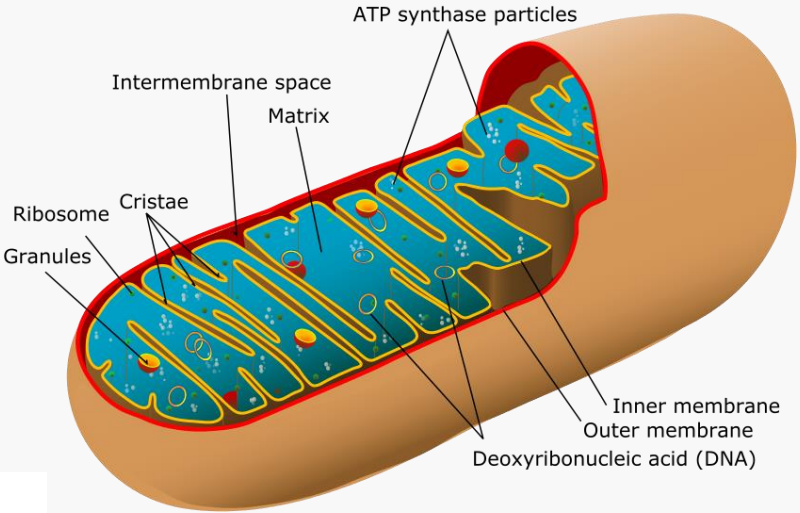
- It is enclosed within two concentric membranes that form the *nuclear* envelope, and it contains molecules of DNA.

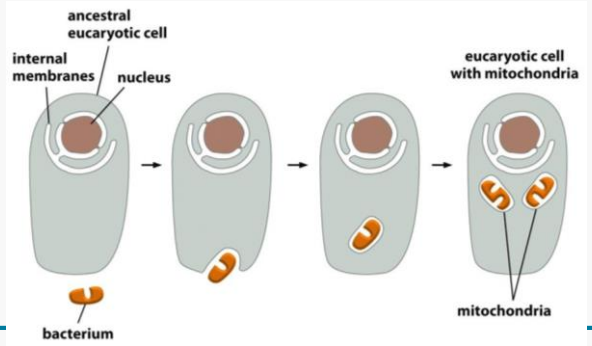
- **Chromatin**: Complex of DNA and proteins that forms chromosomes.
- **Nuclear pore**: Channels that allow movement of molecules between the nucleus and cytoplasm.
- **Nucleoplasm**: Viscous liquid inside the nucleus containing chromatin and nucleoli.
- **Nucleolus**: Dense region where ribosomal RNA is synthesized.



Mitochondria: Powerhouses producing energy

- Mitochondria are present in essentially all eukaryotic cells, and they are among the most conspicuous organelles in the cytoplasm.
- Each mitochondrion possesses two layers of membranes.
- Mitochondria contain their own DNA and reproduce by dividing in two.

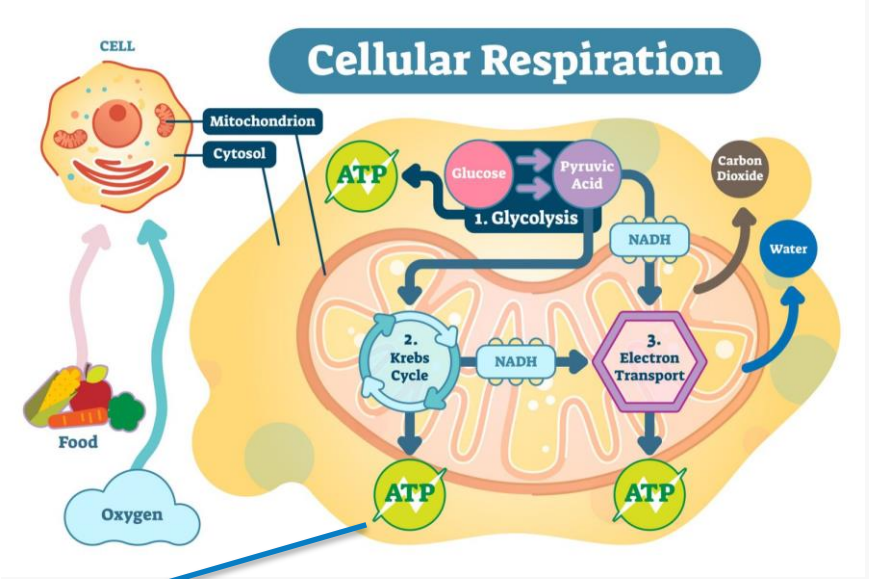


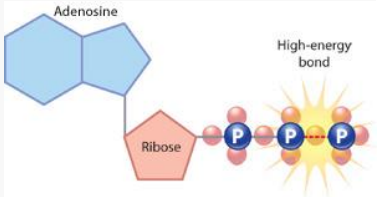


Mitochondria Origin

Mitochondria: Powerhouses producing energy

- Mitochondria are generators of chemical energy for the cell.
- They harness the energy from the oxidation of food molecules, such as sugars, to produce adenosine triphosphate, or **ATP(**Adenosine TriPhosphate**).**
- Because the mitochondrion consumes oxygen and releases carbon dioxide in the course of this activity, the entire process is called **cellular respiration.**



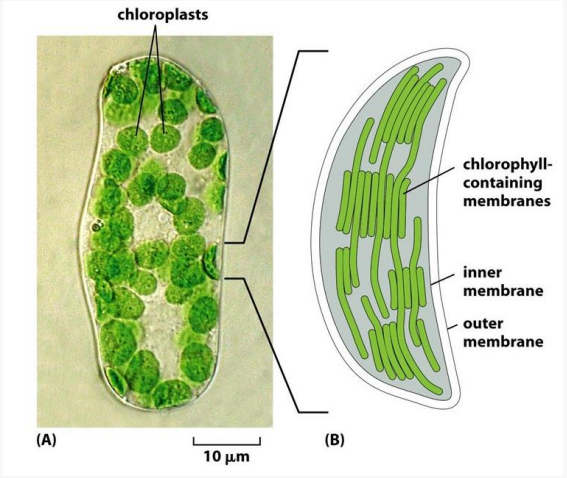


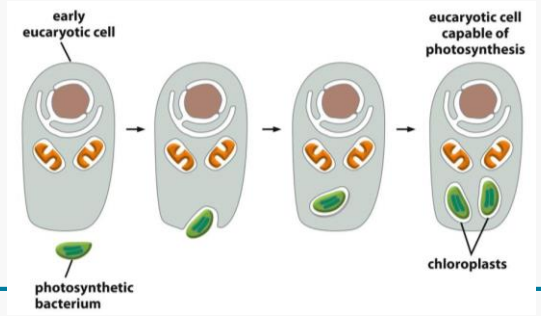
Source

(Glucose) $C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{Cellular respiration}} 6CO_2 + 6H_2O + ATP$

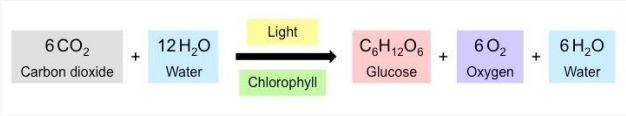
Chloroplasts: Solar panels harnessing sunlight energy

- Plants can get their energy directly from sunlight.
- Chloroplasts are the organelles that enable them to do so by perform photosynthesis.
- They trap the energy of sunlight in chlorophyll molecules and use this energy to drive the manufacture of energy-rich sugar molecules.
- Plant cells can then extract this stored chemical energy when they need it, by oxidizing these sugars in their mitochondria.



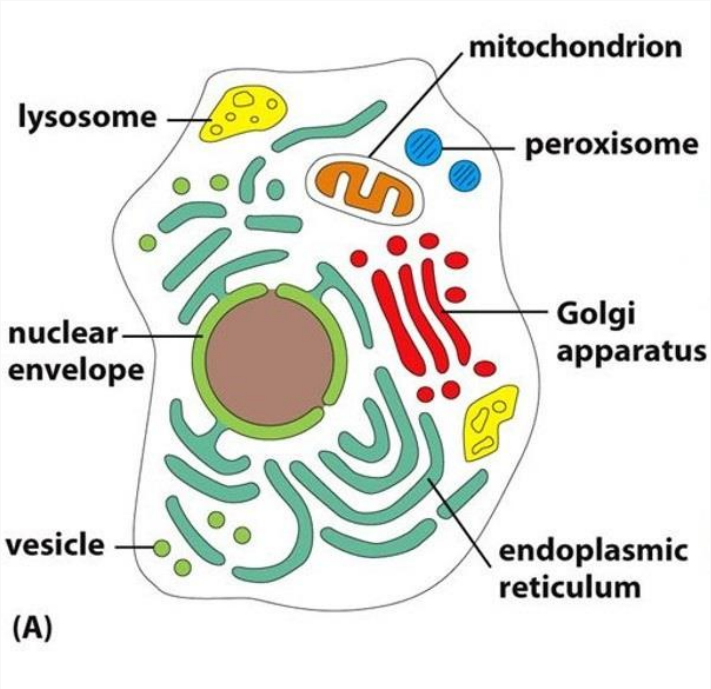


Chloroplast Origin



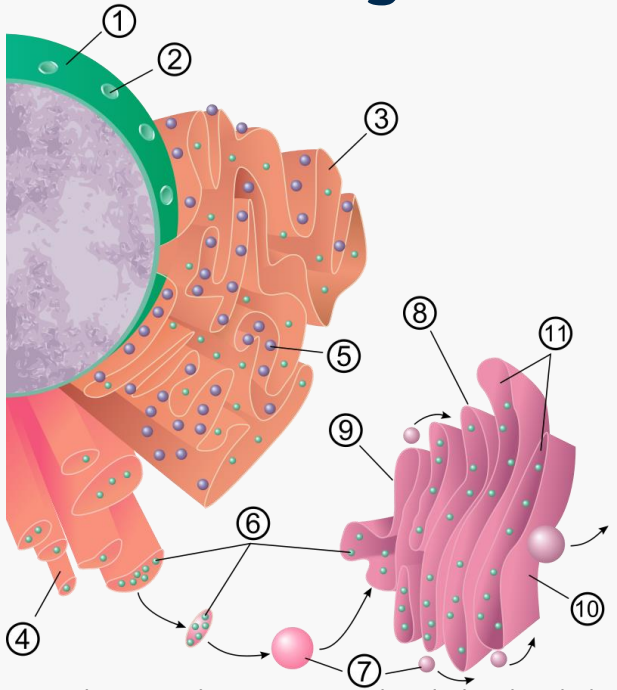
Other Organelles

- Cytoplasm contains many other organelles, mostly surrounded by single membranes, with many distinct functions.
- Some are involved with the cell's ability to import raw materials and to export manufactured substances and waste products .
- Some are enormously enlarged and specialized for the secretion of proteins.
- Others are plentiful in cells specialized for the digestion of foreign bodies.



Endoplasmic Reticulum(ER): Protein Processing Hub

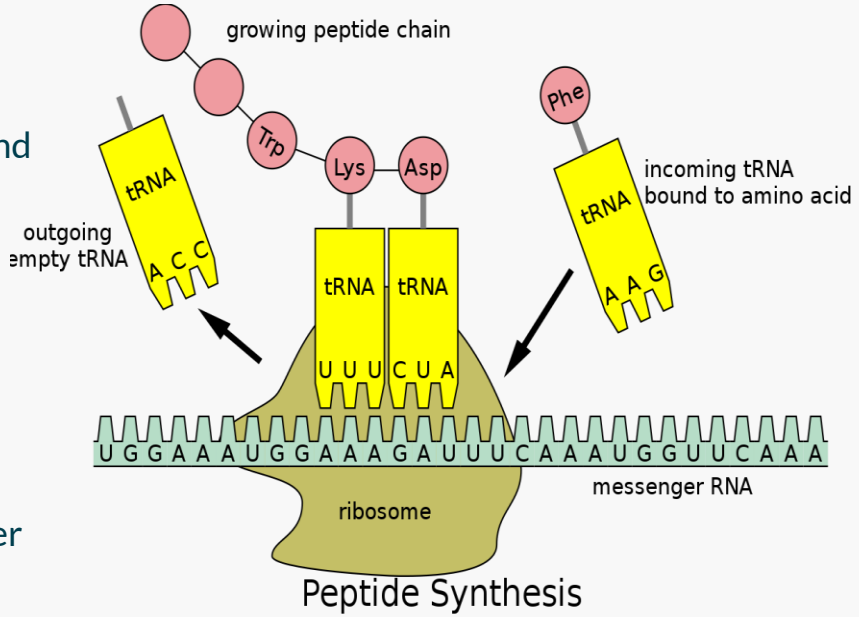
- An interconnected network of folded membranes.
- The ER plays a role in the formation and transport of proteins and lipids and is further divided into two types: rough and smooth.
- The outer surface of the rough endoplasmic reticulum has many ribosomes attached to it.
- The main function of the rough ER is to fold proteins into their final shape.
- The smooth endoplasmic reticulum does not have ribosomes on its surface and is associated with the production of lipids.



1 Nucleus **2** Nuclear pore **3** Rough endoplasmic reticulum (RER) **4** Smooth endoplasmic reticulum (SER) **5** Ribosome on the rough ER **6** Proteins that are transported **7** Transport vesicle **8** Golgi apparatus **9** Cis face of the Golgi apparatus **10** Trans face of the Golgi apparatus **11** Cisternae of the Golgi apparatus

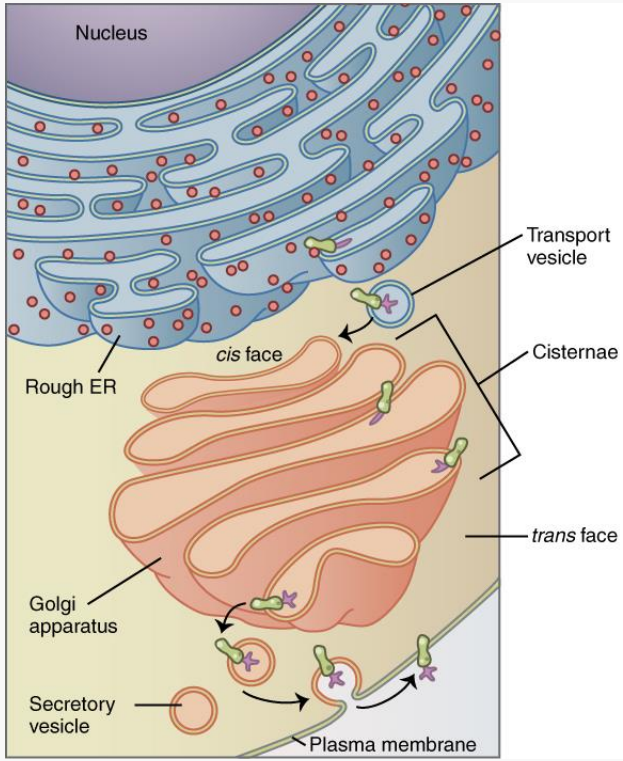
Ribosomes: Protein factories

- Ribosomes are tiny structures which can be found freely in the cytoplasm or attached to the rough endoplasmic reticulum.
- They consist of two ribosomal subunits, one large and one small. These subunits are made of rRNA, or ribosomal RNA, which is made in the nucleolus.
- The ribosomes translate messenger RNA (mRNA), which carries the genetic code from the DNA in the nucleus, into a string of amino acids called a polypeptide chain(Protein).
- These proteins usually needs to be modified by other organelles, such as the endoplasmic reticulum and Golgi apparatus, to become a functional protein.



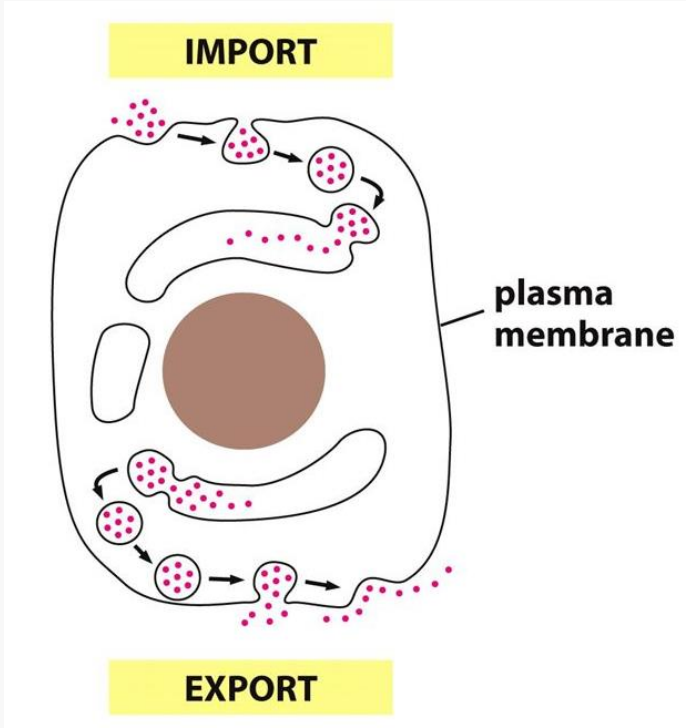
Golgi apparatus: Protein packaging center

- The Golgi body, is a series of flattened membrane sacs called cisternae.
- It functions to package the correct combinations of proteins, lipids, and other chemicals and deliver them to the areas of the cell where they are needed.
- Figure shows how the endoplasmic reticulum and Golgi apparatus interact in a typical animal cell.



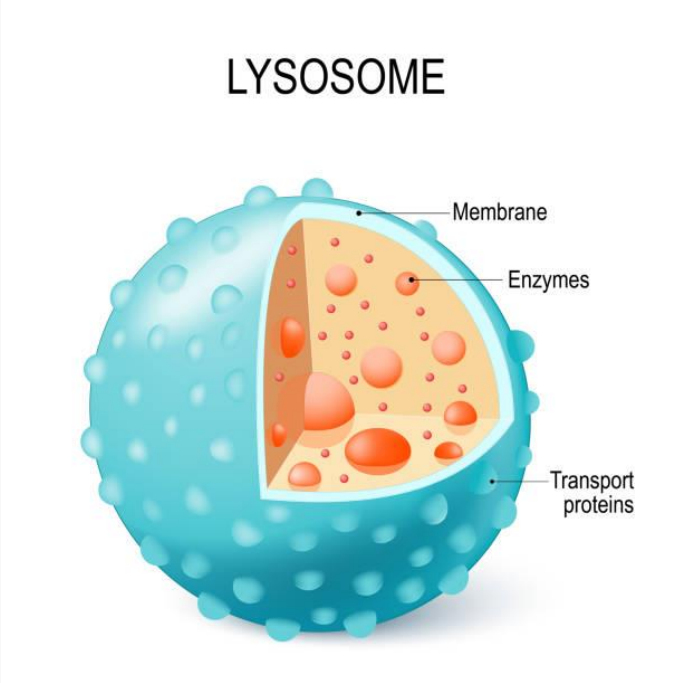
Vesicles: Mini container trucks

- Membranes form many different types of small vesicles.
- They are involved in the transport of materials between one membrane-enclosed organelle and another, or with outside of the cell.
- They pinch off from the membrane of one organelle and fuse with another, like tiny soap bubbles budding from and rejoining larger bubbles.



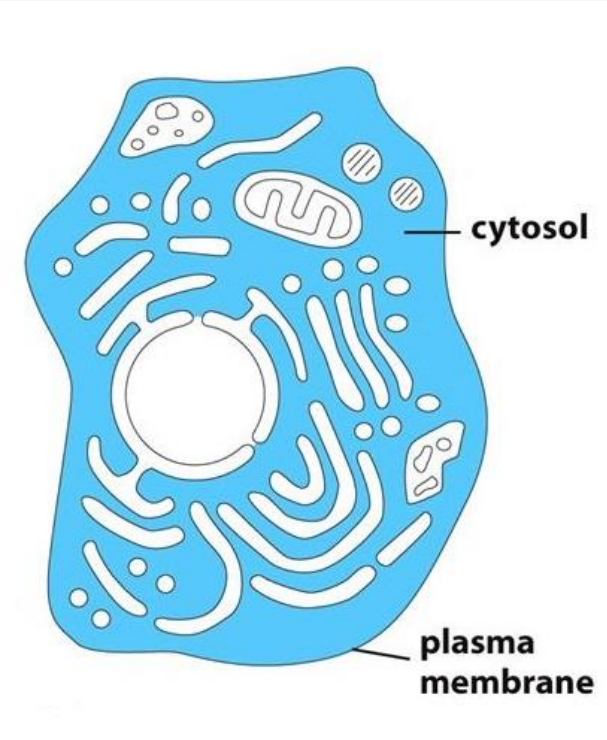
Lysosomes: Cellular recycling centers

- Lysosomes are specialized, membrane-bound vesicles that are made by the Golgi apparatus.
- Lysosomes contain a wide variety of hydrolytic enzymes (acid hydrolases) that break down macromolecules such as nucleic acids, proteins, polysaccharides and old cellular structures or components.
- One lysosome can contain more than 60 different types of digestive enzymes, and the fluid inside is usually quite acidic.



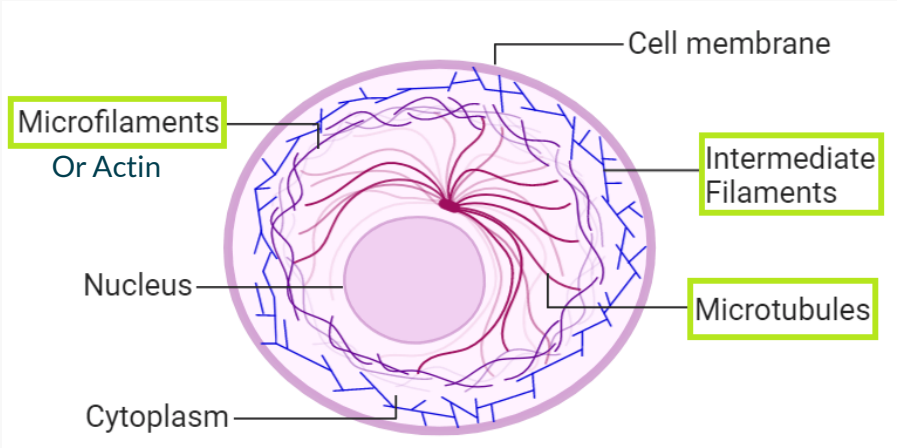
Cytosol: Cellular fluid medium

- Cytosol is the part of the cytoplasm that is not partitioned off within intracellular membranes.
- In most cells, the largest single compartment, a host of large and small molecules, crowded together which makes it more like a water-based gel than a liquid solution.
- Site of many chemical reactions, such as breakdown of nutrient molecules, and manufacture of proteins.
- Ribosomes, the molecular machines that make the protein molecules, often attached to the cytosolic face of the endoplasmic reticulum.

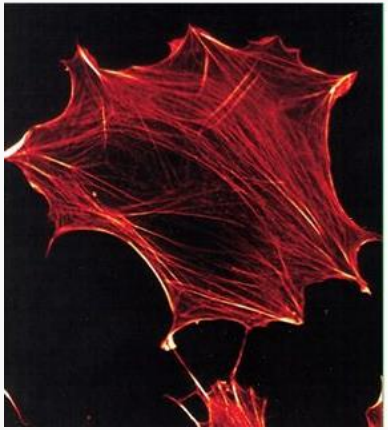


Cytoskeleton: Cellular skeleton for structure and movement

- Cytoplasm is not just a structureless soup of chemicals and organelles.
- Cytoskeleton is responsible for directed cell movements.
- Cytosol is criss-crossed by long, fine filaments of protein. They anchor at one end to the plasma membrane or to radiate out from a central site adjacent to the nucleus.

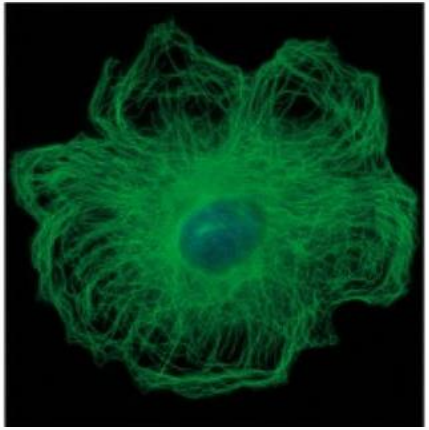


Cytoskeleton: Cellular skeleton for structure and movement



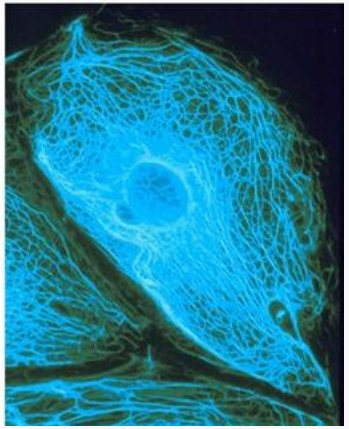
Actin Filament

The thinnest filaments
Present in all eukaryotic cells
Large number inside muscle cells
Part of the machinery that generates contractile forces



Microtubules

The thickest filaments
In dividing cells they form a spectacular array that helps pull the duplicated chromosomes in opposite directions

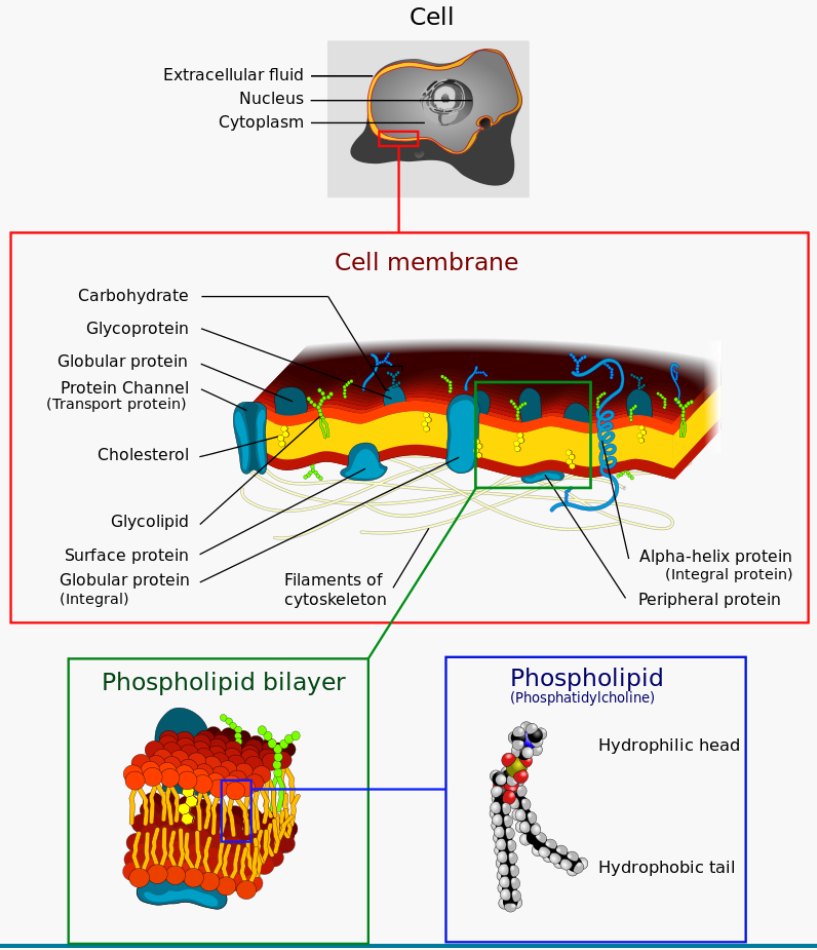


Intermediate Filaments

Strengthen the cell mechanically

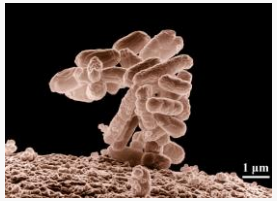
Membrane: Selective cell barrier

- Every cell on Earth uses a membrane to separate and protect its chemical components from the outside environment.
- Its structure is based on a two-ply sheet of lipid molecules about 5 nm—or 50 atoms—thick.
- The membrane is penetrated by highly selective channels and pumps—protein molecules that allow specific substances to be imported and others to be exported.
- Cells are filled with—and surrounded by—solutions of molecules in water, each phospholipid has a hydrophilic (“water-loving”) head and one or two hydrophobic (“water-fearing”) hydrocarbon tails.

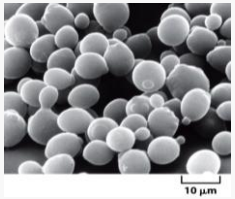


Model Organisms

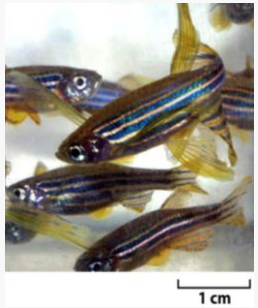
- All cells are thought to be descended from a common ancestor, whose fundamental properties have been conserved through evolution. Thus, knowledge gained from the study of one organism contributes to our understanding of others, including ourselves.
- But certain organisms are easier than others to study in the laboratory.
- Some reproduce rapidly and are convenient for genetic manipulations; others are multicellular but transparent, so that one can directly watch the development of all their internal tissues and organs.



E. coli

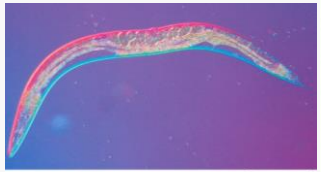


Brewer's yeast



Zebra fish

Drosophila melanogaster



Caenorhabditis elegans


Arabidopsis thaliana

Reference

- Alberts, Bruce, et al. *Essential cell biology*, Chapter1, Introduction to Cells.

- Images adapted from:
  - Essential Cell Biology textbook
  - Additional online resources (hyperlinks)