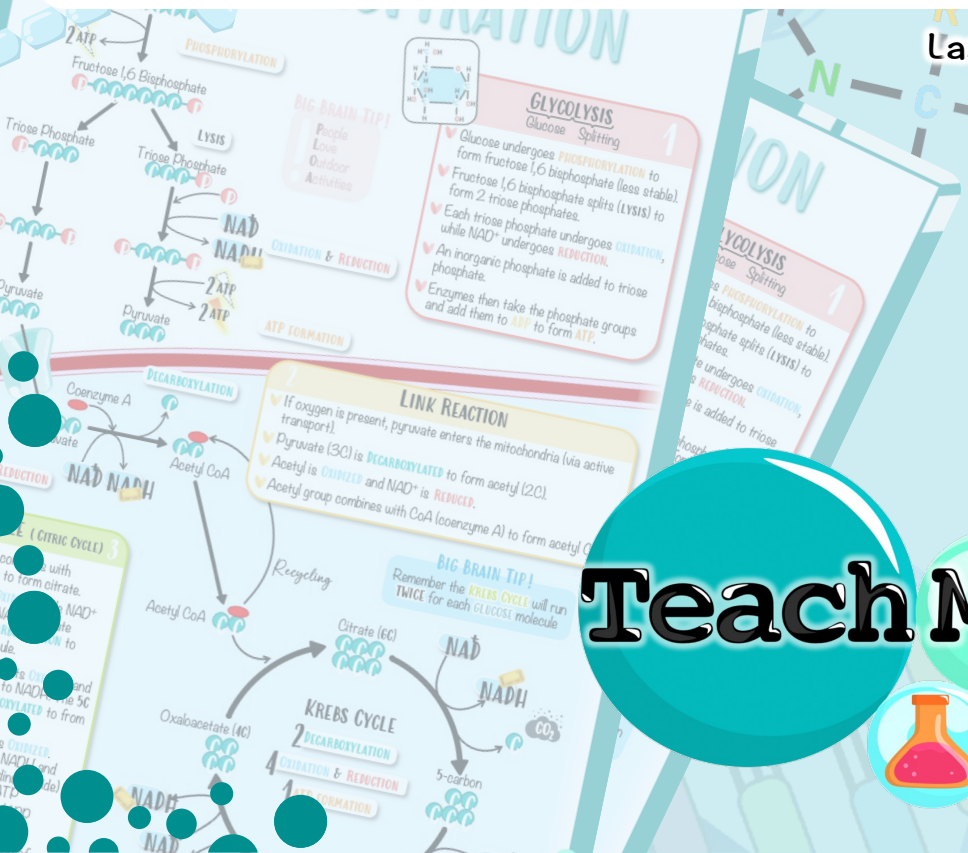
TeachMe

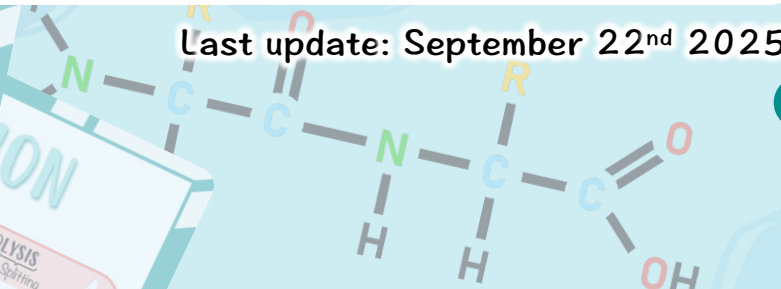
STUDY NOTES

CHAPTER 1 - CELL STRUCTURE

EUKARYOTIC CELLS

Last update: September 22nd 2025

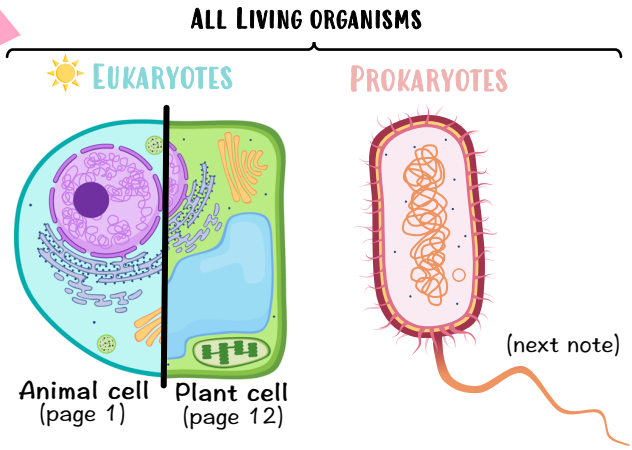




Teach Me

Eukaryotic Cells

All living organisms can be categorized as EUKARYOTIC or PROKARYOTIC. As humans, we are made up of eukaryotic cells, and so are plants and other animals. Bacteria on the other hand are prokaryotes.



Eukaryotic cells

"True" "Nucleus"

Big Brain Tip!
Eu = You

Eukaryotic cells are found in: Animals + Plants + Fungi + Protists

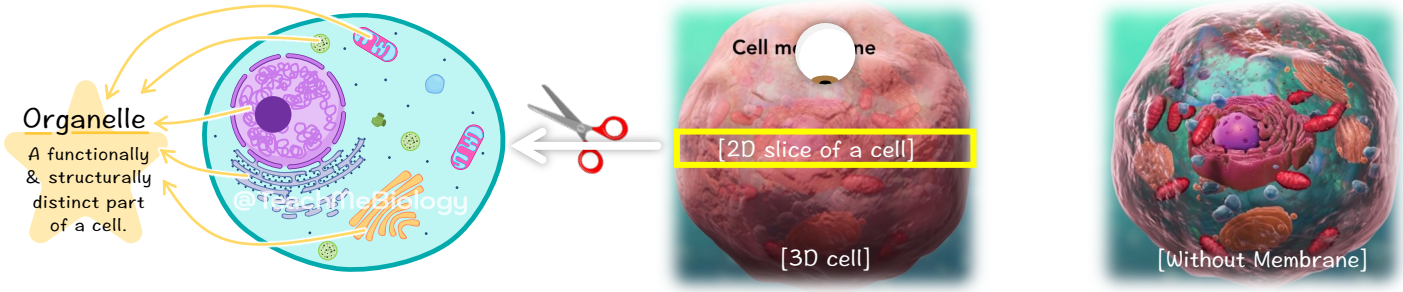
A unique feature of eukaryotic cells is that they are **COMPARTMENTALIZED**, meaning their functions are divided among membrane-bound organelles. Each **ORGANELLE** can perform its own specific function, making the cell more efficient and specialized.

Learning more about eukaryotic cells may helps us save ourselves!

In the rest of this note, we outline the main role and structure of the major eukaryotic organelles for **ANIMAL CELLS** and **PLANT CELLS**.

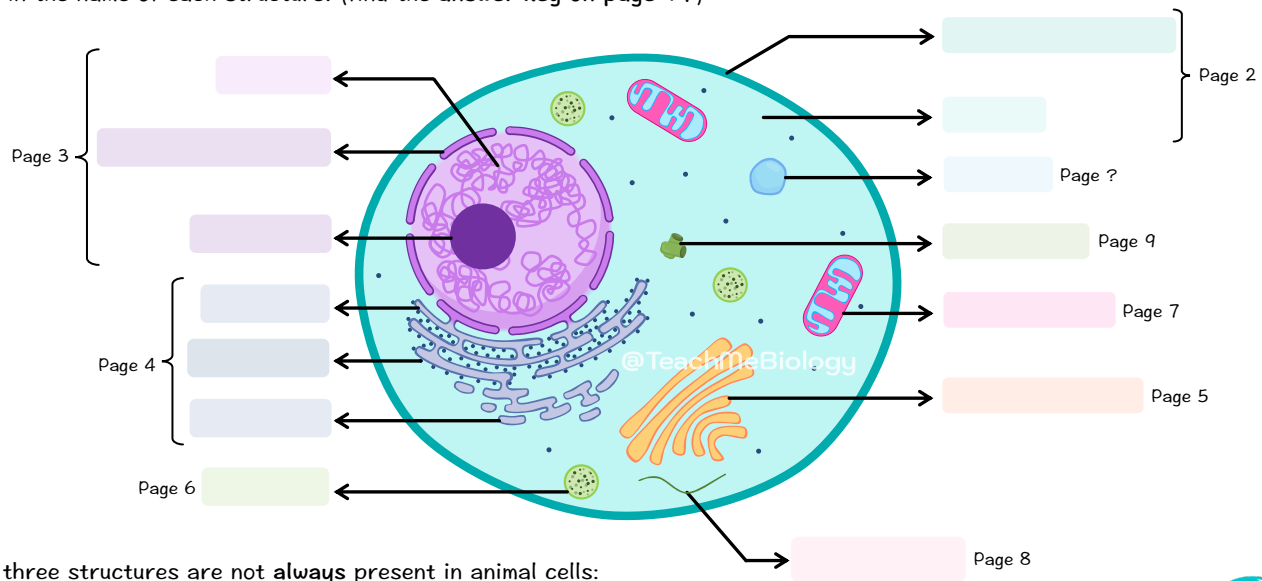
It will surprise you to see how similar they are!

Compartmentalization - Organizing cell activities in separate compartments (organelles) to enhance efficiency.



I. Animal Cells

All the structures you need to know about for animal cells is shown below on the diagram. It can feel overwhelming in the beginning, but over the next pages, we will go through each of the structures one-by-one – then come back to this page and test yourself by filling-in the name of each structure! (find the **answer key on page 17**)



These three structures are not **always** present in animal cells:

Pages 10 & 11

Next, we will explore each organelle in greater detail, considering both its **STRUCTURE** and its **FUNCTION** within the cell. To guide you, look out for the icons:


Indicates the structure can be seen by LIGHT MICROSCOPE


Indicates the structure can be seen by ELECTRON MICROSCOPE

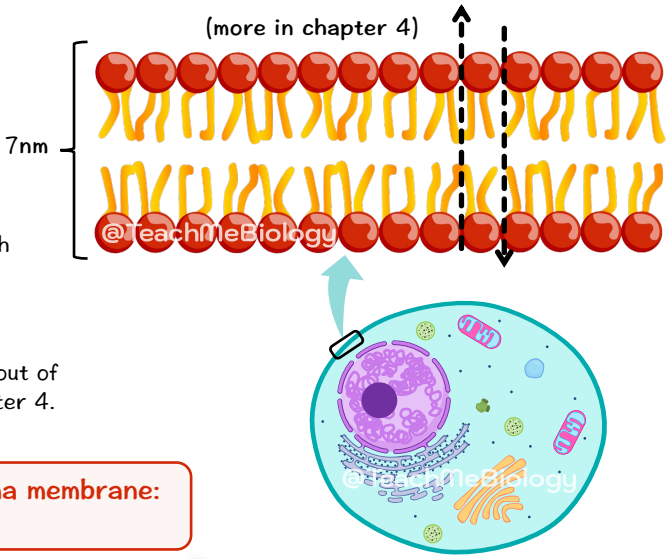
If no icon is present, the organelle cannot be directly observed with these methods. At the end (page 11 for animal cells & page 15 for plant cells), you will find a **SUMMARY** that illustrates how a cell appears when viewed with a light microscope compared to an electron microscope.

Plasma Membrane

Also called the "Cell (surface) membrane"

STRUCTURE

The thin boundary that surrounds the cell, separating its internal environment from the outside. It is made of a phospholipid bilayer with embedded proteins (not shown).



FUNCTION

The plasma membrane controls the movement of substances into and out of the cell, amongst other functions that we will explore further in chapter 4.

Important terminology associated with the plasma membrane: the compartments of a cell.

PROTOPLASM

(cytoplasm + nucleus)

Everything inside the cell.

CYTOPLASM

(cytosol + organelles - nucleus).

Everything inside the the cell except the nucleus.

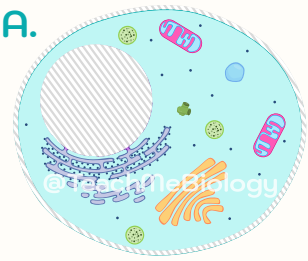
CYTOSOL

Only the aqueous (watery) gel-like fluid portion of the cytoplasm

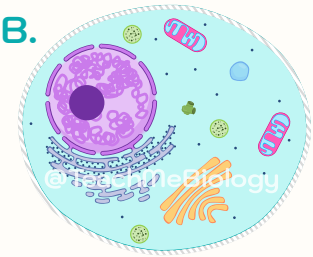
Try for yourself!

Match the following: ***protoplasm, cytoplasm and cytosol*** to the correct diagram that matches its definition as above. Answers at the bottom of page.

A.



B.



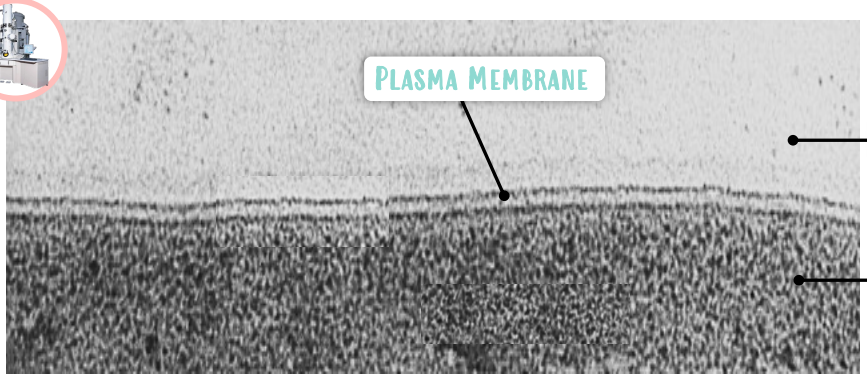
C.

BIG BRAIN TIP!

CYTOSOL and CYTOPLASM are very commonly confused!

Cytosol is like the water in the ocean; The cytoplasm is the water + all the fish.

Imaging

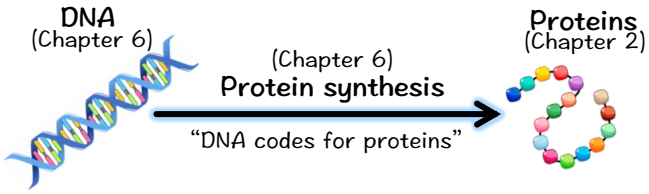


Answer: *A. cytoplasm, B. protoplasm, C. cytosol*

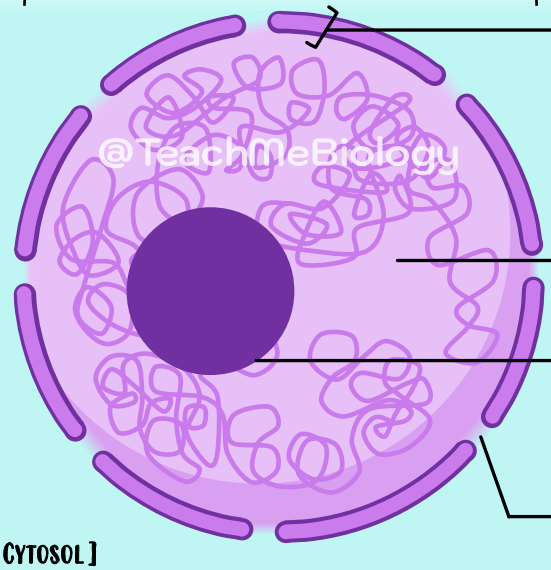
Nucleus

FUNCTION Where genetic material (DNA) is stored.

You can think of DNA as an instruction manual which tells the cell what proteins to make – where each segment of DNA codes for a specific protein.



STRUCTURE 5-10µm



[CYTOSOL]

Nuclear Envelope

(1) Separating DNA from the rest of the cell.
(2) Can disintegrate and reform (for cell division).

Double membrane
↳ Outer: Continuous with the ER*.
↳ Inner: Interacts with DNA. Also important for shape.

*ER = Endoplasmic Reticulum (Page 4)

Nucleoplasm

Jelly-like matter in which the genetic material and other substances float.

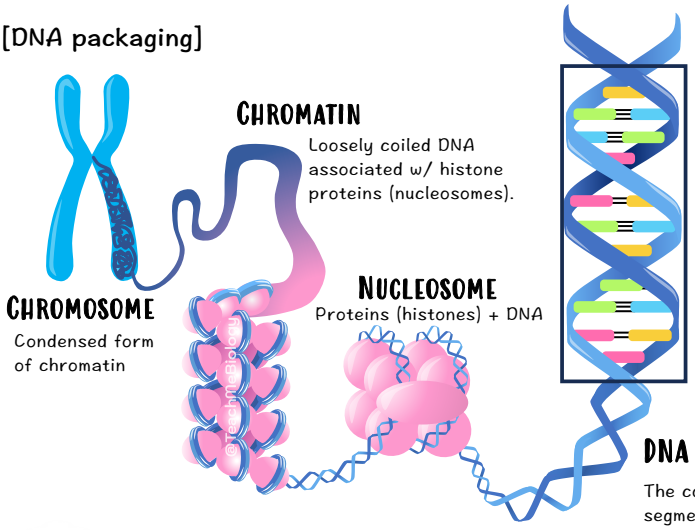
Nucleolus

Site of ribosome synthesis (rRNA + Proteins).
Darkly stained due to lots of protein and rRNA clumped together.

Nuclear Pore

Transport portal between nucleoplasm and the cytoplasm.
↳ Small molecules like mRNA, tRNA, ribosomes, nucleotides, proteins etc...

[DNA packaging]



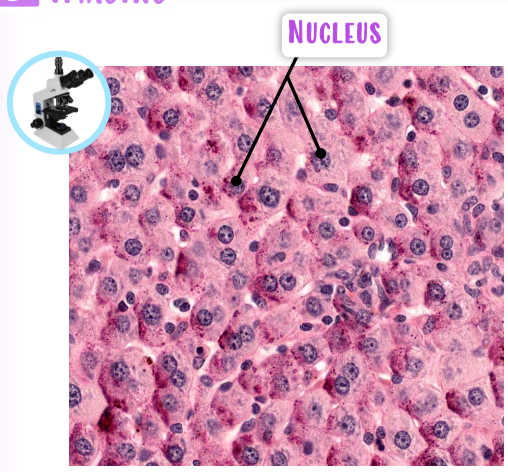
Genes
Section of DNA coding for a specific protein. For example, insulin.

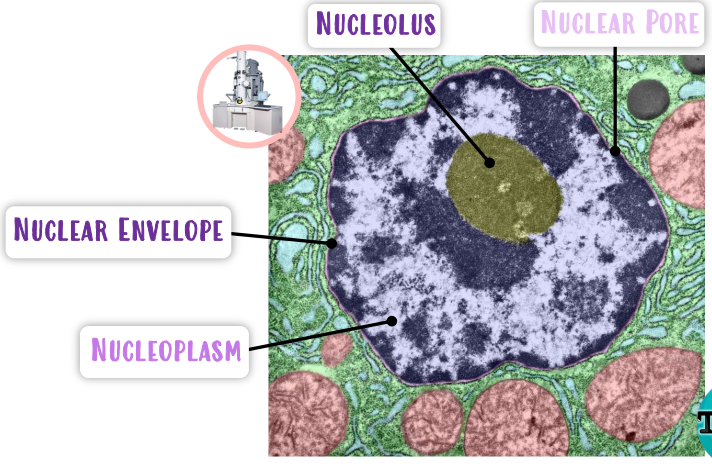
How does all the DNA fit inside the nucleus?

Because of DNA packaging, the long DNA strand is **tightly** coiled and packaged around proteins (histones), forming chromatin that can condense further into chromosomes.

Big Brain Tip!
The nucleus is the largest organelle within a cell, you can easily identify it even with a light microscope!

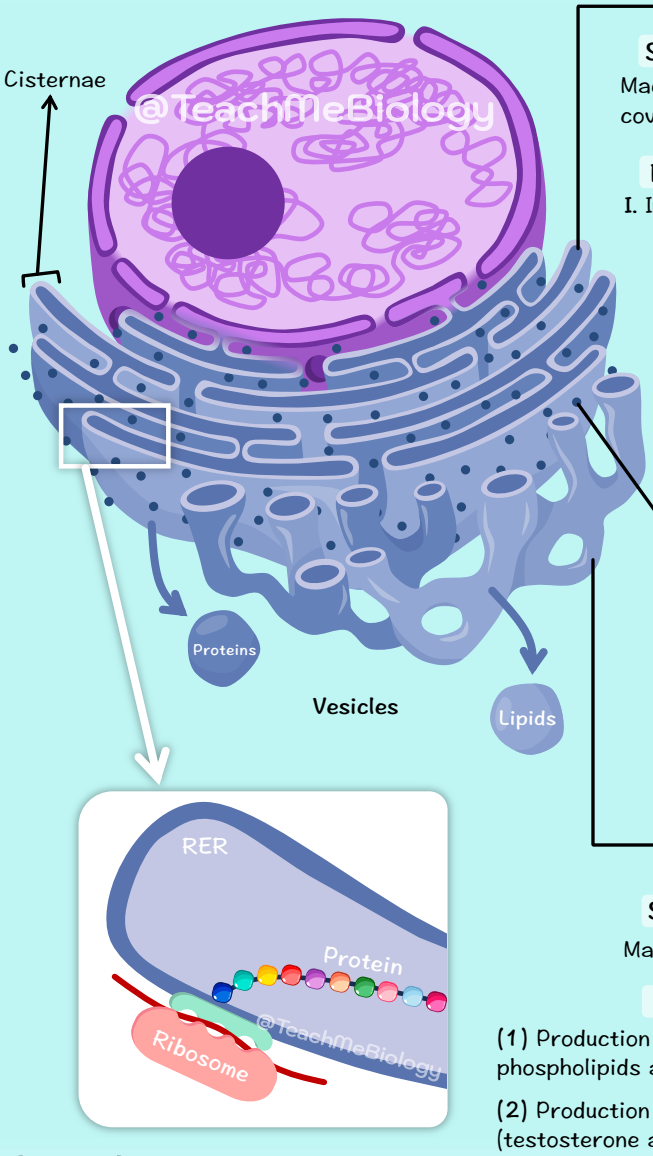
Imaging





Endoplasmic Reticulum (ER) & Ribosomes

The endoplasmic reticulum is comprisedof the ROUGH endoplasmic reticulum (RER) and the SMOOTH endoplasmic reticulum (SER). They are a direct continuation of the nuclear outer membrane.



[CYTOSOL]

[Covered with ribosomes]

Rough Endoplasmic Reticulum (RER)

STRUCTURE

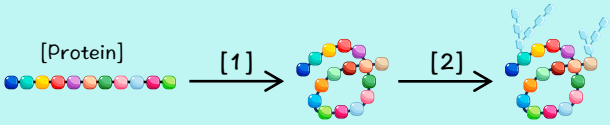
Made of cisternae (flattened, membrane bound sacs/compartments) and is covered with ribosomes on its outer surface.

FUNCTIONS

I. Involved in protein synthesis **(Chapter 6)**

(1) Protein folding

(2) Glycosylation – addition of carbohydrate chains to protein



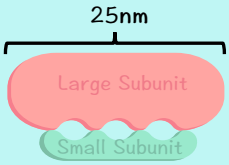
II. Involved in protein transport

Ribosomes [Free or Bound to ER]

STRUCTURE

Not a membrane bound organelle

80S (in eukaryotic cells) - "Svedberg" units



FUNCTION

Protein synthesis

[Lacks ribosomes]

Smooth Endoplasmic Reticulum (SER)

STRUCTURE

Made of cisternae (often tubular) but unlike the RER; it lacks ribosomes.

FUNCTIONS

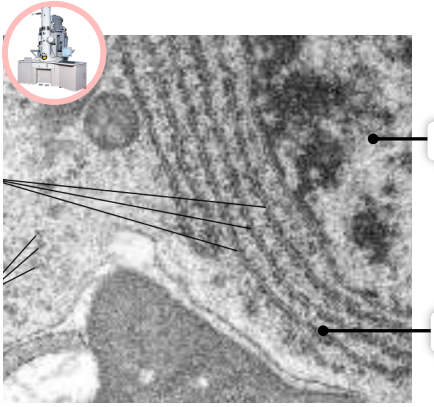
(1) Production of membrane phospholipids and cellular lipids.

(2) Production of sex hormones (testosterone and estrogen).

(3) Storage of calcium ions in ***muscle*** cells. Muscle contraction.

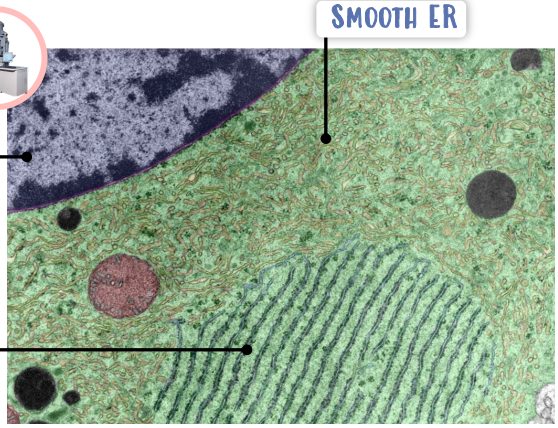
(4) In the liver, detoxification of drugs.

Imaging



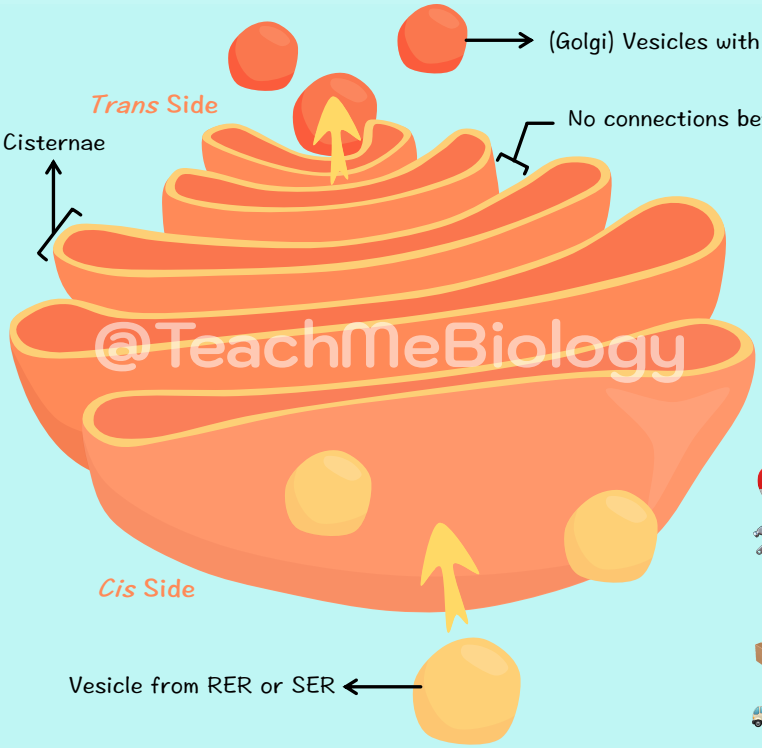
Nucleus

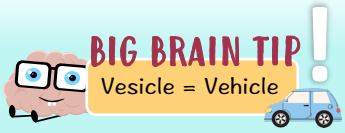
Rough ER



Golgi Apparatus

also known as: Golgi body or Golgi complex





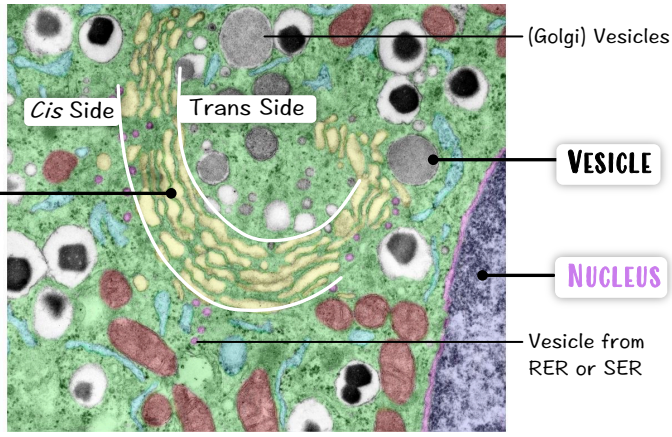
STRUCTURE

Made of cisternae (flattened, membrane bound sacs/compartments). The cis side receives vesicles from the RER and SER and the trans side releases vesicles with the modified materials

FUNCTIONS

- Collect vesicles from the ER
- Modification (further) **(Chapter 4)**
  - Glycosylation – forming glycoproteins & glycolipids.
  - Tagging – attaching signal of target destination.
- Packaging into vesicles
- Distribution of vesicles
  - For use outside or inside the cells

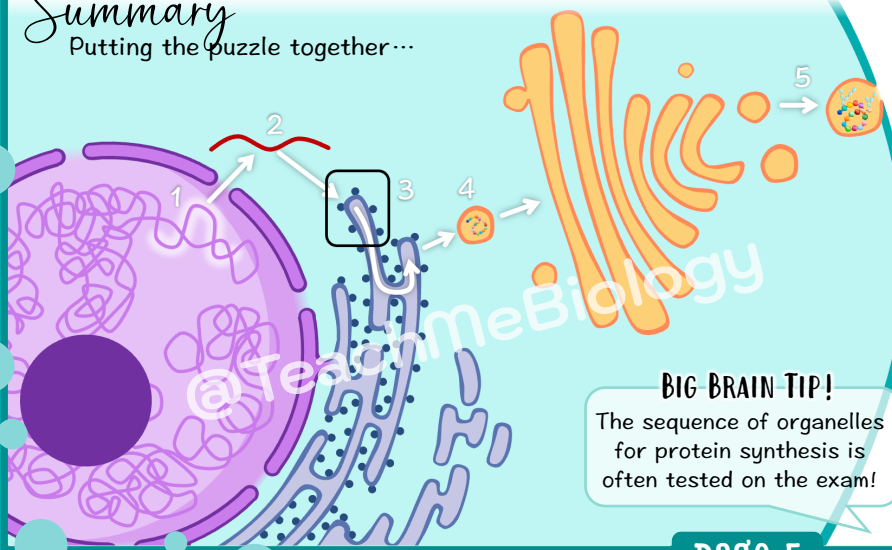
Imaging



BIG BRAIN TIP!
Notice how the TRANS side is CONCAVE, and the CIS side is CONVEX. This is a useful feature to distinguish between the two sides.

Summary

Putting the puzzle together…



1. DNA is read, and a copy is made (red)
2. The copy is read by a ribosome on the RER
3. The protein is created in the ER and transported (zoom-in on page 4)
4. Protein is packaged and transported in a vesicle to the Golgi apparatus (cis side)
5. Modifications are made to the protein, and the modified protein is released and transported from the Golgi (trans side) to the cell membrane (use outside of the cell)

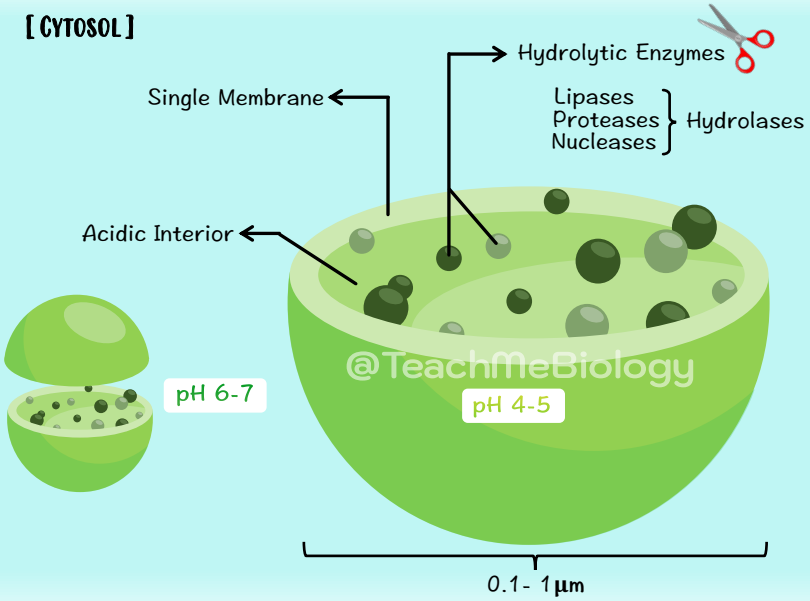
BIG BRAIN TIP!
The sequence of organelles for protein synthesis is often tested on the exam!

Lysosome

A type of vesicle which arises from the **Golgi apparatus**. Contains enzymes (a type of protein) synthesized by the RER.

Big Brain Tip!

You can think of the lysosome as the trash of the cell.

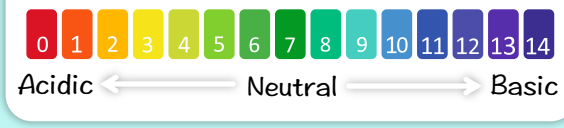


Structure

A single membrane vesicle containing hydrolytic enzymes: used to break down lipids, proteins, nucleic acids.

Did You Know?

pH is a measure of how acidic/basic a solution is on a scale from 0 to 14, 7 being neutral

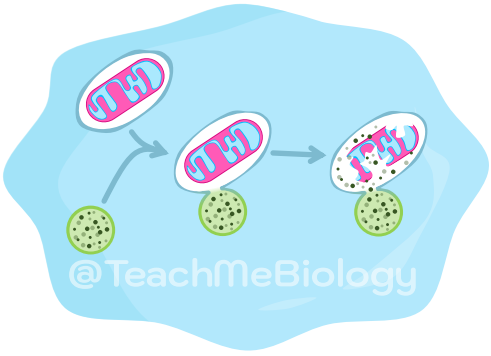


Functions

Lysosomes are intracellular digestive centers

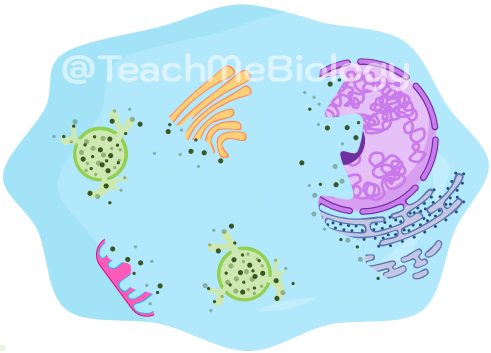
1 Getting rid of unwanted cell components

Getting rid of old molecules or organelles.



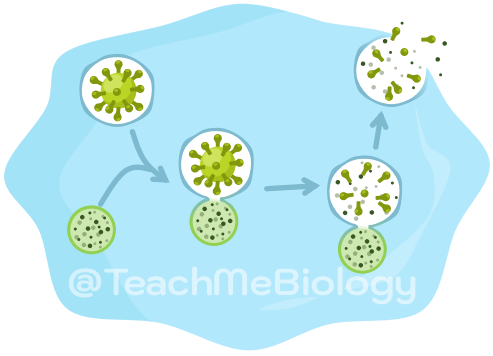
2 Self-Digestion

Contents released into cytoplasm. Autolysis.
e.g. The uterus reduces itself to normal size after pregnancy.



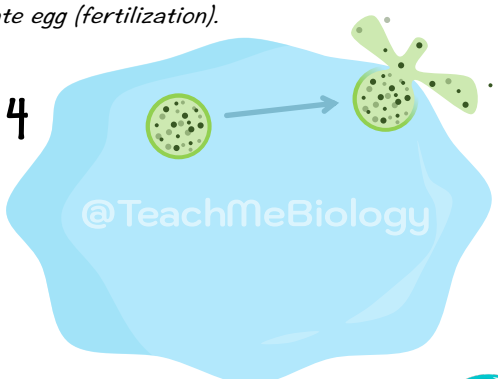
3 Endocytosis

Intake pathogen, fuse with lysosome to destroy it.



4 Exocytosis (Extracellular digestion)

Lysosome contents released to outside of the cell.
e.g. Sperms acrosome releases digestive enzymes to penetrate egg (fertilization).



Mitochondria

Functions

A specialized double membrane organelle in which CELLULAR RESPIRATION occurs.
(Chapter 12)

Cellular respiration is the process by which cells break down glucose with oxygen to release energy (as ATP), producing carbon dioxide and water as byproducts.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$

Glucose

Big Brain Tip!

You can think of ATP as the currency of the cell. Want to transport glucose across the membrane?... That will be 3 ATP please!

The number of mitochondria in a cell depends on the amount of energy used: the brain, liver and skeletal muscle use large amounts of ATP, therefore have LOTS of mitochondria!

Structure

Outer membrane
A membrane that separates the mitochondrial contents from the rest of the cell.

Inter membrane space
A reservoir for hydrogen ions (protons), allowing a high concentration of protons.

Inner membrane
Contains the proteins and enzymes for the final stages of respiration.

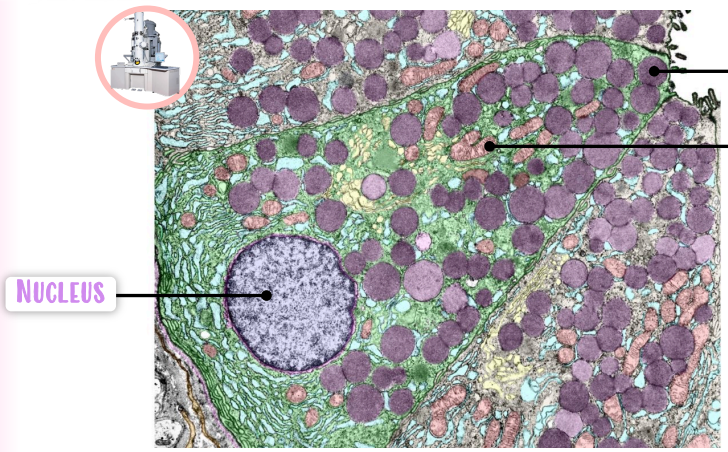
Matrix
A cytosol-like substance that contains the enzymes for the first stages of respiration.

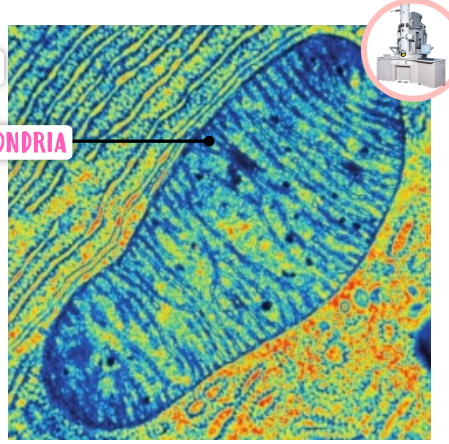
Ribosome
70S

DNA
Genetic material separate from the nucleus

Cristae ≠ cisternae
Folds in the inner membrane. Increase surface area for reactions during cellular respiration.

Imaging





NOTE: Textbooks may say mitochondria can be seen with a light microscope. In practice, they appear only as tiny, indistinct shapes unless specialized dyes or fluorescence techniques are used, so you won't see them clearly with a standard classroom microscope.

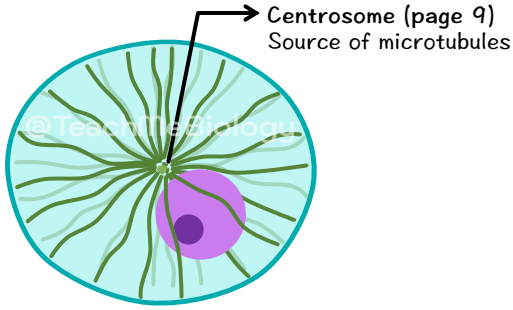
Cytoskeleton

FUNCTIONS

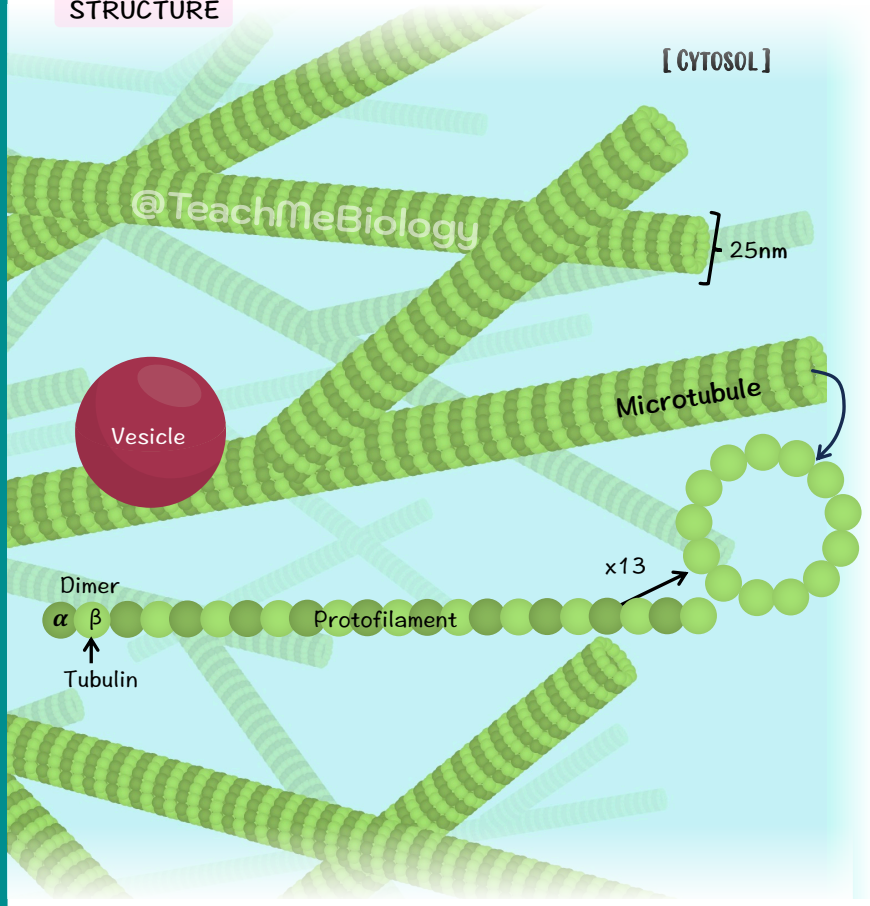
The cytoskeleton is a network of protein filaments in the cytoplasm that gives the cell shape, supports organelles, and helps with movement and transport.

Cytoskeleton includes:

- **Microtubules** — We focus on microtubules
- Intermediate filaments
- Actin filaments



STRUCTURE



Purposes of microtubules include:

Mechanical support

form a scaffold that maintains the cell's shape and resists compression, helping the cell stay structurally stable.

Transport track

act as highways for vesicles, organelles, and molecules to move along them.

Centrioles (see page 9)

make up centrioles, which organize the spindle apparatus during cell division.

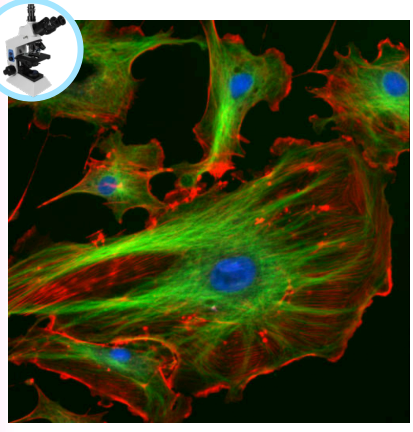
Cell division (Chapter 5)

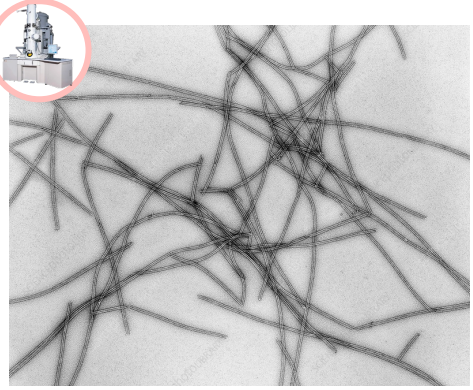
Spindle fibres, made of microtubules, attach to chromosomes and help separate them into daughter cells.

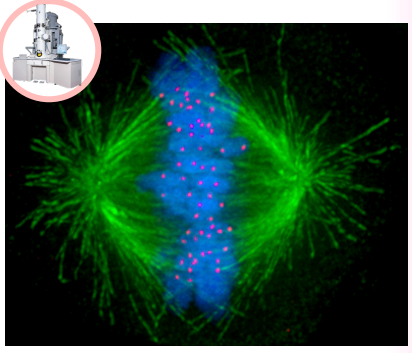
Cilia & flagella (see page????)

form the structural core of cilia and flagella, allowing them to beat and move fluids or the cell itself.

IMAGING







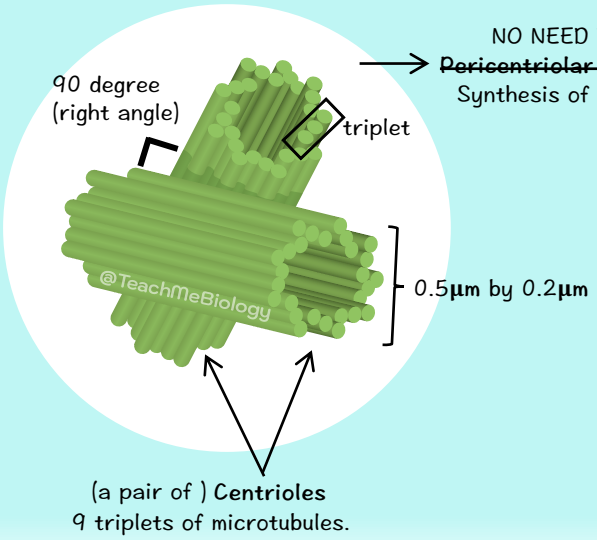
Centrosome

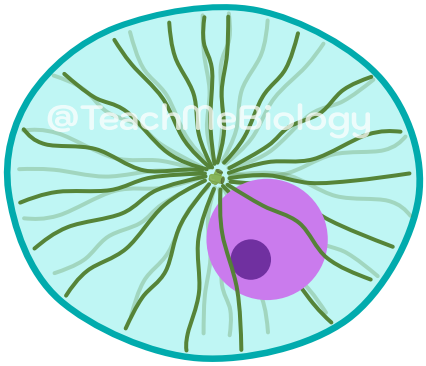
STRUCTURE

Two centrioles at 90° of each other + PCM
Each centriole contains 9 triplets of microtubules

FUNCTIONS

The main microtubule organizing center (MTOC) in animal cells.



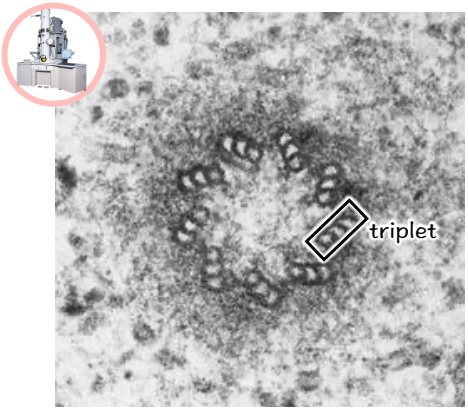


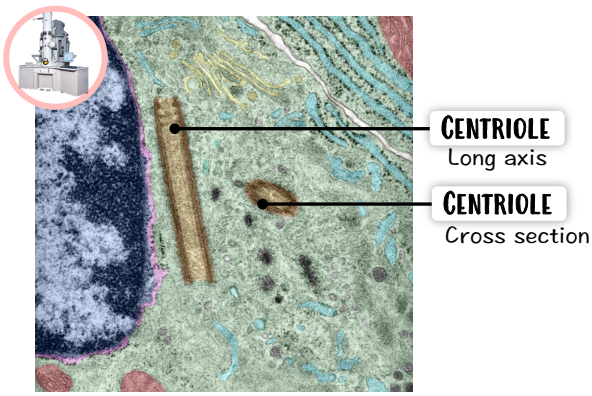
Location - Close to the nucleus

COMMON CONFUSION!

Assembly of microtubules is done NOT by centrioles, but it is done in the centrosome (specifically the pericentriolar matrix). This process is important in **Chapter 5**.
Not found in plant cells.
Centrosomes duplicate before cell division.

IMAGING



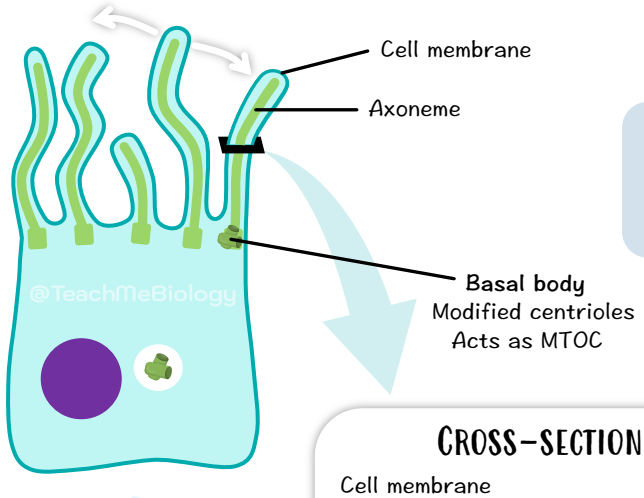


Specialized Structures

[These are structures that only SOME cells have.]

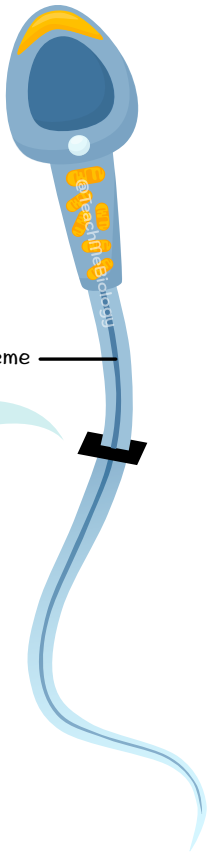
Cilia & Flagella

Whip-like beating extensions of a cell membrane. Cilia and flagella have identical structures (complex), but are used for different purposes:

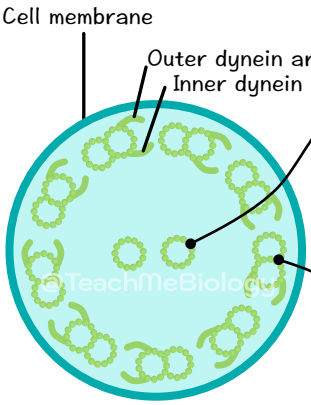


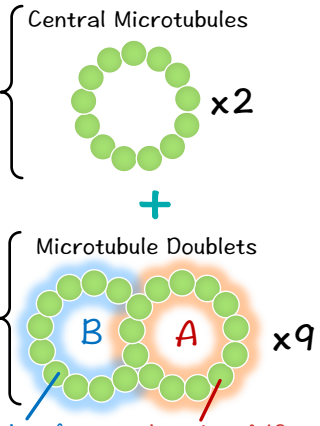
Fun Fact!

The sperm is not only the smallest, but it is also the **ONLY** cell of the human body which has a flagella!

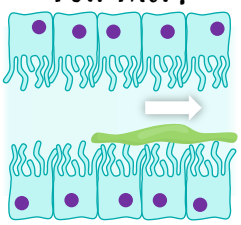


Cross-section structure of axoneme





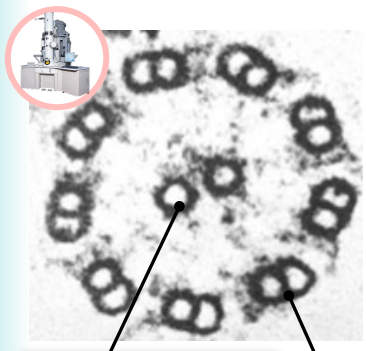
Fun Fact!

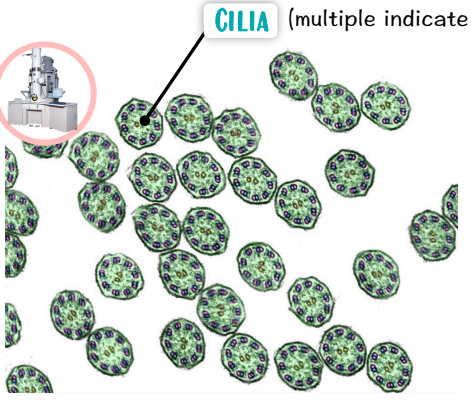


Mucus in your airways is moved upward by the coordinated beating of cilia, carrying trapped microbes and particles toward the throat. This helps prevent infections in the lungs.

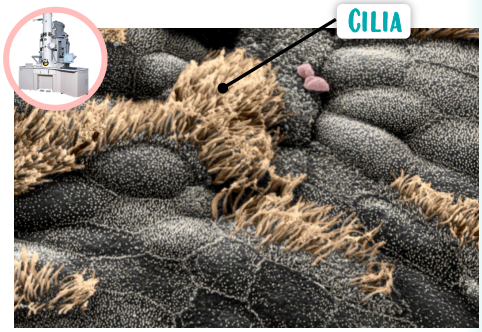
Cilia	Flagella
Short	Long
Many per cell	Few per cell
Used to move surroundings (like mucous)	Locomotion (moving itself)
e.g. respiratory tract	*e.g. sperm cell*

Imaging





(multiple indicate cilia rather than flagella)



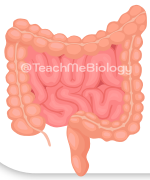
SEM Image

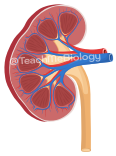
Microvilli

Finger-like extensions of the cell surface membrane which aim at enhancing the surface area of the cell membrane – improving the rate of absorption and secretion.

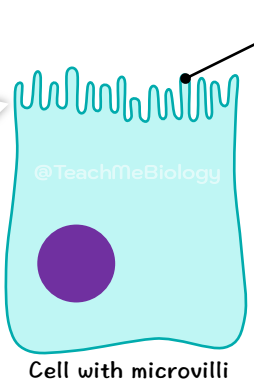
Did you know?

Microvilli are especially abundant on the cells lining the intestines and kidneys, increasing the surface area and allowing more efficient absorption of nutrients and reabsorption of substances.



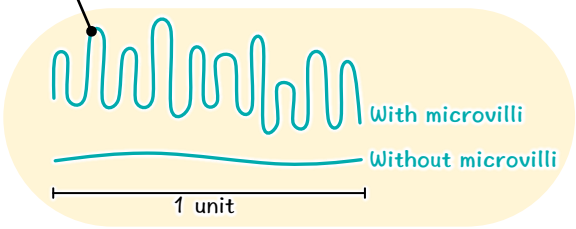


(Chapter 14)



Cell with microvilli

How does it work?

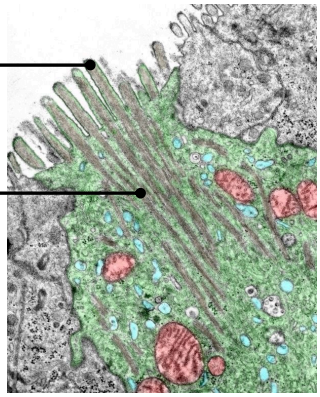


This allows more nutrients or substances to be absorbed efficiently, similar to how a sponge with folds soaks up more liquid than a flat sheet.

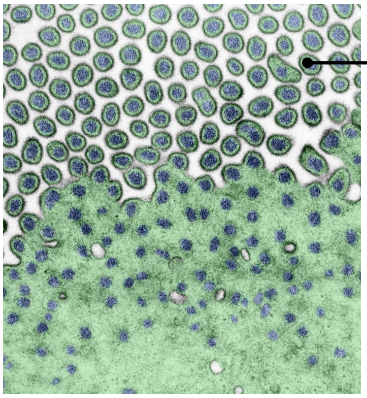
Big Brain Tip!

In comparison to cilia, microvilli do not contain microtubules, and they are non-motile (don't move).

Imaging



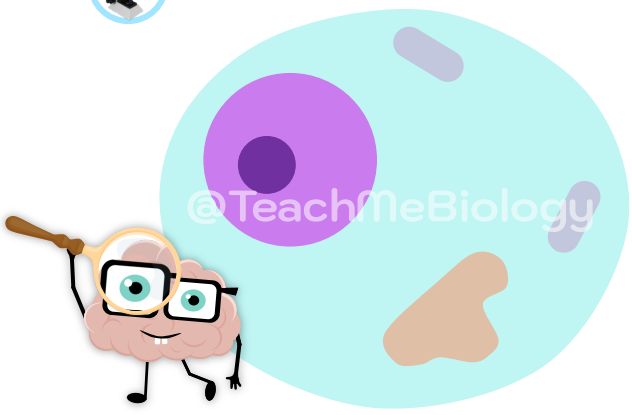
Gives structure to the microvilli (you don't need to memorize)



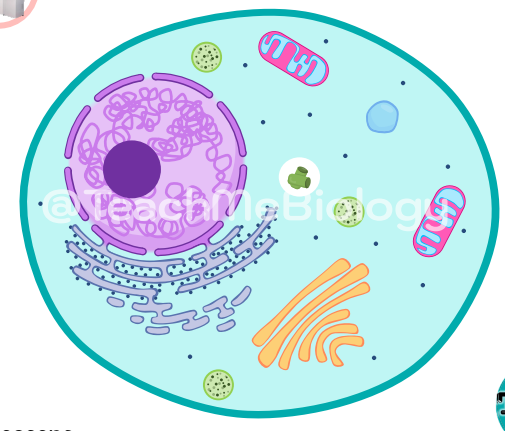
Ultrastructure Summary

Below you can find a visual summary of all the structures we can observe using a light microscope in comparison to what we can see using an electron microscope. This should help you remember which structures are seen by which method!

Light microscope



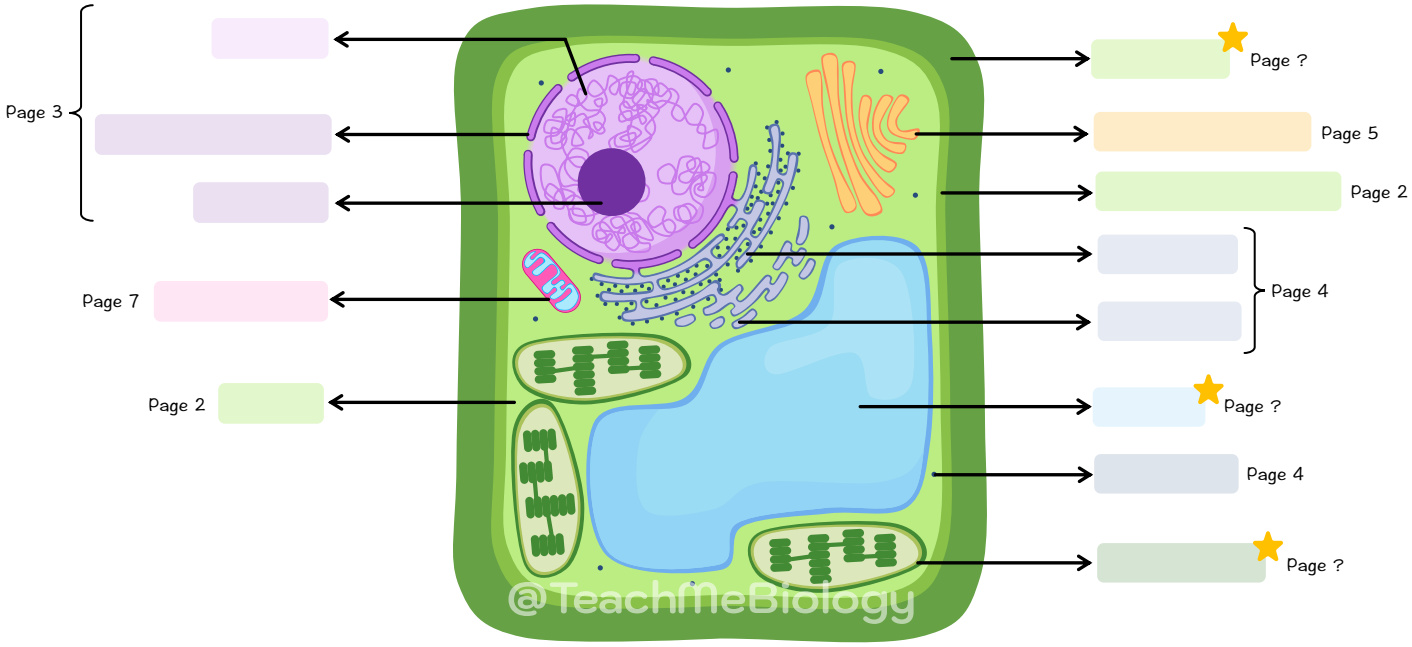
Electron microscope



Ultrastructure – The structures that can only be seen by electron microscope.

11. Plant Cells

All the structures you need to know about for plant cells are shown below on the diagram. But you may notice we have already learned about some of these structures when learning about animal cells. Test yourself by filling in the diagram with the structures we already learned about, new structures have a ★ next to them, learn them first in the next pages, then come back to fill them in! (find the **answer key on page 17**)



Chloroplast

Functions

A specialized double membrane organelle in which photosynthesis occurs. (Chapter 13)

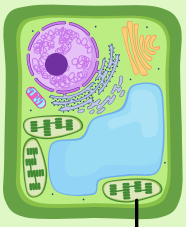
Photosynthesis is the process by which light energy is used to convert carbon dioxide and water into glucose and oxygen.

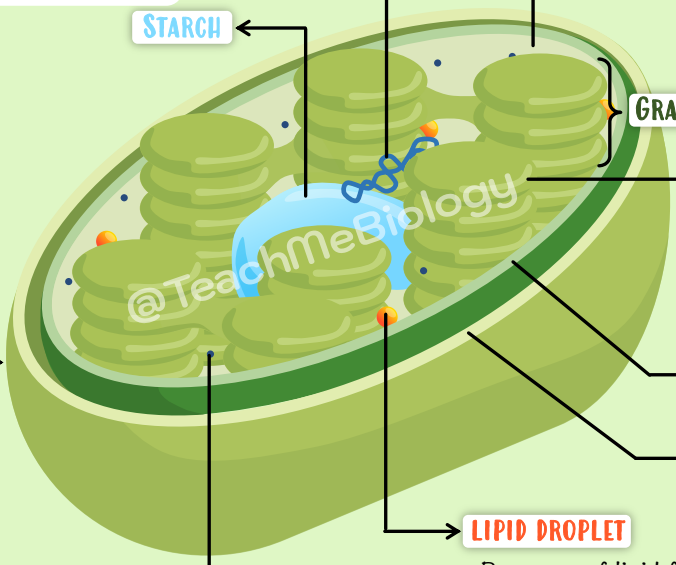
$$6CO_2 + 6H_2O + ATP \rightarrow C_6H_{12}O_6 + 6O_2$$

Glucose

Structure

Chloroplasts occur mostly within the leaves





Light independent part of photosynthesis.

Granum: A stack of thylakoids.

Thylakoid: Flattened, membrane bound, fluid-filled sac. Site of light-dependent reactions of photosynthesis.

Envelope: Double membrane

Reserves of lipid for making membrane.

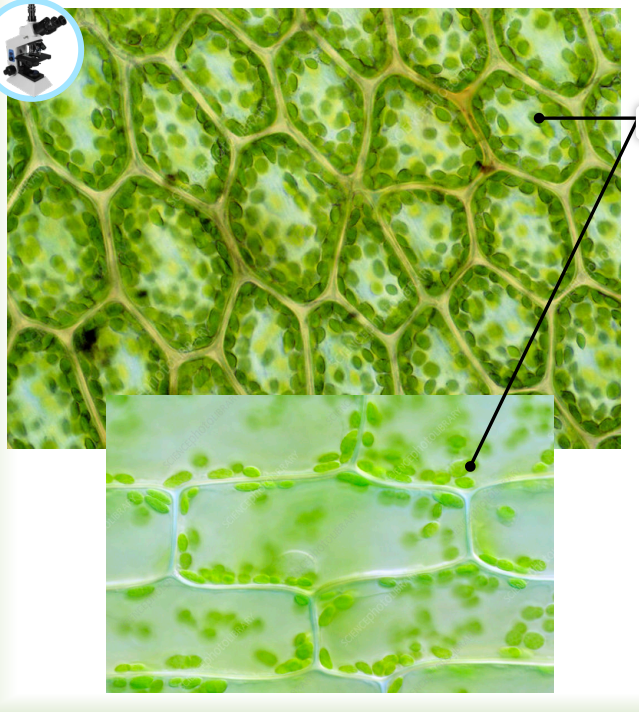
Ribosome: 70S

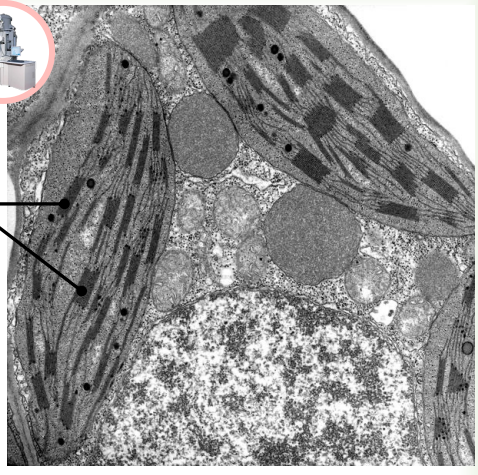
3-10µm

Big Brain Tip!

In this chapter just make sure to understand the big picture: more details are in chapter 13 when we learn about photosynthesis.

Imaging





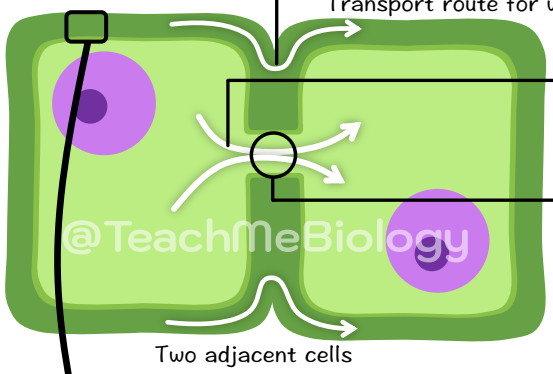
Colored TEM image of chloroplast

Cell Wall

FUNCTIONS

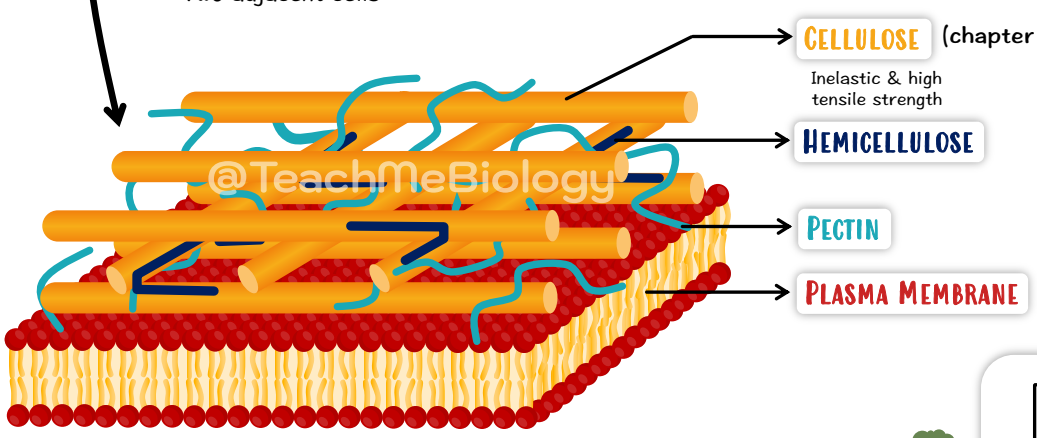
A layer surrounding a cell, outside of the plasma membrane.
(1) Transport. It is permeable (allows substances to pass through).
(2) It provides mechanical strength
(3) Prevents the cell from bursting by osmosis.

STRUCTURE

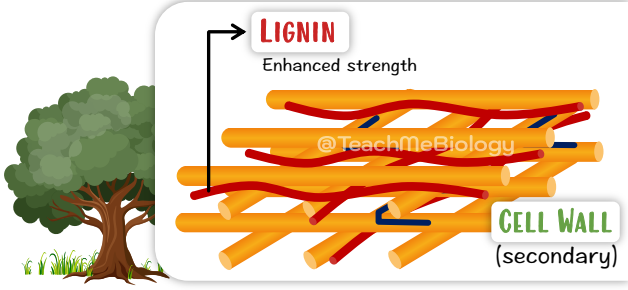


The cell wall, being porous, allows water and ions to move between cells via two pathways:

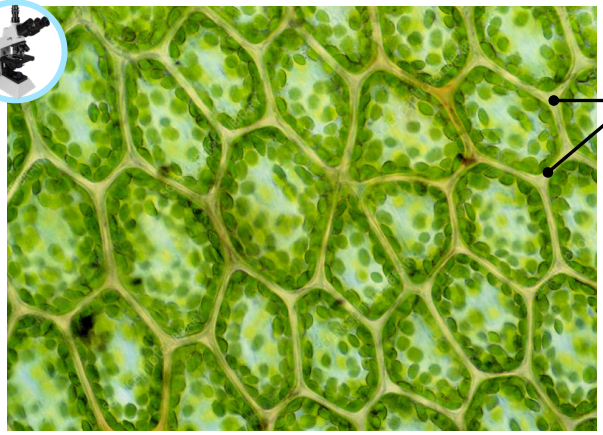
the **Apoplast**, through the cell walls and intercellular spaces, and the **Symplast**, through the cytoplasm of adjacent cells connected by plasmodesmata.



The **PRIMARY CELL WALL** forms first while the cell is still growing. Once the cell has reached its full size, a **SECONDARY CELL WALL** may then be deposited inside the primary wall, making it thicker, more rigid, and often lignified (like bark).



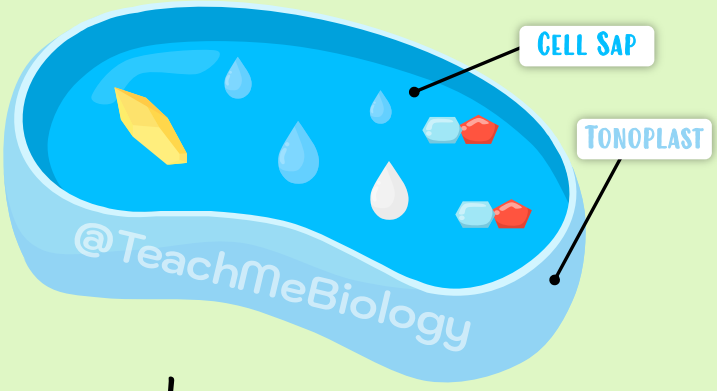
Imaging



Vacuole

Structure

A membrane-bound organelle which arises from the **Golgi Apparatus**. It is surrounded by a membrane called the **TONOPLAST**, and contains **CELL SAP** (a solution of water, salts, sugars, enzymes, and waste products)



Big Brain Tip!

It's useful to remember one or two of the functions of a vacuole.

Functions

Food & waste storage

Food: Sucrose, protein, mineral salts.
Waste: Such as crystals of calcium oxalate.

Lysosomal activity

May contain hydrolases and acts as lysosomes.

Support

Contains a concentrated solution, resulting in water entry by osmosis. Leads to vacuole inflation/pressure buildup. Turgid cell.

Growth in size

Osmotic uptake increase the volume of plant cells during growth.

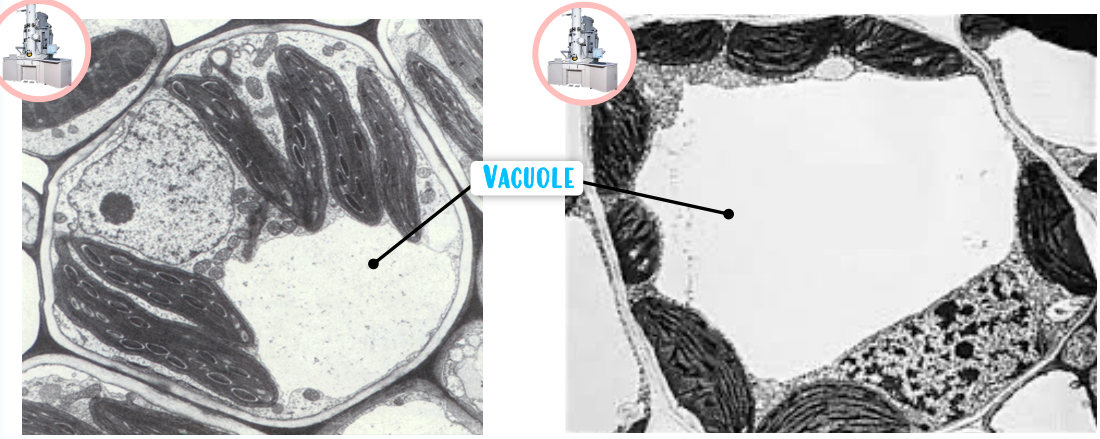
Secondary Metabolites

Molecules that not essential for growth and development.

Anthocyanins – pigments responsible for the colors of flowers and fruits (attracts pollinators)

Alkaloids – deter herbivores from eating the plan

Imaging



Notice how large the vacuoles are in plant cells!

Notice how we didn't talk about the vacuole in animal cells.

ANIMAL CELLS ALSO HAVE VACUOLES, but they are much smaller in size and are only transient. Therefore, they do not play such a big role as they do in plant cells.

Ultrastructure Summary

Below you can find a visual summary of all the structures we can observe using a light microscope in comparison to what we can see using an electron microscope. This should help you remember which structures are seen by which method!

Light Microscope

Electron Microscope

Quick Question!

You have now learned about two organelles which originate from the Golgi apparatus. The vacuole is one. Do you remember the other one?

Eukaryotic Cell Structures Summary

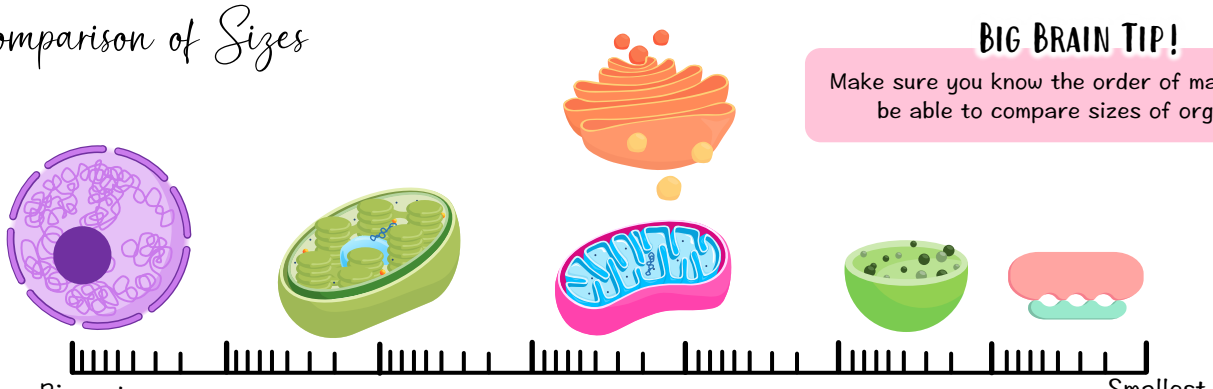
Cell Component	Function
Single membrane	
Lysosome	A vesicle involved in cellular digestion. Arise from Golgi body. Contains hydrolytic enzymes.
Rough ER	Covered with ribosomes. Site of protein synthesis. Protein folding and transport.
Smooth ER	Not covered with ribosomes. Diverse array of function depending which cell type is being considered.
Golgi Apparatus	Involved in collecting proteins from RER, modifying, packaging and distributing them (in vesicles).
Vacuole	A vesicle. Arises from Golgi apparatus. Contains water, which keeps the cell turgid. Has additional functions.
Double membrane	
Nucleus	Contains the genetic code (DNA). Within is the nucleolus which is the site of ribosome synthesis.
Mitochondria	Site of ATP synthesis during cellular respiration.
Chloroplast	Site of photosynthesis. @TeachMeBiology
Others (Not membrane bound)	
Cell wall	It surrounds the cell. Made of cellulose (in plants). Serves strength purpose.
Plasma membrane	Selectively permeable membrane. Controls the movement of substances in and out of the cell.
Cytosol	Aqueous, jelly-like substance that the organelles and molecules float in.
Cytoskeleton	Network of fibres including microtubules, actin, and intermediate filaments. Wide array of functions.
Ribosomes (80S)	Site of protein synthesis. Could be free or bound to RER.
Centrosome	Consists of a pair of centrioles. They are involved in synthesis of microtubules (used in cell movement and division). MTOC.

Key Found only in animals Found only in plants

Plant cells vs. Animal cells

Plant Cells	Animal Cells
Has chloroplast	No chloroplast
Has cell wall (cellulose) - Rigid	No cell wall – Flexible
Large vacuole present	Small vacuoles (rare)
Stores starch	Stores glycogen
No centrosome	Has centrosome @TeachMeBiology
No cilia, flagella, or microvilli	May have cilia, flagella or microvilli
Plasmodesmata present	Plasmodesmata absent

Comparison of Sizes

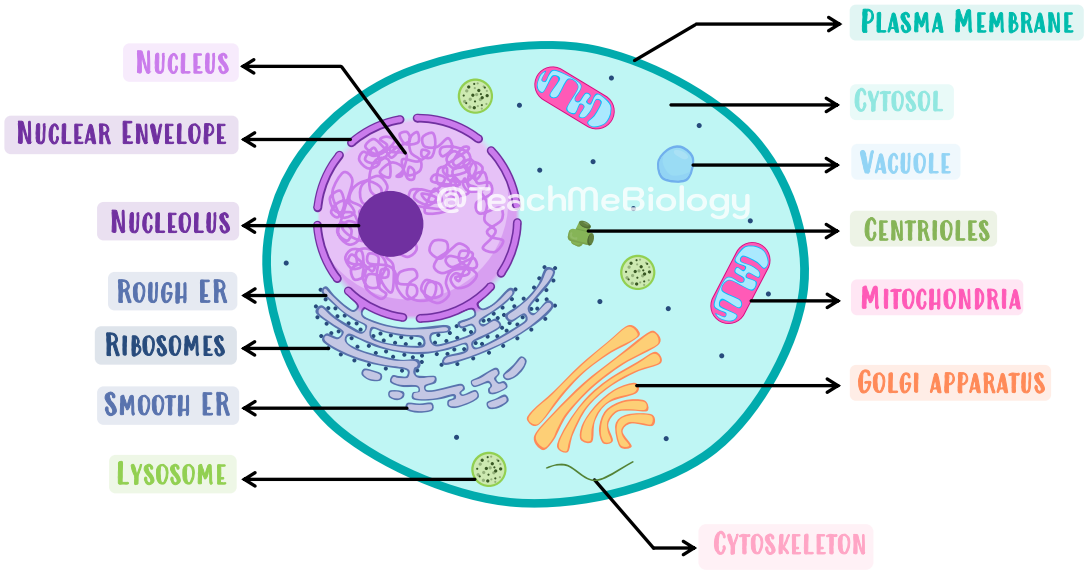


Big Brain Tip!

Make sure you know the order of magnitude and be able to compare sizes of organelles.

A common concept often tested on the exam is the ability to understand the size comparison between the different organelles and knowing the order of magnitude. E.g., chloroplasts are smaller than the nucleus but are much larger than ribosomes.

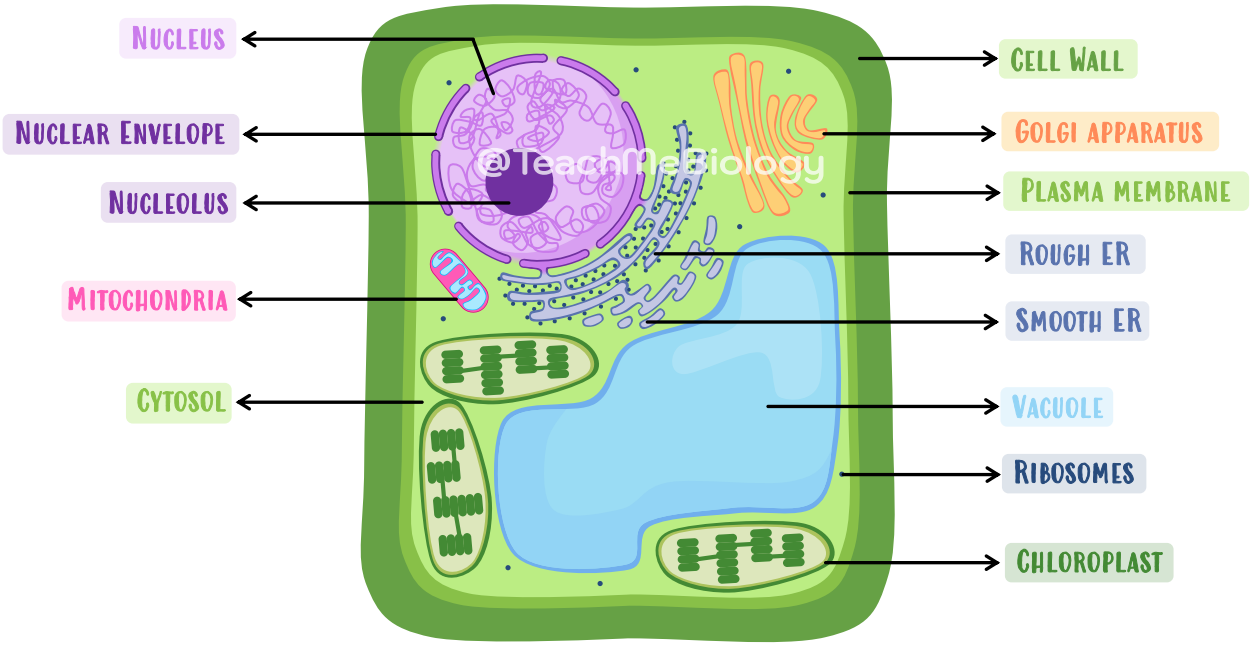
Answer Key - Eukaryotic Animal Cell Structures



These three structures are not **always** present in animal cells:

Flagella Cilia Microvilli

Answer Key - Eukaryotic Plant Cell Structures



With a special thanks to "HistologyGuide.org, T.Clark Brelje and Robert L. Sorenson, University of Minnesota, Minneapolis, MN"