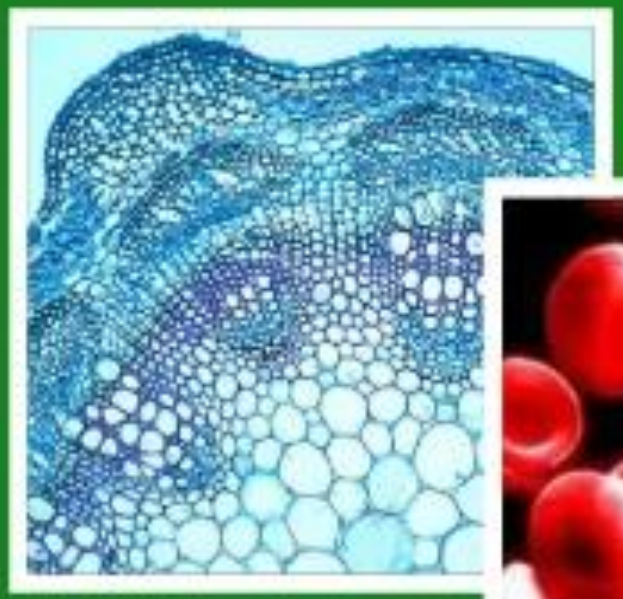
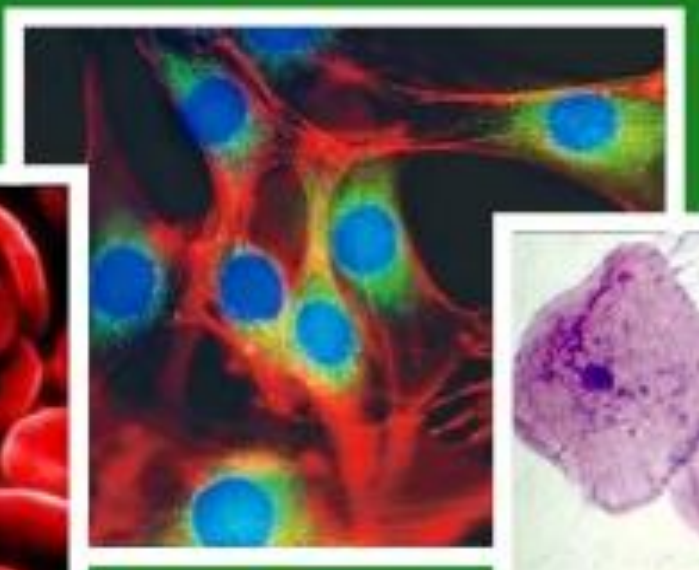
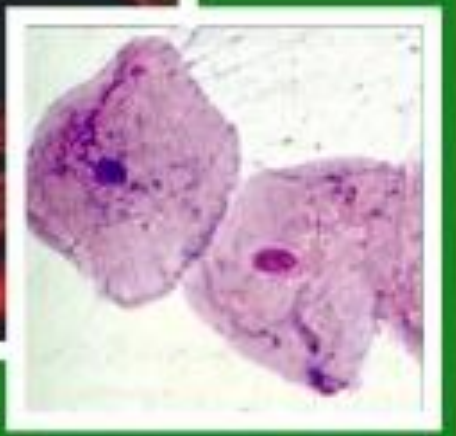
Chapter 2

Cells

The Building Blocks of Life



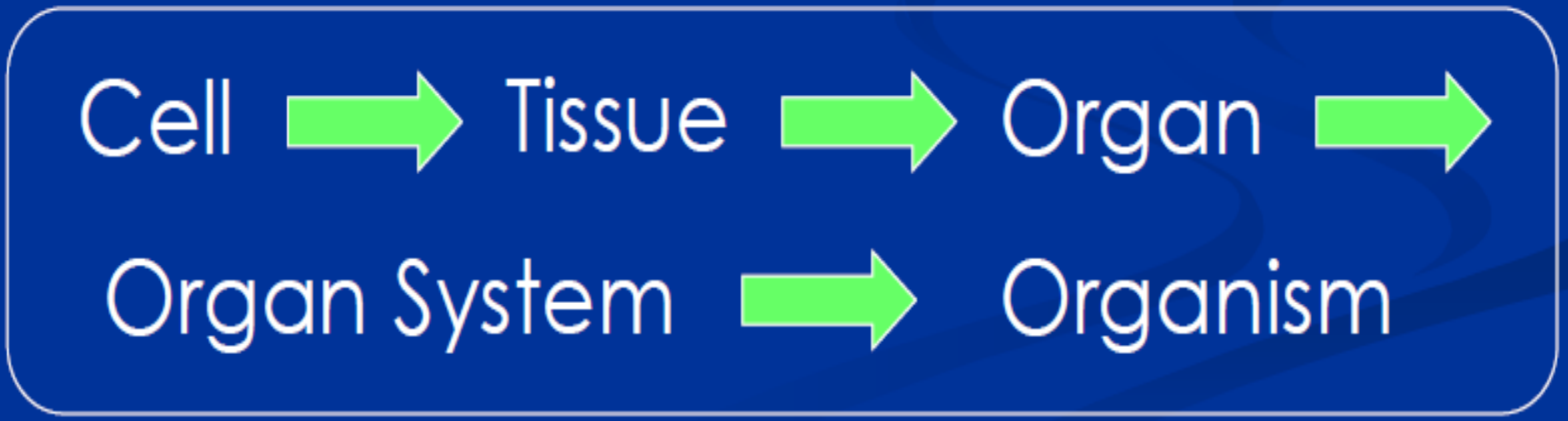




What are Cells?

- Are the basic **structural** and **functional** units of life
- Cells can exist:
  - Singly as independent **unicellular** organisms
  - As part of **multicellular** organisms
    - Such cells are modified for specific functions

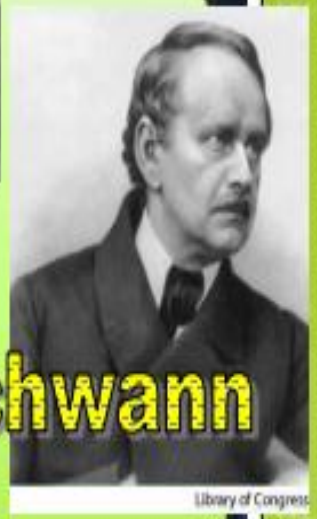
- A cell is the basic structural and functional unit of all living things
  - **Eukaryotic** & Prokaryotic
  - **Animal** & Plant
- How cells fit into the rest of the body's organization



Discovery of the Cell?

- 1665, **Robert Hooke** examined thin slices of cork and other plant materials contained microscopic compartments; named it cells

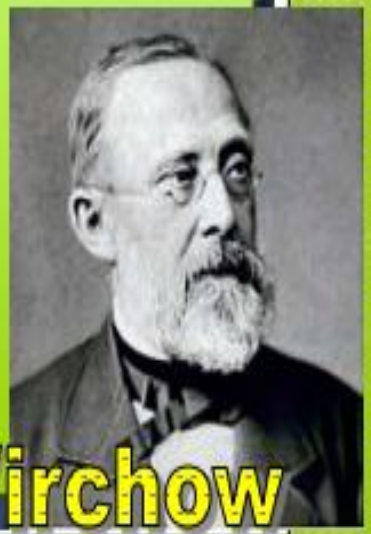
- **Anton Van Leeuwenhoek** made further observations of the cells of plants , animals and microorganisms



- **Matthias Schleiden** –all plants are composed cells
- **Theodore Schwann**– all animals are composed of cells

- **Rudolf Virchow**- proposed the **cell theory**

- 1840,**Purkinje** named the cell contents **protoplasm**



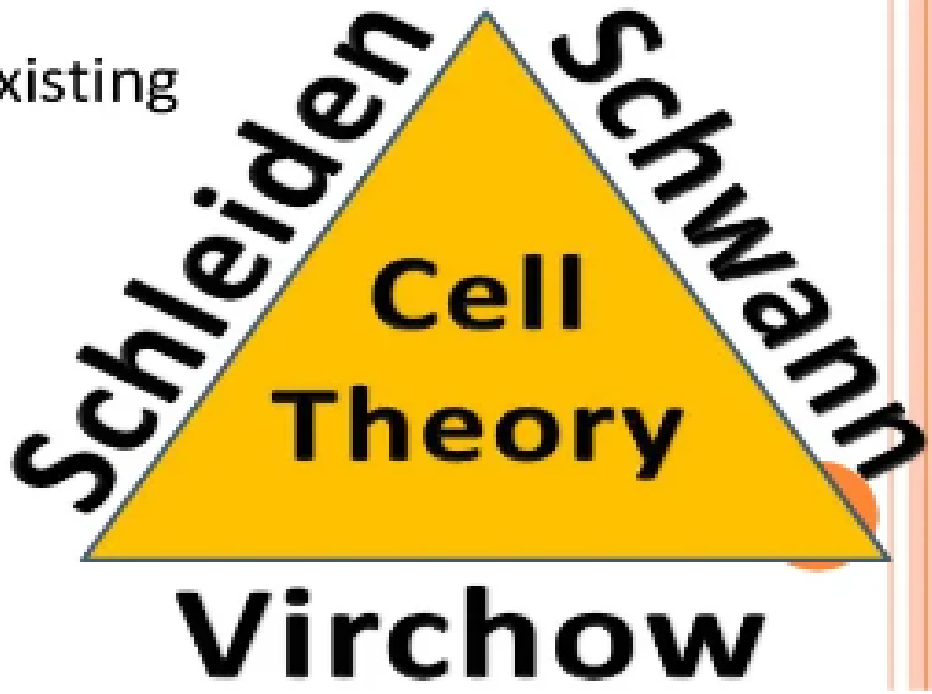
CELL THEORY

- Proposed by **Matthais Schleiden** and **Theodor Schwann** in **1839**:-

  -All living things are made up of cells.

  -Cells are the smallest working unit of all living things.

  -All cells come from pre-existing cells through cell division.

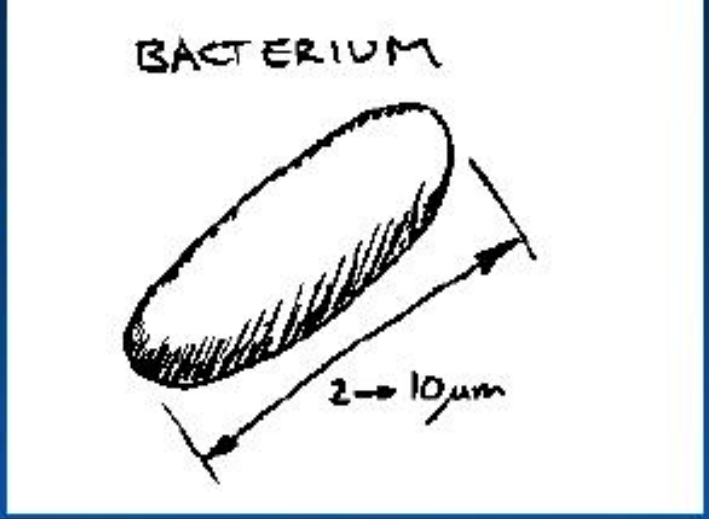


Cell Diversity

- Size
- Shape
- Internal Organization

Cell Diversity- Size

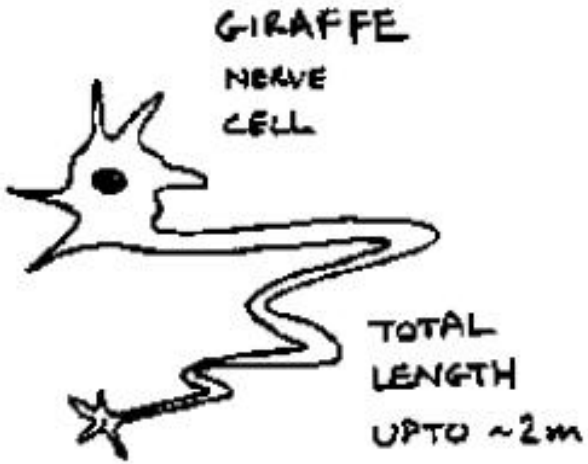
Smallest Cells:



Biggest Cells:

6 inches long, 5 inches wide, 3 pounds

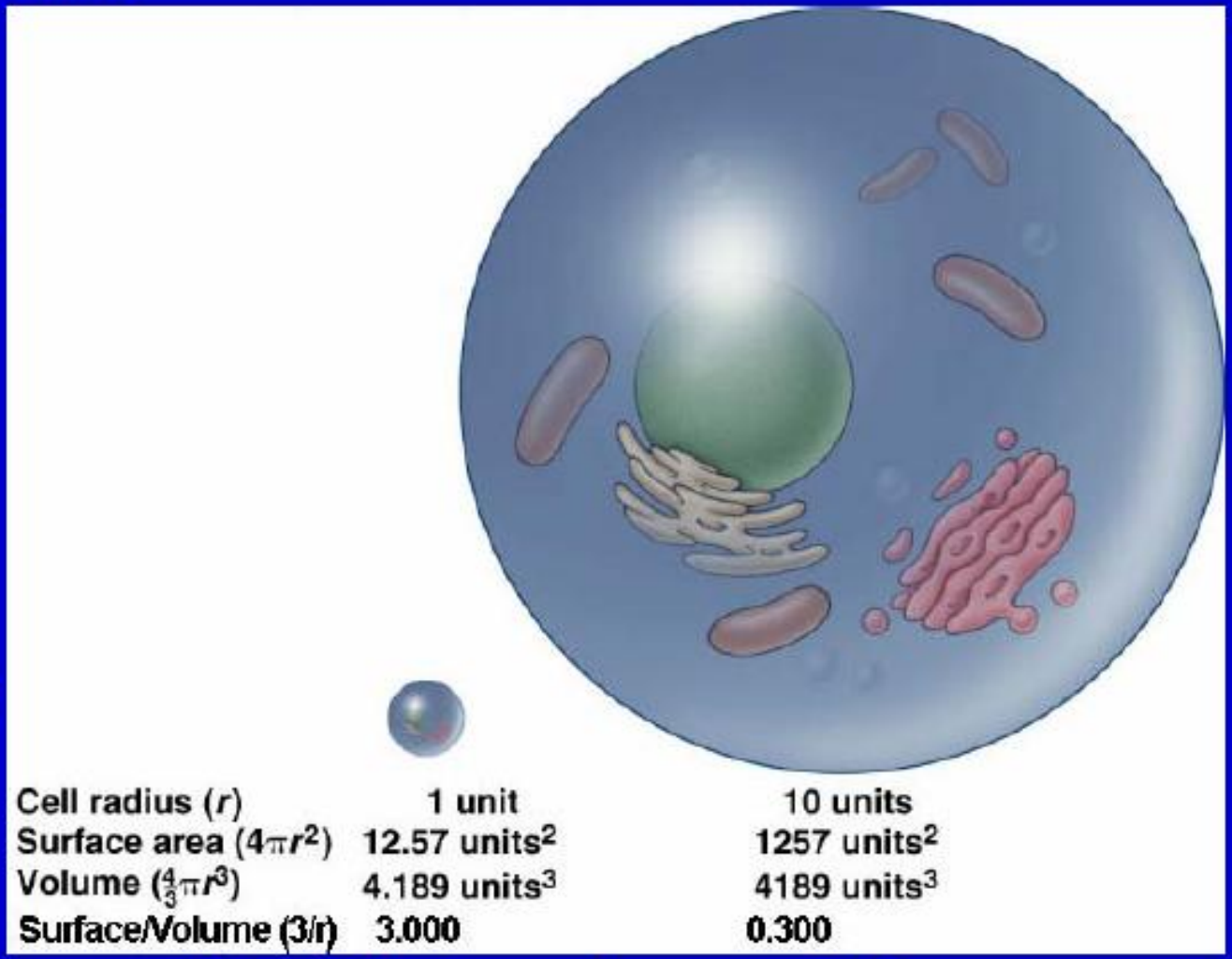
Longest Cells:



Why are cells small?

As cell size increases the volume increases much faster than the surface area.

Cells obtain nutrients, gain information and rid waste through their plasma membrane.

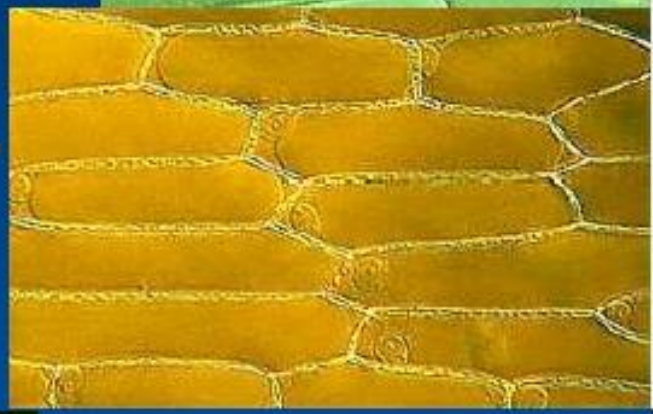


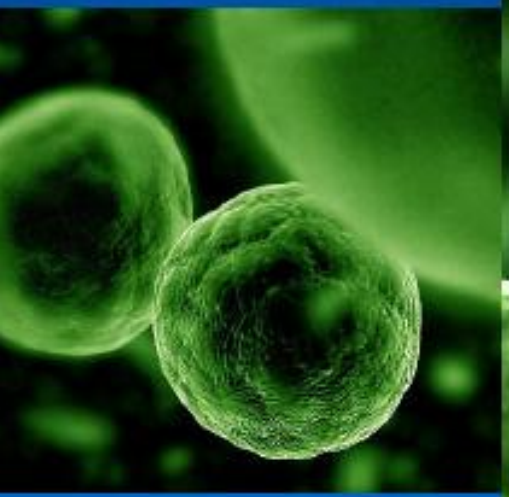
Cell radius (r)	1 unit	10 units
Surface area ($4\pi r^2$)	12.57 units^2	1257 units^2
Volume ($\frac{4}{3}\pi r^3$)	4.189 units^3	4189 units^3
Surface/Volume (3/r)	3.000	0.300

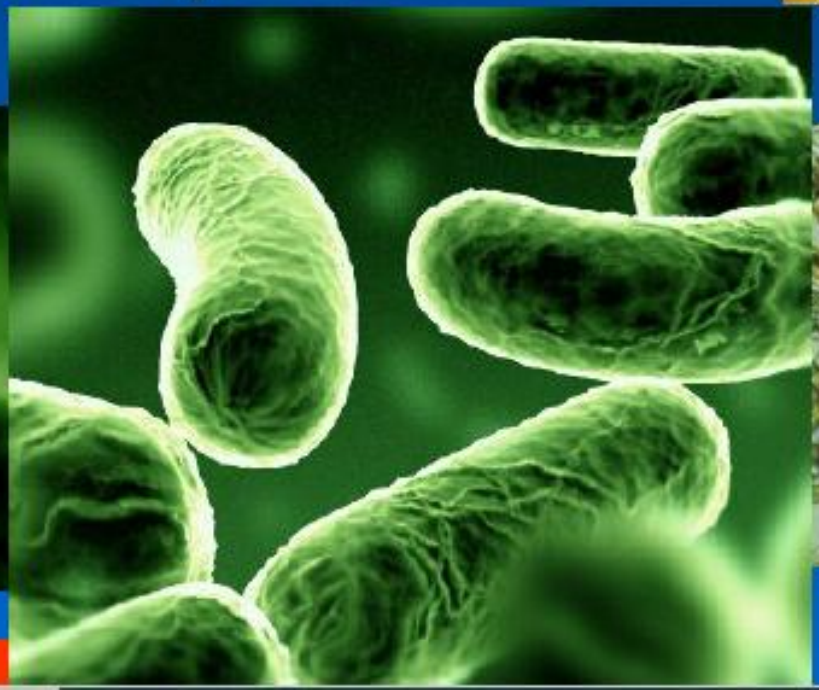
As cell size increases, a cell's ability to exchange with its environment becomes limited by the amount of membrane area that is available for exchange.

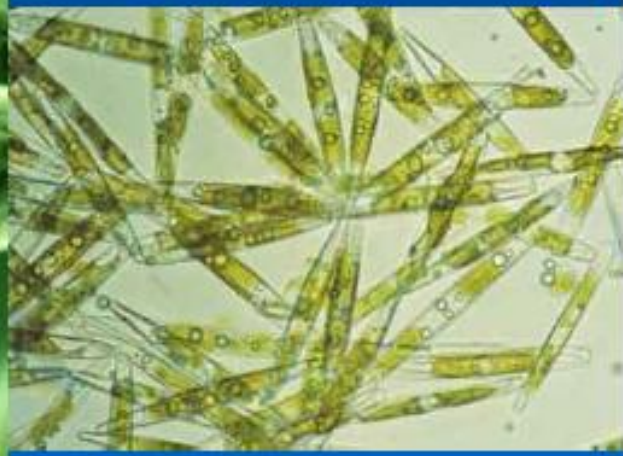
Cell Diversity- Shape

- Cells differ widely in shape.
- Most cells are roughly cuboidal or spherical.

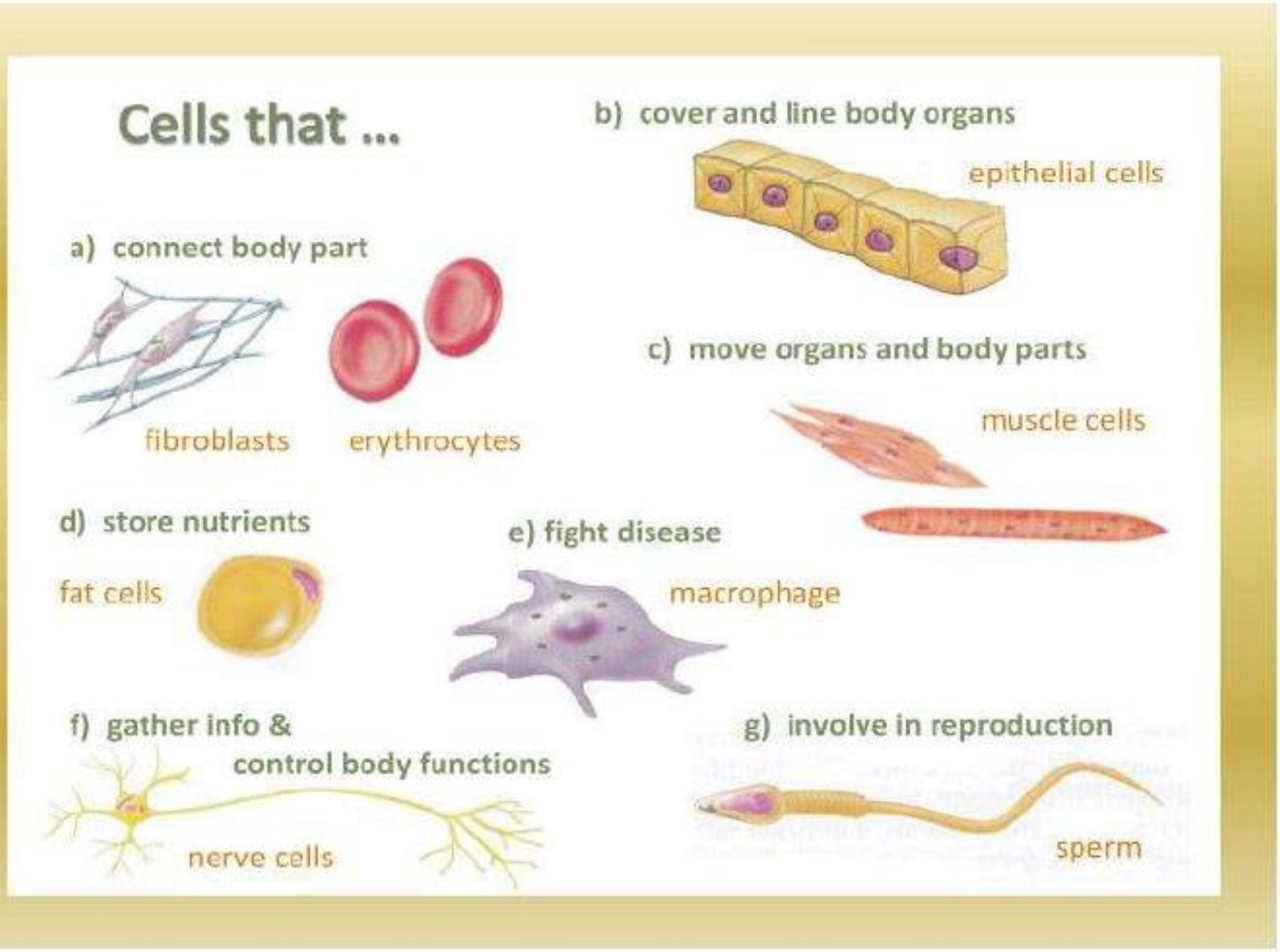








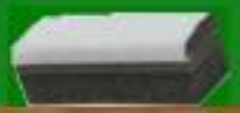
Diverse cell shapes to perform specific functions in body



Observing Cells

Microscopes are required to visualize cells.

- **Light microscopes**
  - can magnify objects up to 1000 x
  - Light micrographs are colour images
- **Electron microscopes**
  - can magnify objects up to 200 000 x
  - Electron micrographs are black-and-white images

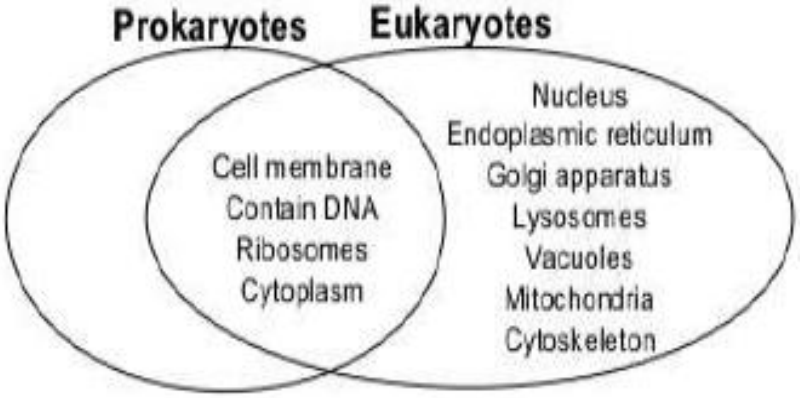


Cells shows diversity in internal organization

- Nucleus: contains DNA which directs the activity of the cell
- Organelle: a cell component that performs specific functions in the cell

Two types of cellular organization- Prokaryotic and Eukaryotic cells depending on their internal organization

- Eukaryotes: cells that contain a nucleus and membrane-bound organelles
- Prokaryotes: cells that lack nuclei and membrane-bound organelles



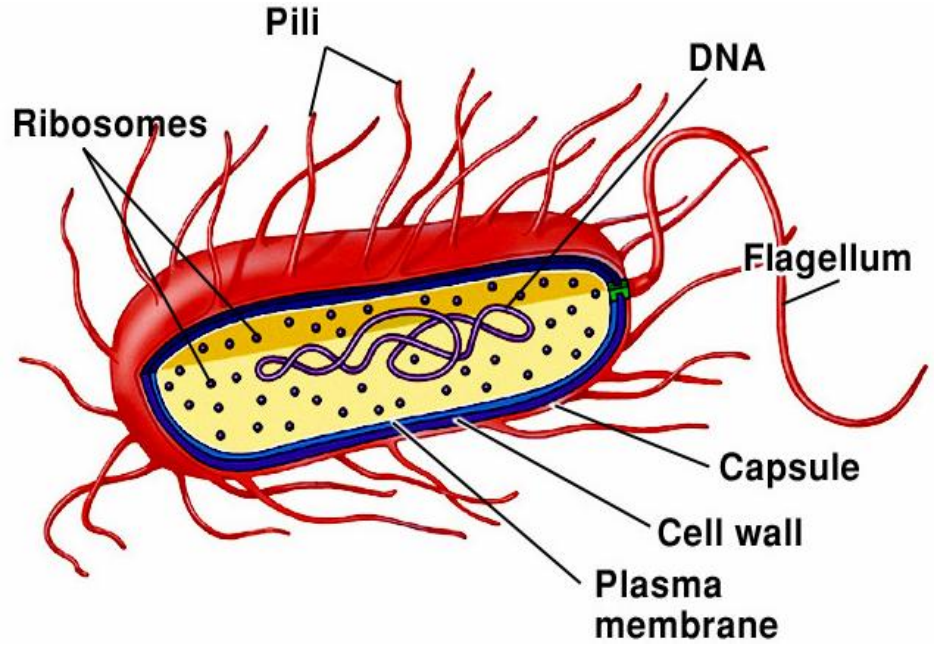
Prokaryotic and eukaryotic cells

Prokaryotic cells - relatively simple cells – lack nuclear membrane and many organelles - bacteria and their relatives are all Prokaryotic.

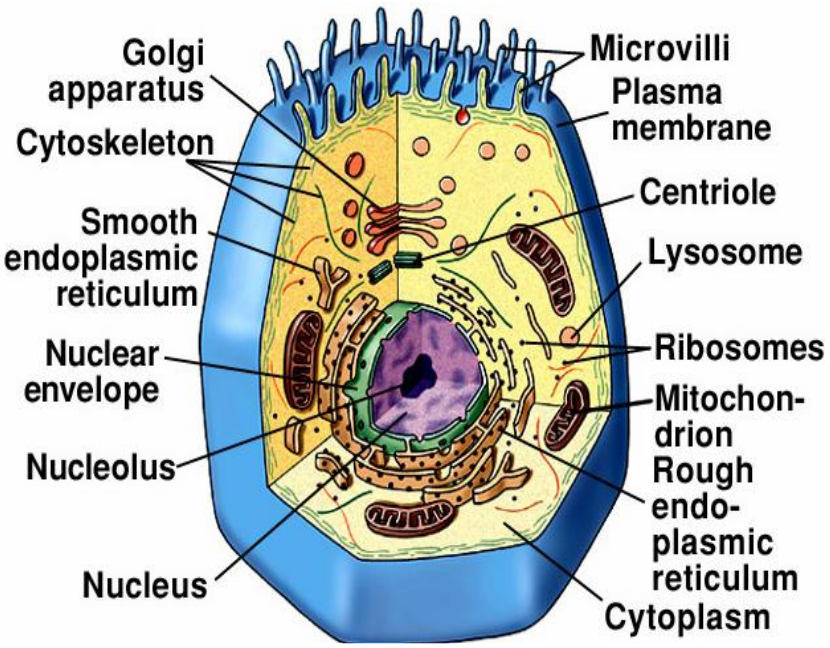
Eukaryotic cells– more complex cells - have a nucleus and many organelles - all cells of plants, animals, fungi, and protists.

Prokaryotic: 1-10 µm
(1 µm = .001 mm)

Eukaryotic: 10 - 100 µm



Prokaryotic cell

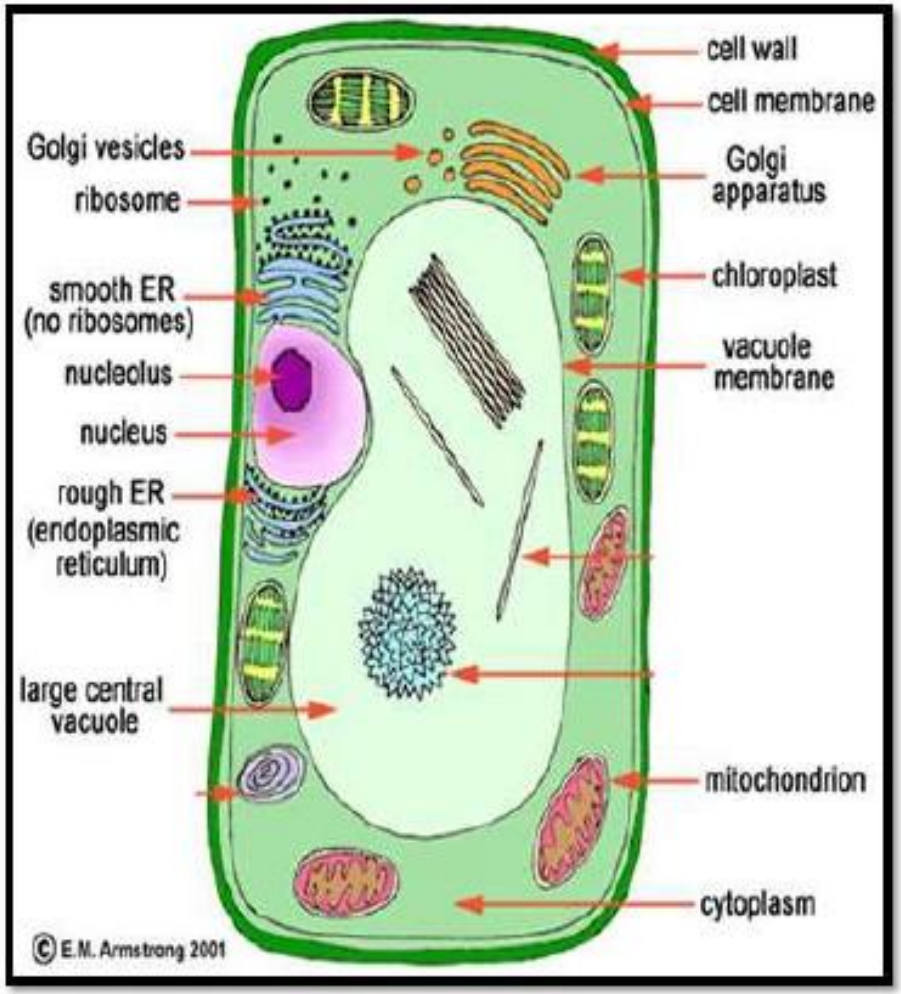


Eukaryotic cell

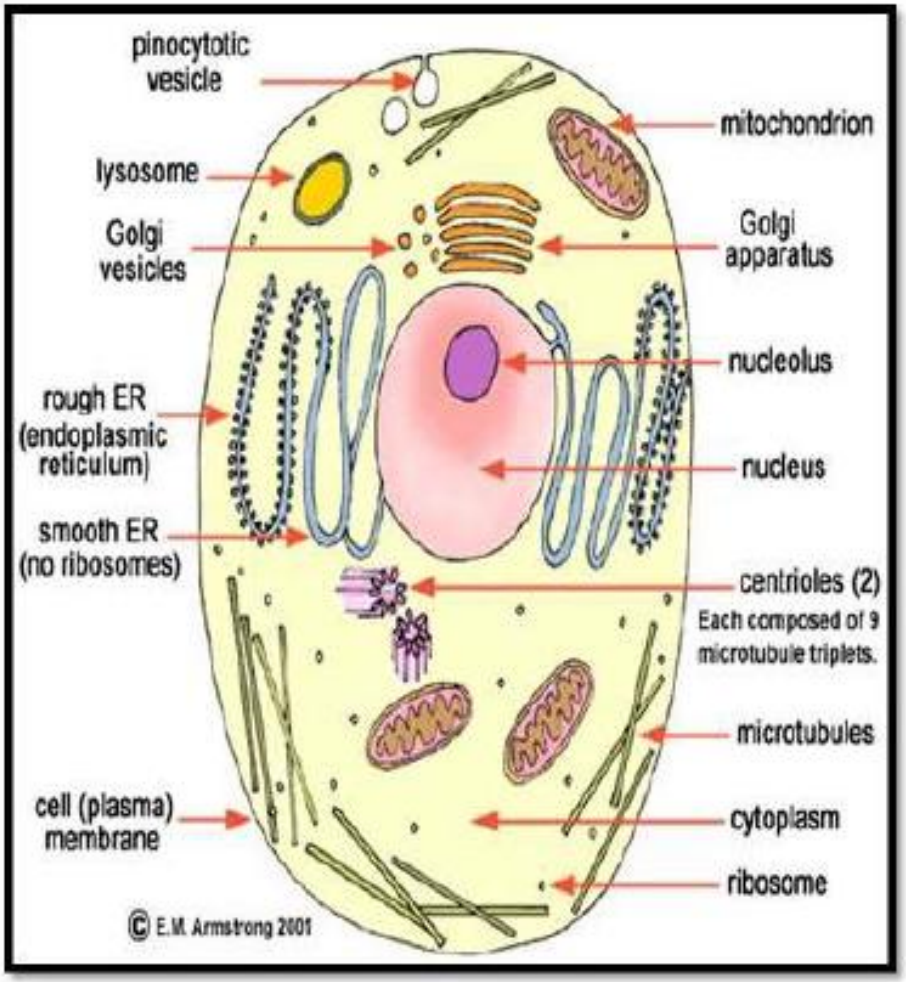
	Prokaryotes	Eukaryotes
nucleus?	NO (nucleoid)	YES
membrane-bound organelles?	NO	YES (Many)
size	1 - 10 μm	10 - 50 μm
when evolved?	3.5 billion years ago	1.5 billion years ago
cytoplasm?	YES	YES
cell membrane?	YES	YES
cell wall?	Some Do	Plants
ribosomes?	YES	YES
DNA?	Circular Free Floating	Chromosomes in Nucleus
examples	Bacteria	Plants, Animals, Fungi, and Protists

Eukaryotic cells- Plant and animal cells are eukaryotic

Plant Cell



Animal Cell



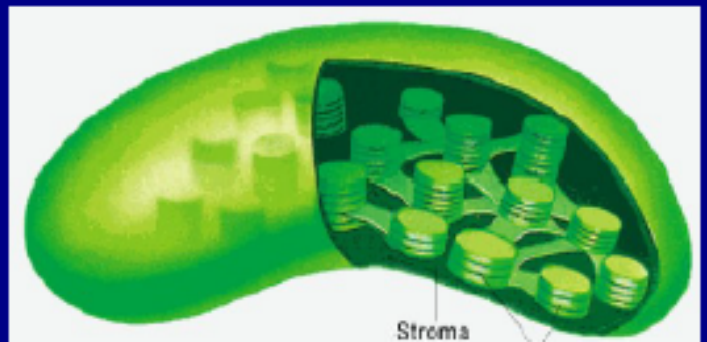
Animal cells versus plant cells- major differences

*****No cell wall, no chloroplasts and small vacuoles in animal cells.

- Animal cells are very similar to plant cells except for the following major differences:
  - Animal cells do not contain chloroplasts
  - Animal cells are not surrounded by cell walls
  - The vacuoles in plants are much larger than those of animals

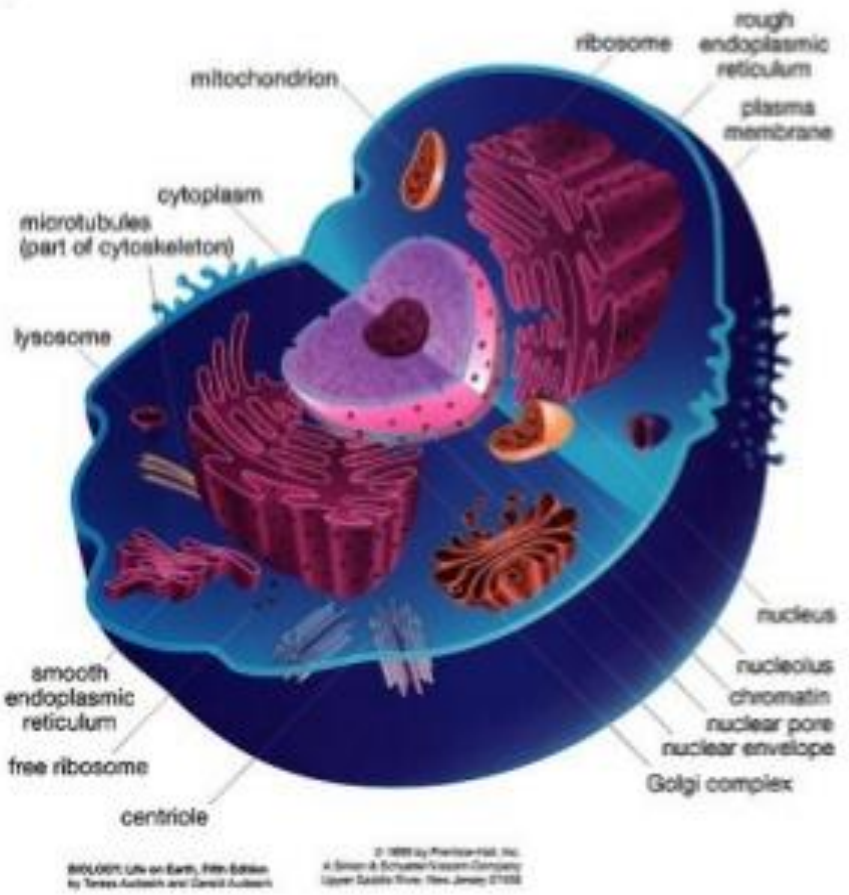
The three new structures for a plant cell

- **Cell Wall**: This wall provides extra support for the cell and gives it a shape. In other words, if there was no cell wall then the cell would have no shape.
- **Chloroplasts**: These make food for the plant. They are green.
- **Chorophyll**: This is very important in making the food for the plant. This structure takes in sunlight and makes sugar for the plant to eat and become green.



Cell Organelles

- Organelle= "little organ"
- Found only inside **eukaryotic cells**
- **Organelles are structures that have specific jobs within cells**
- All the stuff in between the organelles is cytosol
- Everything in a cell except the nucleus is cytoplasm



Cell Structure:
PROTOPLASM – The Living Matter of Cells

Properties

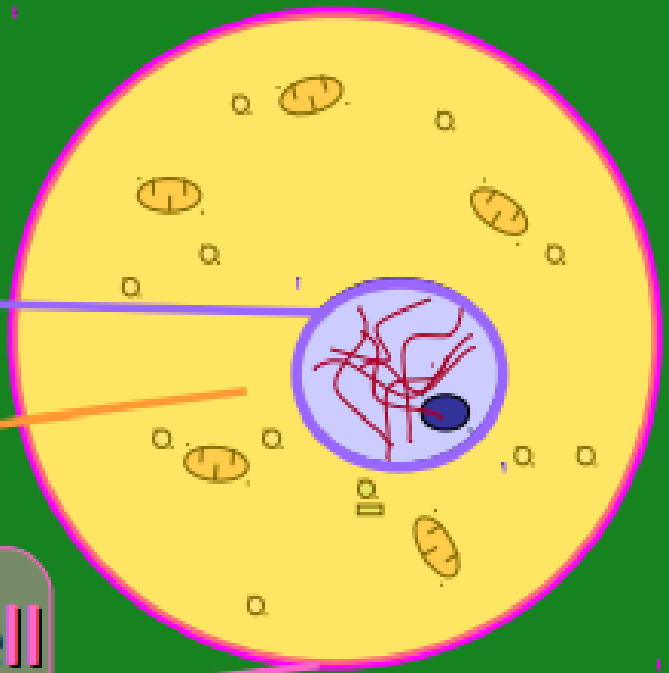
- Mixture
- 70-90% water
- Mineral salts and organic compounds

Consists of:

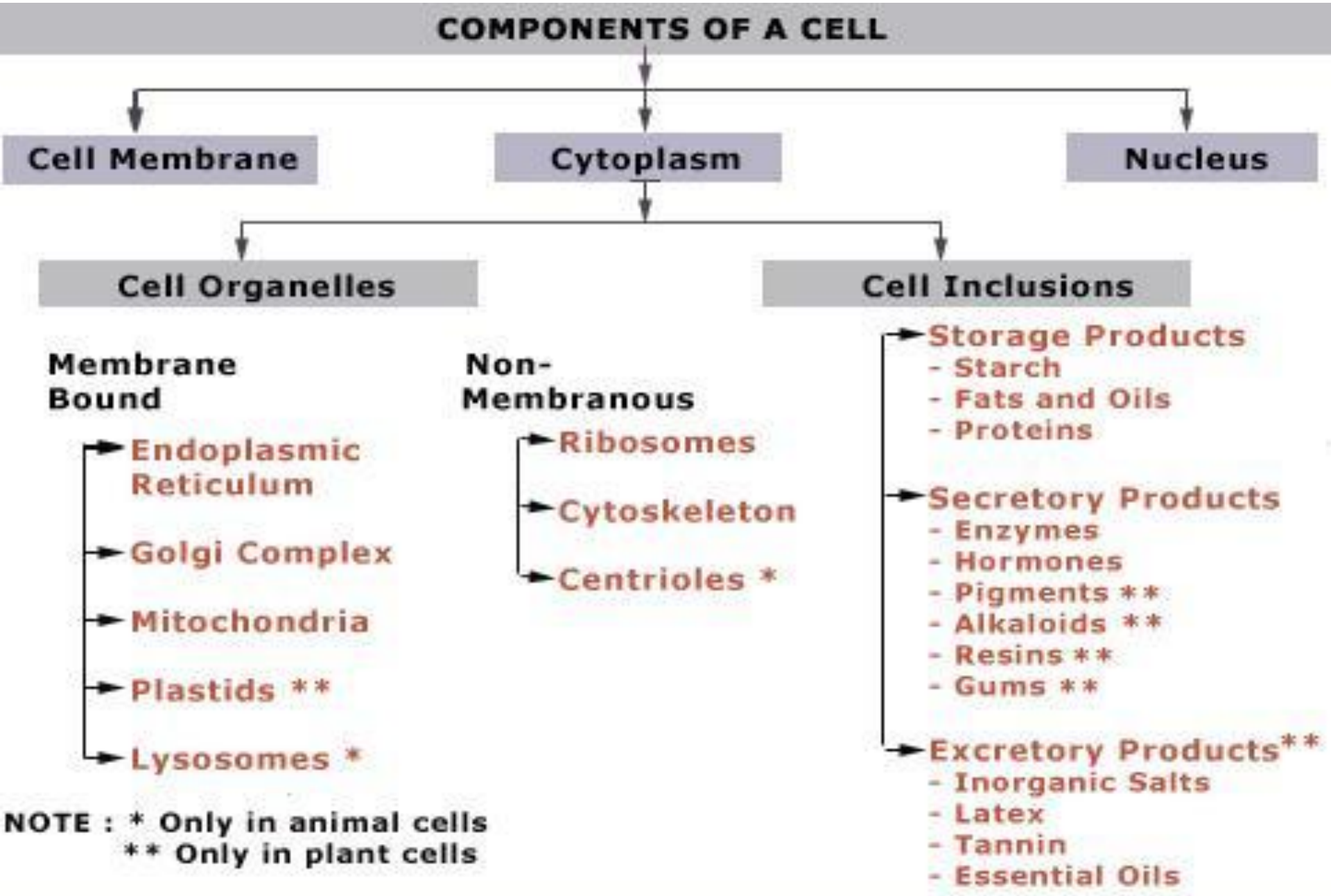
(1) Nucleus

(2) Cytoplasm

(3) Plasma/Cell membrane



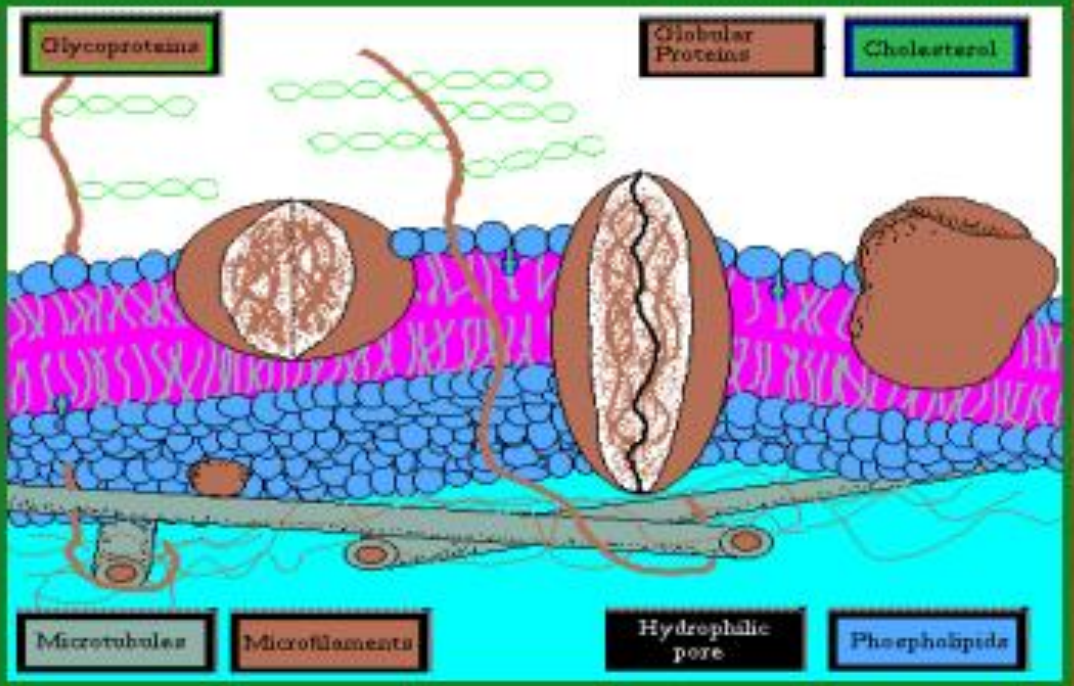
Cellular Classification



Cell Structure:
Plasma/Cell Membrane

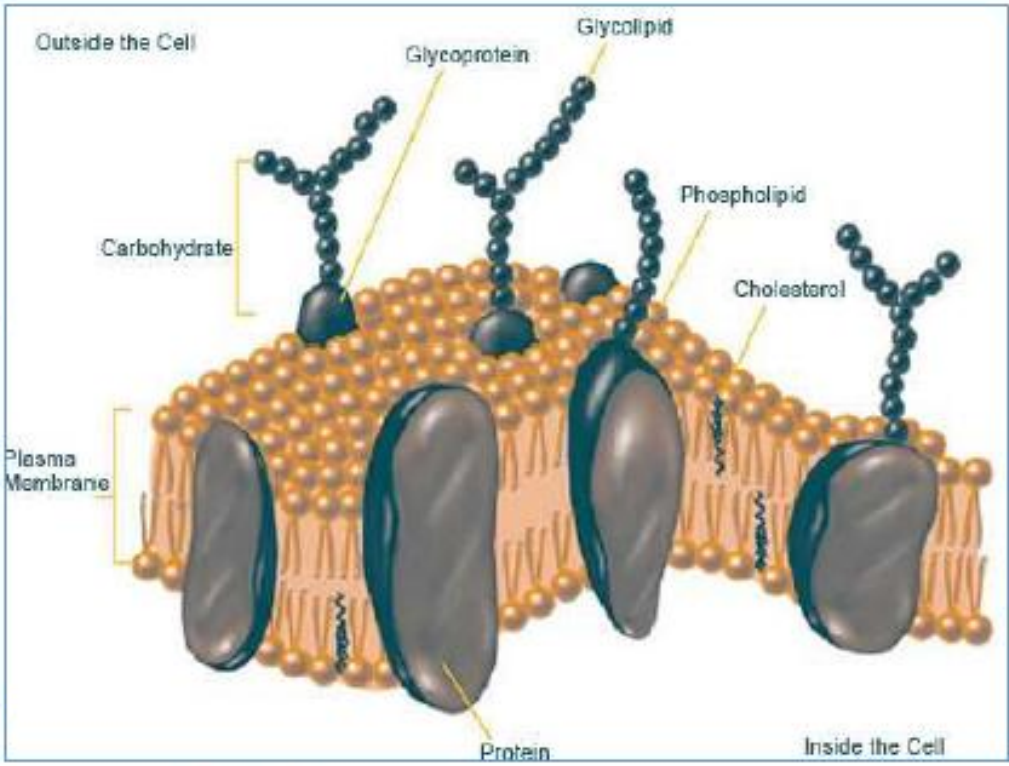
Properties

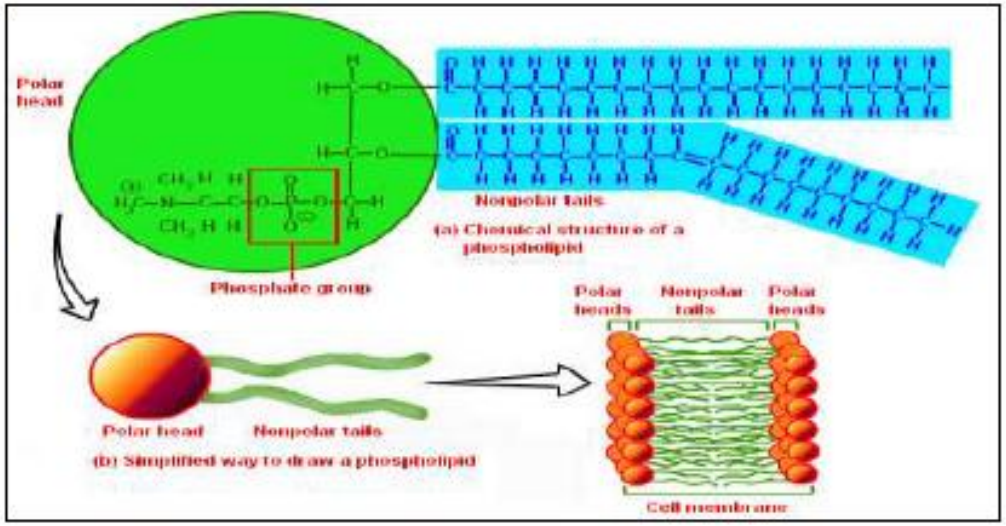
- Present in ALL living cells
- Made up of fats and proteins
- Porous
- Partially permeable
- Controls the exchange the substances between the cells and their environment



2) Plasma membrane is amphipathic in nature, composed of phospholipids

The phospholipids are arranged in two layers called **phospholipid bilayer-** one is outer layer and other is inner layer. **The outer layer is called outer leaflet. The inner layer is called inner leaflet.** Each phospholipid has **a polar head- which gives it a hydrophillic property and a non-polar tail which is a fatty acid tail giving it a hydrophobic property. This kind of property of having both hydrophobic and hydrophilic region is called Amphipathic.** The hydrophillic heads of the outer layer faces extracellular fluid and hydrophillic heads of the inner layer faces cytoplasmic fluid.

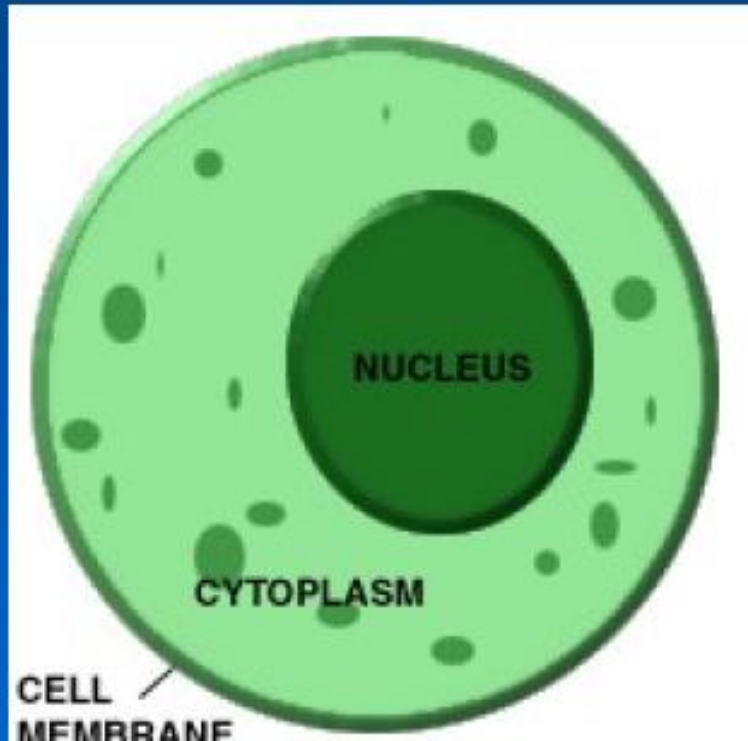




Cytoplasm

- **Structure: gelatin-like fluid that lies inside the cell membrane**
- **Function: -contains salts, minerals and organic molecules**

  -surrounds the organelles



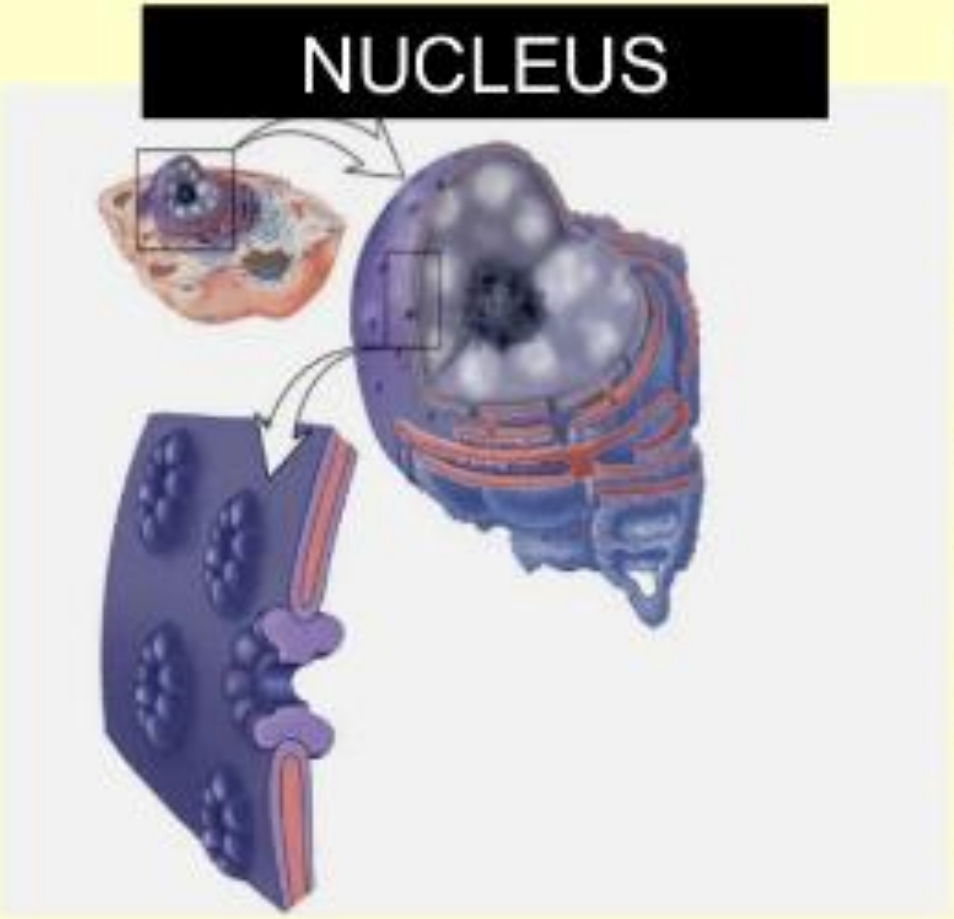
Cytoplasm

1) **Cytoplasm:** The region of the cell that is within the plasma membrane includes the fluid, the cytoskeleton, and all of the organelles except the nucleus is called the cytoplasm.

2) The part of the cytoplasm that includes molecules and small particles, such as ribosomes, but not membrane bound organelles is the cytosol. The cytosol surrounds the organelles and account for about 55 % of the total cell volume.

3) **Cytosol:** About 20% of the cytosol is made up of protein and contains 75-90% water and various dissolved solutes and suspended particles. Among these are various ions, glucose, amino acids, fatty acids, proteins, lipids, ATP, and waste products. The cytosol is the site of many chemical reactions that maintain cell structures and allow cellular growth.

NUCLEUS



Information processing and administrative center of the cell

Most prominent organelle present in the cell

Occupies 10% of total cell volume

Size varies with the cell type

Every cell of human body contain nucleus, exception is erythrocytes

Contains genetic material DNA

STRUCTURE OF NUCLEUS

1) Largest organelle in animal cell and composed of following parts:

a) **Nuclear membrane** is the double membrane, containing many different types of proteins in the membrane.

Nuclear membrane has the outer membrane that is continuous with the rough endoplasmic reticulum (RER) and inner membrane is continuous with the space called lumen of the RER.

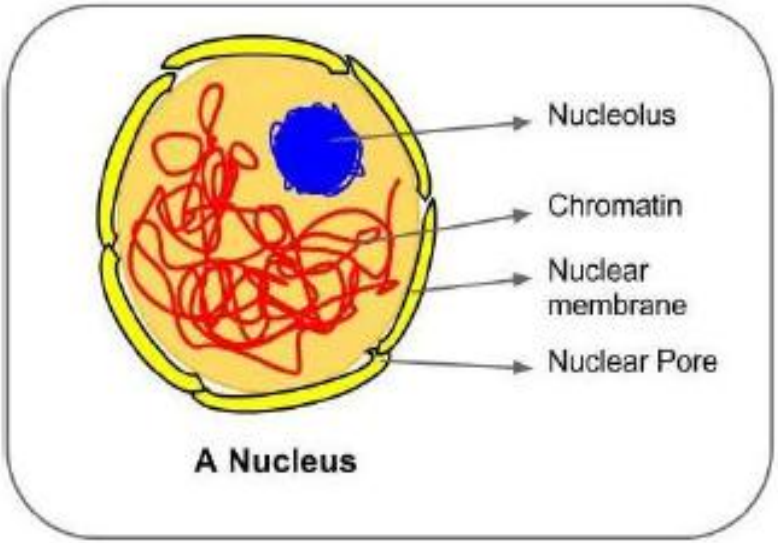
b) **Nuclear pore** is the region where the outer and inner nuclear membrane fuses. The region contains "specific protein complexes" acting as gatekeeper for entry of materials in and out of the nucleus.

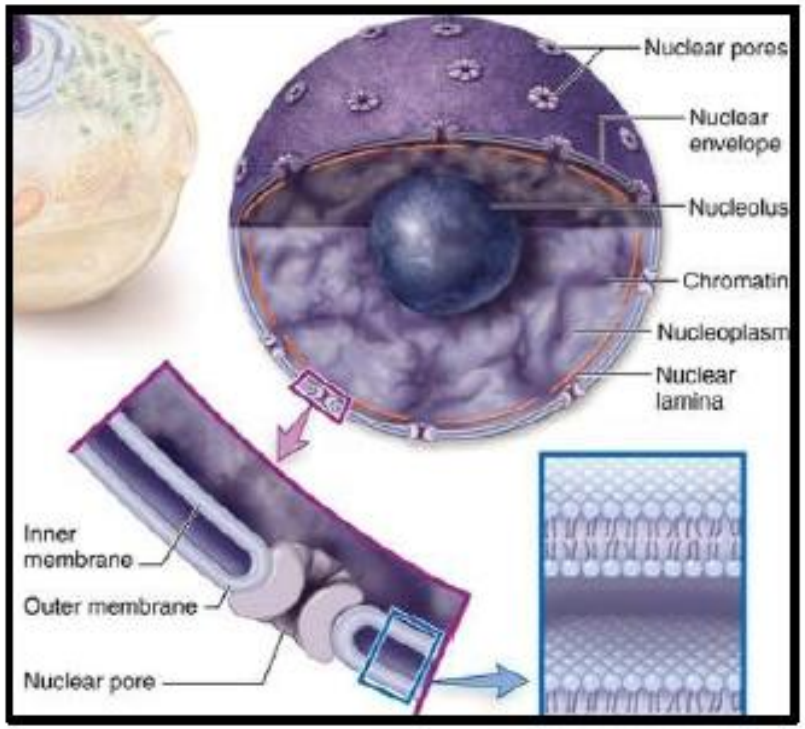
c) Nucleolus. It is the dense region inside the nucleus which is without membrane, and site for ribosomal RNA (rRNA) and transfer RNA (tRNA) synthesis. DNA is concentrated in the process of rRNA synthesis.

d) Nucleoplasm. The non-nucleolar portion of the nucleus that contain condensed **concentrated DNA.**

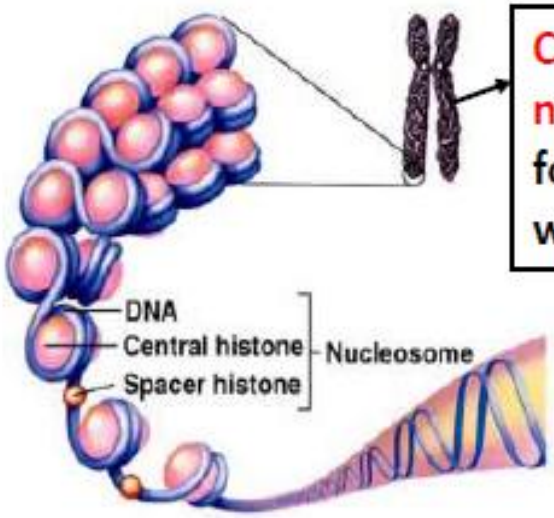
*****Function of the nucleus**: Head of the cell as it directs the cellular activities. It contains genetic material DNA in the chromosomes.

Structure of Nucleus and DNA





Chromatin in nucleus: chromatin is DNA as a thread-like material



Chromosomes in nucleus: condensed form of chromatin when cells divide

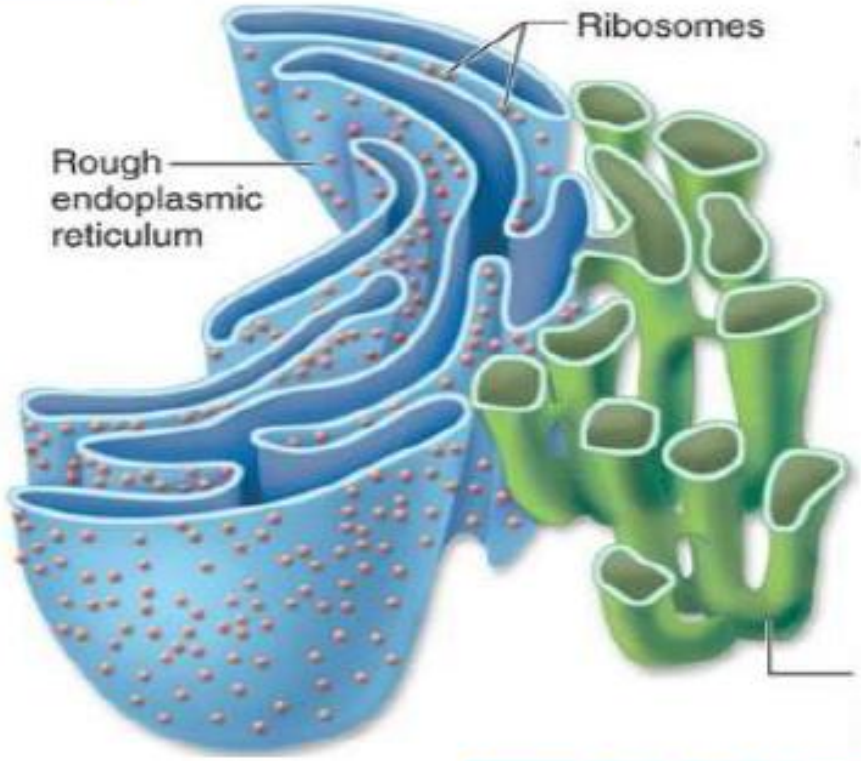
Endoplasmic reticulum

1) Largest membrane in eukaryotic cell. They exists as closed, flattened membrane-bound sacs.

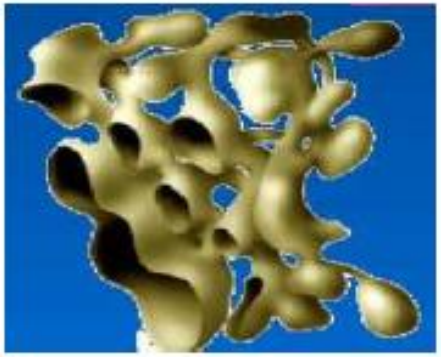
a) Rough endoplasmic reticulum (RER) has ribosomes attached in them giving them rough appearance.

Smooth endoplasmic reticulum (SER) has no ribosomes

b) RER is present near the nucleus and continuous with the outer membrane of the nuclear envelop.



RER



SER

RER functions:

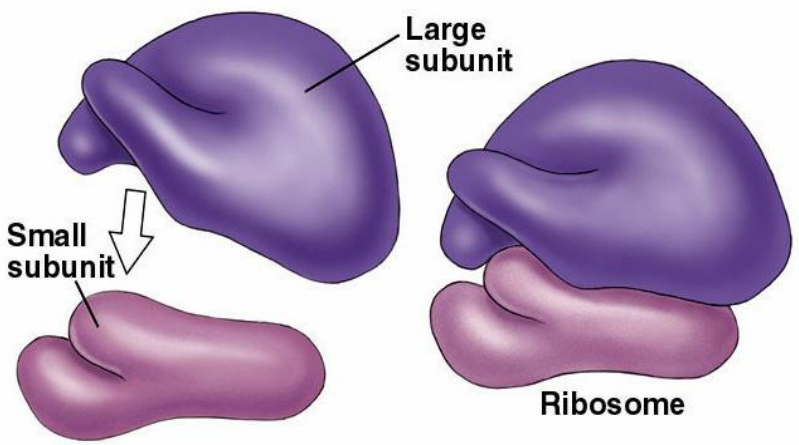
1) Major site for **Protein synthesis**. Synthesize membrane proteins, organelle proteins and secretory proteins.
2) Abundant in cells that are actively involved in secreting specific proteins such as antibodies, digestive enzymes, insulin hormone.
3) Plasma cells secrete antibodies, pancreatic aciner cells produces digestive enzymes such as pancreatic enzymes, islets of Langerhans in pancreas secrete insulin and glucagon. Cytosol of these cells are highly filled with RER and its secretory vesicles.

SER functions

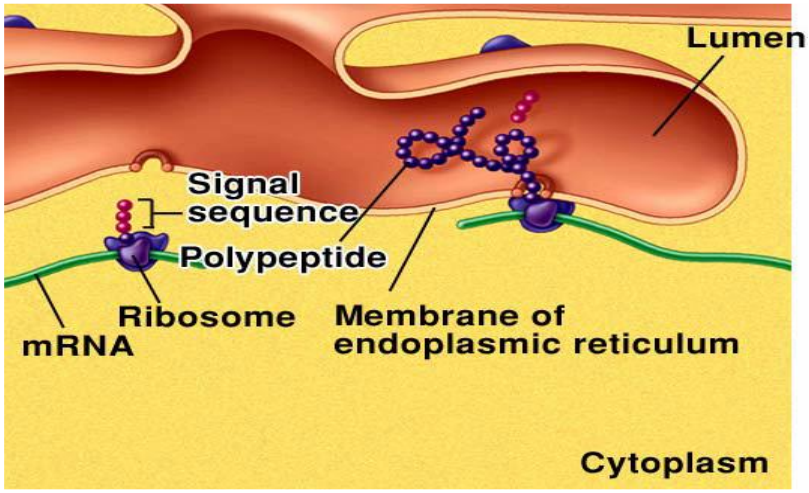
- **Synthesize fatty acids and phospholipids**.
- Contain certain enzymes **which detoxify chemicals** such as pesticides and converting them into water soluble conjugated products that can be secreted from the body. **Abundant in liver cells.**

Ribosome

Ribosomes are either free or attached to the rough ER and play a role in protein synthesis.



- Made of protein and rRNA molecules
- Two subunits - large and small - each made of protein and ribosomal RNA (rRNA)
- Subunits associate when they are synthesizing proteins



- Ribosome assembly begins in the nucleolus and is completed in the cytoplasm

- rRNA is synthesized in the nucleolus

- Protein synthesis occurs on ribosomes that are free-floating in the cytoplasm and on ribosomes attached to endoplasmic reticulum (ER)

Golgi apparatus

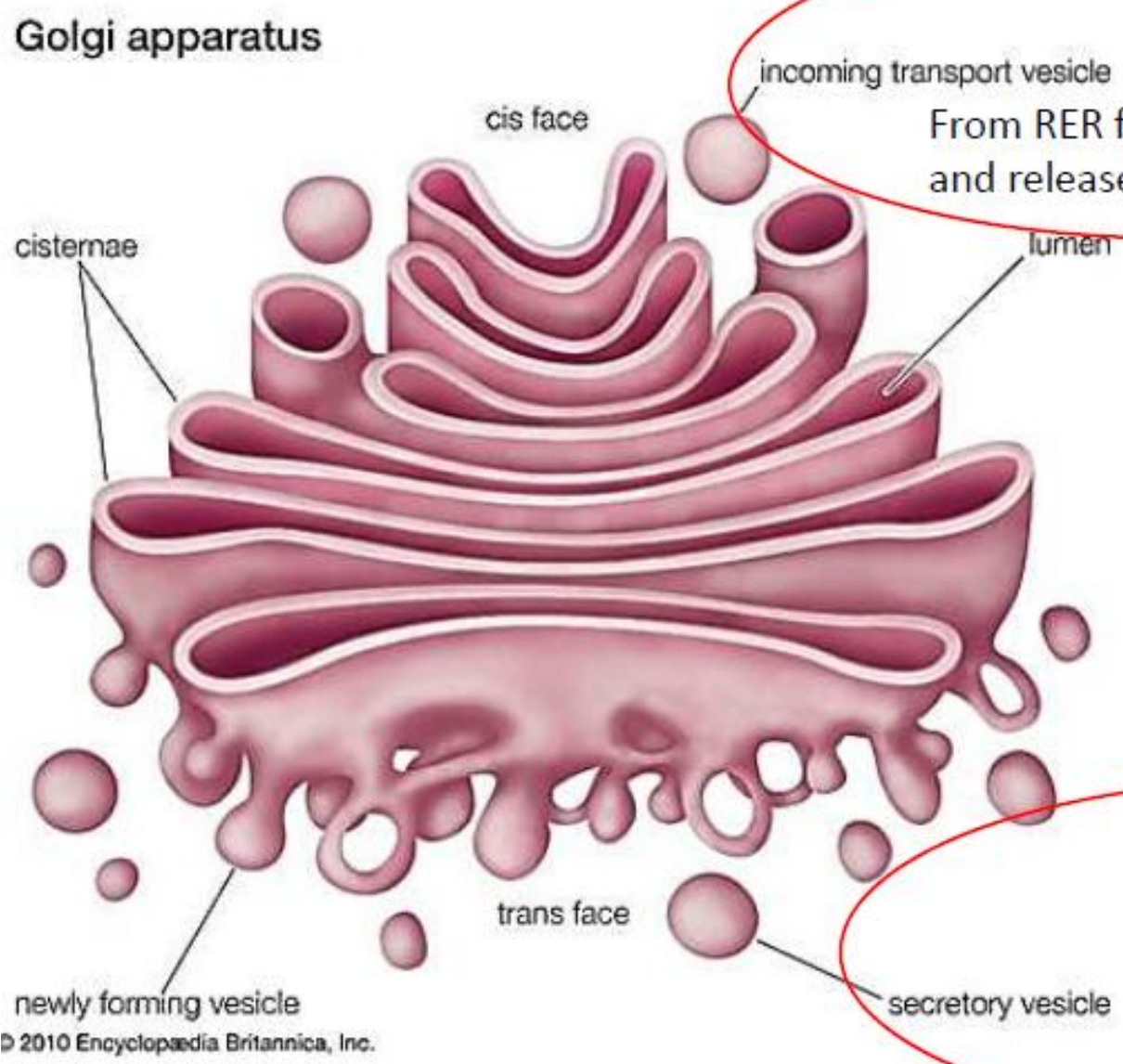
1) Golgi body are made up of flattened membrane bound sacs **called as cisternae.**

2) **Cisternae** forms stack. Stack has three defined regions- **cis, medial and trans**.

3) Golgi body is the "**sorting center of the cell**". In other words, they are involved in **collection, packaging and distribution of proteins to different parts of the cell**. This is done by modifying proteins which are synthesized in RER. Modification of **protein involves posttranslational modification such as adding sugar residues to the protein forming glycoproteins, proteoglycans.**

4) **Secretory vesicles** budded off from RER fuse with the cis region of Golgi body where they deposit their contents. They are then transferred to medial to trans region. Each region contains specific enzymes that modify proteins to be secreted and membrane proteins differently depending on their structure and their final destinations (meaning whether they have to be in the membrane in the form of transporter, channels, enzymes or remain in the cytoplasm).

Golgi apparatus structural view



From RER fuse with the cis region and release the materials

Medial region of golgi where enzymes modifies the synthesized proteins

Trans face secretory vesicles: Carry modified materials/processed proteins and transported to final destinations

Mitochondria

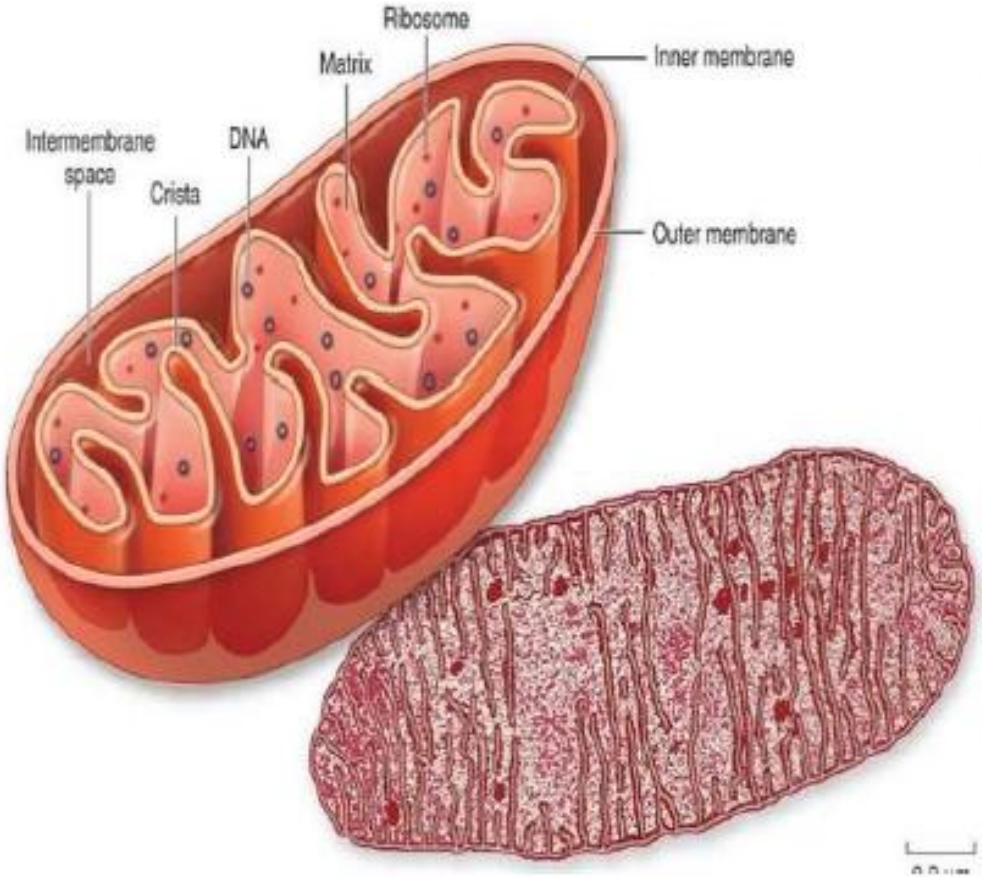
1) **Mitochondria are known as power house/power plant of the cell involved in cellular respiration**.

This is because they are the main center for generating ATP molecules which are the energy molecules. Glucose absorbed by the cell undergoes aerobic degradation within the mitochondria producing ATP molecules. **This is also called cellular respiration**. One glucose molecule generates 30 ATP molecules.

$$\textbf{1 molecule of Glucose} + O_2 \rightarrow CO_2 + H_2O + \textbf{30 ATP}$$

2) Mitochondria are self-duplicating organelle because it contains its own DNA which codes for several proteins that are required for mitochondria itself.

Mitochondria structure



1) **Mitochondria are made up of two membranes.** The outer membrane is composed of 50% lipids and 50% proteins. The **inner membrane has infoldings** or projections called as **cristae** and has 20% lipids and 80% proteins. The inner membrane is the site of ATP production through the **process of oxidative phosphorylation and electron transport chain**.

2) **Intermembrane space**: the space between two membranes of mitochondria is intermembrane space.

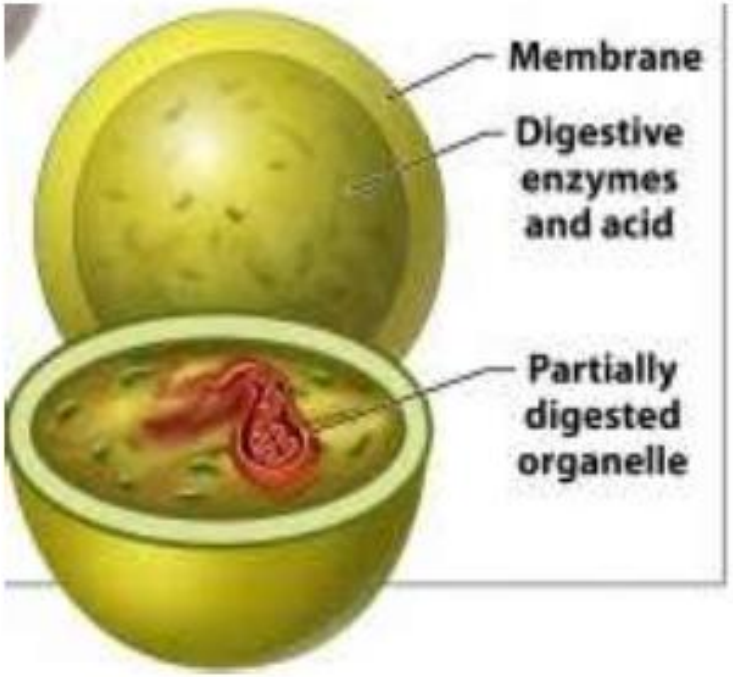
3) **Mitochondrial Matrix**: the central space where the cristae lies is called the mitochondrial matrix. The matrix contains **ribosomes and DNA.**

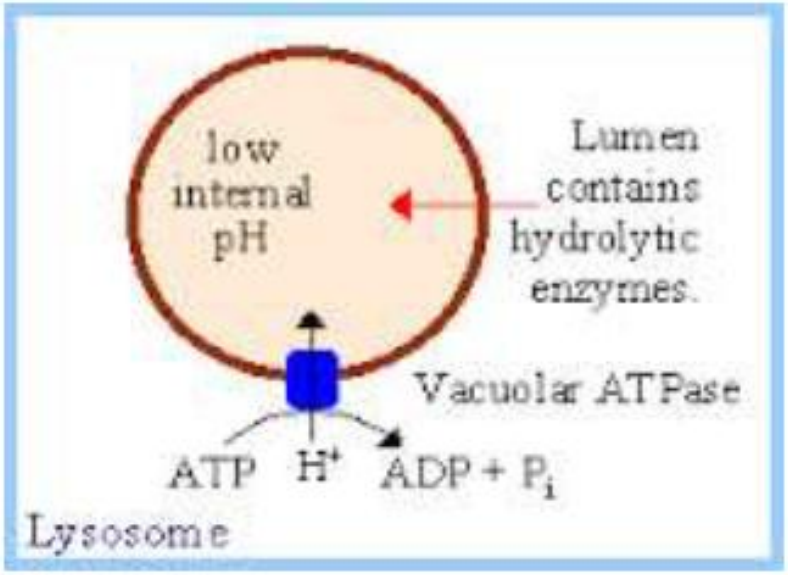
Lysosomes

1) Called as **"Digestive plant of the cell". In simple words, lysosomes recycle cellular waste products and consumed material**
2) Exclusively found in animal cell.
3) They are single membraned small vesicles containing digestive enzymes to break down macromolecules such as proteins, lipids, carbohydrates, nucleic acids.
4) **"Autophagy"** means eating oneself. **Lysosome degrade damaged, or unnecessary cell organelles such as an aged mitochondria and other cell constituents.** The alternate source of intracellular building blocks and substrates are regenerated for new cell formation.
5) **Example: the tail of a tadpole, which is destroyed to make tailless frog.**

Lysosomes structural view

6) Lysosomes degrade material that is internalized by the cell membranes such as bacteria or other germs or other foreign materials. **The internal environment of lysosome is acidic that is pH is 4 to 5. The low internal pH is maintained by vacuolar ATPase that actively pumps H^+ ions.** Enzymes that are functional in this pH are hydrolytic enzymes called **Hydrolases** (eg. Nucleases that degrade RNA and DNA), **proteases** (degrade variety of proteins and peptides), **acid phosphatases** (remove phosphate group from mononucleotides).



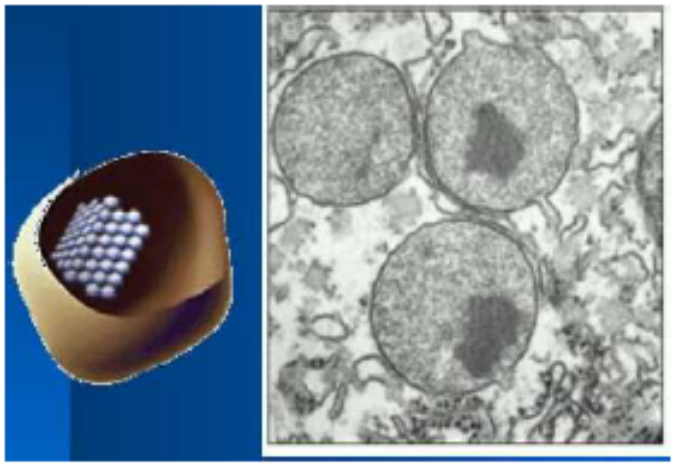


Peroxisomes

1) **Single membrane**-bound organelles found in all types of animal cells except RBCs (Red Blood Cell).

2) Function: i) **Detoxification** of various toxic molecules for example alcohol. ii) **Break down of fatty acids** to produce acetyl groups that are transported into the cytosol and used in the synthesis of cholesterol and other metabolites.

3) Contains **oxidases** and **catalase enzymes**. These enzymes use molecular oxygen to oxidize organic substances. For example, beta oxidation of fatty acids. In such oxidative processes, hydrogen peroxide (H_2O_2) is formed in the body, which is very corrosive and poisonous substance. However, **catalase** enzyme is abundant in peroxisome which converts hydrogen peroxide into water and oxygen.



Cytoskeleton

a) **Cytoskeleton of the cell exists as cytoskeletal fibres** that form networks and bundles that support cellular membranes, help organize organelles and participate in cargo movement, and cell movement.

b) **Three kinds of cytoskeletal fibres** are found within the cell:

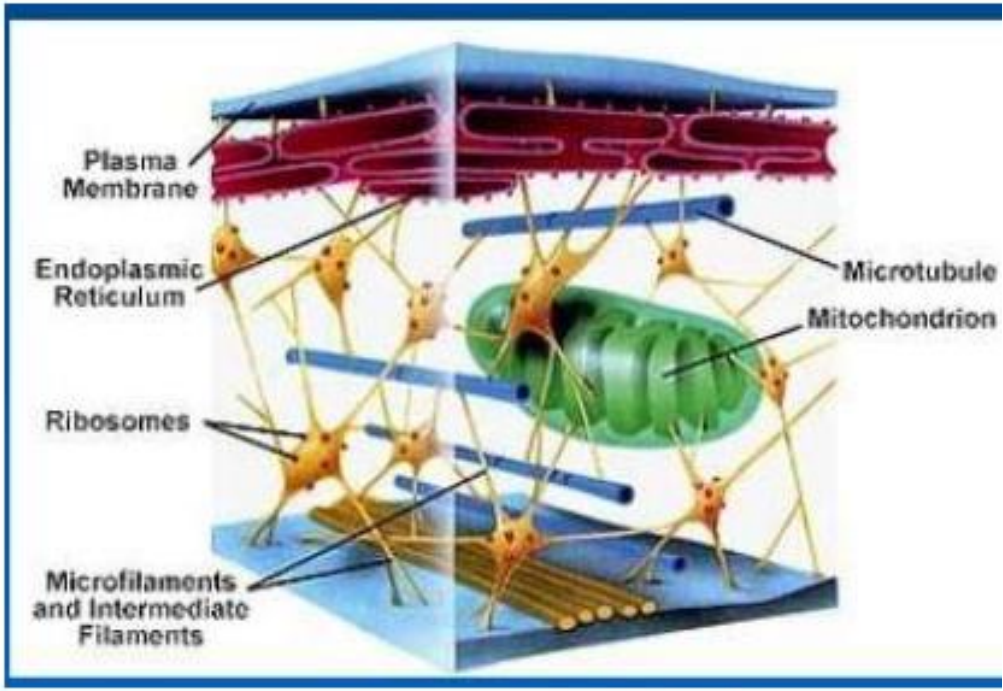
i) Microfilaments. Appearance as **two interwined strands**. They are made up of actin protein and therefore also known as actin filaments. **Actin forms core of the microvilli (finger-like projections in the intestinal epithelial cells for absorption of molecules).** The other kind of plasma membrane projections also have actin filaments. Also present in **dendrites and axon of a neuron**. Role of actin is structural support and various intracellular movements.

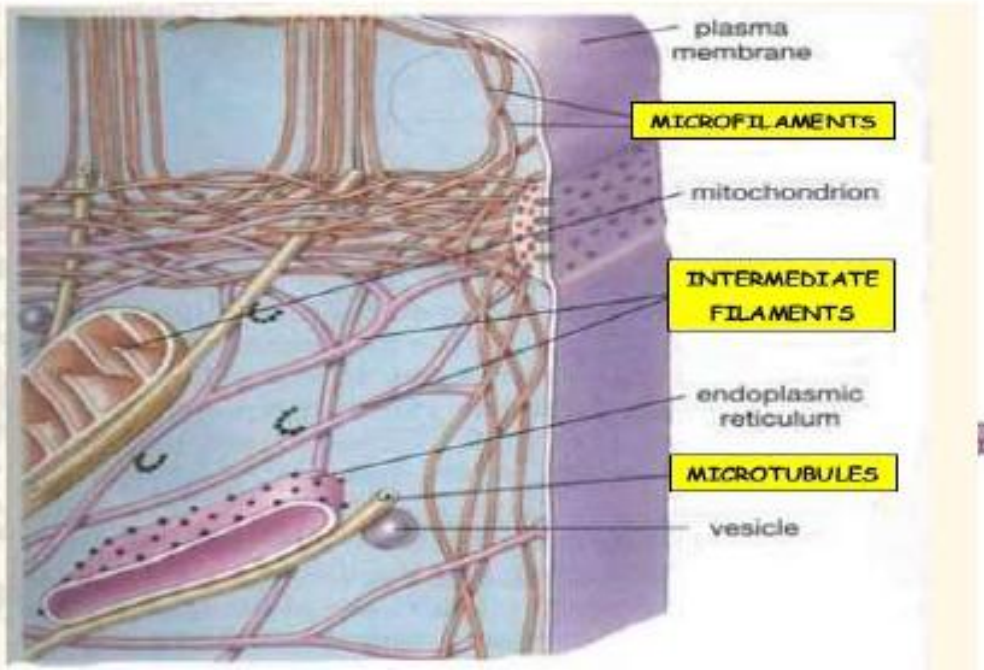
ii) Microtubules. Appearance as kind of **hollow tubes**. They are made up of **alpha-tubulin and Beta- tubulin monomers**. Their important functions are to support the cell, organelle movement within the cell, and during cell division they help movement of chromosomes.

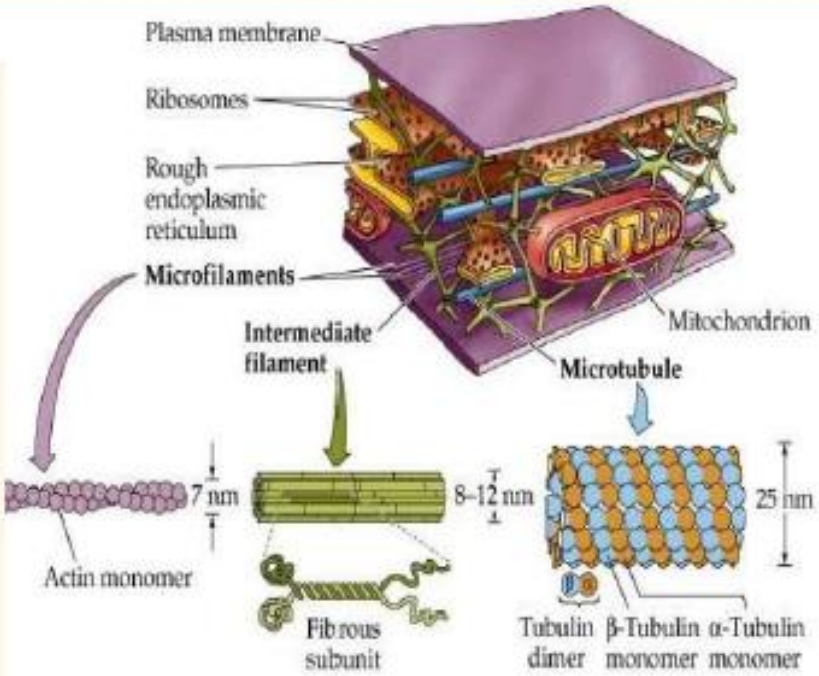
iii) Intermediate filaments. They are fibrous proteins supercoiled into thick cables. Important functions are support for nucleus, formation of nuclear lamina, cell adhesion.

iv) Overall function of cytoskeleton are: cell shape, organelle movements, cell motility, cell polarity, chromosomes movement.

Cytoskeleton structural view



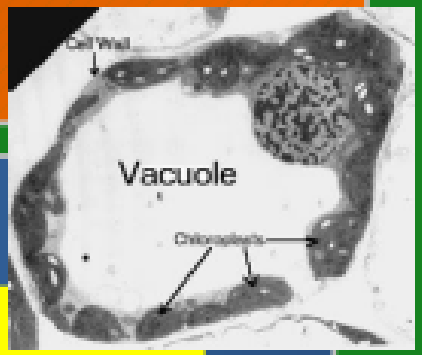




Cell Structure:
Vacuole(s)

Structure

- Fluid filled space enclosed by a membrane



Function

Animal Cell

- Many small vacuoles
- Contains water and food substances
- Usually exists temporarily

Plant Cell

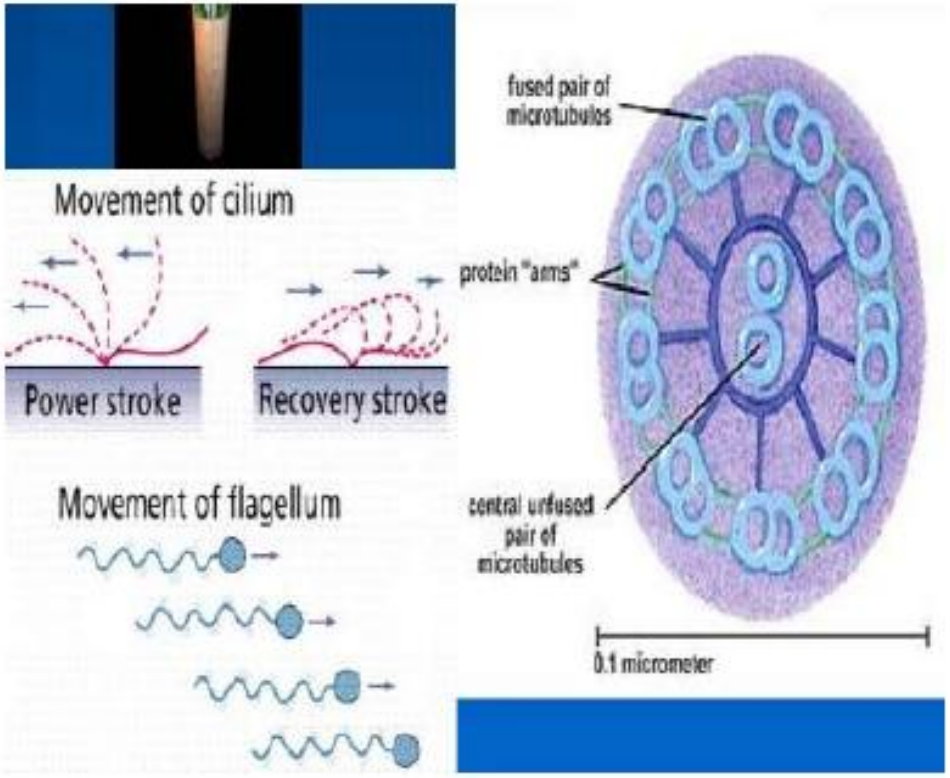
- One large central vacuole
- Contains cell sap (Dissolved substances e.g sugars, mineral salts and amino acids)

Cilia and flagella

1) **Cilia and flagella** are hair-like organelles that extend from the surface of cells.
2) **Cilia and flagella** are made up of microtubules.
3) Main function is cell motility/ helps in cell movement, steady movement of fluid along cell's surface

Cilia are large in numbers, and are found in cell surfaces of respiratory tract that help sweep foreign particles trapped in mucus away from lungs. Uterine lining also have cilia that sweeps oocytes towards uterus.

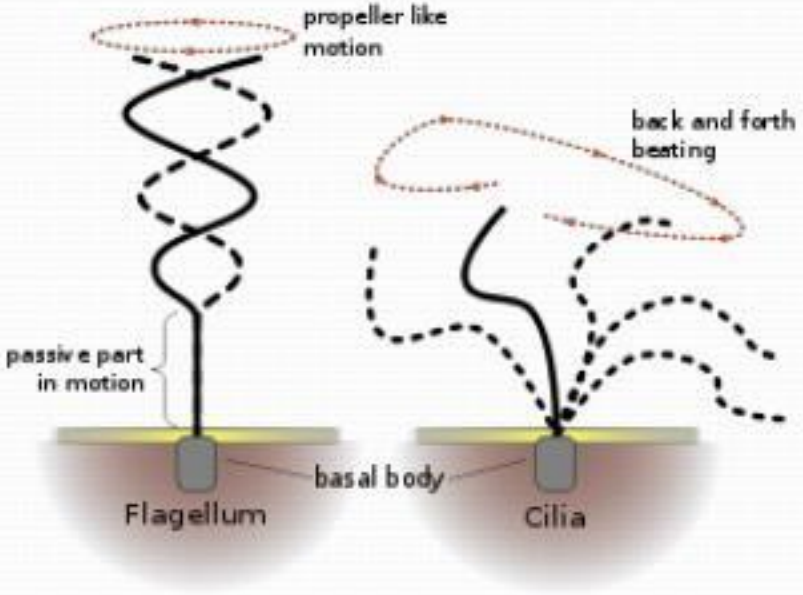
Flagella is found in sperm cell's tail which propels the sperm towards its possible union with an oocyte



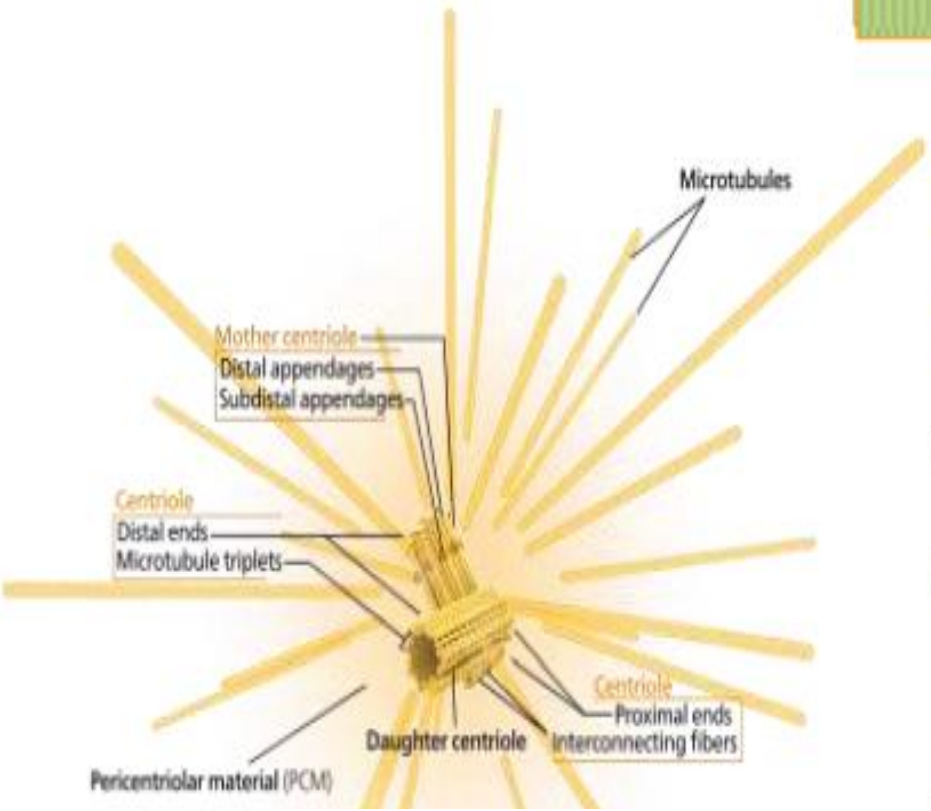
Flagella & Cilia

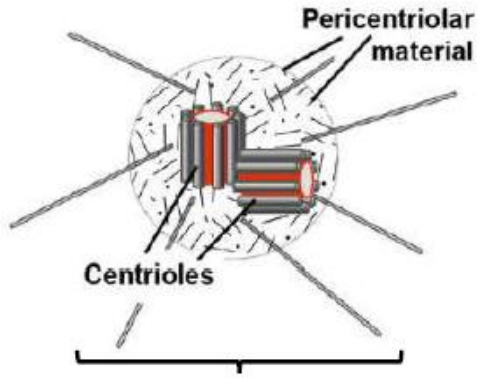
Whip-like appendages of cells that are the main source of movement in Eukaryotic cells.

- Flagella
  - 1-2 Long appendages
  - Tail like appendage.
- Cilia
  - Several short appendages.
  - Usually lines the cell.



Centrosome





Centrosome

- quite near the nucleus
- Inside of it is the centriole
- **Centriole—**

pair of small rod –like structure

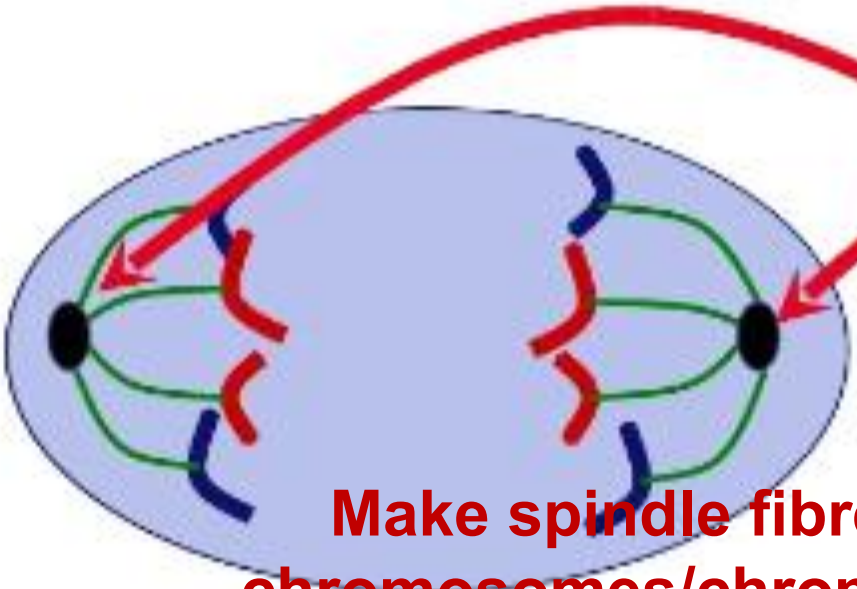
there are attached microtubules in the wall

Function:

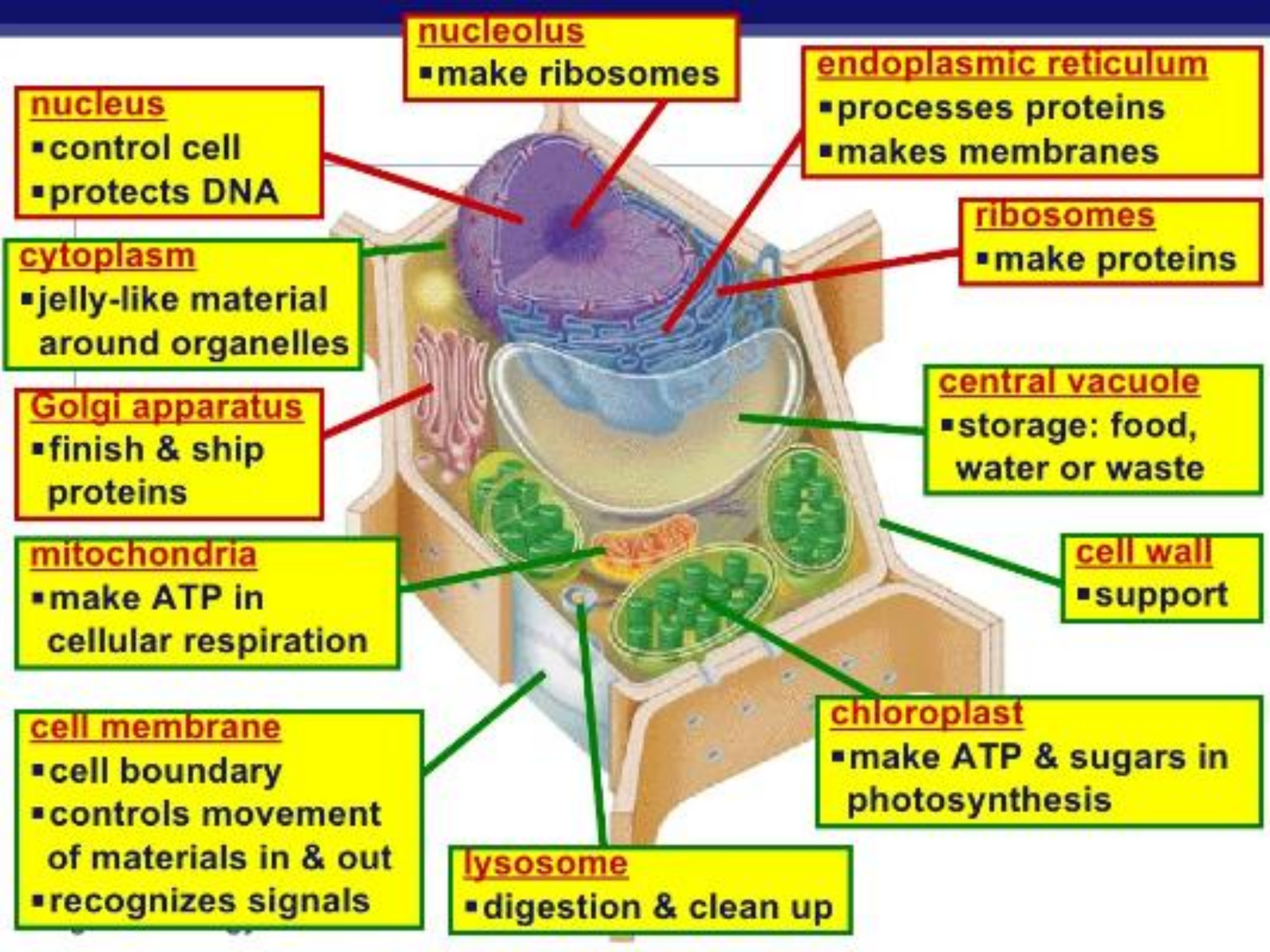
active in the process of cell division(mitosis)

Centrioles

- **Function**
  - **help coordinate cell division**
    - only in animal cells
- **Structure**
  - one pair in each cell



Make spindle fibres which help separate chromosomes/chromatids during cell division


nucleolus
▪make ribosomes
endoplasmic reticulum
▪processes proteins
▪makes membranes
nucleus
▪control cell
▪protects DNA
ribosomes
▪make proteins
cytoplasm
▪jelly-like material around organelles
central vacuole
▪storage: food, water or waste
Golgi apparatus
▪finish & ship proteins
mitochondria
▪make ATP in cellular respiration
cell wall
▪support
chloroplast
▪make ATP & sugars in photosynthesis
cell membrane
▪cell boundary
▪controls movement of materials in & out
▪recognizes signals
lysosome
▪digestion & clean up