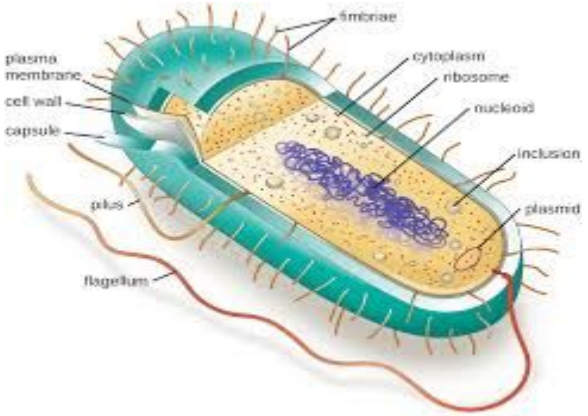
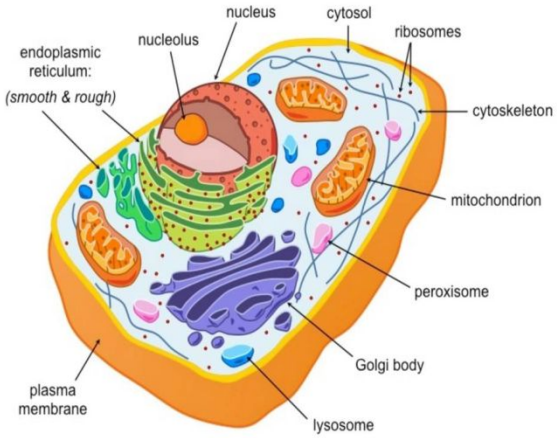
The Cell

The Cellular Level of Organization

- **A cell is the basic unit of all living things**
- Prokaryotic cells - simple cells that have no nucleus. Most are unicellular bacteria.
- Eukaryotic cells - complex cells with a nucleus and subcellular structures (organelles).
- All fungi, plants, and animals are eukaryotes



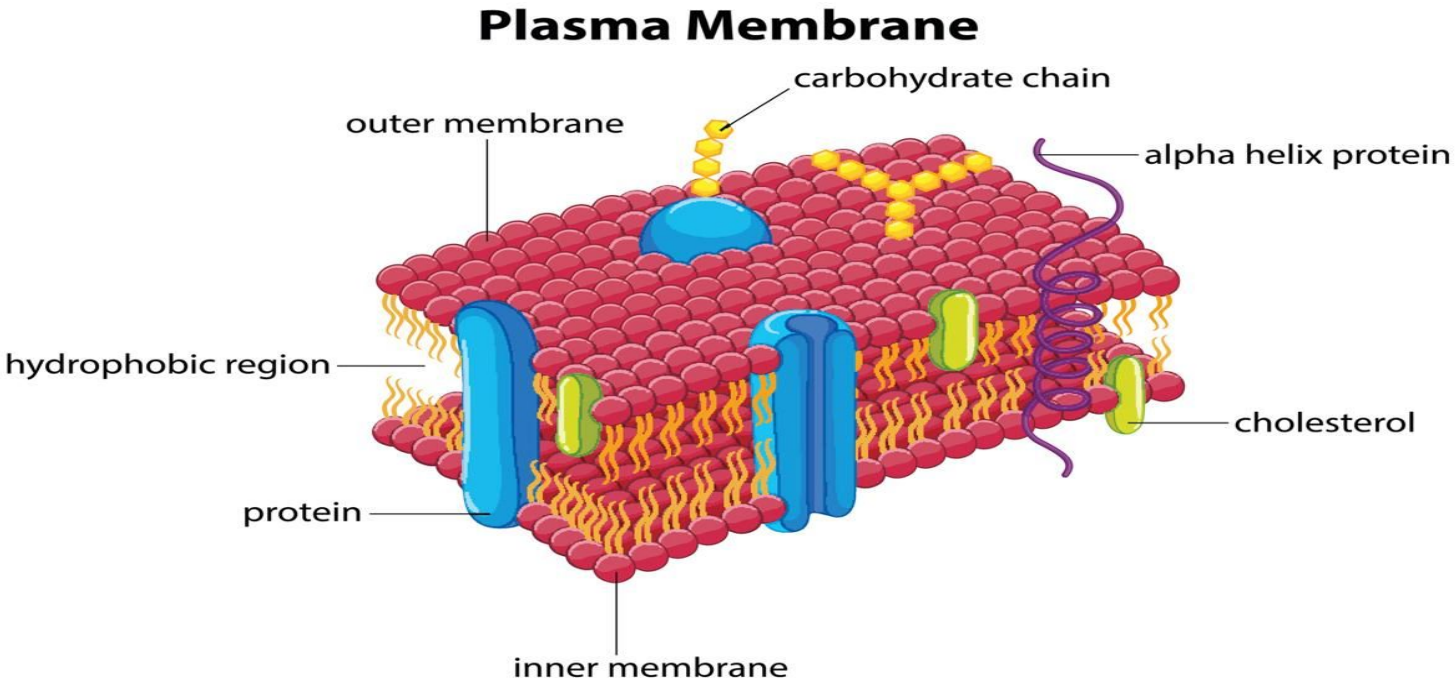


Eukaryote Cells

- Plasma membrane - forms the cell's outer boundary and separates the cell's internal environment from the outside environment. A selectively permeable barrier
- Cytoplasm - a gelatin-like substance, plus structural fibers that contains all the cellular contents between the plasma membrane and the nucleus.
  - cytosol is the fluid portion (mostly water).
  - Organelles are cellular structures embedded in the cytosol
- Nucleus - large organelle that contains DNA in molecules called chromosomes. Each chromosome consists of a single molecule of DNA and associated packaging proteins. A chromosome contains thousands of hereditary units called genes.

Plasma Membrane

- a flexible semipermeable regulator that:
  - Covers and protects the cell
  - Controls what goes in and comes out
  - Links to other cells



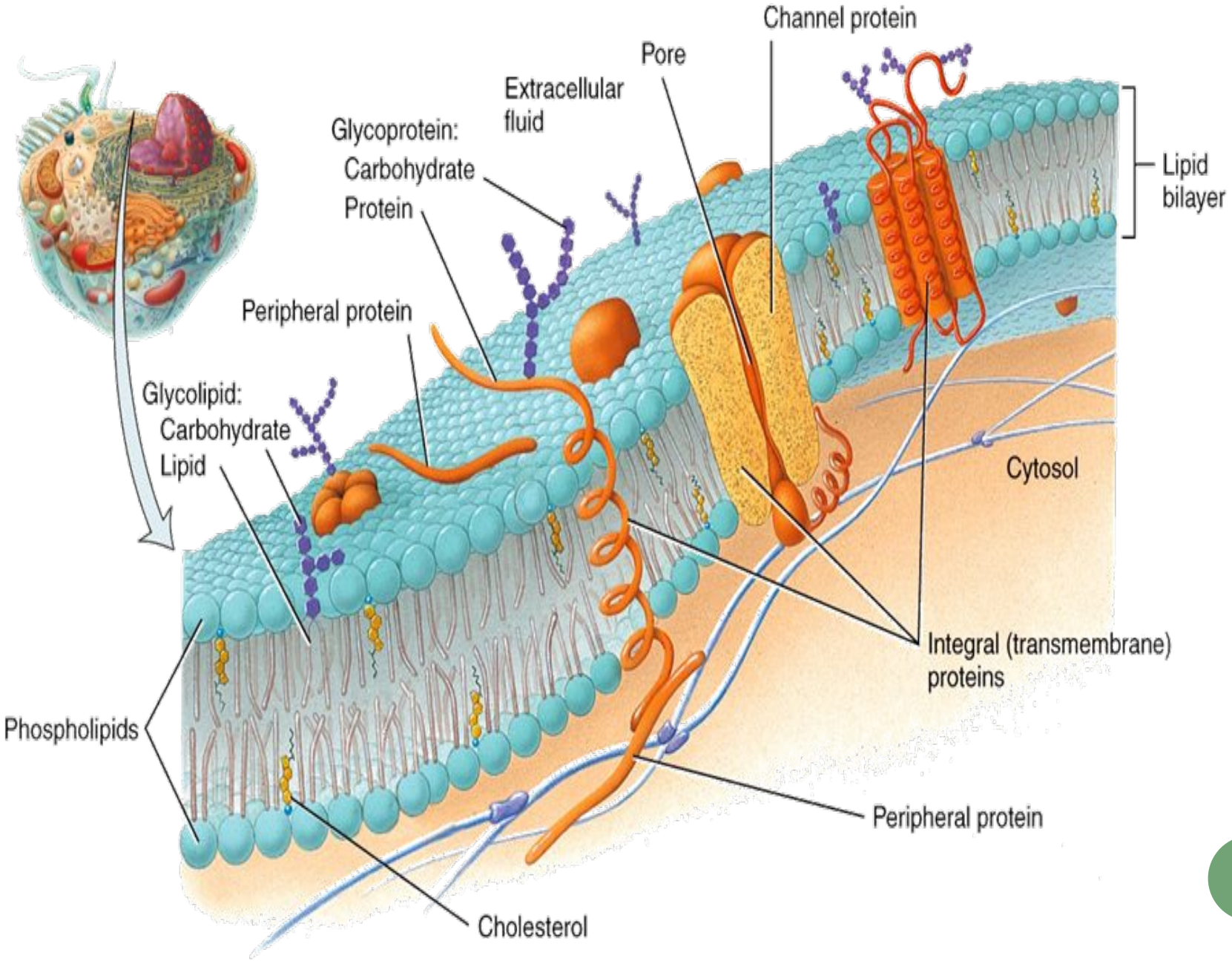
Fluid Mosaic Model

- describes the arrangement of molecules within the membrane:
  - They resemble a sea of phospholipids with protein “icebergs” floating in it.
  - The lipids act as a barrier to certain polar substances.
  - The proteins act as “gatekeepers”, allowing passage of specific molecules and ions

https://youtu.be/moPJkCbKjBs

The Structure of the plasma membrane

- Phospholipids form a lipid bilayer - cholesterol and glycolipids (sugar-lipids) also contribute.
- Integral proteins - extend into or through the bilayer.
  - Transmembrane proteins (most integral proteins) span the entire lipid bilayer.
  - Peripheral proteins attach to the inner or outer surface but do not extend through the membrane.

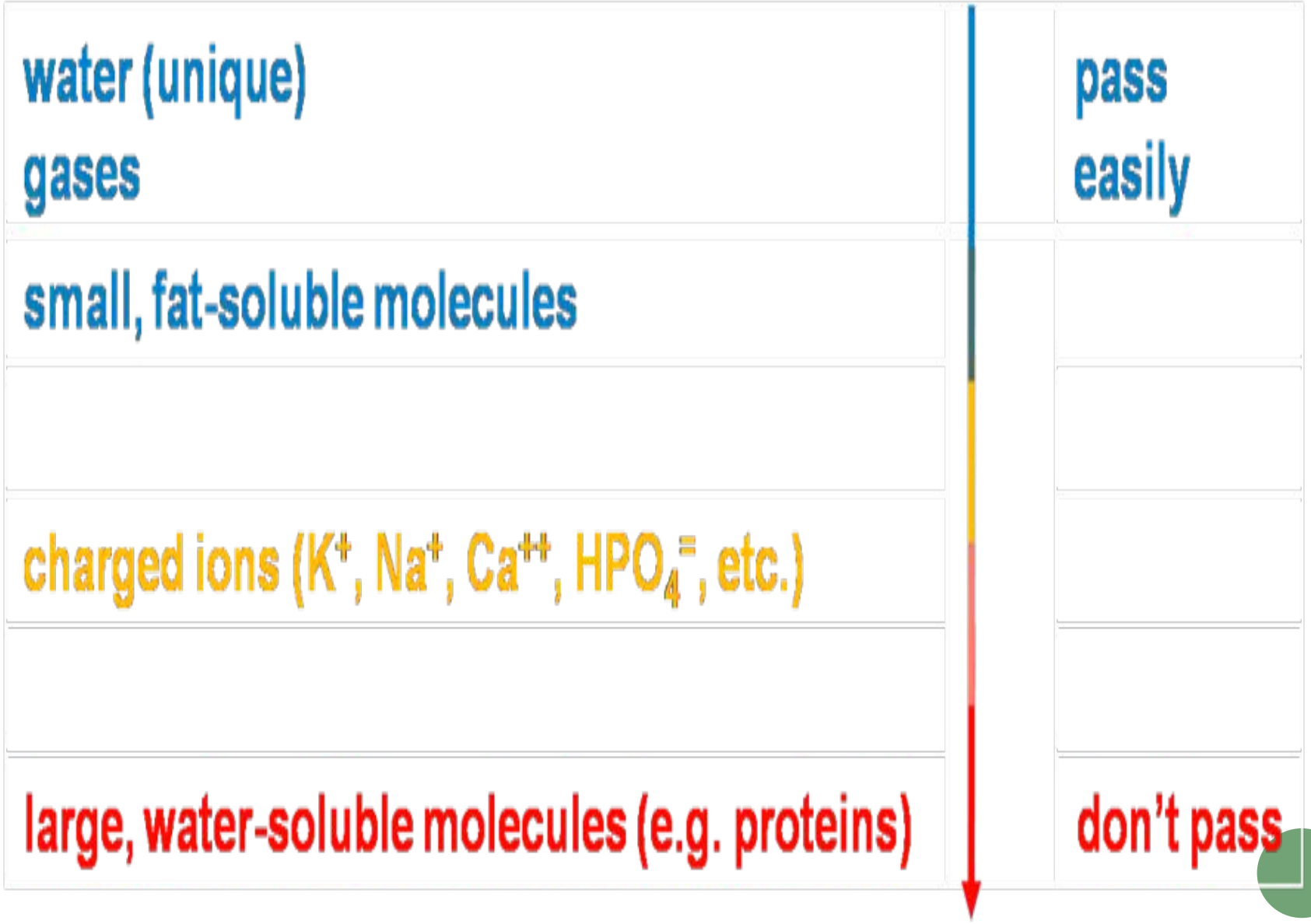

Channel protein
Pore
Extracellular fluid
Glycoprotein:
Carbohydrate
Protein
Lipid bilayer
Peripheral protein
Glycolipid:
Carbohydrate
Lipid
Cytosol
Integral (transmembrane) proteins
Phospholipids
Peripheral protein
Cholesterol

Functions of the Membranes

- Some integral proteins are ion channels.
- Transporters - selectively move substances through the membrane.
- Receptors - for cellular recognition; a ligand is a molecule that binds with a receptor.
- Enzymes - catalyze chemical reactions
- Others act as cell-identity markers.

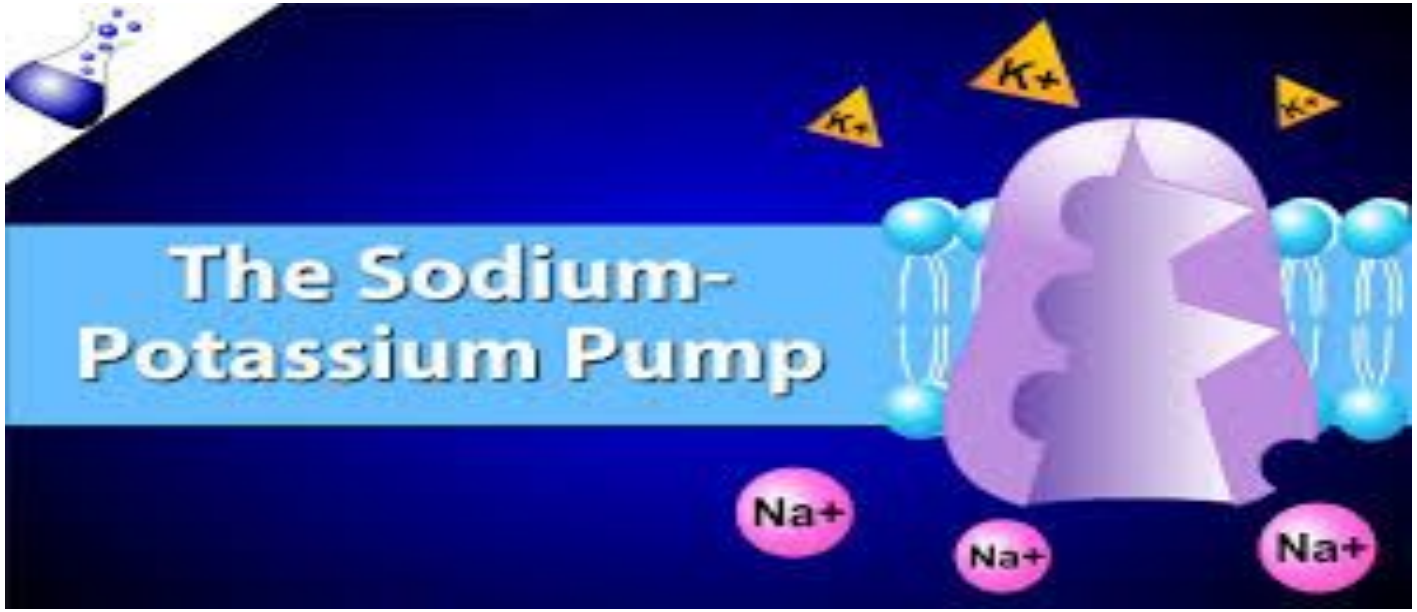
Selective permeability

- Distribution of lipids and the proteins embedded in the cell membrane allows some substances across but not others
- Rule of thumb: small, neutrally-charged, lipid-soluble substances can freely pass
  - Water is a special case - it is highly polar, yet still freely permeable.
    - because it's a very small molecule
    - high osmotic pressure difference between the inside and the outside the cell
- https://youtu.be/ePGqRaQiBfc


water (unique)
gases
pass
easily
small, fat-soluble molecules
charged ions (K^+, Na^+, Ca^{++}, $HPO_4^=$, etc.)
large, water-soluble molecules (e.g. proteins)
don't pass

- For those substances that are needed by the cell but for which the membrane is impenetrable (impermeable), transmembrane proteins act as channels and transporters.
- They assist the entrance of certain substances that either can't pass at all (glucose) or for which the cell needs to hasten passage (ions).

https://youtu.be/bPFKDdWlCg



Transport Processes

Terminology

Tonicity - a measure of the solutions ability to change the volume of a cell by altering their water content

Isotonic solution -any solution in which a cell maintains its normal shape and volume, (same concentration)

Hypertonic solution- a solution that causes cells to shrink due to loss of water through osmosis

Hypotonic solution - a solution that causes cells to swell and perhaps rupture due to gain of water by osmosis

Hemolysis - escape of hemoglobin from the interior of a red blood cell into the surrounding medium, results from a disruption of the cell membrane by toxins, drugs, freezing, thawing or hypotonic solution

Crenation - shrinkage of a cell

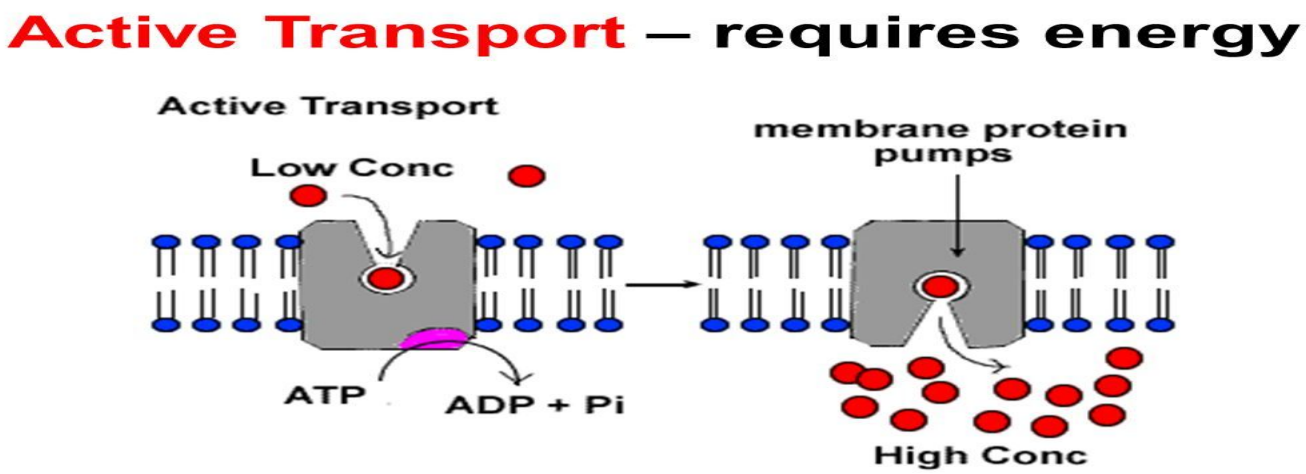
https://youtu.be/BGtLQSfFQsA

Passive Processes

- involve substances moving across the cell membranes without the input of any energy
- move “with” or “down” their concentration gradient
  - Diffusion of solutes
  - Diffusion of water (called osmosis)
  - Facilitated diffusion (requires a specific channel or a carrier molecule, but no energy is used)

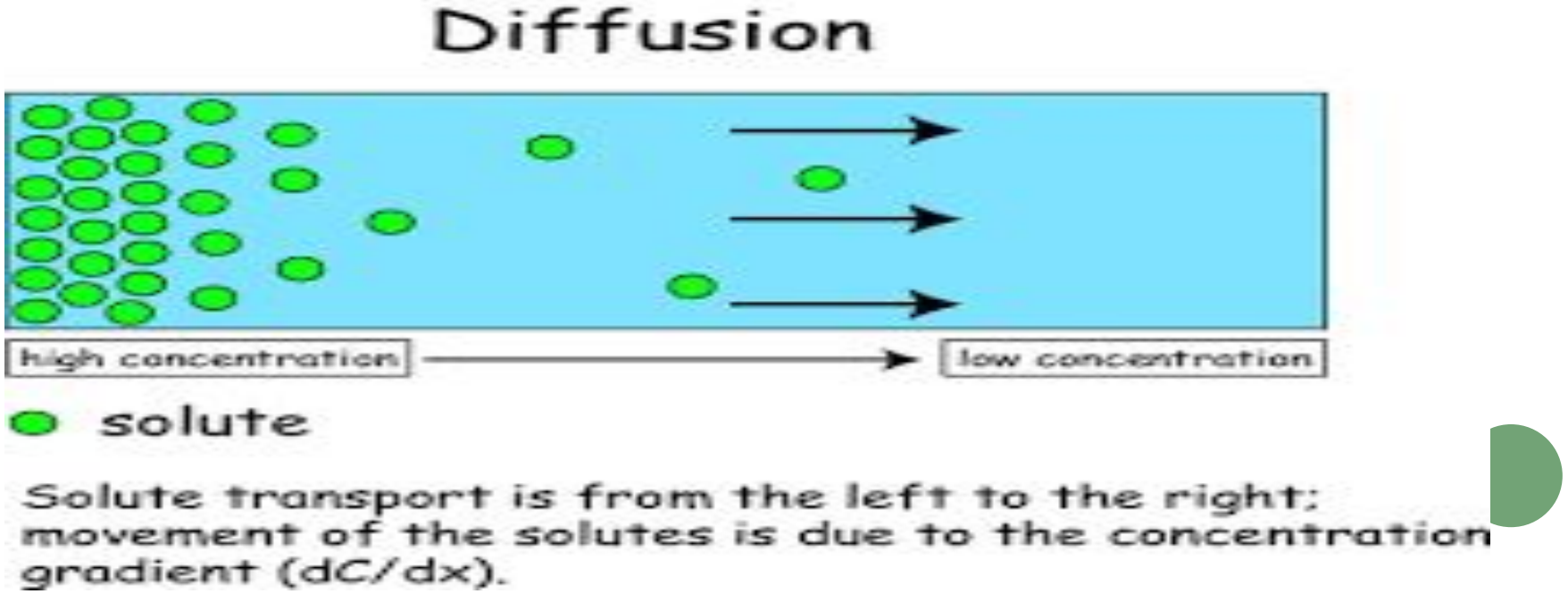
Active Processes

- involve the use of energy, primarily from the breakdown of ATP, to move a substance against its gradient
  - Various types of transporters are used, and energy is required



Passive Transport - Diffusion

- passive spread of particles through random motion, from areas of high concentration to areas of low concentration



Factors affecting Diffusion Rate

1. Amount of substance and the steepness of the concentration gradient. Greater the difference in concentration = higher the rate of diffusion
2. Temperature :the higher the temperature = faster the rate of diffusion
3. Surface area :the larger the membrane surface area = faster the rate of diffusion
4. Diffusion distance : the greater the distance over which diffusion must occur = takes longer
5. Mass of the diffusing substance – the greater the mass of diffusing particles = slower the rate

Channel-Mediated Facilitated Diffusion

- transmembrane proteins that allow certain solutes (based on channel size and charges of the amino acids lining the channel) to pass through the lipid bilayer into or out of the cell, based on concentration gradients. The channels can be either leakage channels that are always open, or gated channels that are controlled by chemical or electrical signals

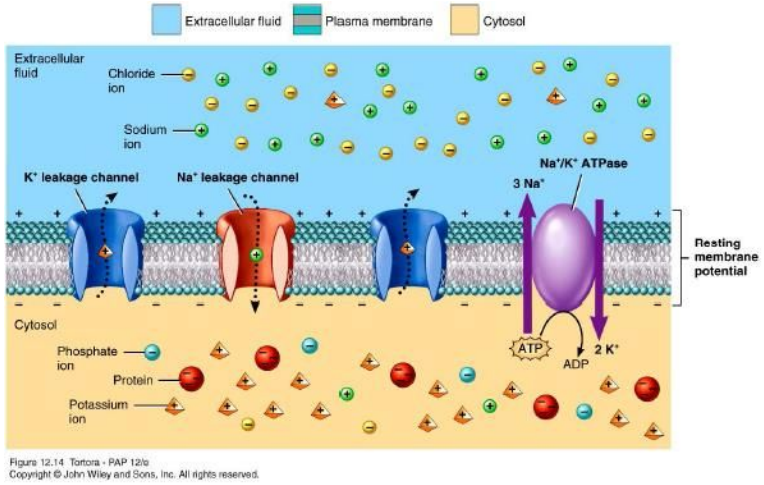


Figure 12.14 Tortora - PAP 12/e

Types of channel Mediated Facilitated Diffusion

- Ligand-gated ion channels (LICs, LGIC), also commonly referred to as ionotropic receptors, are a group of transmembrane ion-channel proteins which open to allow ions such as Na+, K+, Ca2+, and/or Cl− to pass through the membrane in response to the binding of a chemical messenger (i.e. a ligand), such as a neurotransmitter.

Mechanical And Voltage gated channels

- Mechanical Gated
  - ion channels that open in response to mechanical movement of adjacent structures include touch sensors in the skin
- Voltage Gated
  - Ion channels that open or close in response to changes in the membrane potential are termed voltage-gated. Especially important are voltage-gated Na+, Ca++, K+, and Cl- ion channels,

Examples of Gated Channels

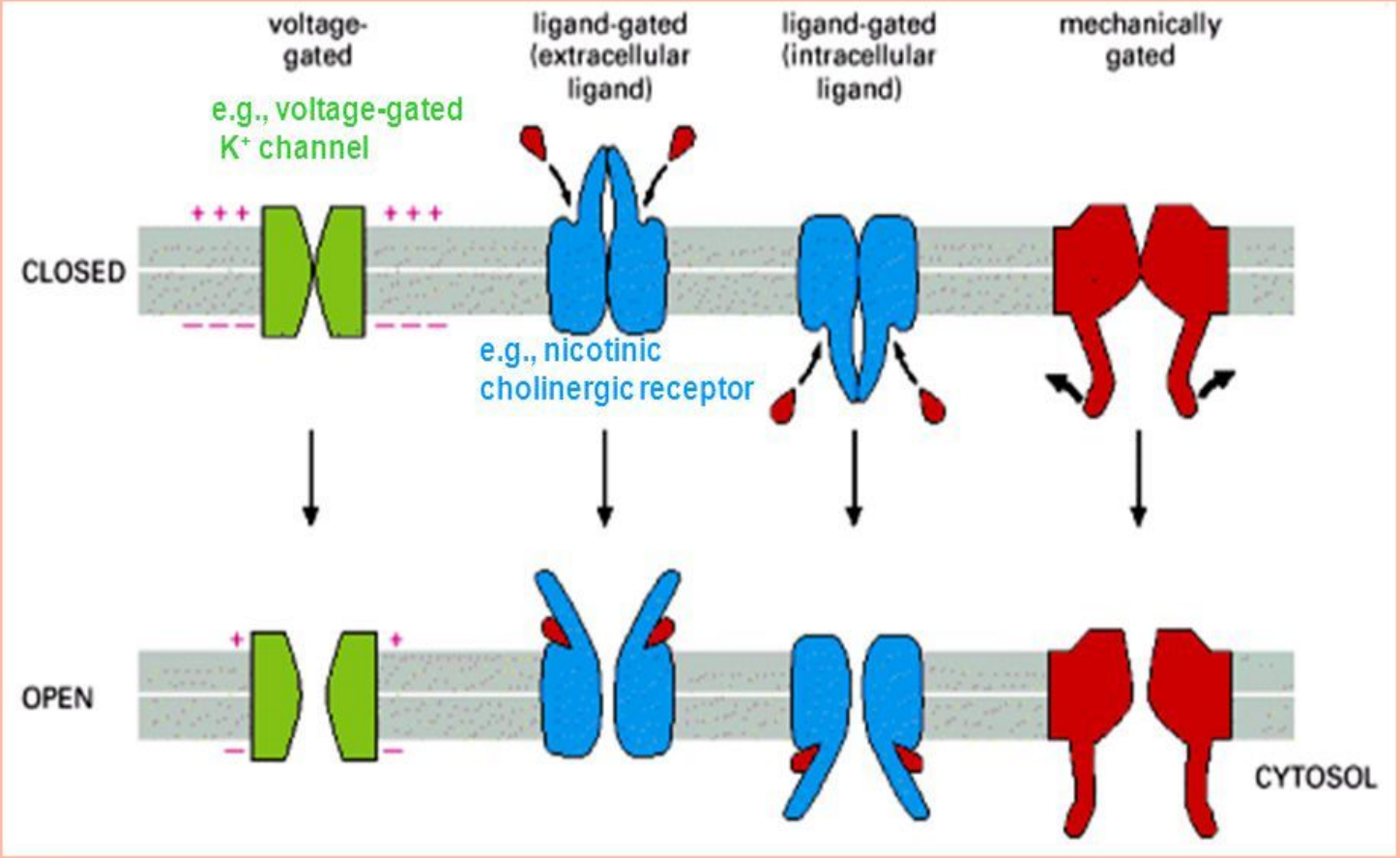


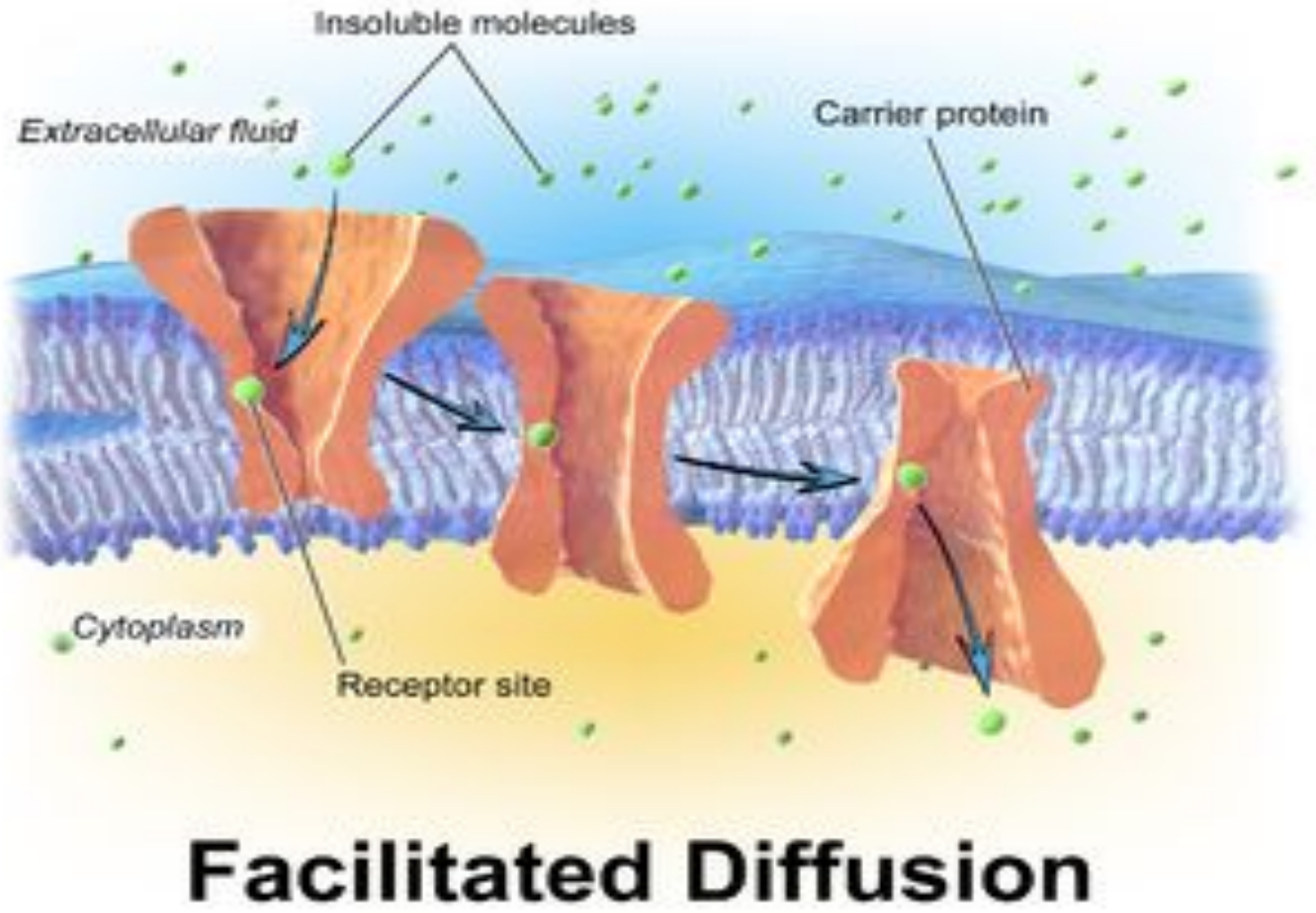
Fig. 11-21
Alberts *et al.*,
Molecular Biology of the Cell

Carrier – Mediated Facilitated Diffusion

- movement of molecules across the cell membrane via special transport proteins that are embedded in the plasma membrane by actively taking up or excluding ions
  - An example of Carrier-Mediated Facilitated Diffusion is the passage of glucose across the cell membrane

https://youtu.be/O15WUHckx6M

Glucose crossing plasma membrane



Osmosis

- net movement of water through a selectively permeable membrane from an area of high water concentration to one of lower water concentration.
- Water can pass through plasma membrane in 2 ways:
  - through lipid bilayer by simple diffusion
  - through aquaporins (integral membrane proteins)
    - also called water channels, are integral membrane proteins from a larger family of major intrinsic proteins that form pores in the membrane of biological cells, mainly facilitating transport of water between cells

Passive Transport Review

- https://youtu.be/J5pWH1r3pgU

Active transport

- Solutes can also be actively transported across a plasma membrane against their concentration gradient ([low] to [high]) by using energy (usually in the form of ATP)
- There are 2 sources of energy that could be used
  - Primary Active Transport
  - Secondary Active Transport

Primary Active Transport

- Energy obtained from hydrolysis of ATP
- ATP changes the shape of a transporter protein, which pumps a substance across the plasma membrane against the concentration gradient
- Transporter proteins that carry out primary active transport are called pumps

Sodium Potassium pump

- The pump, with bound ATP, binds 3 intracellular Na+ ions
- ATP is hydrolyzed, leading to phosphorylation of the pump at a highly conserved aspartate residue and subsequent release of ADP
- Conformational change in the pump exposes the Na+ ions to the outside
- The phosphorylated form of the pump has a low affinity for Na+ ions, so they are released
- The pump binds 2 extracellular K+ ions
- This causes the dephosphorylation of the pump, reverting it to its previous conformational state, transporting the K+ ions into the cell
- The unphosphorylated form of the pump has a higher affinity for Na+ ions than K+ ions, so the two bound K+ ions are released
- ATP binds, and the process starts again

https://youtu.be/2-icEADP0J4

Secondary Active Transport

Energy stored in an ionic concentration gradient

- A transporter protein simultaneously binds to another substance and then changes its shape so that both substances can cross the membrane at the same time
  - If the transporters move the substances at the same direction they are called symporters
  - If the transporters move two substances in opposite directions across the membrane they are called antiporters

Transport in a vesicle

Vesicle - a small spherical sac formed by budding off from a membrane

- Endocytosis - materials move into a cell in a vesicle formed from the plasma membrane
  - Three types:
    - receptor-mediated endocytosis
    - Phagocytosis
    - pinocytosis
- Exocytosis - vesicles fuse with the plasma membrane, releasing their contents into the extracellular fluid
- Transcytosis - a combination of endocytosis and exocytosis

Cytoplasm

- Cytosol - intracellular fluid, surrounding the organelles
  - The site of many chemical reactions
  - Energy is usually released by these reactions.
  - Reactions provide the building blocks for cell maintenance, structure, function and growth.
- Organelles
  - Specialized structures within the cell

Cytoplasm – The Cytoskeleton

- Network of protein filaments throughout the cytosol
- Provides structural support for the cell
- Types
  - Microfilaments-Microfilaments, or actin filaments, are the thinnest filaments of the cytoskeleton and are found in the cytoplasm of eukaryotic cells. The polymers of these linear filaments are flexible but still strong, resisting crushing and buckling while providing support to the cell

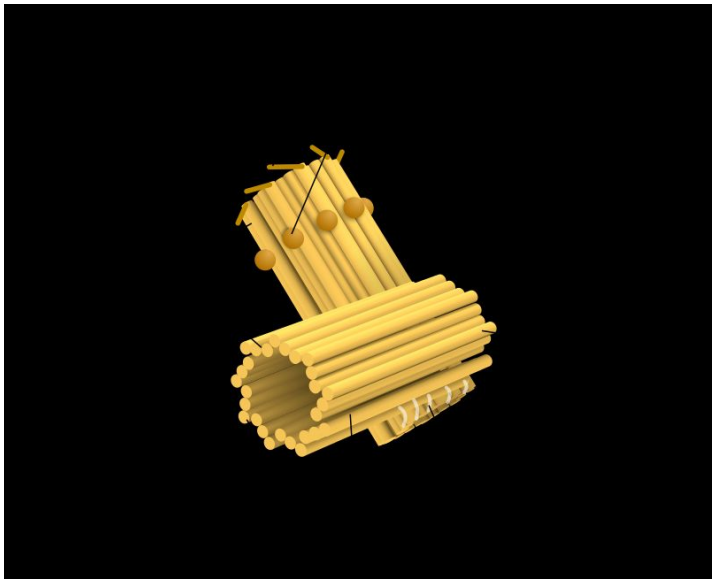
Types of Protein Filaments

- Intermediate filaments - Their main role lies in providing mechanical support to the cell, as well as participating in organization of the chromatin in the cell nucleus
- Microtubules - These straight, hollow cylinders are found throughout the cytoplasm of all eukaryotic cell and carry out a variety of functions, ranging from transport to structural support. Act as a conveyer belt to move organelles about the cell

https://youtu.be/4BAGI6LbHeo

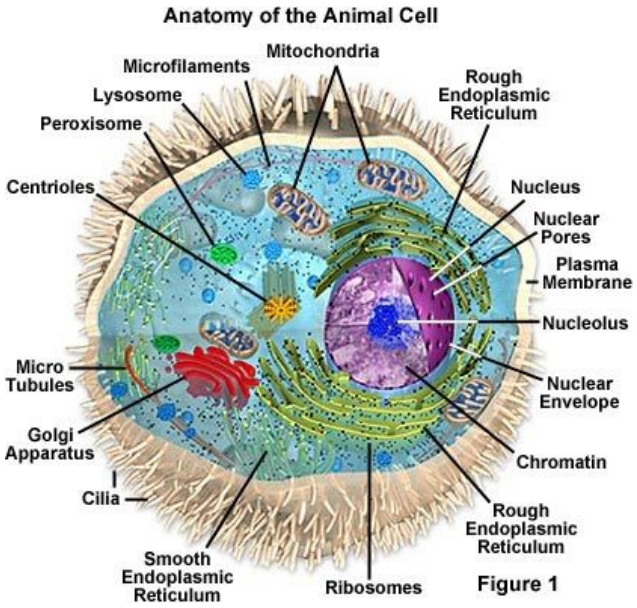
Centrosome

- Centrosome - located near the nucleus, consists of two centrioles and pericentriolar material
- an organelle that is the main place where cell microtubules are organized. Also, it regulates the cell division cycle, the stages which lead up to one cell dividing in two.



Cilia & Flagella

- Cilia - short, hair-like projections from the cell surface, move fluids along a cell surface
- Flagella - longer than cilia, move an entire cell; only example is the sperm cell's tail

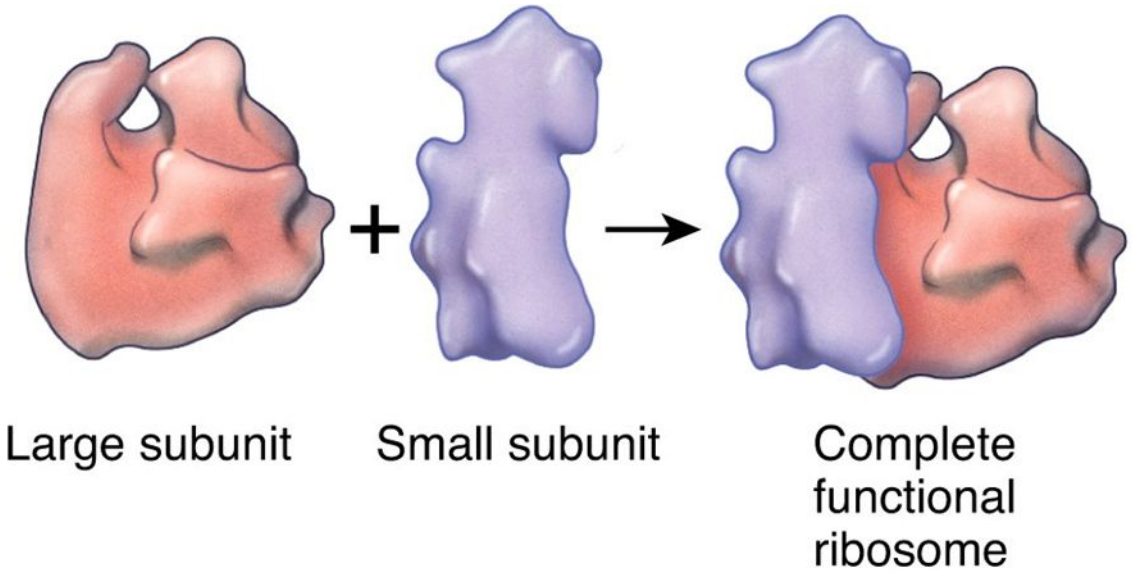


Ribosomes

- Sites of protein synthesis
- Ribosomes occur both as free particles and as particles attached to the membranes of the endoplasmic reticulum in eukaryotic cells
- Ribosomes abundant in cells. A single actively replicating eukaryotic cell may contain as many as 10 million ribosomes
- The size of the ribosomes varies, depending on the cell type and on factors such as whether the cell is resting or replicating
- made up of ribosomal proteins

Ribosome Subunits

- Each ribosome is composed of two subunits, a larger one and a smaller one, each of which has a characteristic shape.



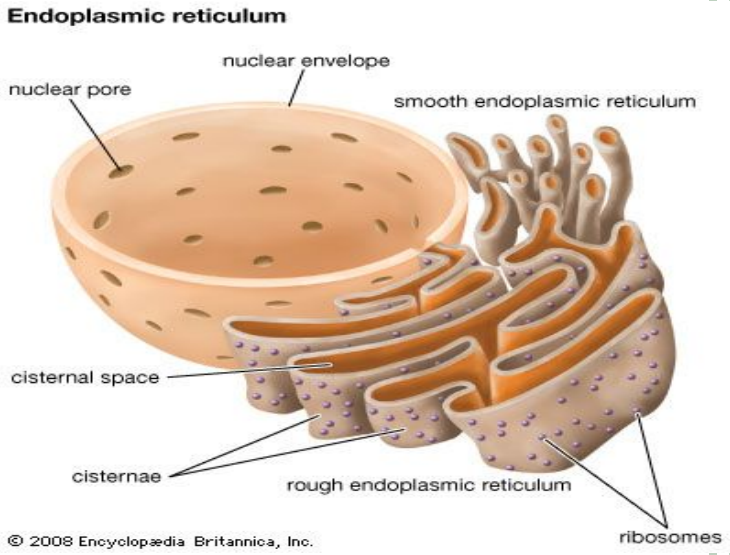
Details of ribosomal subunits

Ribosome and Protein Synthesis

- Ribosomes are the sites at which information carried in the genetic code is converted into protein molecules
- Ribosomal molecules of messenger RNA (mRNA) determine the order of transfer RNA (tRNA) molecules that are bound to nucleotide triplets (codons)
- The order of tRNA molecules ultimately determines the amino acid sequence of a protein
- Molecules of rRNA catalyze the peptidyl transferase reaction, which forms peptide bonds between the amino acids, linking them together to form proteins.
- The newly formed proteins detach themselves from the ribosome site and migrate to other parts of the cell for use

Endoplasmic Reticulum

- Continuous network of membranes in the shape of flattened sacs or tubules
- serves multiple functions, being important particularly in the synthesis, folding, modification, and transport of protein
- ER usually constitutes more than half of the membranous content of the cell
- Two types of ER
  - rough ER and smooth ER.



Rough Endoplasmic Reticulum

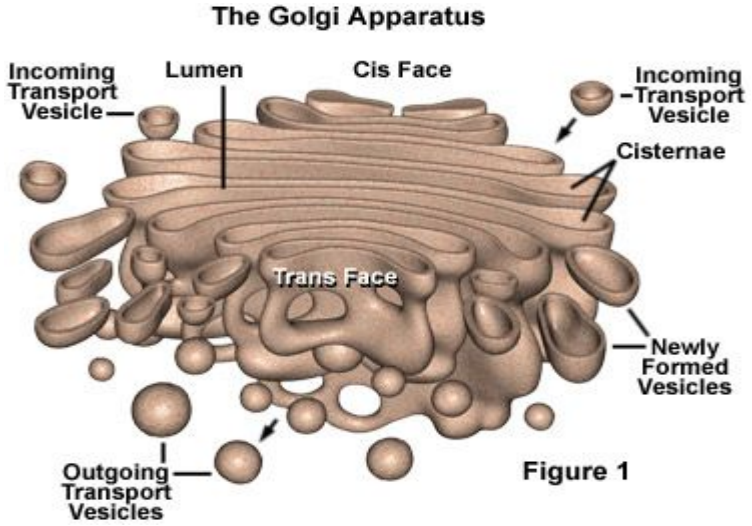
- rough appearance, which is due to the ribosomes attached to its outer surface.
- Rough ER lies immediately adjacent to the cell nucleus, and its membrane is continuous with the outer membrane of the nuclear envelope
- Proteins synthesized by the rough ER have specific final destinations. Some proteins remain within the ER, others are sent to the Golgi apparatus

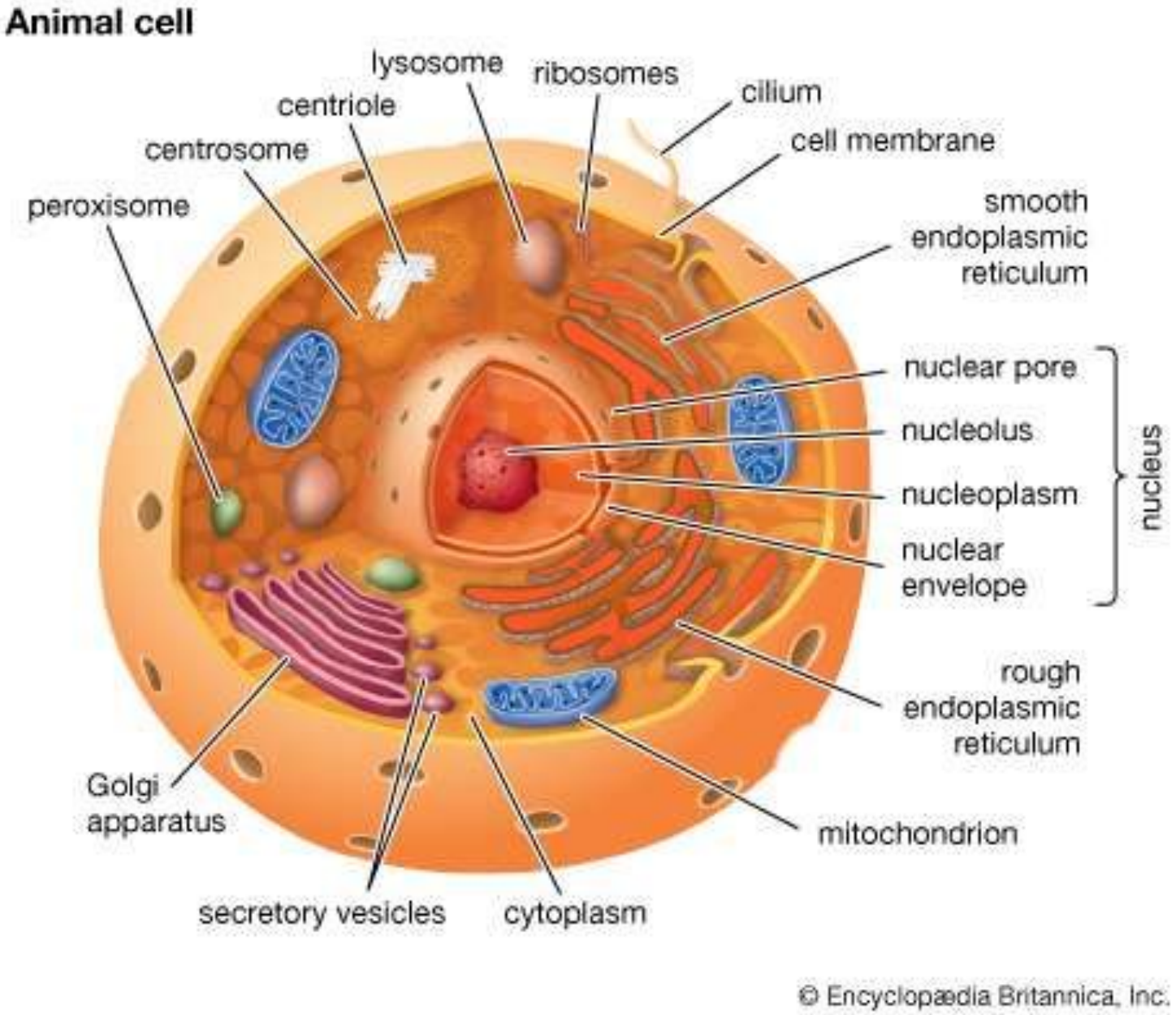
Smooth Endoplasmic Reticulum

- not associated with ribosomes, and its functions differ
- Involved in the synthesis of lipids, including cholesterol and phospholipids, which are used in the production of new cellular membrane
- In certain cell types, smooth ER plays an important role in the synthesis of steroid hormones from cholesterol. In cells of the liver, it contributes to the detoxification of drugs and harmful chemicals. The sarcoplasmic reticulum is a specialized type of smooth ER that regulates the calcium ion concentration in the cytoplasm of striated muscle cells

Golgi Complex

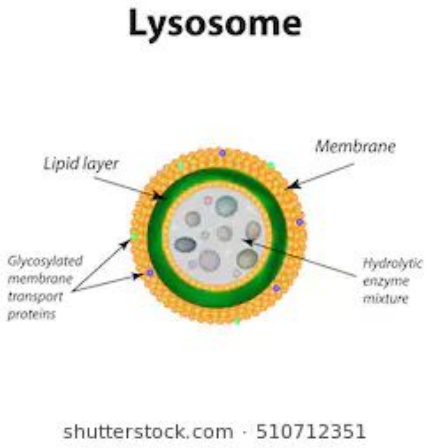
- Consists of 3–20 flattened, membranous sacs called cisternae.
- Functions
  - Modify, sort, and package proteins for transport to different destinations.
- Proteins are transported by various vesicles




Animal cell
lysosome
ribosomes
cilium
centriole
centrosome
cell membrane
peroxisome
smooth endoplasmic reticulum
nuclear pore
nucleolus
nucleoplasm
nuclear envelope
nucleus
rough endoplasmic reticulum
Golgi apparatus
mitochondrion
secretory vesicles
cytoplasm
© Encyclopædia Britannica, Inc.

Lysosomes

- Lysosomes - vesicles that form from the Golgi complex and contain powerful digestive enzymes
- Lysosomes are also in charge of cellular homeostasis, plasma membrane repair, cell signaling, and energy metabolism
- Actively related to maintaining health and fighting diseases in their host organisms
- Lysosomes can vary greatly in size



Peroxisomes & Proteasomes

- Peroxisomes
  - Smaller than lysosomes
  - Detoxify several toxic substances such as alcohol
  - Abundant in the liver
- Proteasomes
  - Continuously destroy unneeded, damaged, or faulty proteins
  - Found in the cytosol and the nucleus

PEROXISOME

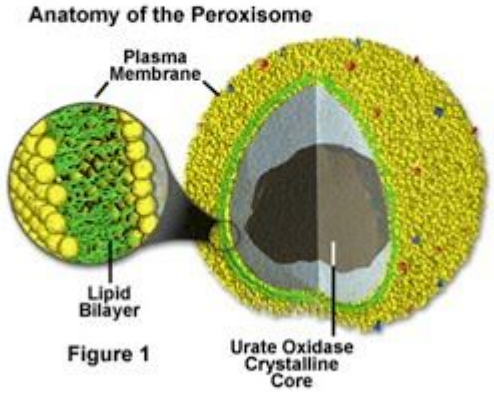
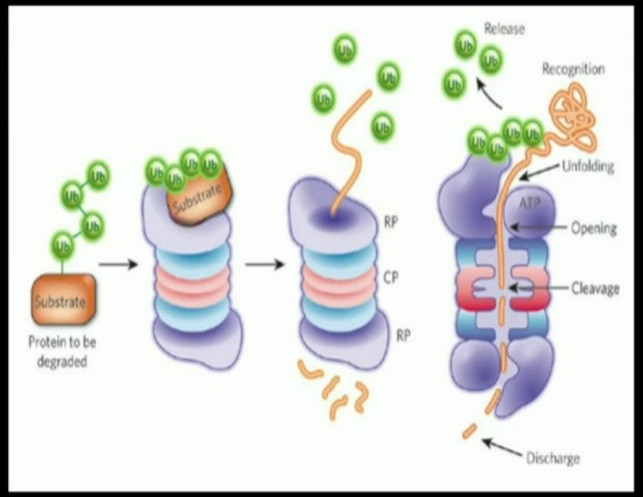


Figure 1

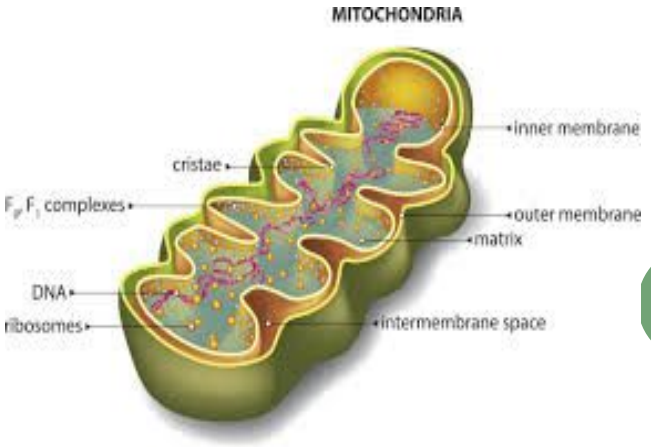
Proteasome Functions



Mitochondria

the “powerhouses” of the cell

- Generate ATP
- More prevalent in physiologically active cells: muscles, liver and kidneys
- Have inner and outer mitochondrial membranes similar in structure to the plasma membrane
- Self-replicate during times of increased cellular demand or before cell division
- Contain own DNA



Nucleus

- Spherical or oval shaped structure
- Usually most prominent feature of a cell
- Nuclear envelope - a double membrane that separates the nucleus from the cytoplasm
- Nuclear pores - numerous openings in the nuclear envelope, control movement of substances between nucleus and cytoplasm
- Nucleolus - spherical body that produces ribosomes
- Genes - the cell's hereditary units, control activities and structure of the cell
- Chromosomes - long molecules of DNA combined with protein molecules

Nucleus

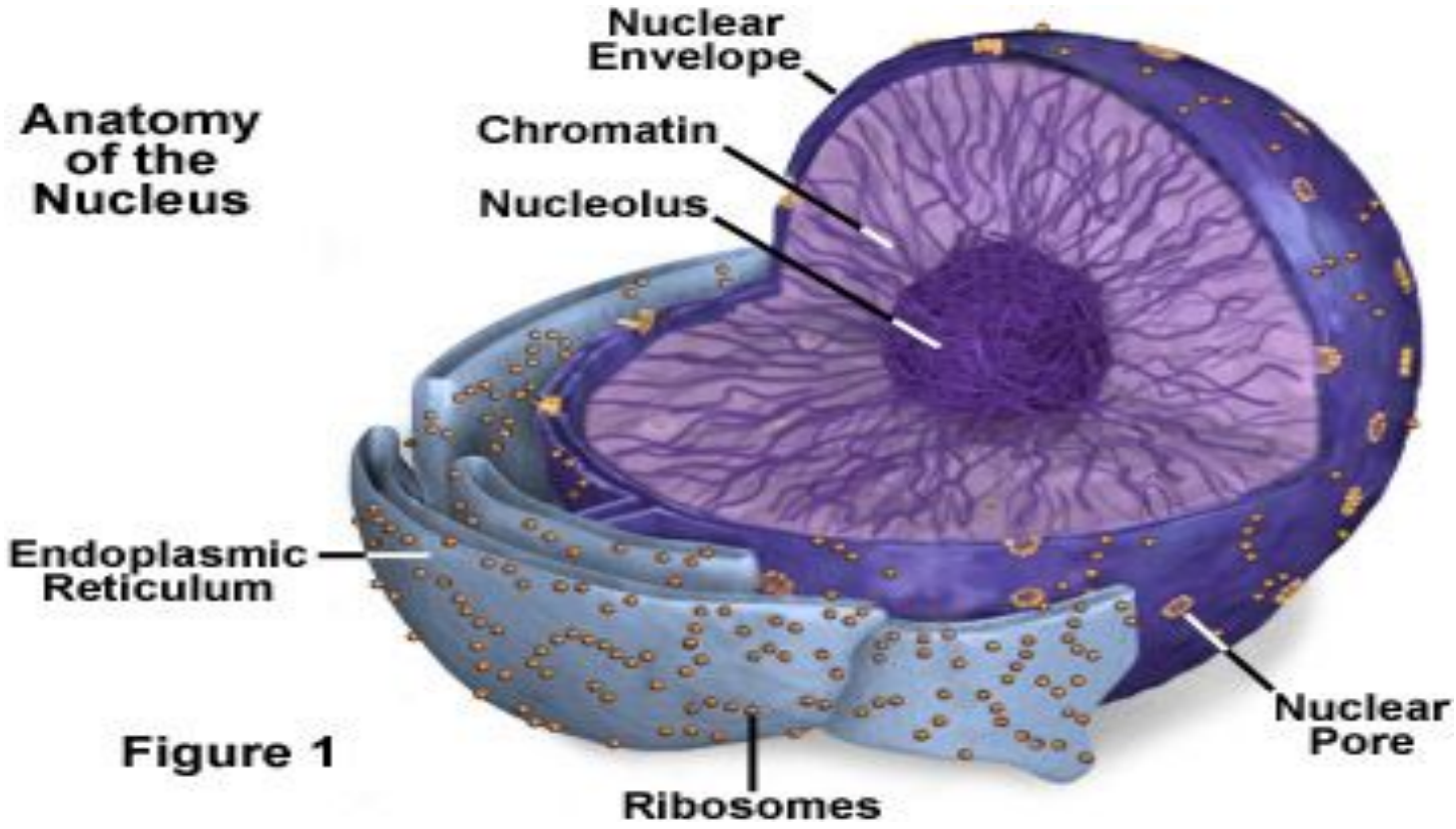


Figure 1

https://youtu.be/RKmaq7jPnYM

Protein Synthesis Review

https://youtu.be/oefAI2x2CQM

Somatic Cell Division

Mitosis

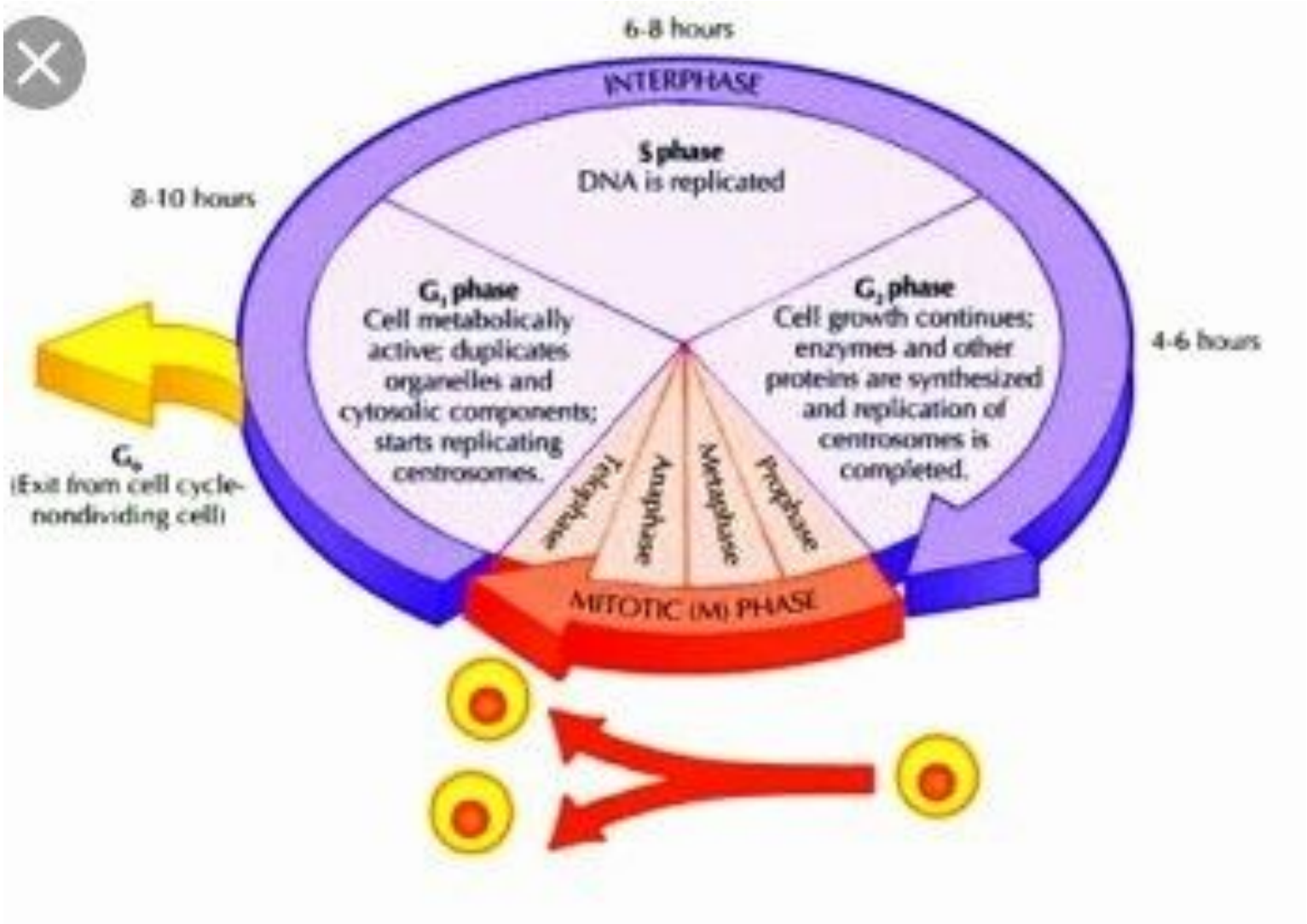
Somatic Cell Division

- The cell cycle is a sequence of events in which a body cell duplicates its contents and divides in two
- Human somatic cells contain 23 pairs of chromosomes (total = 46)
- The two chromosomes that make up each pair are called homologous chromosomes (homologs)
- Somatic cells (any cell of living organism other than reproductive cells) contain two sets of chromosomes and are called diploid cells

Interphase

- phase of the cell cycle in which a typical cell spends most of its life.
- 3 phase G1, S, G2
  - G1 occurs right after cells have divided. During G1,
  - S a cell copies its DNA. DNA replication is a massive effort that requires a lot of proteins. Since DNA does not exist by itself in a cell but is packaged by proteins, more packaging proteins must also be made during the S phase
  - G2 cell prepares to enter mitosis.

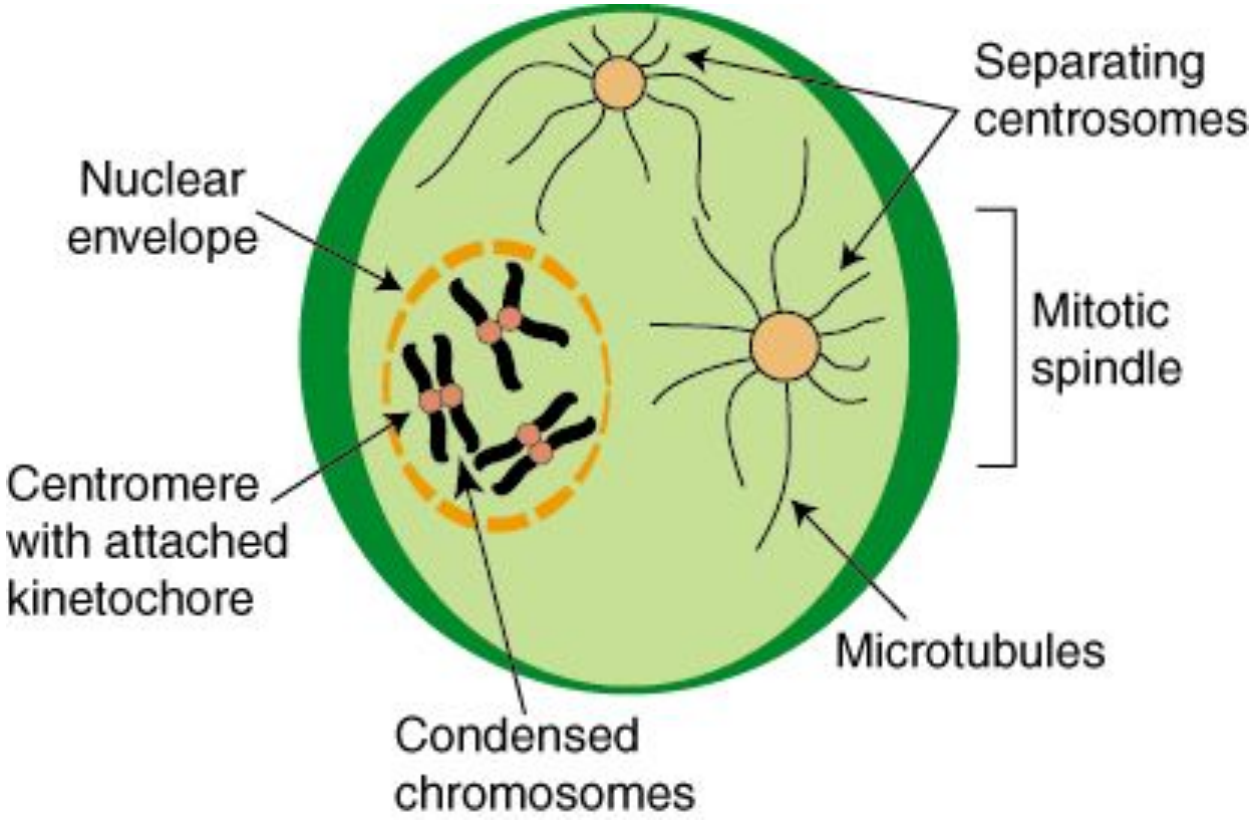
Phases of cell life



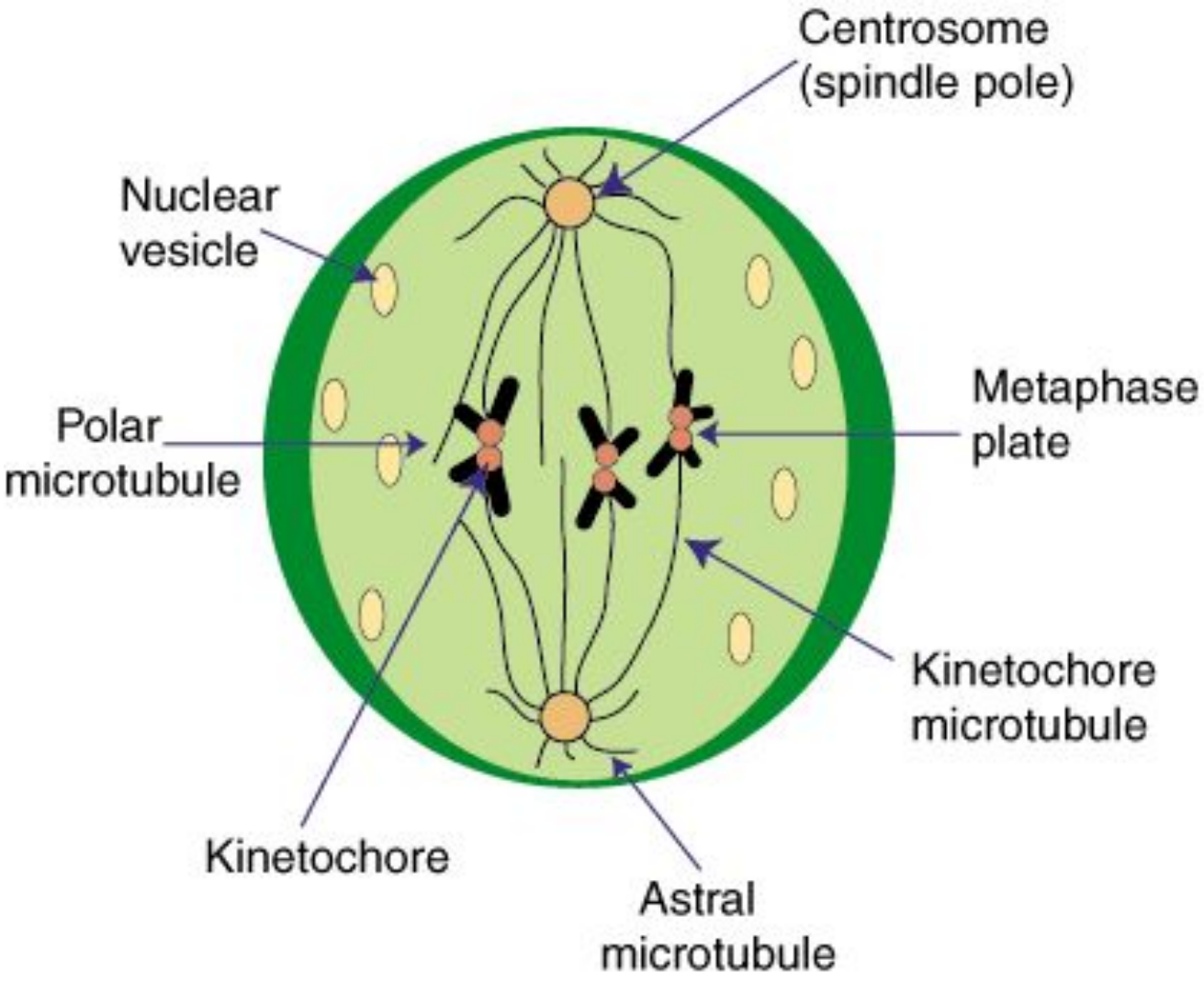
Nuclear Mitosis

- Mitotic phase - consists of a nuclear division (mitosis) and a cytoplasmic division (cytokinesis) to form two identical cells
- Nuclear Mitosis – 4 phases
  - Prophase - the chromatin fibers change into chromosomes.
  - Metaphase - microtubules align the centromeres of the chromatid pairs at the metaphase plate.
  - Anaphase - the chromatid pairs split at the centromere and move to opposite poles of the cell; the chromatids are now called chromosomes
  - Telophase - two identical nuclei are formed around the identical sets of chromosomes now in their chromatin form

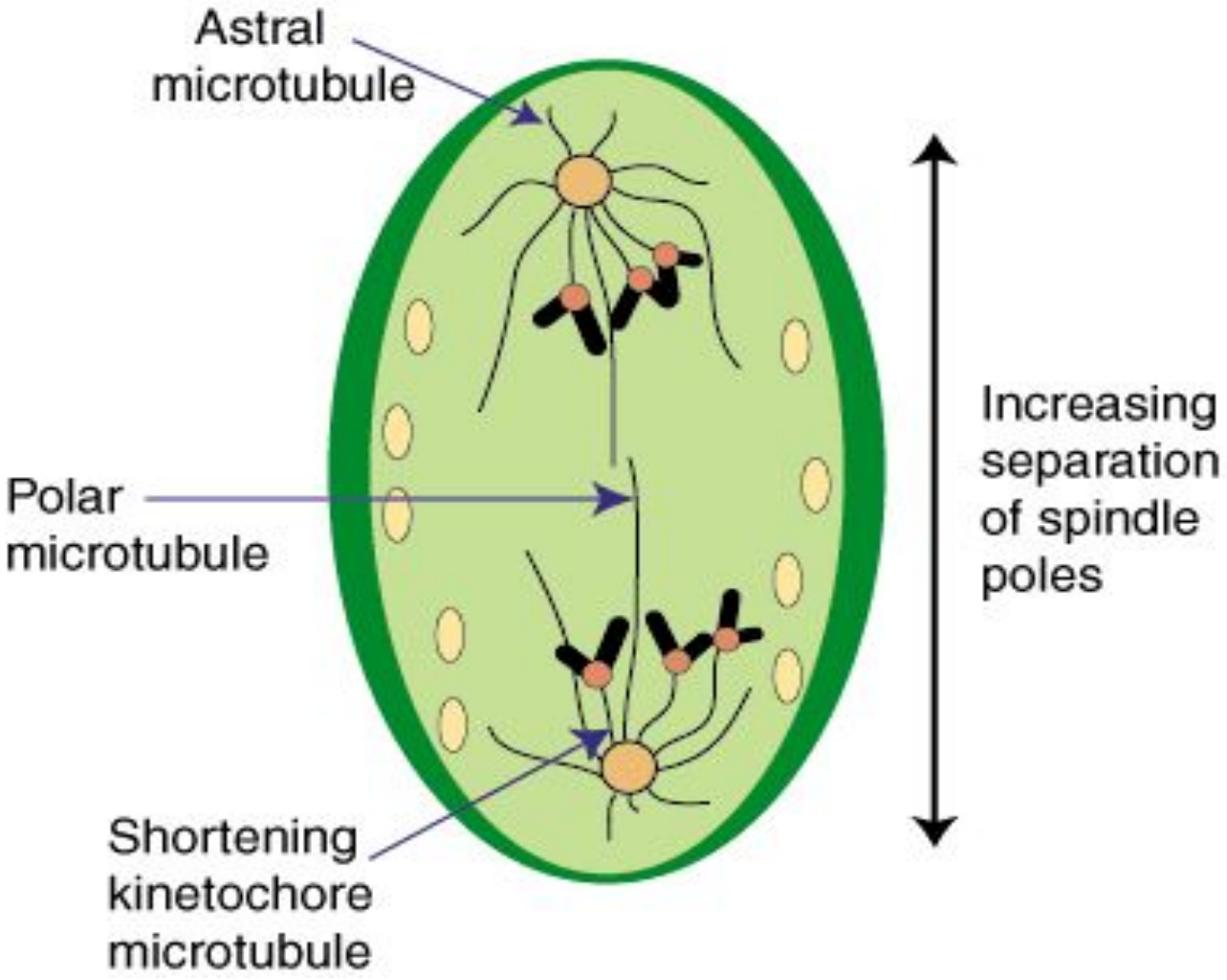
PROPHASE


Separating centrosomes
Nuclear envelope
Mitotic spindle
Centromere with attached kinetochore
Microtubules
Condensed chromosomes

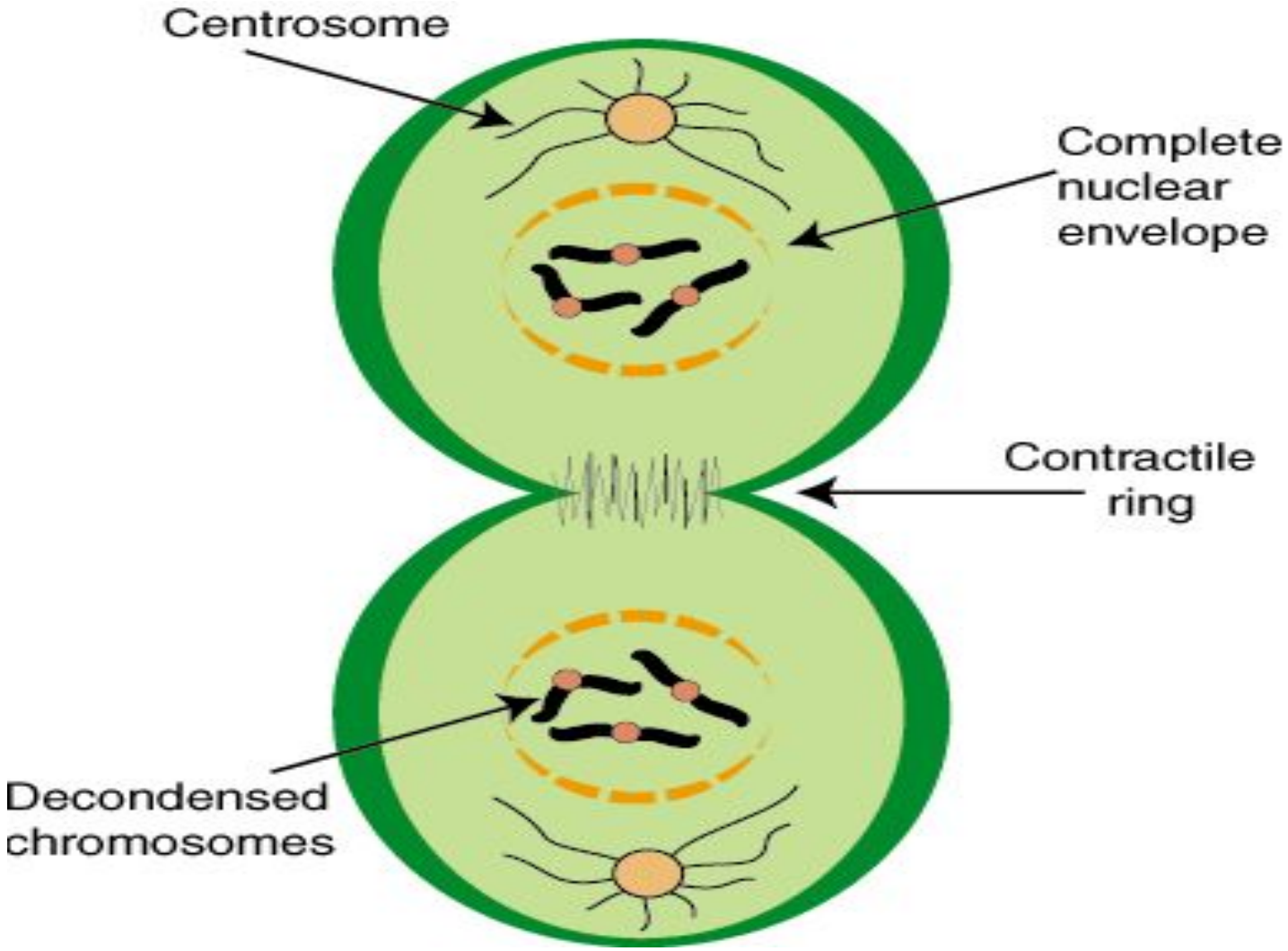
Metaphase


Centrosome
(spindle pole)
Nuclear
vesicle
Polar
microtubule
Metaphase
plate
Kinetochore
microtubule
Kinetochore
Astral
microtubule

Anaphase


Astral microtubule
Polar microtubule
Shortening kinetochore microtubule
Increasing separation of spindle poles

Telephase

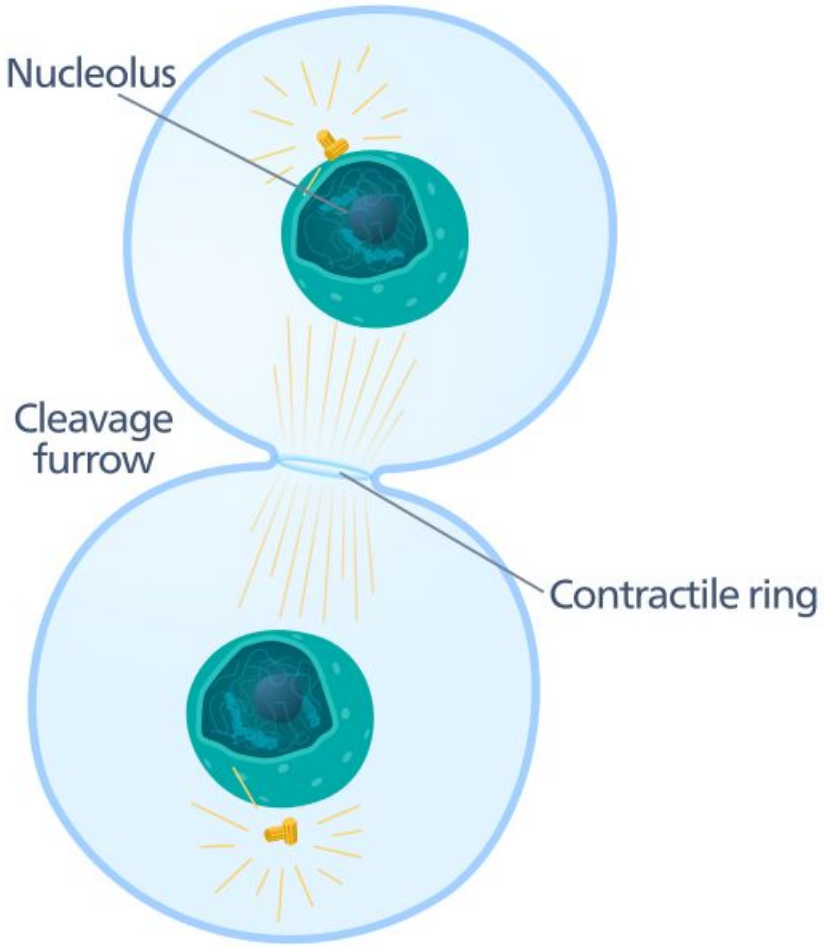

Centrosome
Complete nuclear envelope
Contractile ring
Decondensed chromosomes

Cytoplasmic Division - Cytokinesis

- Division of a cell's cytoplasm to form two identical cells
- Usually begins in late anaphase
- The plasma membrane constricts at its middle, forming a cleavage furrow
- The cell eventually splits into two daughter cells.
- Interphase begins when cytokinesis is complete

https://youtu.be/f-ldPgEfAHI

Cytokinesis



Reproductive Cell Division

- During sexual reproduction, each new organism is the result of the union of two gametes (fertilization), one from each parent.
- Meiosis - reproductive cell division that occurs in the gonads (ovaries and testes) that produces gametes with half the number of chromosomes.
- Haploid cells - gametes contain a single set of 23 chromosomes.
- Fertilization restores the diploid number of chromosomes (46).

Meiosis I and II

- Meiosis occurs in two successive stages: meiosis I and meiosis II .
- Each of these two stages has 4 phases: prophase, metaphase, anaphase, and telophase.
- Summary - Meiosis I begins with a diploid cell and ends with two cells having the haploid number of chromosomes; in Meiosis II, each of the two haploid cells divides, and the net result is four haploid gametes that are genetically different from the original diploid starting cell

https://youtu.be/VzDMG7ke69g

Cellular Diversity

- The average adult has nearly 100 trillion cells.
- There are about 200 different types of cells.
- Cells come in a variety of shapes and sizes.
- Cellular diversity permits organization of cells into more complex tissues and organs