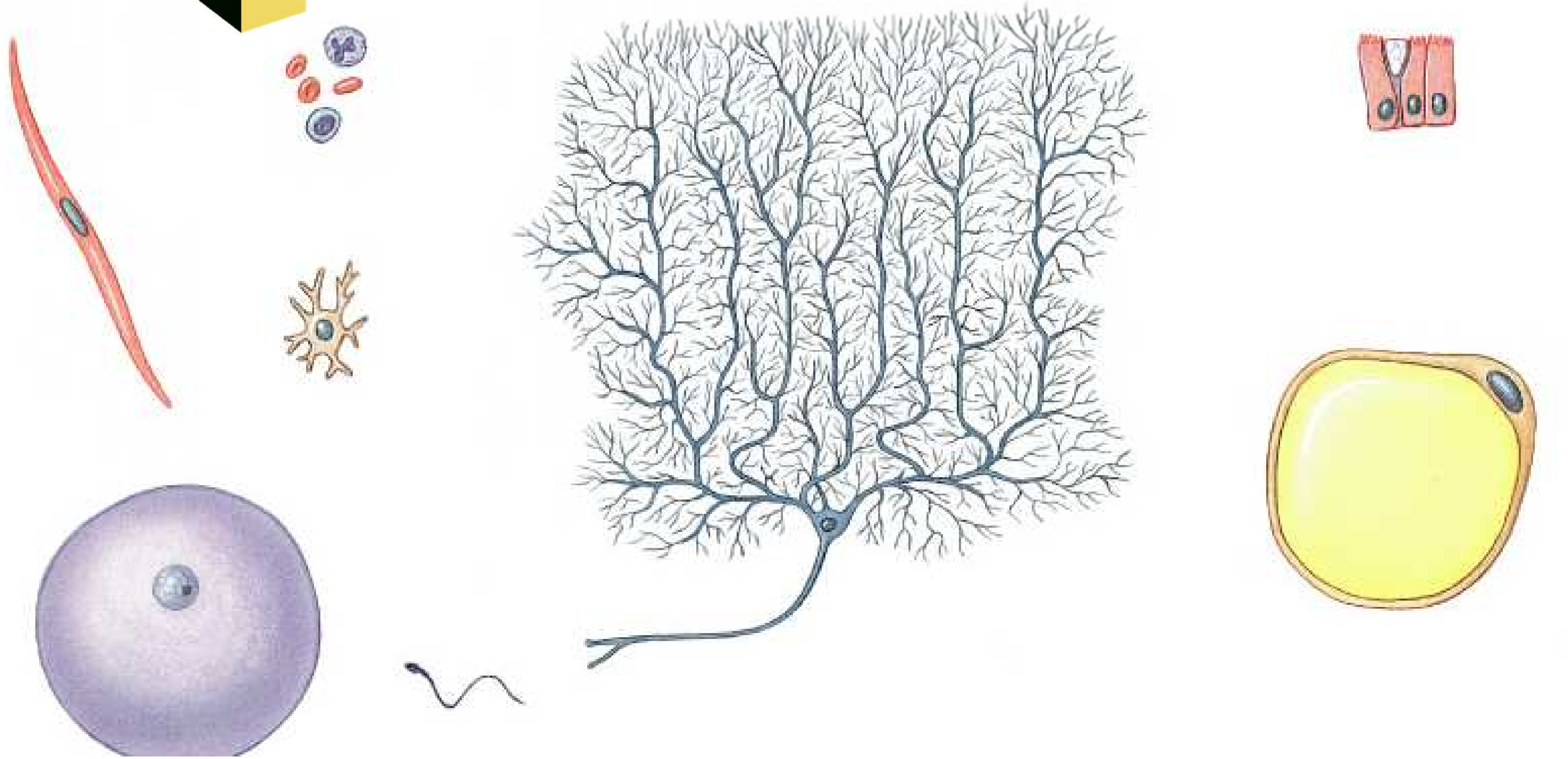
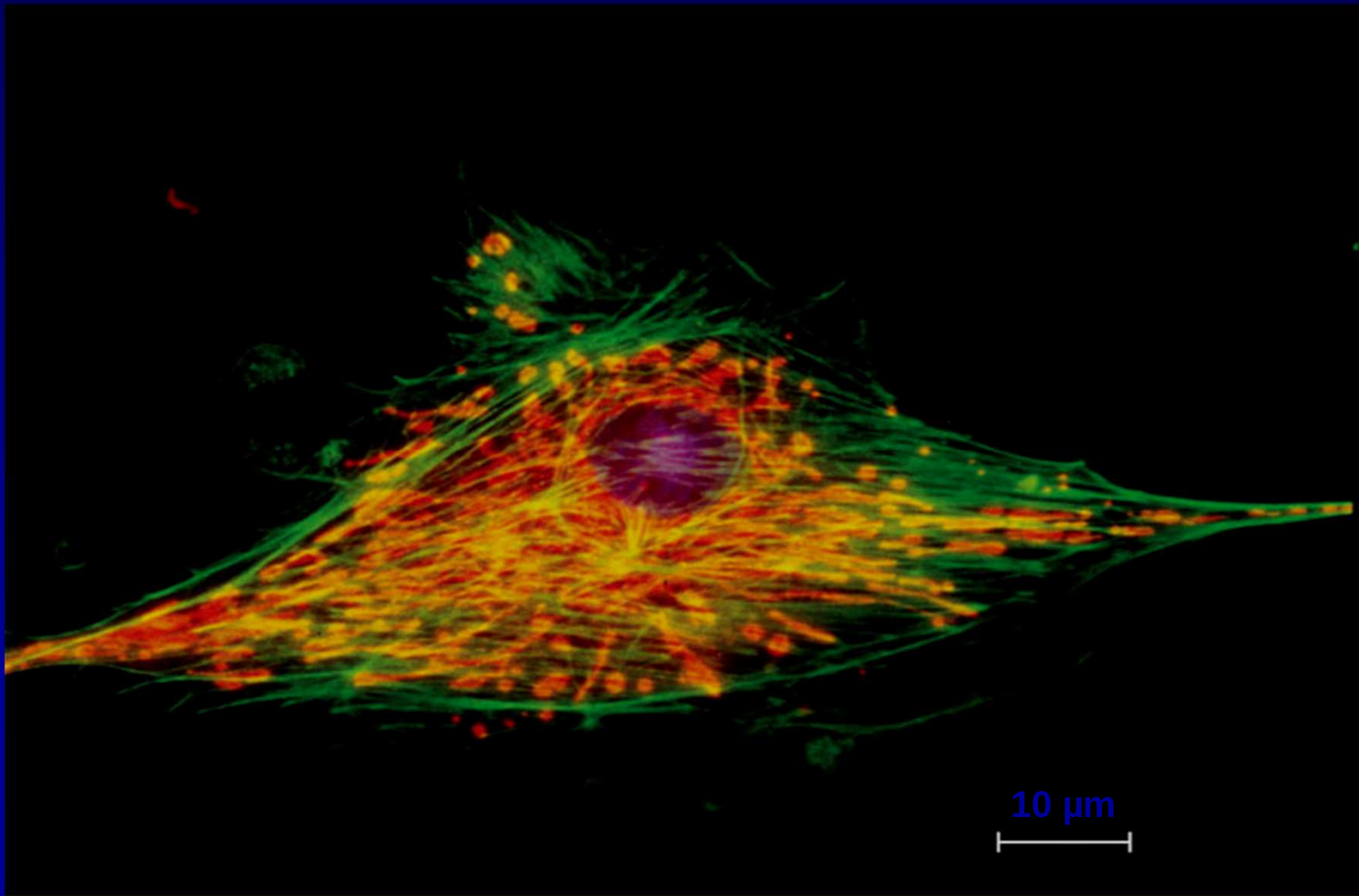
The Cell



Overview:
The Importance of Cells

- All organisms are made of cells
- The cell is the simplest collection of matter that can live

Cell structure is correlated to cellular function



Concept

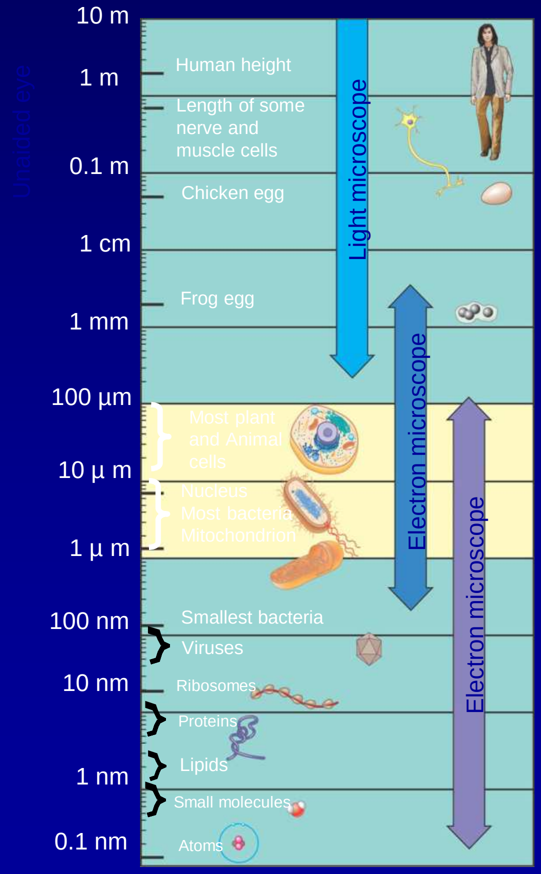
- To study cells, biologists use microscopes and the tools of biochemistry

Microscopy

- Scientists use microscopes to visualize cells that are too small with the naked eye
- **Light microscopes (LM.s)**
  - Pass visible light through a specimen
  - Magnify cellular structures with lenses
- **Electron microscopes (EM.s)**
  - Focus a beam of electrons through a specimen (TEM) or onto its surface (SEM)

Different types of microscopes

- Can be used to visualize different sized cellular structures



Measurements

1 centimeter (cm) = 10^{-2} meter (m) = 0.4 inch

1 millimeter (mm) = 10^{-3} m

1 micrometer (µm) = 10^{-3} mm = 10^{-6} m

1 nanometer (nm) = 10^{-3} mm = 10^{-9} m

Concept

Eukaryotic cells have internal membranes that compartmentalize their functions

_ Two types of cells make up every organism

- – Prokaryotic
- – Eukaryotic

Comparing Prokaryotic and Eukaryotic Cells

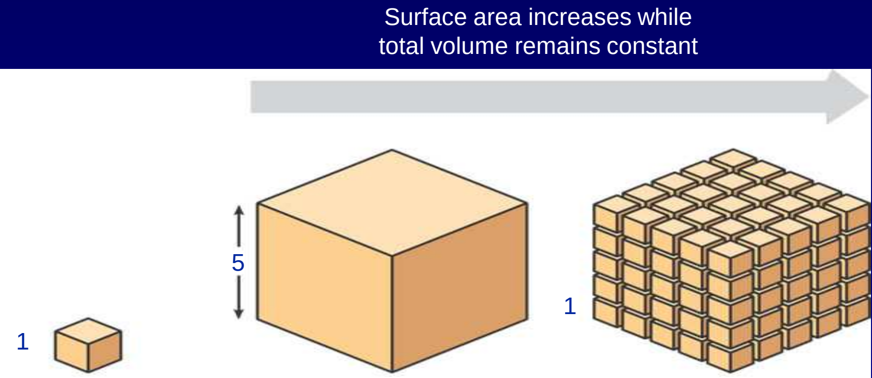
- All cells have several basic features in common
  - They are bounded by a plasma membrane They contain a semi-fluid substance called the cytosol
  - They contain chromosomes
  - They all have ribosomes

- Eukaryotic cells
  - Contain a true nucleus, bounded by a membranous nuclear envelope
  - Are generally quite a bit bigger than prokaryotic cells
  - The logistics of carrying out cellular metabolism sets limits on the size of cells
  - Have extensive and elaborately arranged internal membranes, which form organelles

- Prokaryotic cells
  - Do not contain a nucleus
  - Have their DNA located in a region called the nucleoid

A smaller cell

Has a higher surface to volume ratio, which facilitates the exchange of materials into and out of the cell



Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-to-volume ratio (surface area ÷ volume)	6	12	6

Key Points:

1. Structure (and importance) of cell membrane
2. Structure (and function) of organelles
3. Interconnections between cells to maintain structural stability in body tissues.

Anatomy of a typical cell

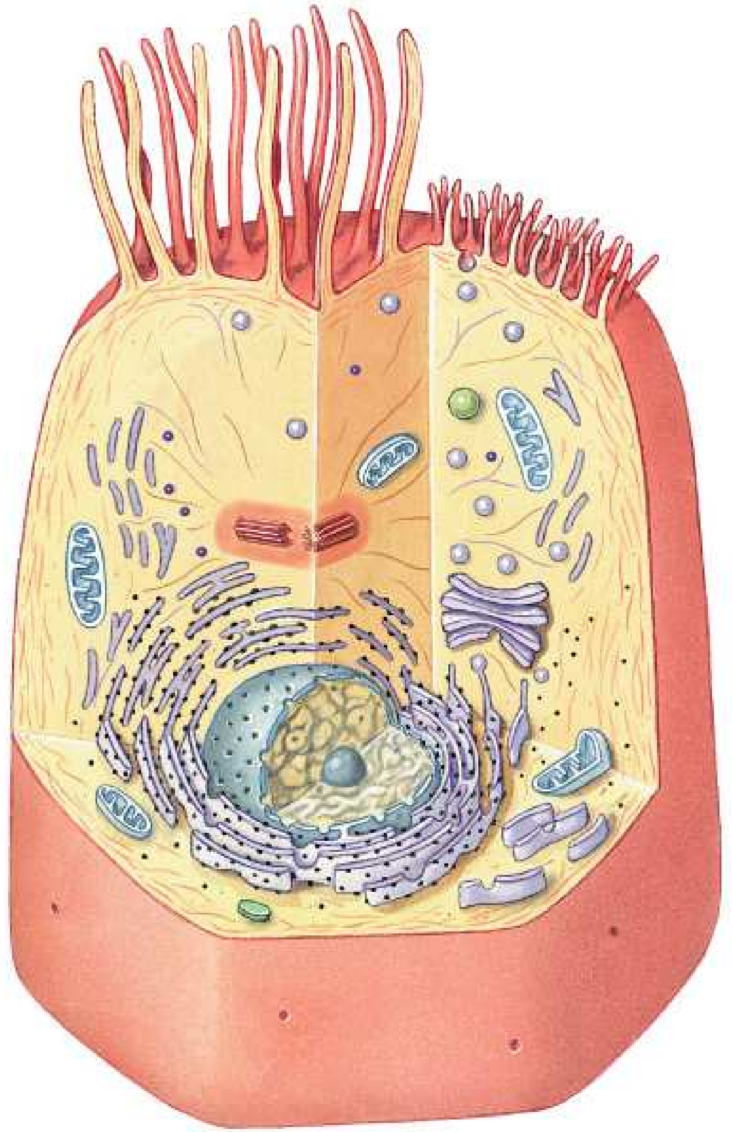
1. **Cell membrane**

2. **Cytoplasm**

cytosol

non-membranous organelles

membranous organelles



Cytology – science about structure, function and development of cells and noncelllular structures

Cell – limited by active membrane structuraly arenged system of bipolimers, which form nucleus and cytoplasm, take part in metabolism, protection and renewal cells as system

Components of cell: cell membrane, cytoplasm and nucleus

Noncellular structure

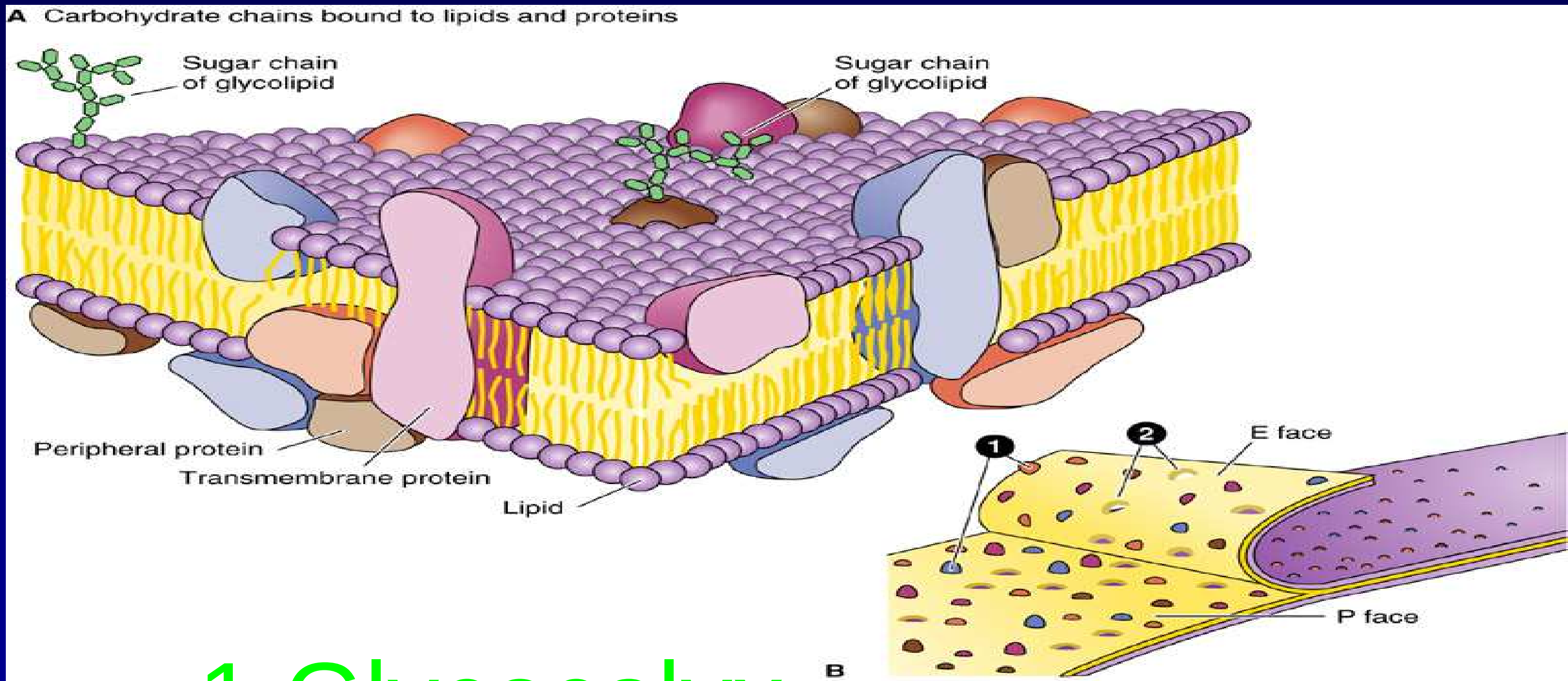
_ Nucleated:

- symplast (sceletal muscular fibers)
- syncytium (spermatogenesis, ovogenesis)

_ Nonnucleated:

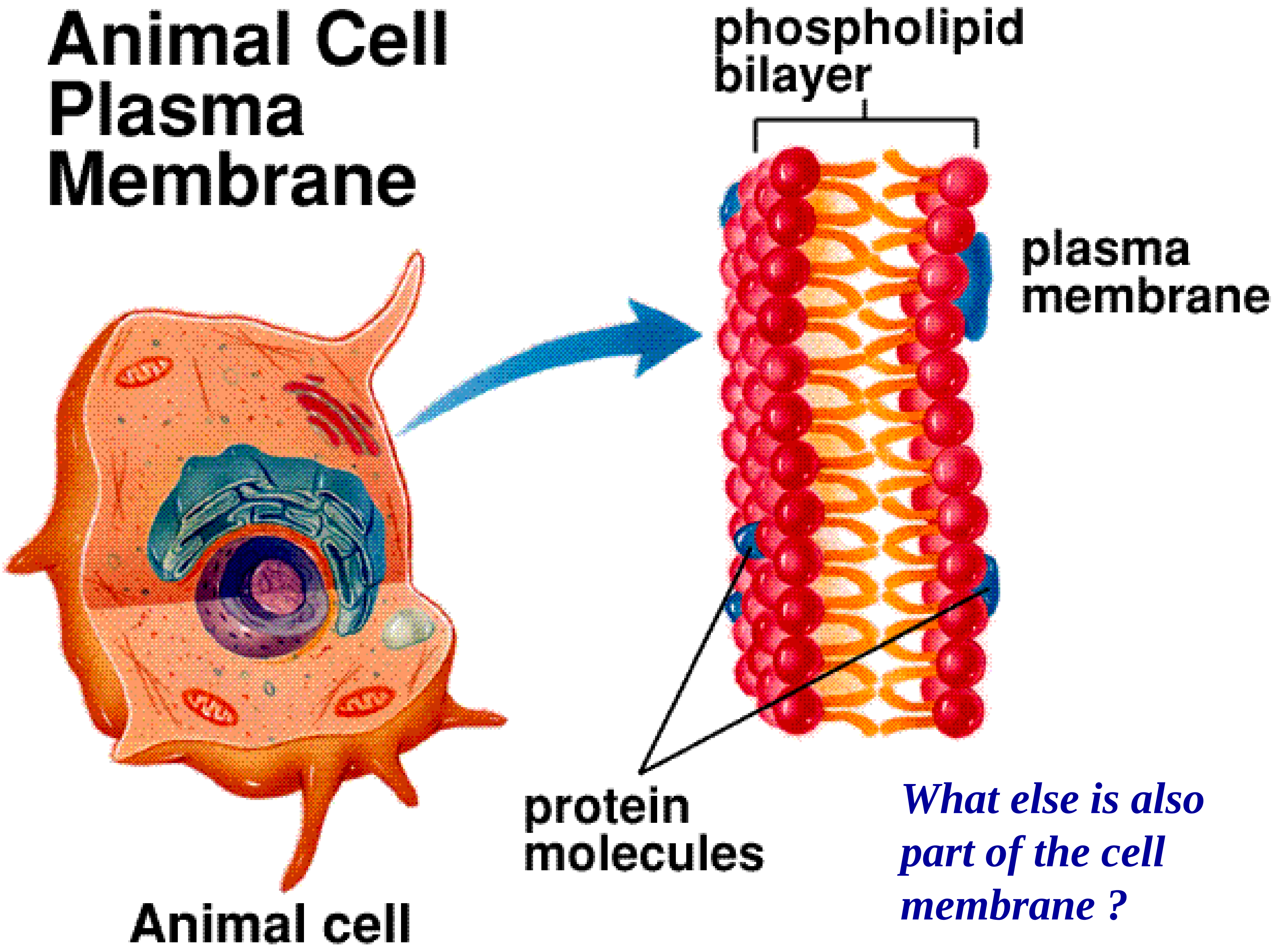
- Extracellular matrix
- Erythrocytes and platelates

Fluid-mosaic structure of the cell membrane



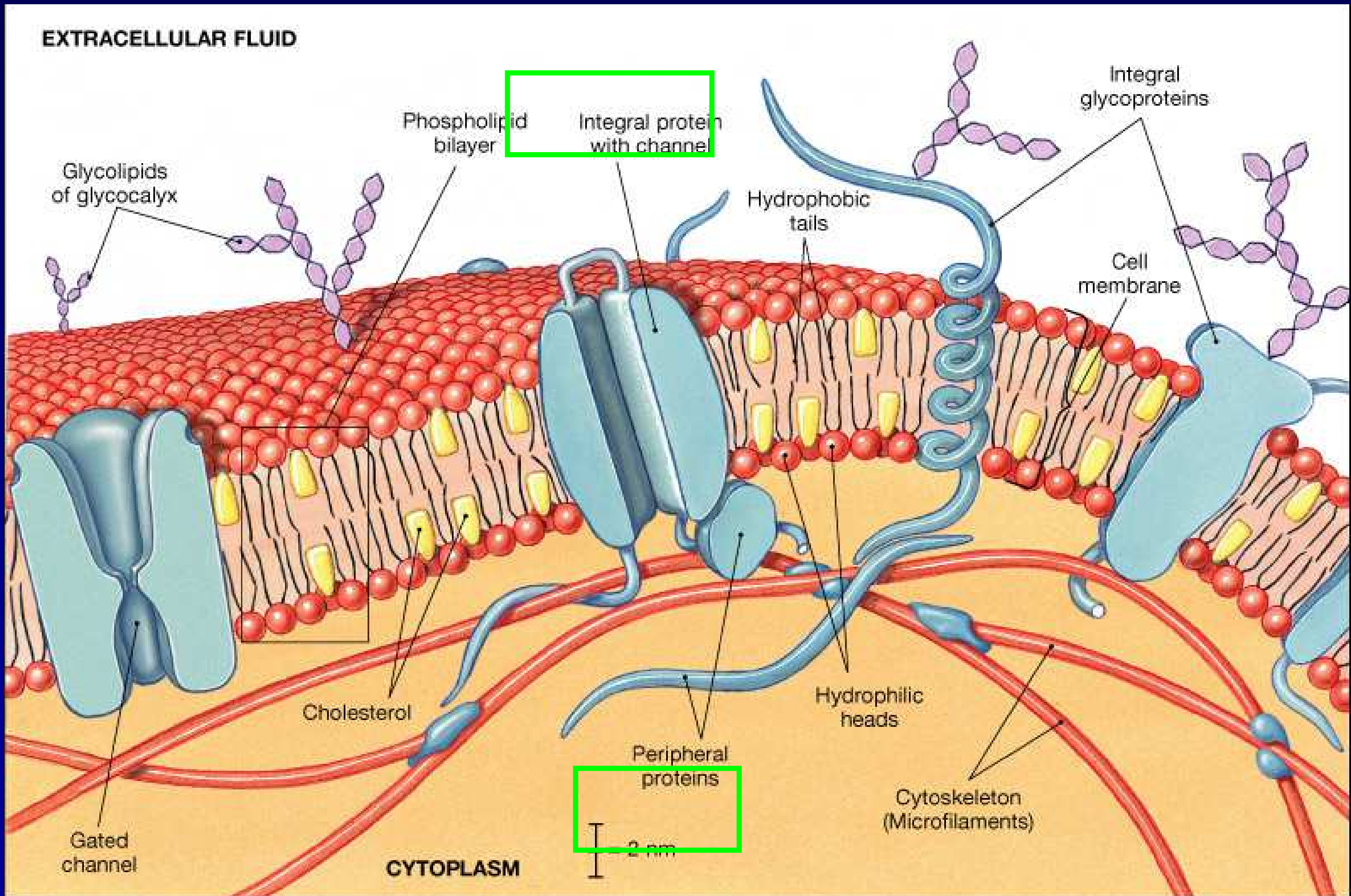
1.Glycocalyx
2. Bilipid layer
3. Cortical layer

Animal Cell Plasma Membrane

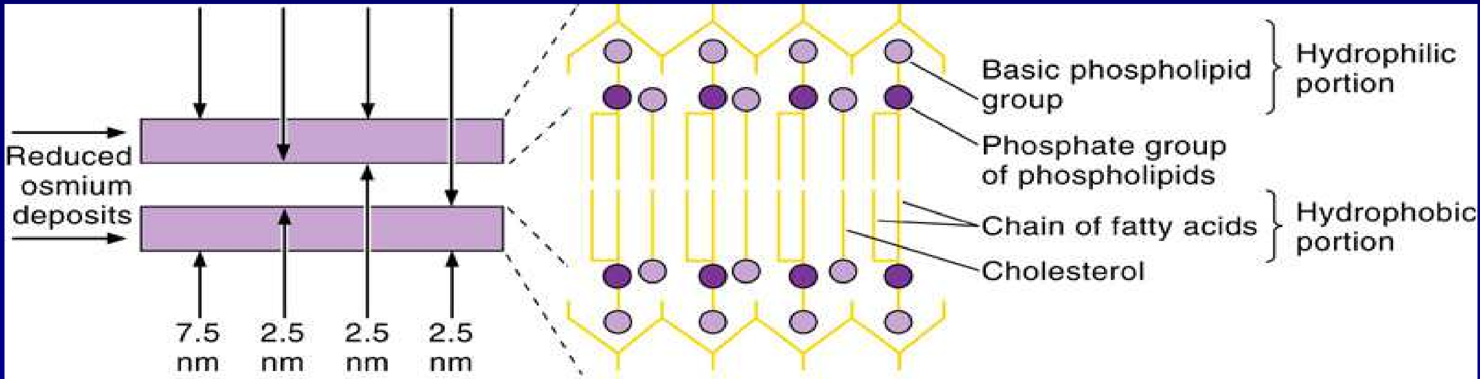


What else is also part of the cell membrane ?

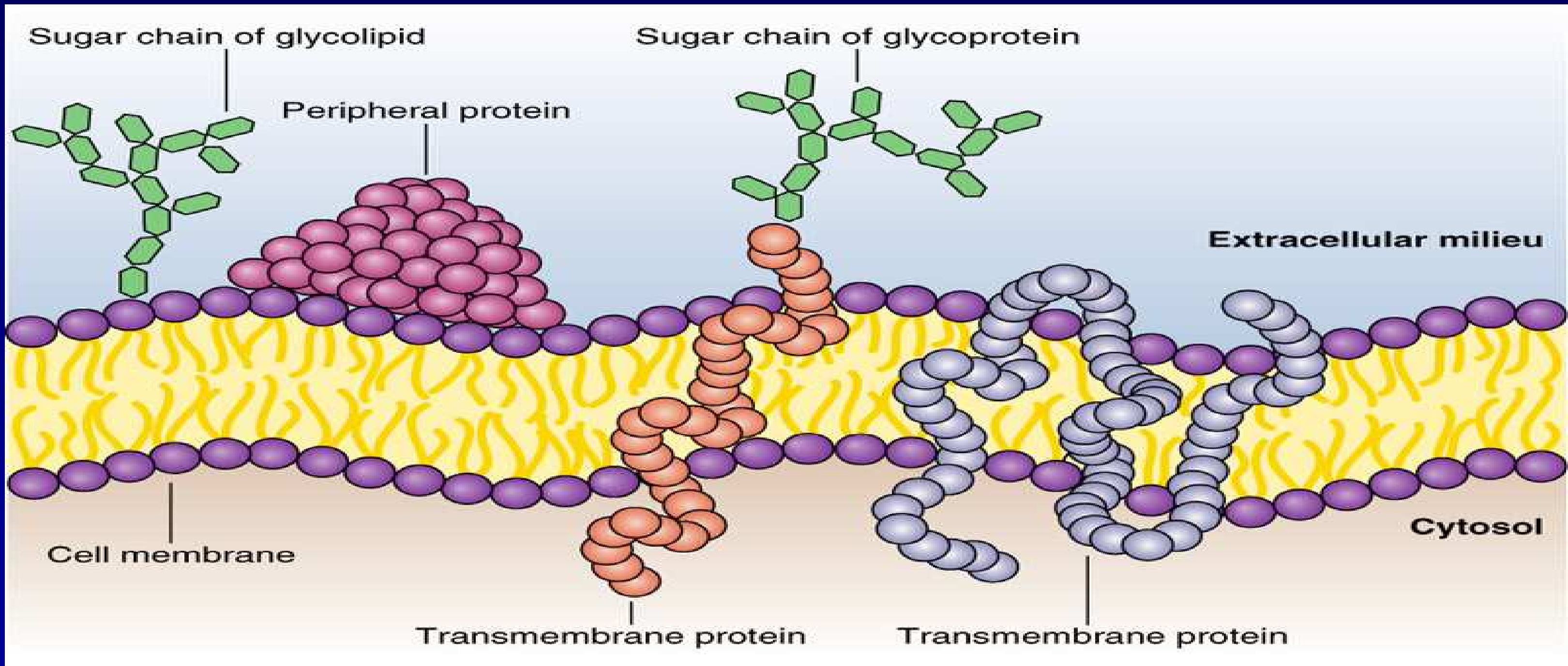
Cell membrane (plasma membrane, plasmalemma)



Cell membrane scheme



Cell membrane proteins



Functions of cell membrane

a) endocytosis:
- fagocytosis
- pinocytosis

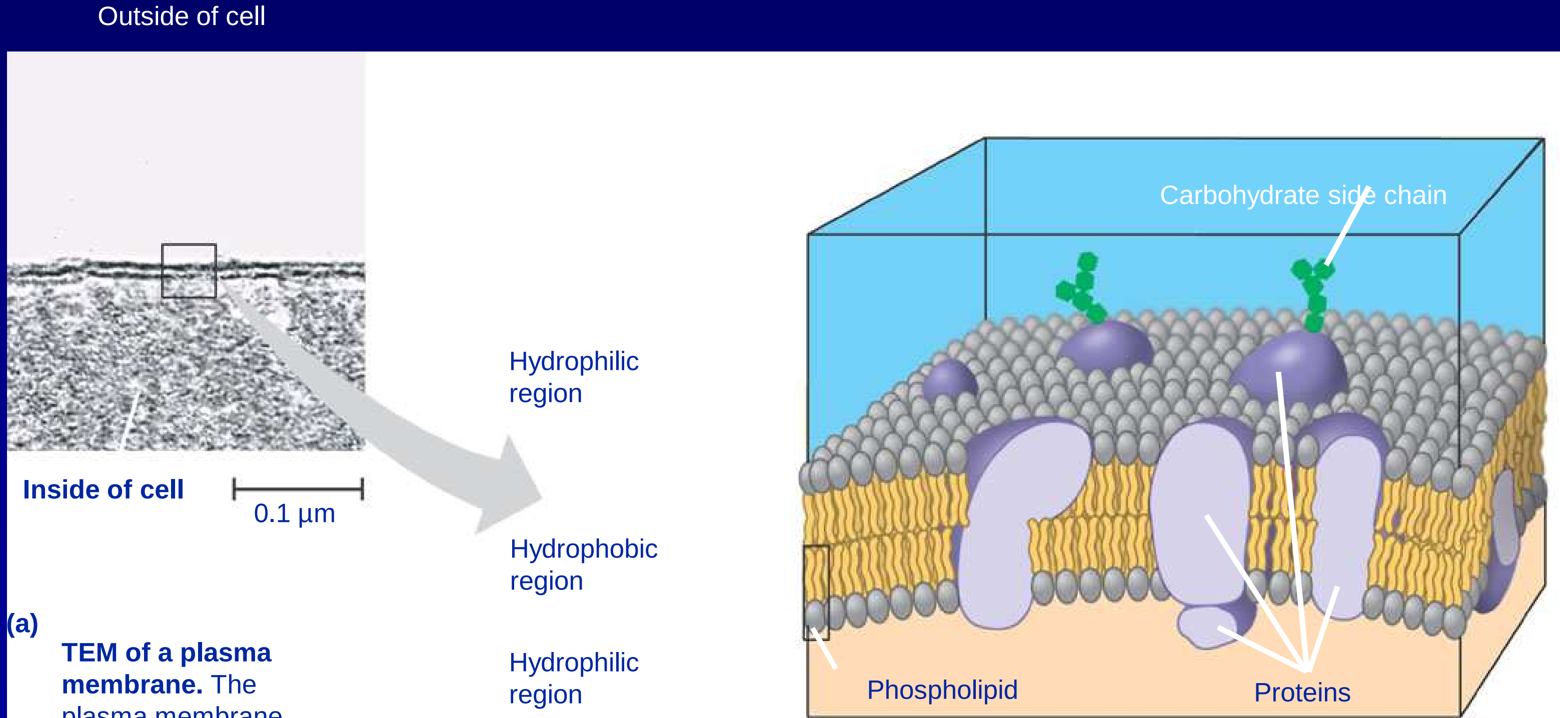
a) esocytosis:
- Secretion
- Excretion

2. Perimembrane metabolism
3. Cell reception
4. Junctions:

a) adhesive (tight, adherent),
b) isolated (desmosome, gap)
c) communicative (necsus, synapse)

The plasma membrane

- Functions as a selective barrier
- Allows sufficient passage of nutrients and waste



(a) **TEM of a plasma membrane.** The plasma membrane, here in a red blood cell, appears as a pair of dark bands separated by a light band.

(b) Structure of the plasma membrane

Concept

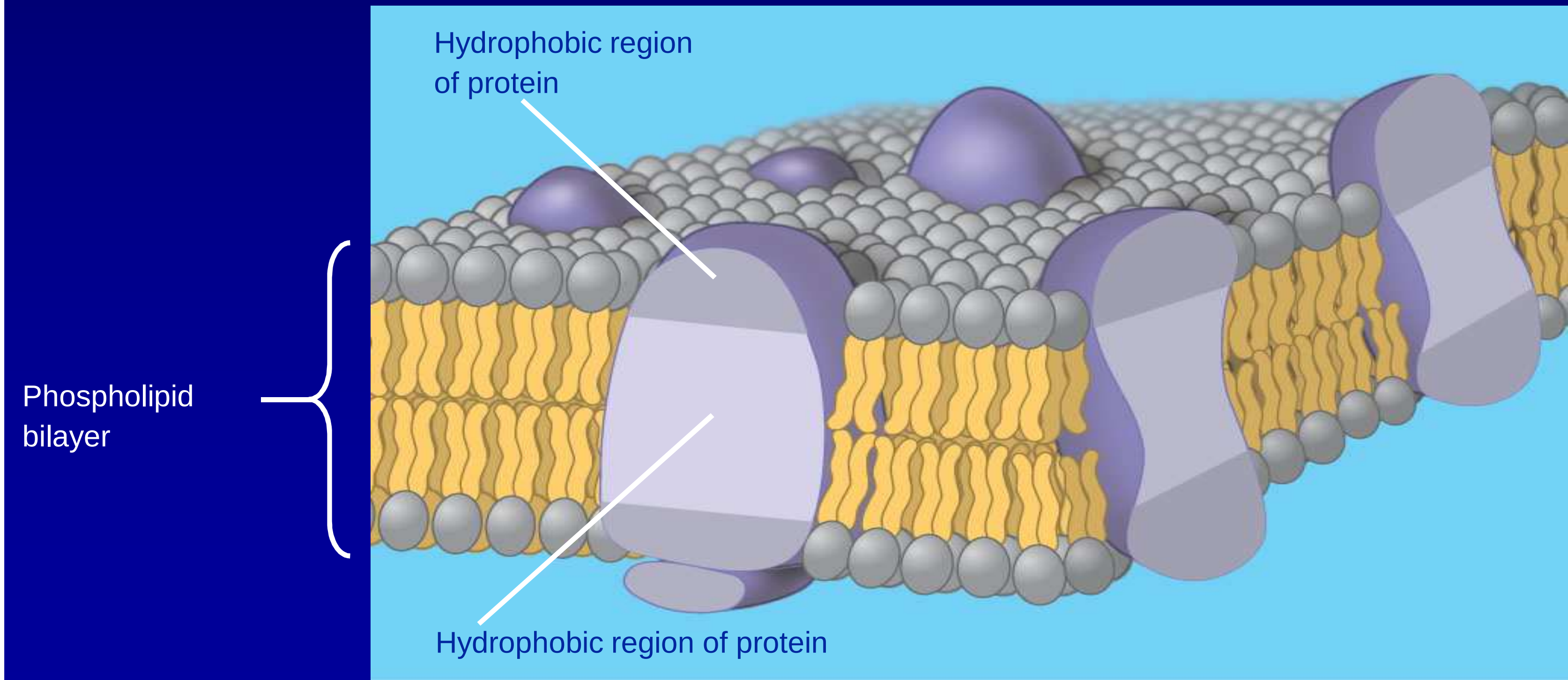
- Cellular membranes are fluid mosaics of lipids and proteins
- Phospholipids
  - Are the most abundant lipid in the plasma membrane
  - Are amphipathic, containing both hydrophobic and hydrophilic regions

The Davson-Danielli sandwich model of membrane structure

- Stated that the membrane was made up of a phospho-lipid bi-layer sandwiched between two protein layers
- Was supported by electron microscope pictures of membranes

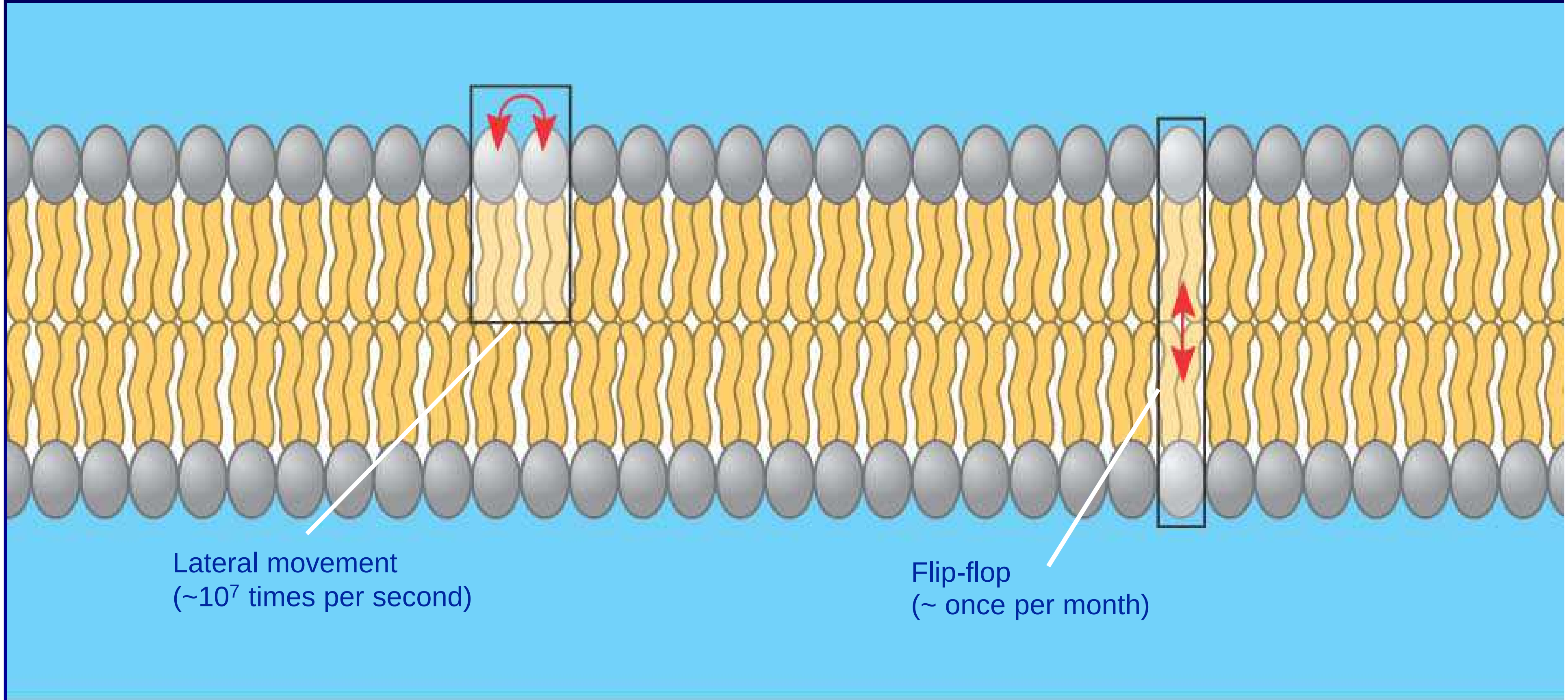
_ In 1972, Singer and Nicolson

– Proposed that membrane proteins are dispersed and individually inserted into the phospho-lipid bi-layer



The Fluidity of Membranes

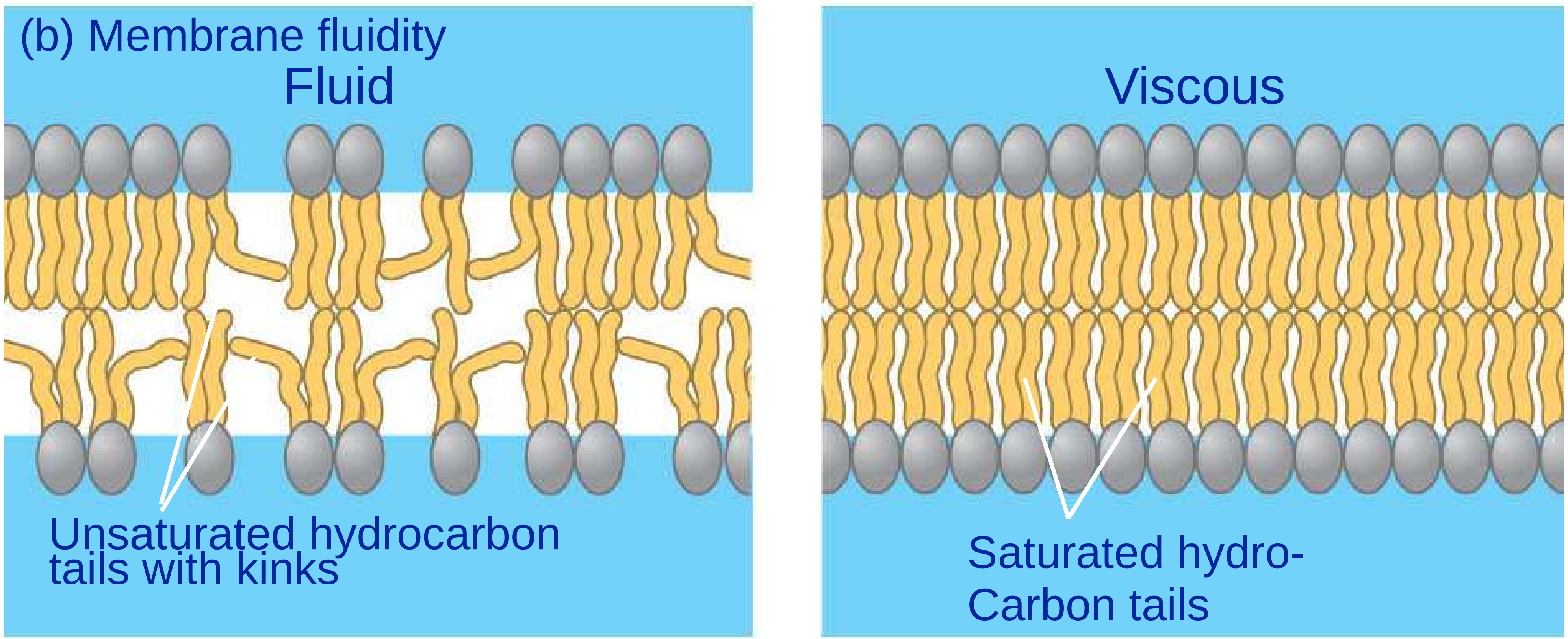
- Phospholipids in the plasma membrane
  - Can move within the bi-layer



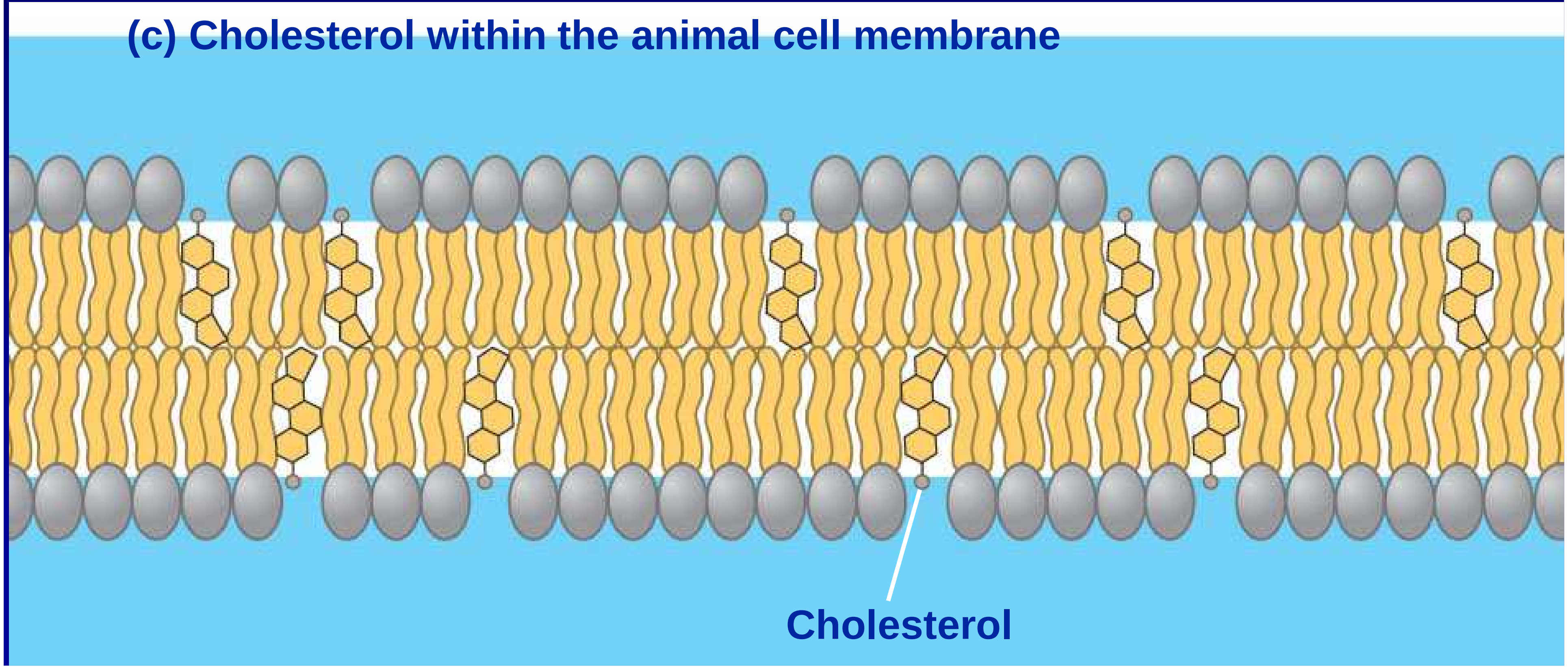
(a) Movement of phospholipids

– The type of hydrocarbon tails in phospholipids

- Affects the fluidity of the plasma membrane

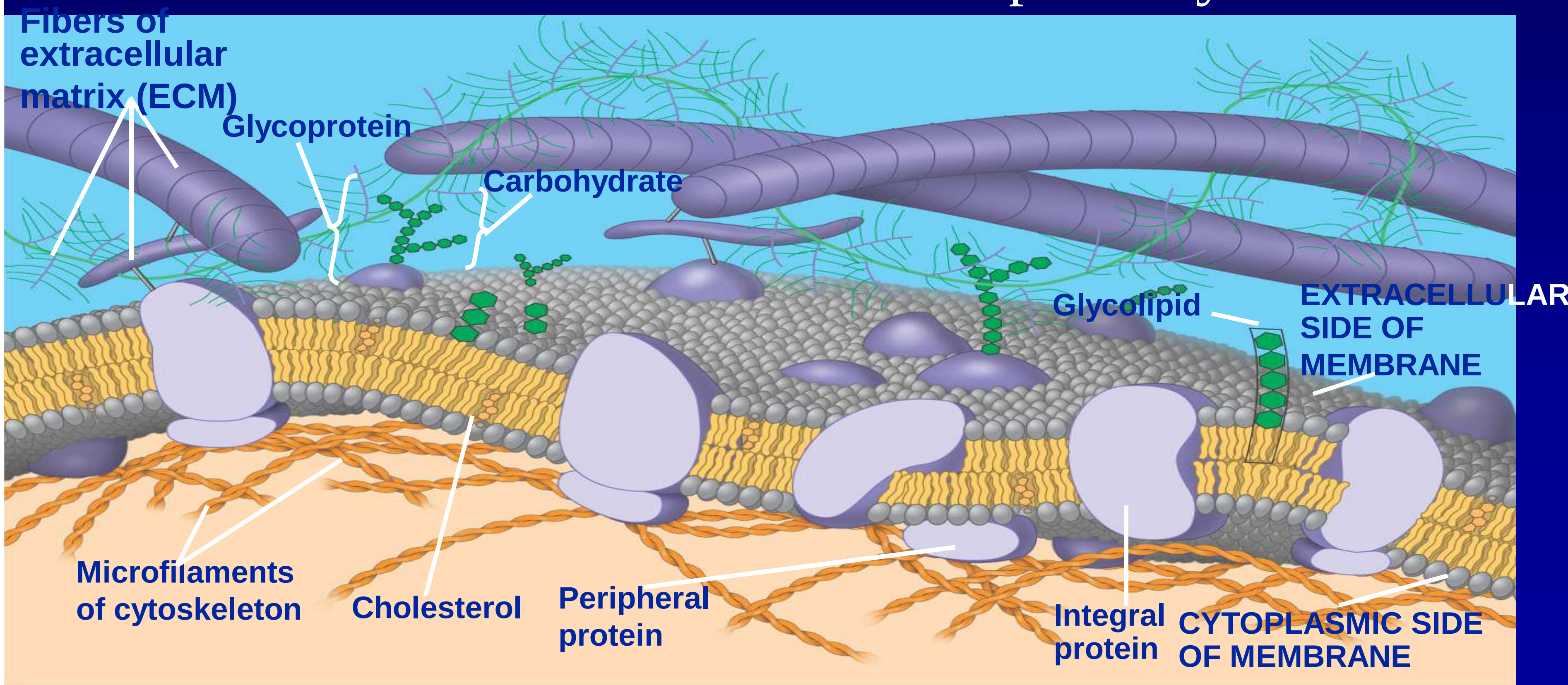


- The steroid cholesterol
  - Has different effects on membrane fluidity at different temperatures



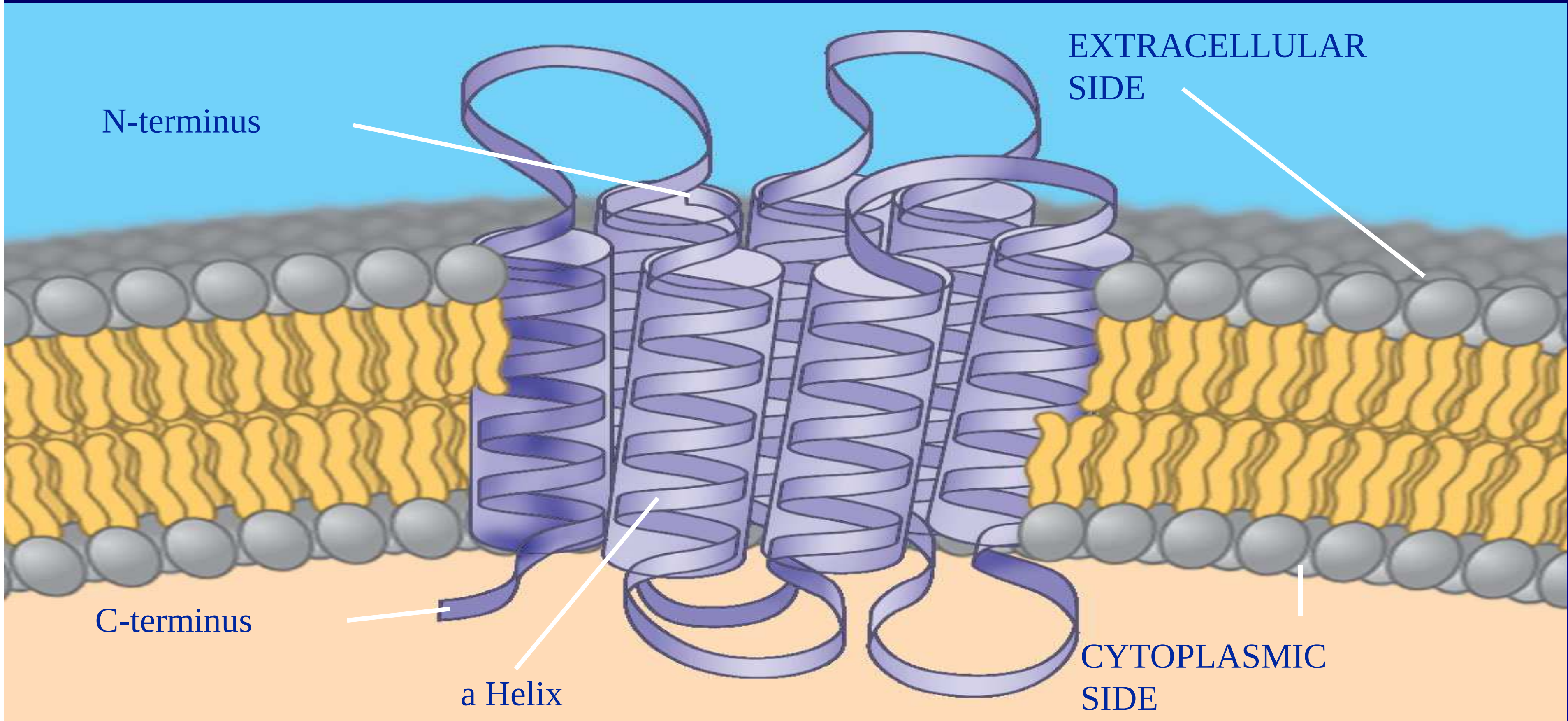
Membrane Proteins and Their Functions

- A membrane
  - Is a collage of different proteins embedded in the fluid matrix of the lipid bilayer



– Integral proteins

- Penetrate the hydrophobic core of the lipid bilayer
- Are often transmembrane proteins, completely spanning the membrane



Peripheral proteins

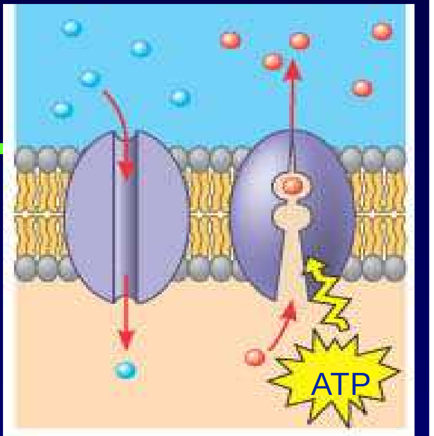
- Are appendages loosely bound to the surface of the membrane

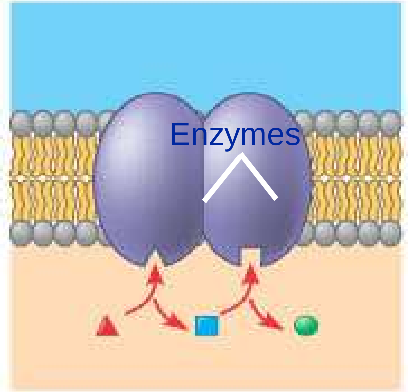
_ An overview of six major functions of membrane proteins

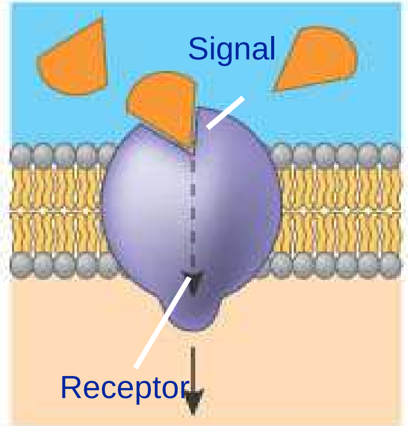
(a) Transport. (left) A protein that spans the membrane may provide a hydrophilic channel across the membrane that is selective for a particular solute. (right) Other transport proteins shuttle a substance from one side to the other by changing shape. Some of these proteins hydrolyze ATP as an energy ssource to actively pump substances across the membrane.

(b) Enzymatic activity. A protein built into the membrane may be an enzyme with its active site exposed to substances in the adjacent solution. In some cases, several enzymes in a membrane are organized as a team that carries out sequential steps of a metabolic pathway.

(c) Signal transduction. A membrane protein may have a binding site with a specific shape that fits the shape of a chemical messenger, such as a hormone. The external messenger (signal) may cause a conformational change in the protein (receptor) that relays the message to the inside of the cell.



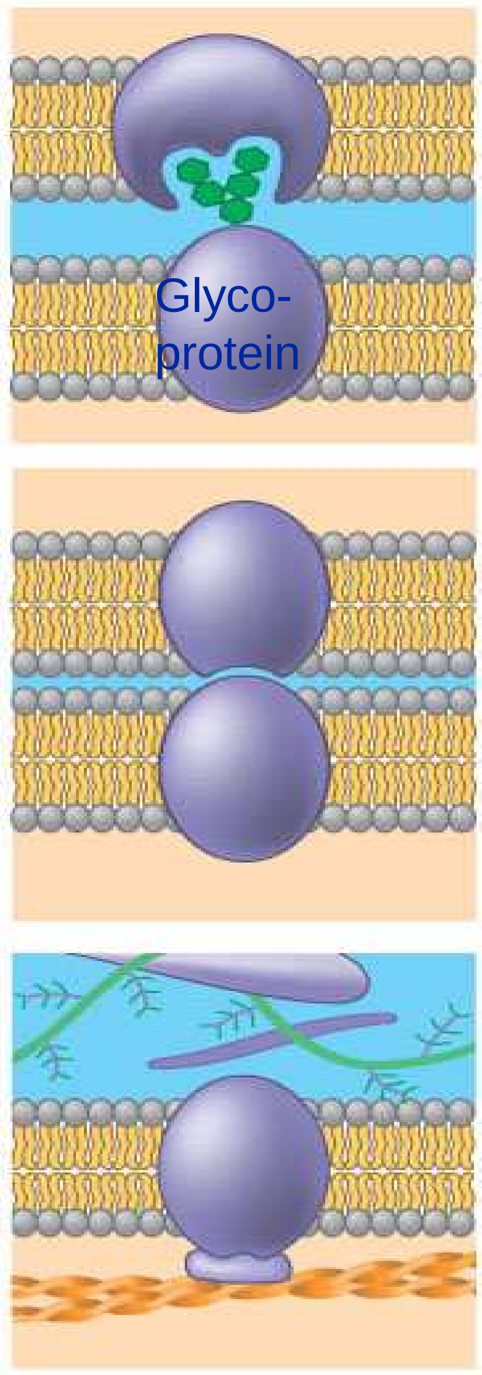




(d) Cell-cell recognition. Some glyco-proteins serve as identification tags that are specifically recognized by other cells.

(e) Intercellular joining. Membrane proteins of adjacent cells may hook together in various kinds of junctions, such as gap junctions or tight junctions

(f) Attachment to the cytoskeleton and extracellular matrix (ECM). Microfilaments or other elements of the cytoskeleton may be bonded to membrane proteins, a function that helps maintain cell shape and stabilizes the location of certain membrane proteins. Proteins that adhere to the ECM can coordinate extracellular and intracellular changes



The Role of Membrane Carbohydrates in Cell-Cell Recognition

- Cell-cell recognition
  - Is a cell’s ability to distinguish one type of neighboring cell from another

- Membrane carbohydrates
  - Interact with the surface molecules of other cells, facilitating cell-cell recognition

Synthesis and Sidedness of Membranes

- Membranes have distinct inside and outside faces
- This affects the movement of proteins synthesized in the endomembrane system

- Membrane proteins and lipids
  - Are synthesized in the ER and Golgi apparatus

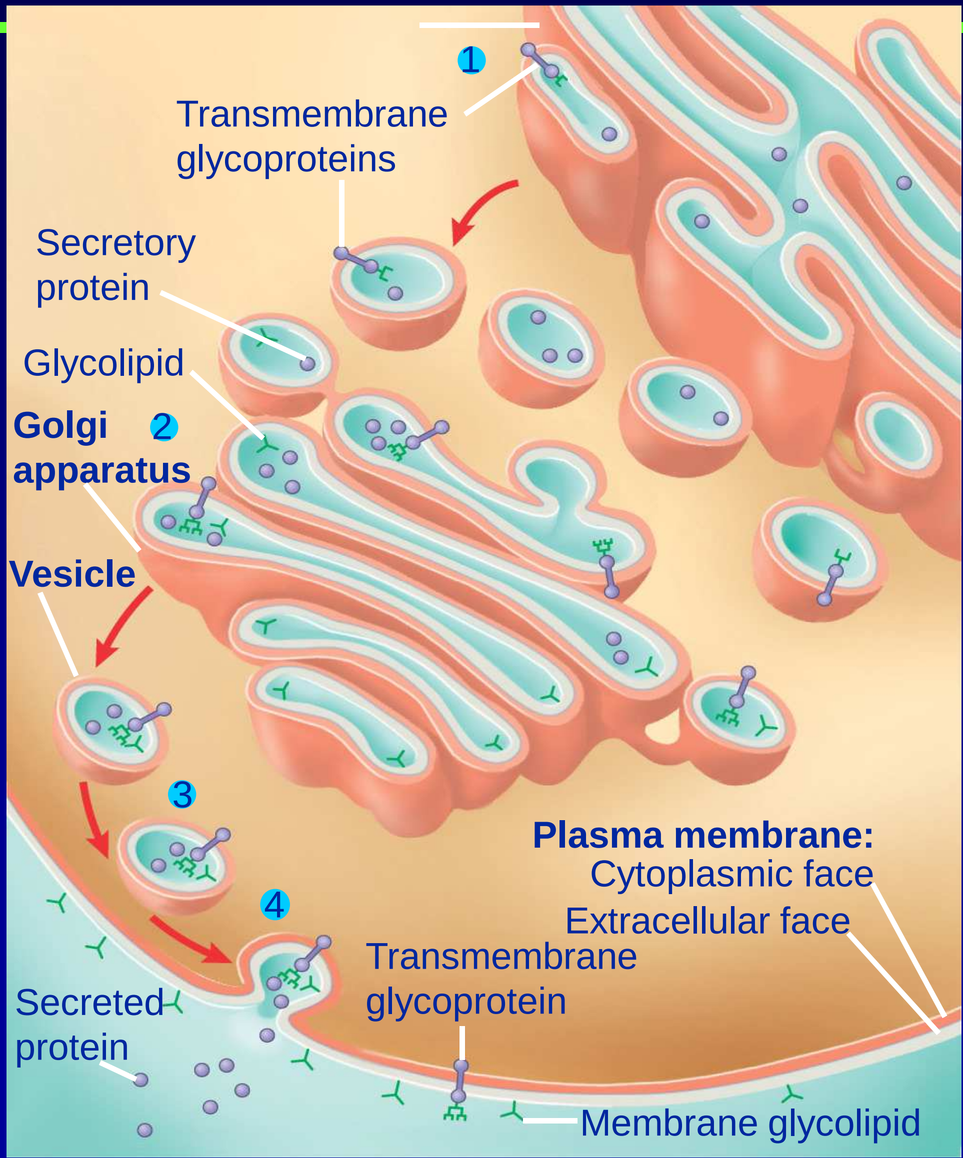


Figure 7.10

- Concept 7.2: Membrane structure results in selective permeability
- A cell must exchange materials with its surroundings, a process controlled by the plasma membrane

The Permeability of the Lipid Bilayer

- Hydrophobic molecules
  - Are lipid soluble and can pass through the membrane rapidly
- Polar molecules
  - Do not cross the membrane rapidly

Transport Proteins

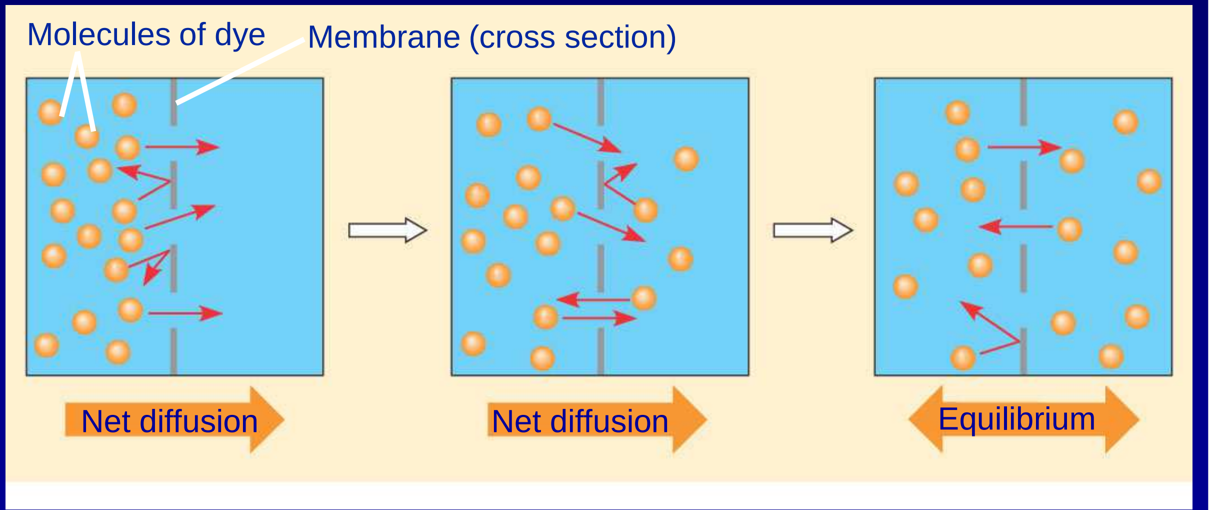
- Transport proteins
  - Allow passage of hydrophilic substances across the membrane

- Concept : Passive transport is diffusion of a substance across a membrane with no energy investment

Diffusion

– Is the tendency for molecules of any substance to spread out evenly into the available space

(a) Diffusion of one solute. The membrane has pores large enough for molecules of dye to pass through. Random movement of dye molecules will cause some to pass through the pores; this will happen more often on the side with more molecules. The dye diffuses from where it is more concentrated to where it is less concentrated (called diffusing down a concentration gradient). This leads to a dynamic equilibrium: The solute molecules continue to cross the membrane, but at equal rates in both directions.



– Substances diffuse down their concentration gradient, the difference in concentration of a substance from one area to another

(b) Diffusion of two solutes. Solutions of two different dyes are separated by a membrane that is permeable to both. Each dye diffuses down its own concentration gradient. There will be a net diffusion of the purple dye toward the left, even though the *total* solute concentration was initially greater on the left side.

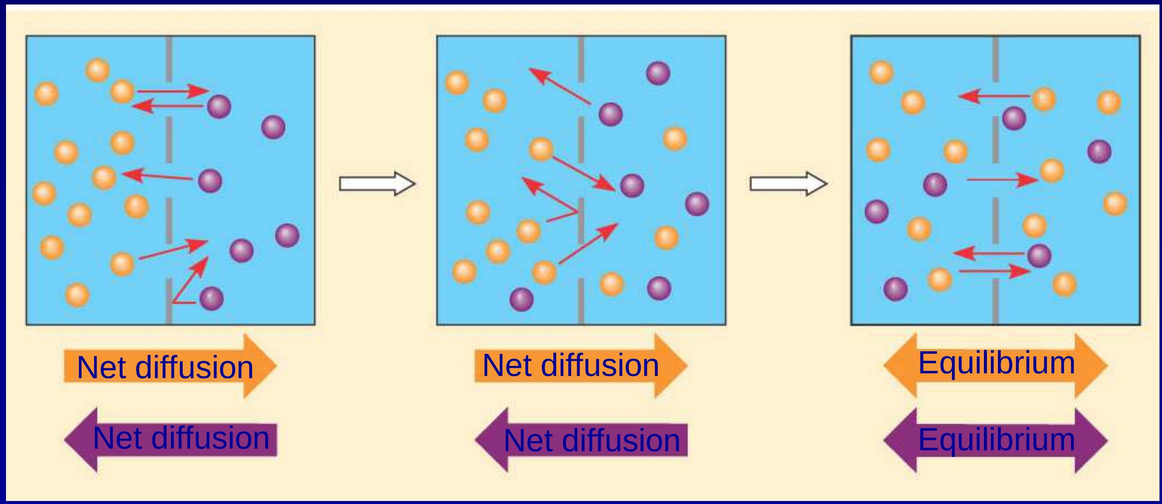
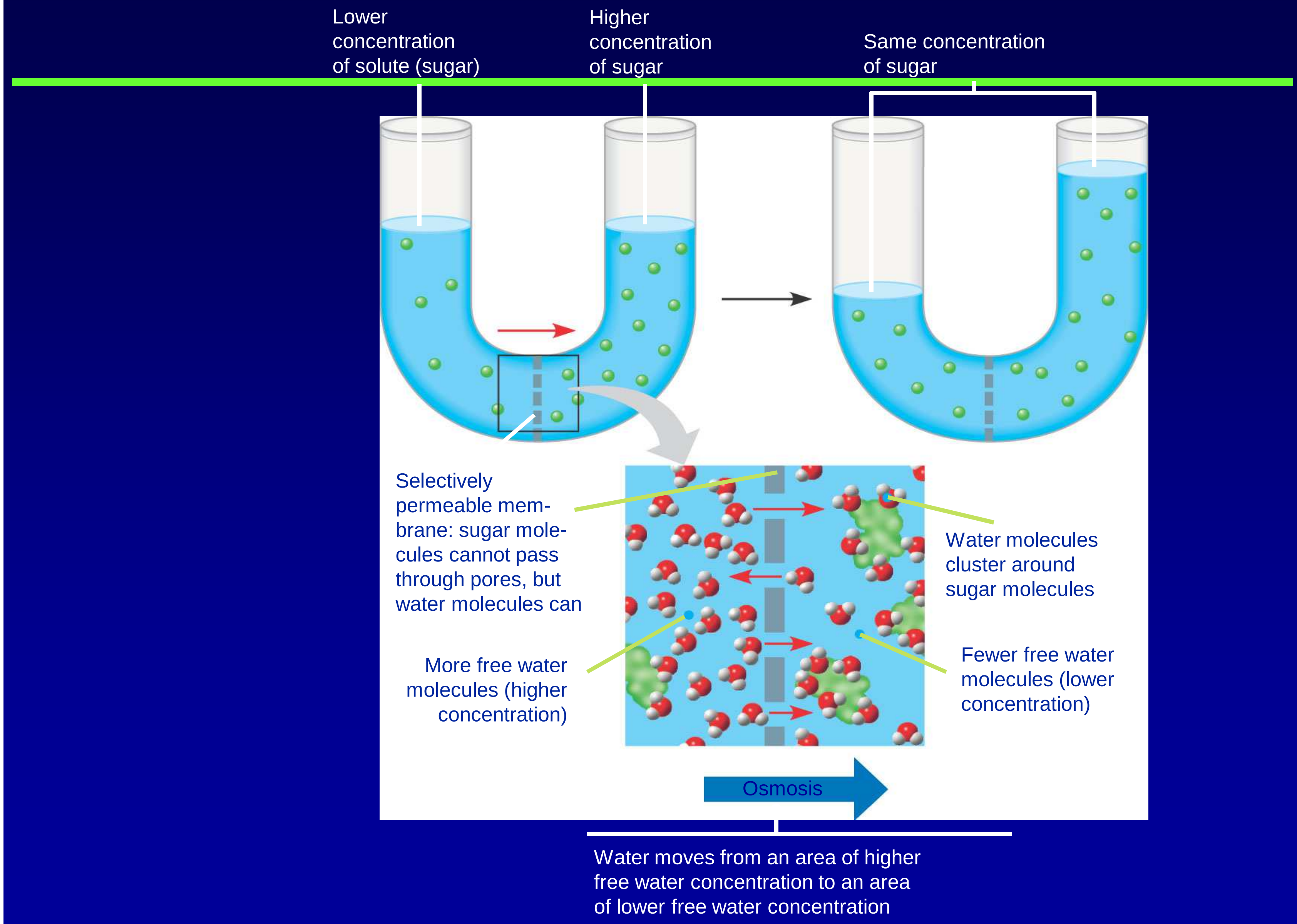


Figure 7.11 B

Effects of Osmosis on Water Balance

- Osmosis
  - Is the movement of water across a semipermeable membrane

– Is affected by the concentration gradient of dissolved substances



Water Balance of Cells Without Walls

- Tonicity
  - Is the ability of a solution to cause a cell to gain or lose water
  - Has a great impact on cells without walls

- If a solution is isotonic
  - The concentration of solutes is the same as it is inside the cell
  - There will be no net movement of water

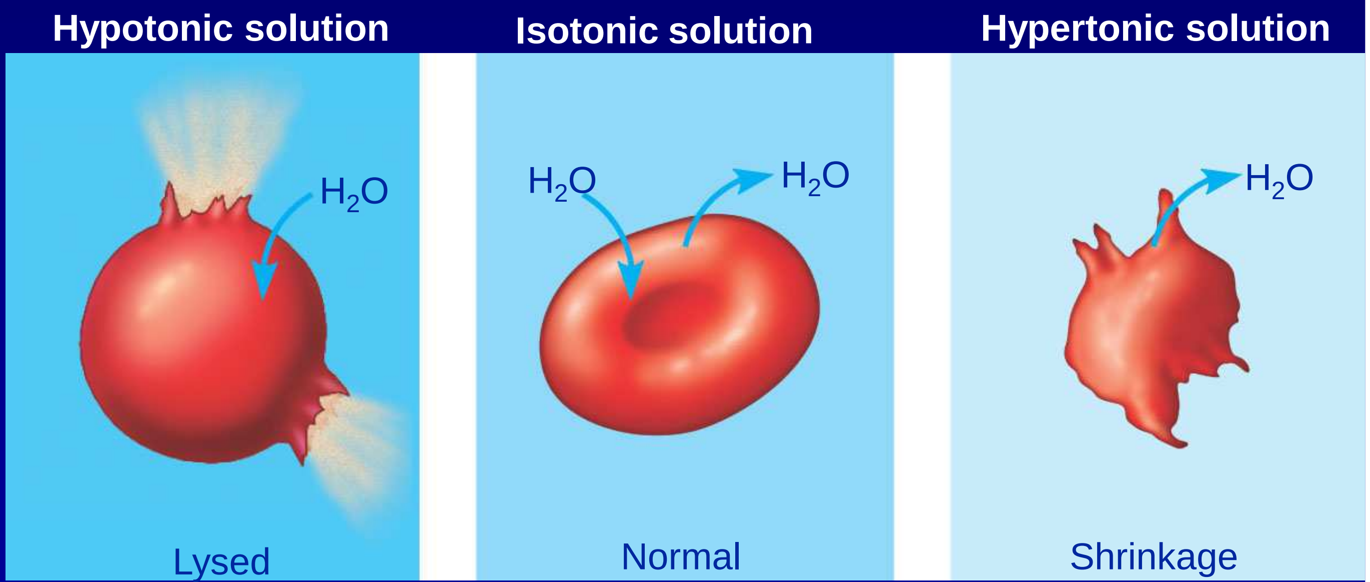
- If a solution is hypertonic
  - The concentration of solutes is greater than it is inside the cell
  - The cell will lose water

- If a solution is hypotonic
  - The concentration of solutes is less than it is inside the cell
  - The cell will gain water

– Animals and other organisms without rigid cell walls living in hypertonic or hypotonic environments

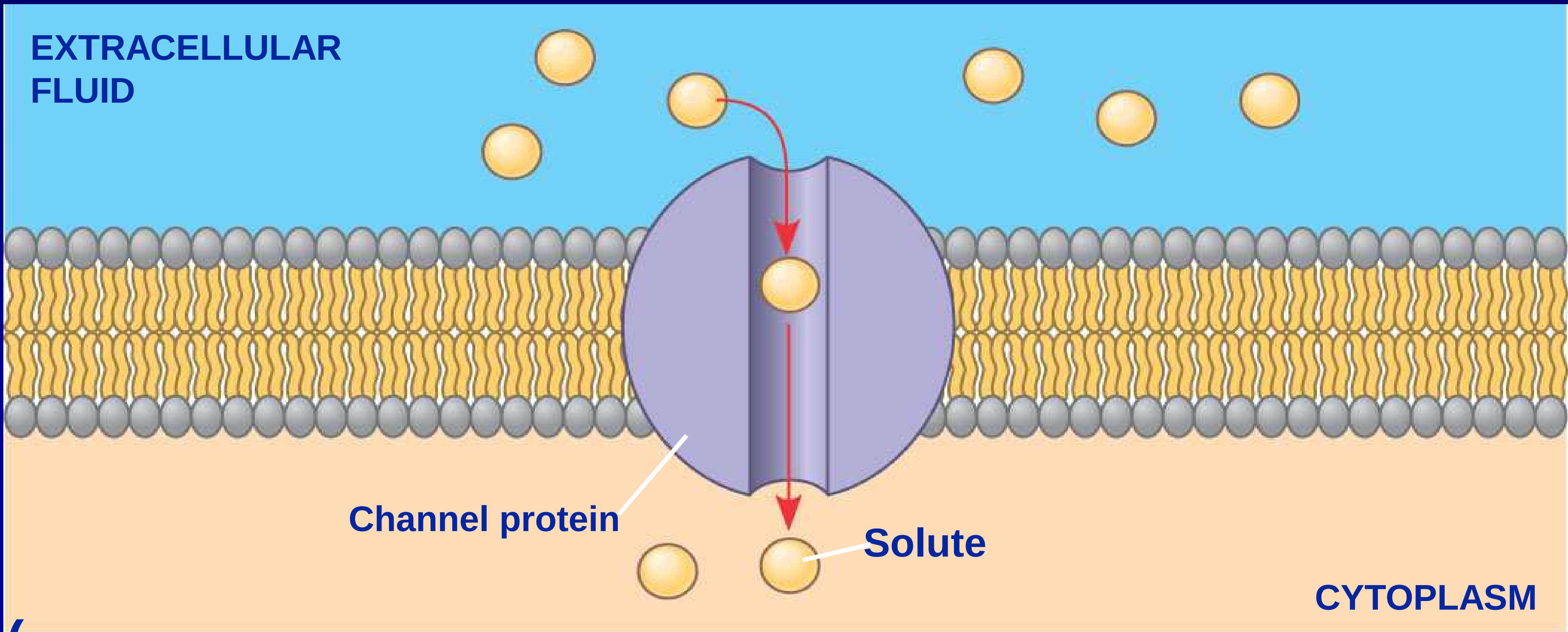
– Must have special adaptations for osmoregulation

(a) Animal cell. An animal cell fares best in an isotonic environment unless it has special adaptations to offset the osmotic uptake or loss of water.



Facilitated Diffusion: Passive Transport Aided by Proteins

- Channel proteins
  - Provide corridors that allow a specific molecule or ion to cross the membrane



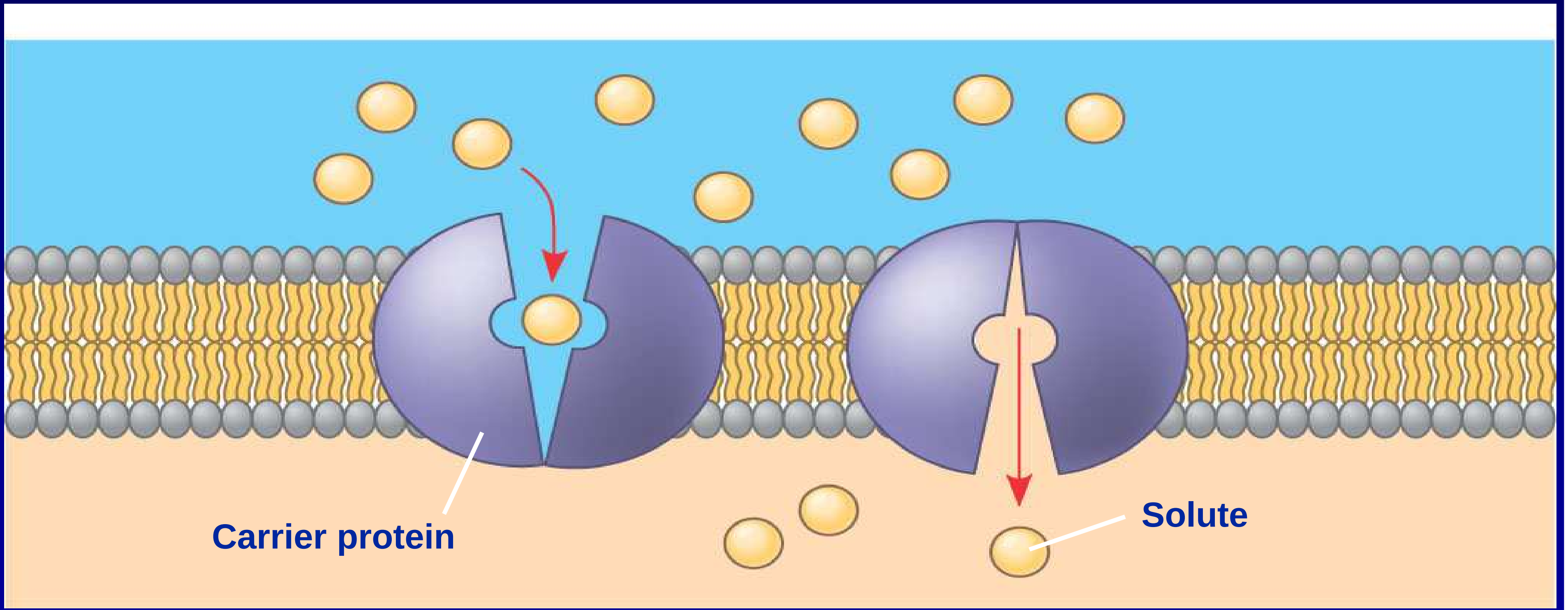
(a) A channel protein (purple) has a channel through which water molecules or a specific solute can pass.

Facilitated Diffusion: Passive Transport Aided by Proteins

_ In facilitated diffusion

– Transport proteins speed the movement of molecules across the plasma membrane

- Carrier proteins
  - Undergo a subtle (little) change in shape that translocates the solute-binding site across the membrane



(b)
A carrier protein alternates between two conformations, moving a solute across the membrane as the shape of the protein changes. The protein can transport the solute in either direction, with the net movement being down the concentration gradient of the solute.

_Concept

_ Active transport uses energy to move solutes against their gradients

The Need for Energy in Active Transport

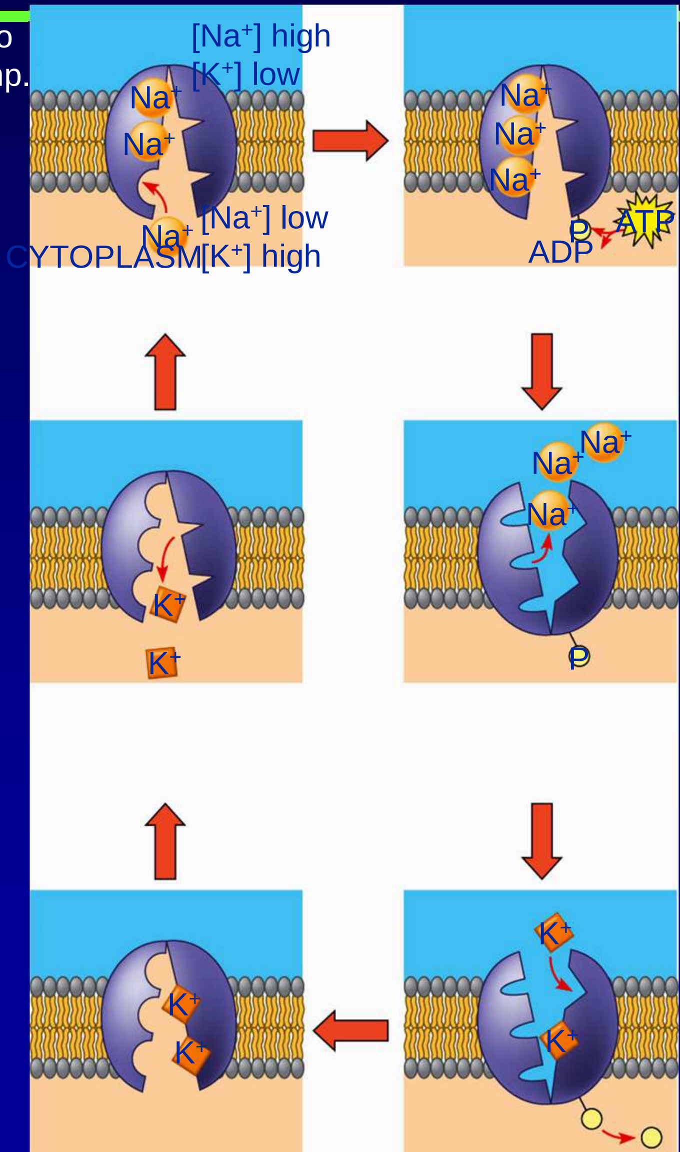
- Active transport
  - Moves substances against their concentration gradient
  - Requires energy, usually in the form of ATP

The sodium-potassium pump

– Is one type of active transport system

❶ Cytoplasmic Na^+ binds to the sodium-potassium pump.

❷ Na+ binding stimulates phosphorylation by ATP.



❸ K^+ is released and Na^+ sites are receptive again; the cycle repeats.

❹ Phosphorylation causes the protein to change its conformation, expelling Na^+ to the outside.

Figure 7.16

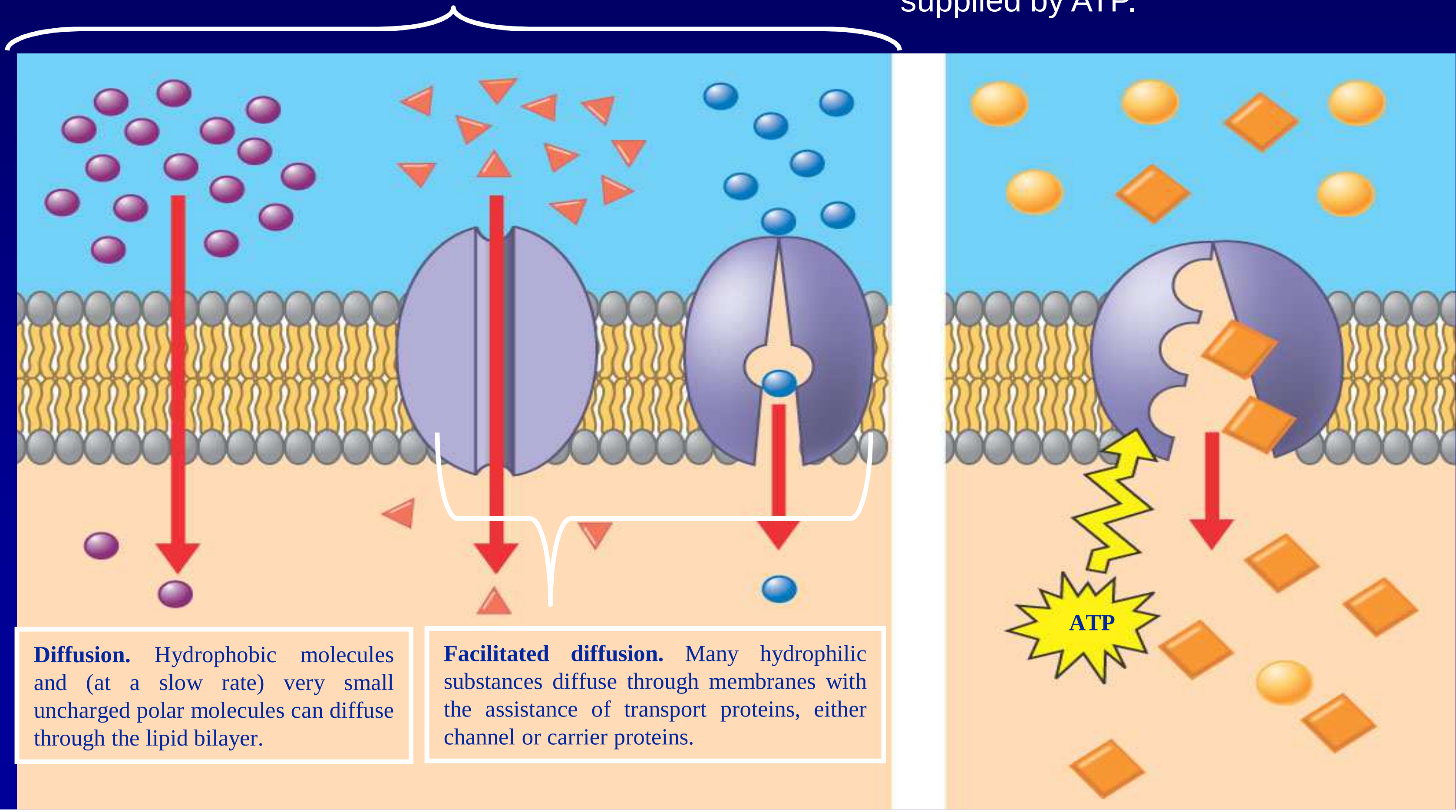
❺ Loss of the phosphate restores the protein's original conformation.

❻ Extracellular K^+ binds to the protein, triggering release of the Phosphate group.

Review: Passive and active transport compared

Passive transport. Substances diffuse spontaneously down their concentration gradients, crossing a membrane with no use of energy by the cell. The rate of diffusion can be greatly increased by transport proteins in the membrane.

Active transport. Some transport proteins act as pumps, moving substances across a membrane against their concentration gradients. Energy for this work is usually supplied by ATP.

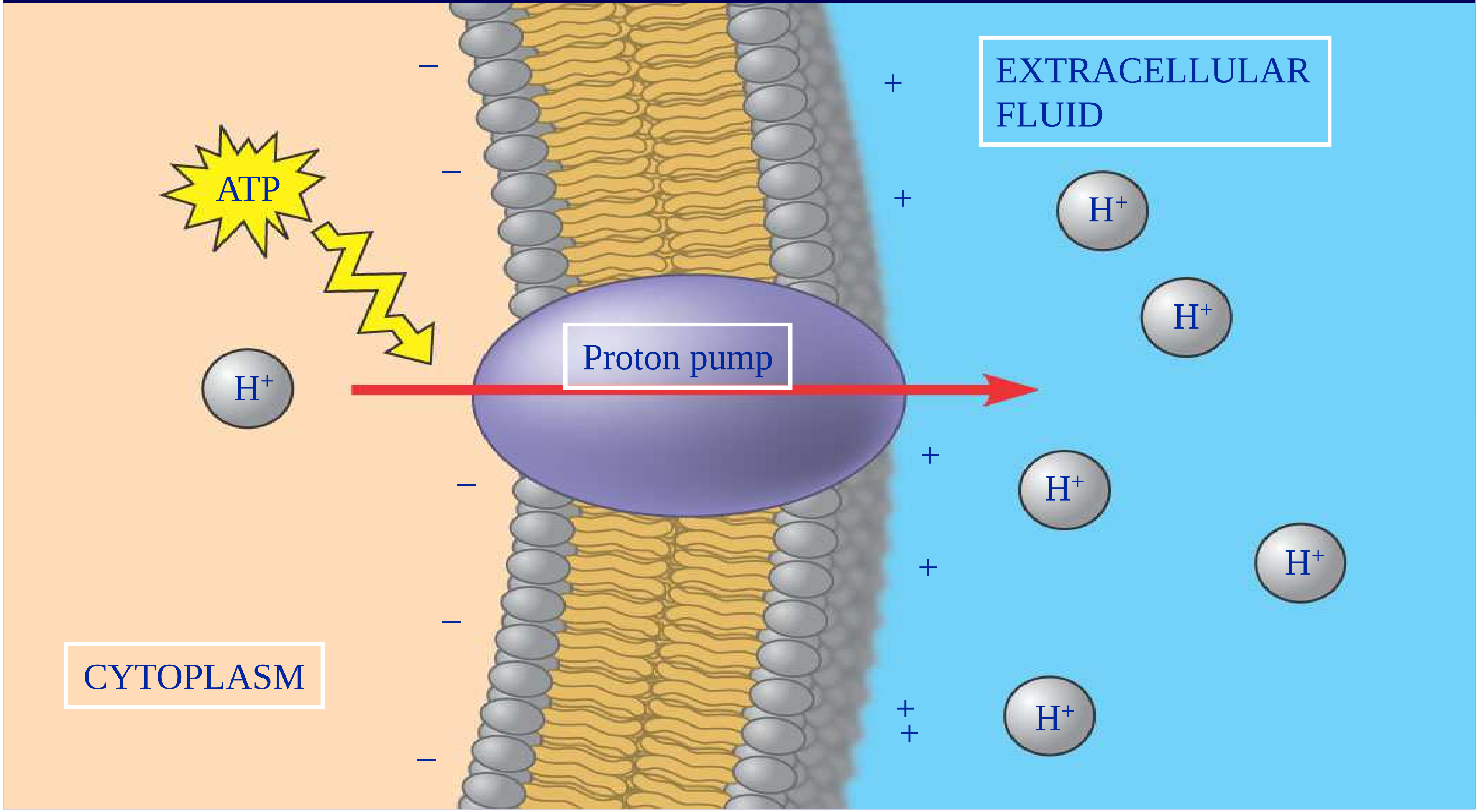


Maintenance of Membrane Potential by Ion Pumps

- Membrane potential
  - Is the voltage difference across a membrane
- An electrochemical gradient
  - Is caused by the difference in concentration of ions across a membrane

_ An electrogenic pump

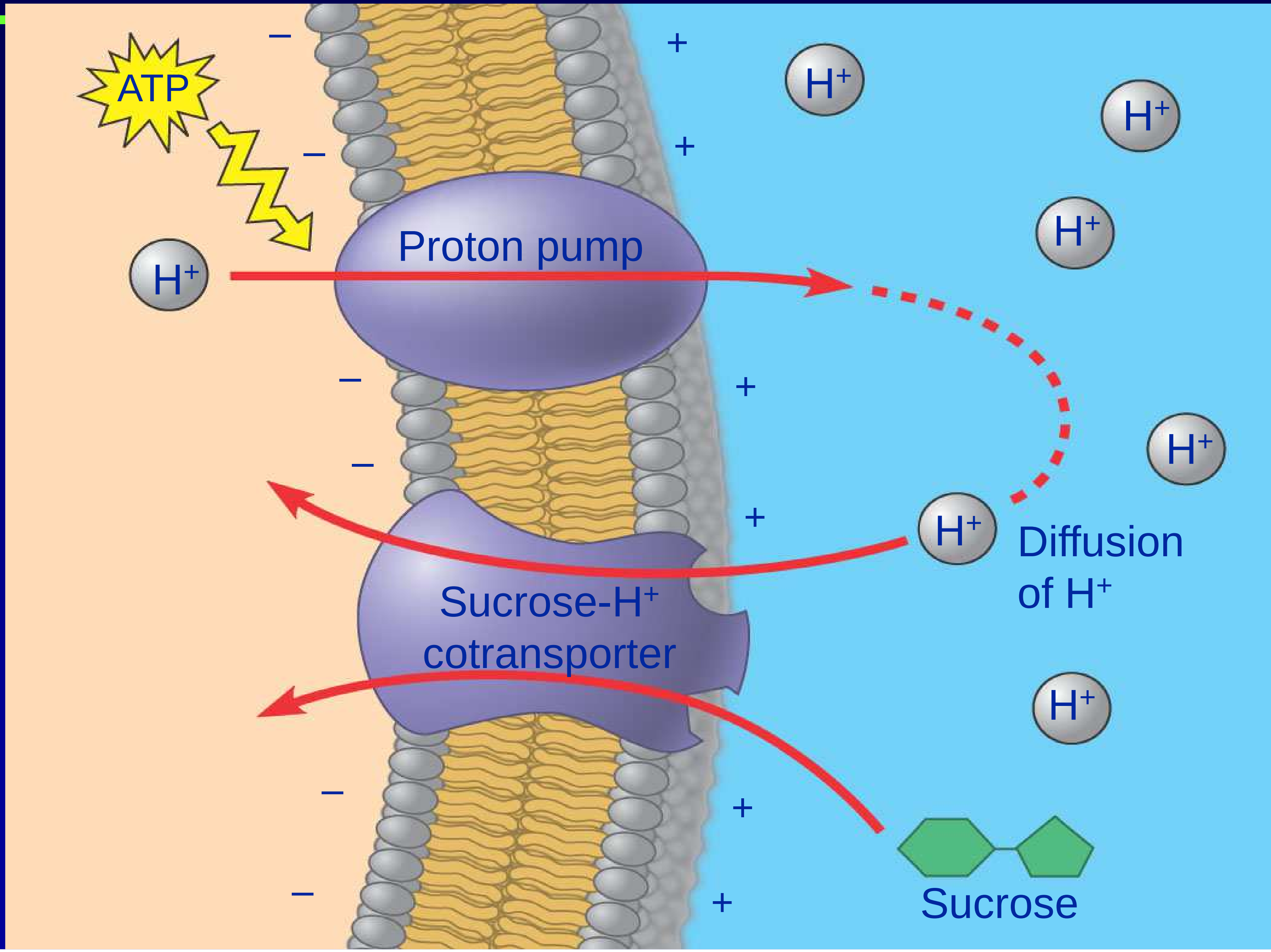
– Is a transport protein that generates the voltage across a membrane



Cotransport: Coupled Transport by a Membrane Protein

- Cotransport
  - Occurs when active transport of a specific solute indirectly drives the active transport of another solute

– Cotransport: active transport driven by a concentration gradient



_Concept

_ Bulk transport across the plasma membrane occurs by exocytosis and endocytosis

_ Large proteins

– Cross the membrane by different mechanisms

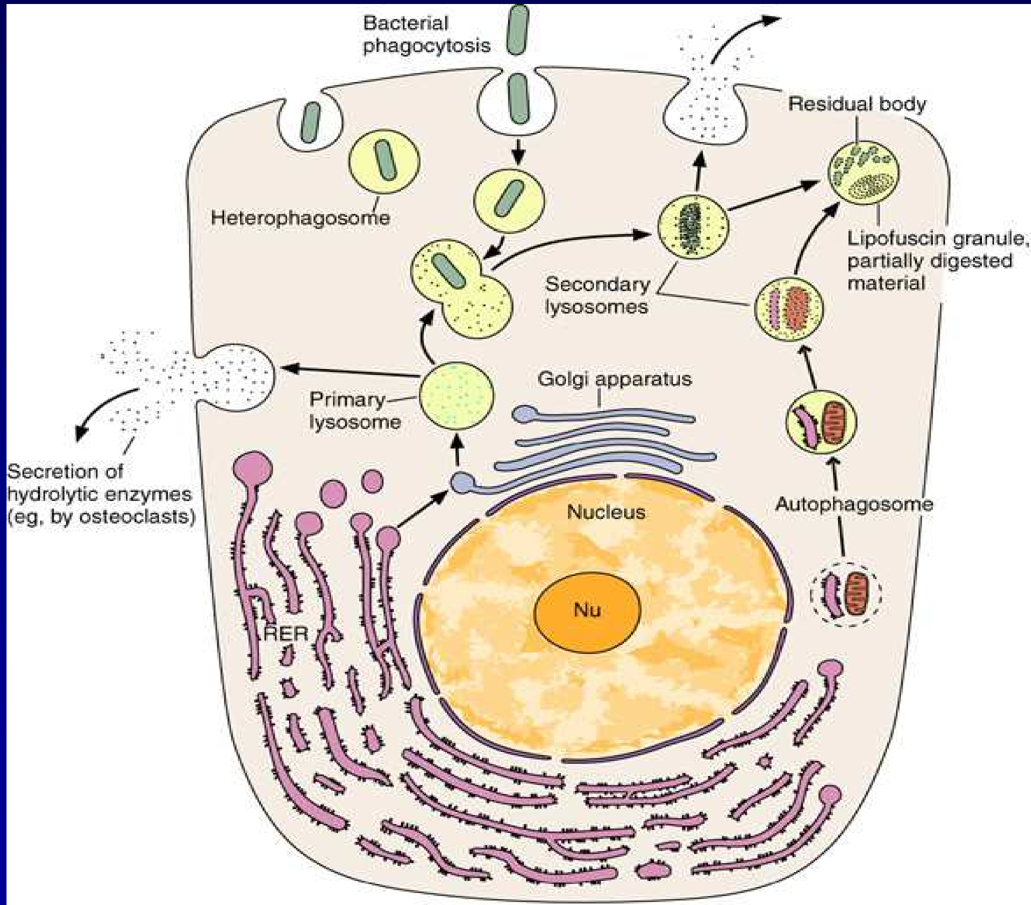
Exocytosis

- In exocytosis
  - Transport vesicles migrate to the plasma membrane, fuse with it, and release their contents

Endocytosis

- In endocytosis
  - The cell takes in macromolecules by forming new vesicles from the plasma membrane

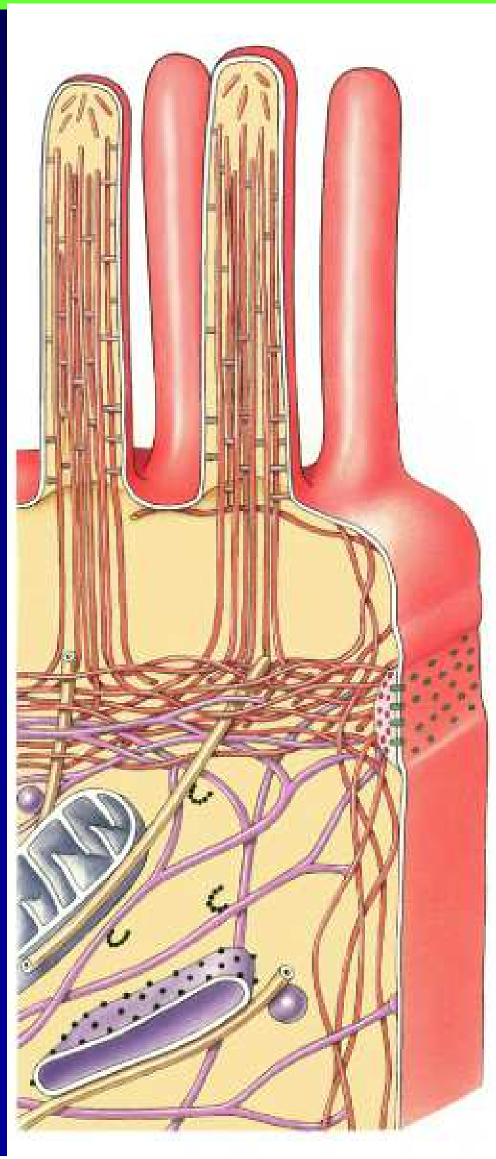
Cell



Bacterial phagocytosis
Residual body
Heterophagosome
Lipofuscin granule, partially digested material
Secondary lysosomes
Primary lysosome
Golgi apparatus
Secretion of hydrolytic enzymes (eg, by osteoclasts)
Nucleus
Autophagosome
Nu
RER

Non-membranous Organelles

- Cytoskeleton
- Microvilli
- Cilia, centrioles, flagellum
- Ribosomes



Organelles

- General
- 1. Microscopic and submicroscopic

Membranebounded:	Membraneless:
1. Mitochondrion	1. Ribosome
2. endoplasmatic reticulum (rough and smooth)	2. Microfilament
3. Golgi apparatus	3. Microtubules
4. Lysosome	4. Cell center
5. Peroxisome	5. Proteasome

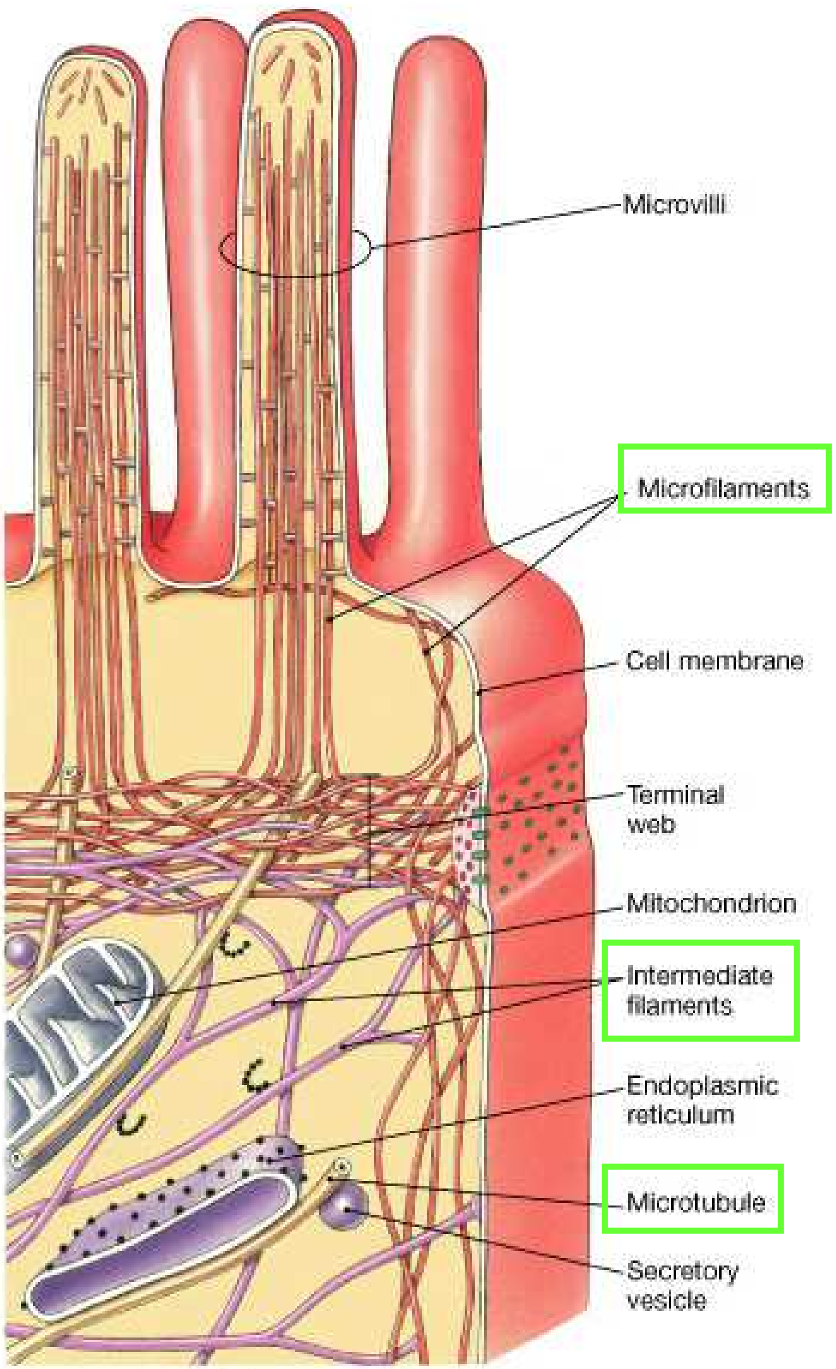
- Special
  - Cilia
  - Flagella
  - Fibrilles (myo-, tono-, neurofibrilles)

Cytoskeleton

4 major components:

1. Microfilaments (mostly actin)
2. Intermediate filaments
3. Thick filaments (composed of myosin subunits)
4. Microtubules (composed of tubulin subunits)

Fu: support & movement of cellular structures & materials



(a)

Cytoskeleton

These include;

- Microfilaments
- Myosin
- Intermediate filaments
- Microtubules

- They often form complex meshwork that maintains cell shape and stability and responsible for cell movement

Microfilaments

- Measures approx. 1.0µm long and 5.8nm diam.
- They are composed of the protein actin in association with other 2 proteins; troponin and tropomyosin found in muscles
- Actin is also found in microvilli and stereocilia where they play a supportive role.

Myosin

- Occurs on in muscles in its thickest form and measures approx. 1.5µm long and 15nm in diam
- The interraction between actin and myosin filaments causes changes in cell shape, movement as well as separation of dividing cells

Intermediate filaments

- Measures 8-10nm in diam and includes;

  -Neurofilaments(neurons)

  -Glial filaments (astrocytes)

  -Tonofilaments/keratin filaments (epithelial cells)

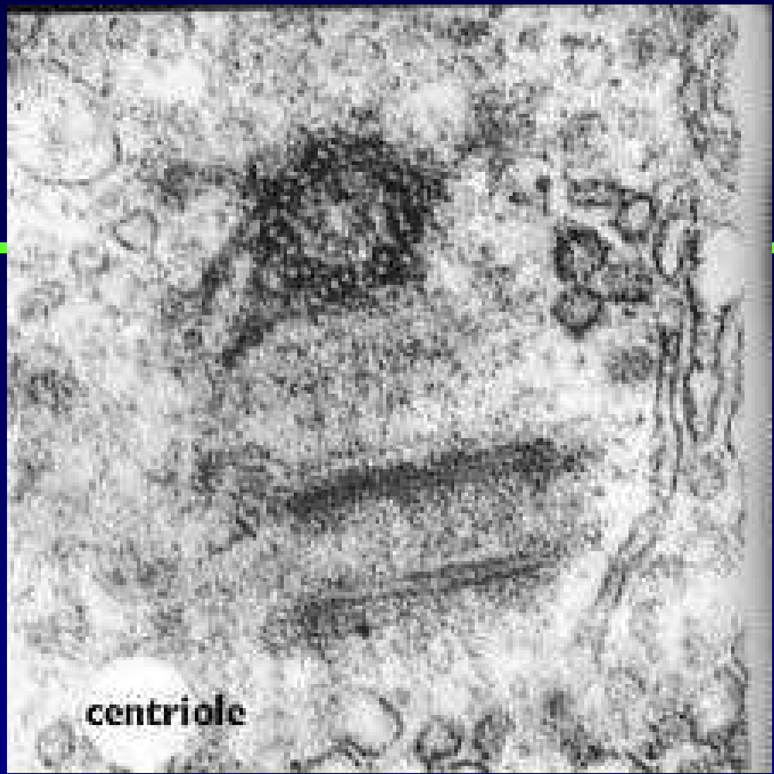
  -Vimentin filaments (in most other cells)
- These filaments help in maintenance of shape and form epithelial adhesions (desmosomes)

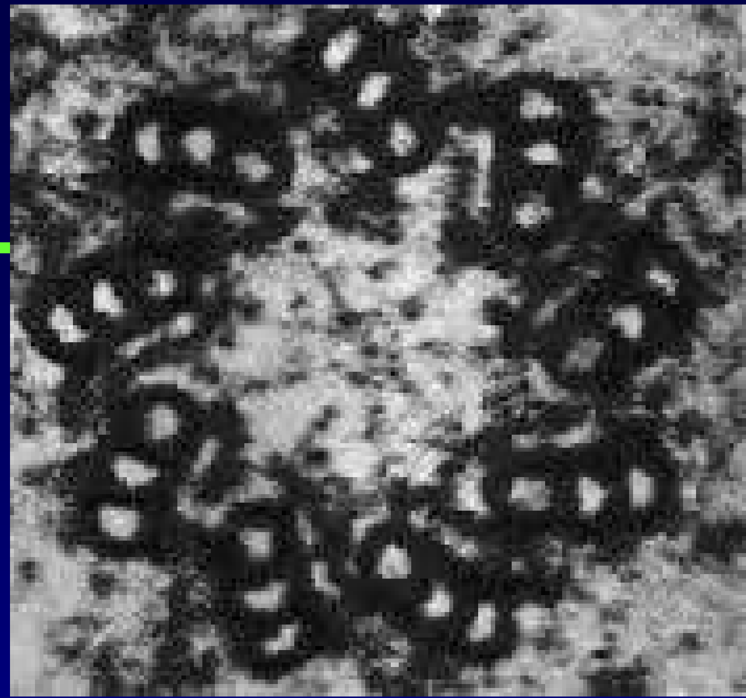
Microtubules

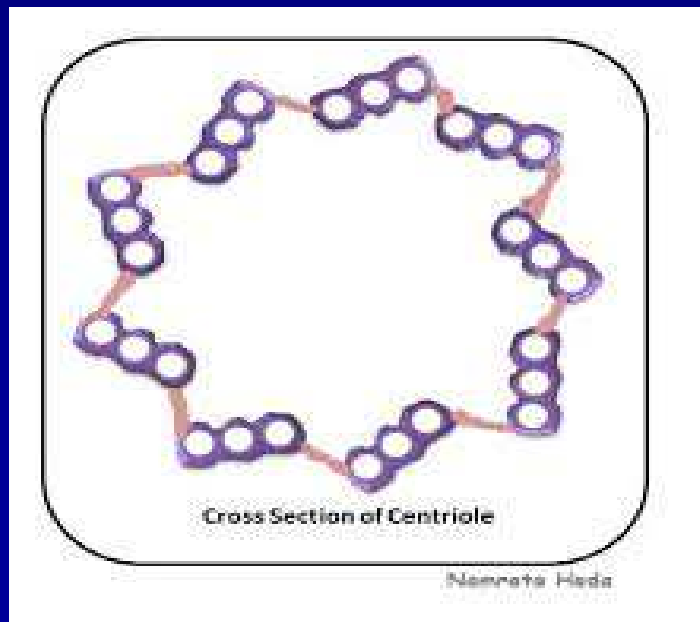
- Vary in length but measures approx. 25nm in diam
- They are stable, permanent structures in cilia, flagella, centrioles and basal bodies
- Microtubules are important for growth of nerve cell processes and transport of various organelles from the perikaryon to the periphery
- Antimitotic drugs such as colchicine and vincristine inhibit their assembly thereby interfering with cell division

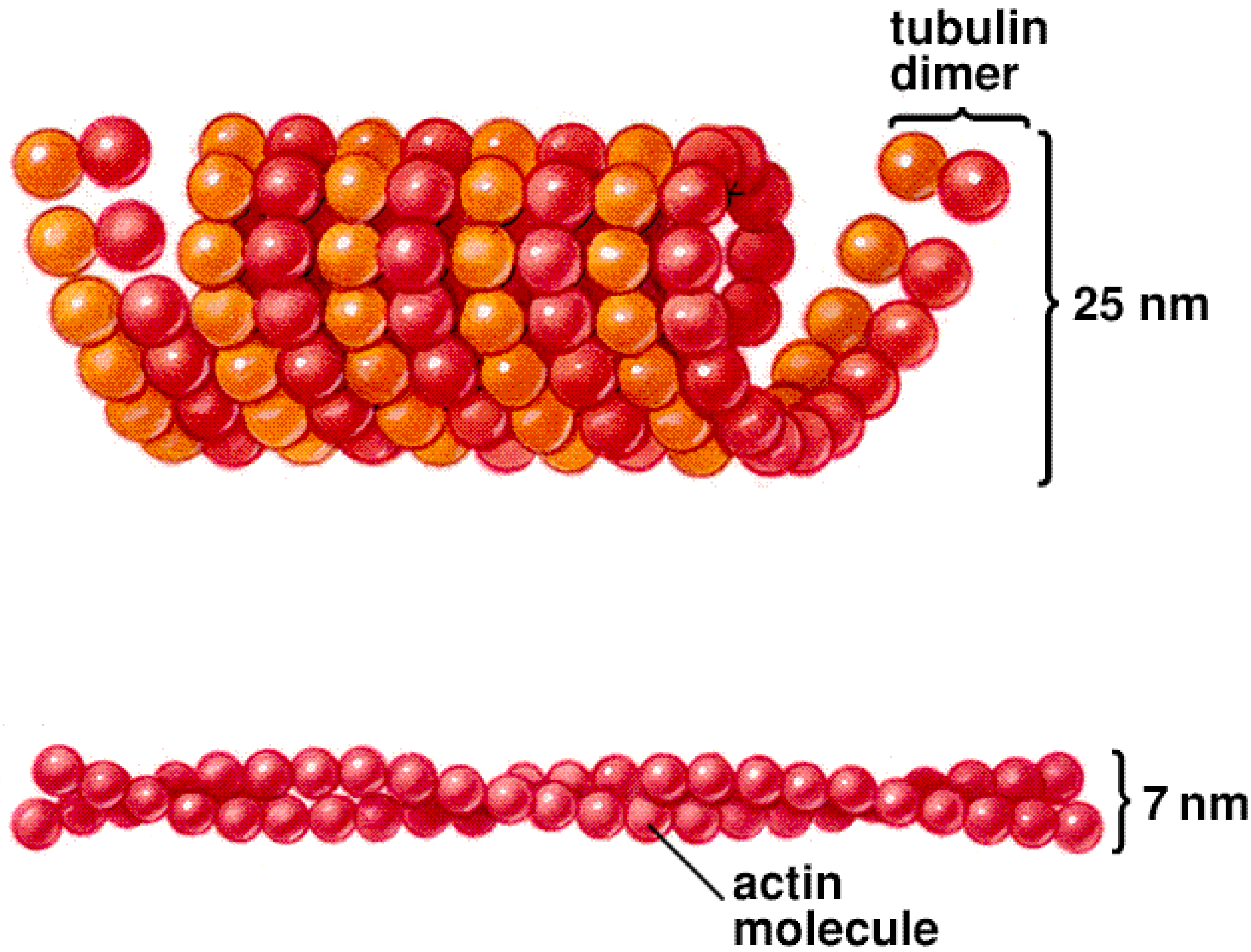
Centrioles

- Comprise of 9 groups of 3 microtubules in longitudinal and parallel orientation
- They form a cylinder 0.1-0.2µm in diam and 0.2-0.3mm long
- Each centriole is surrounded by finely granular, pericentriolar material


centriole



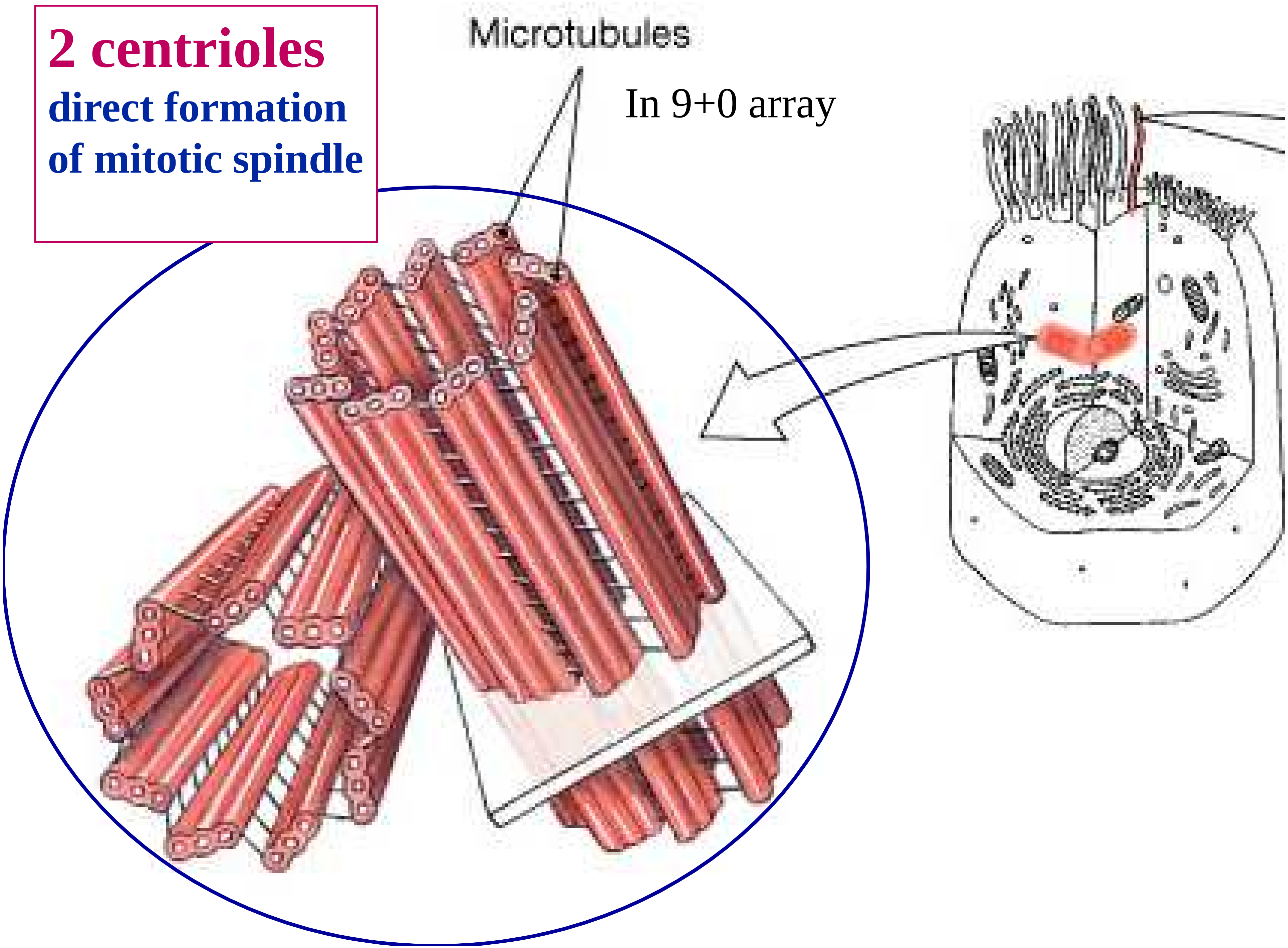

Cross Section of Centriole
Namrata Heda



tubulin
dimer
25 nm
7 nm
actin
molecule

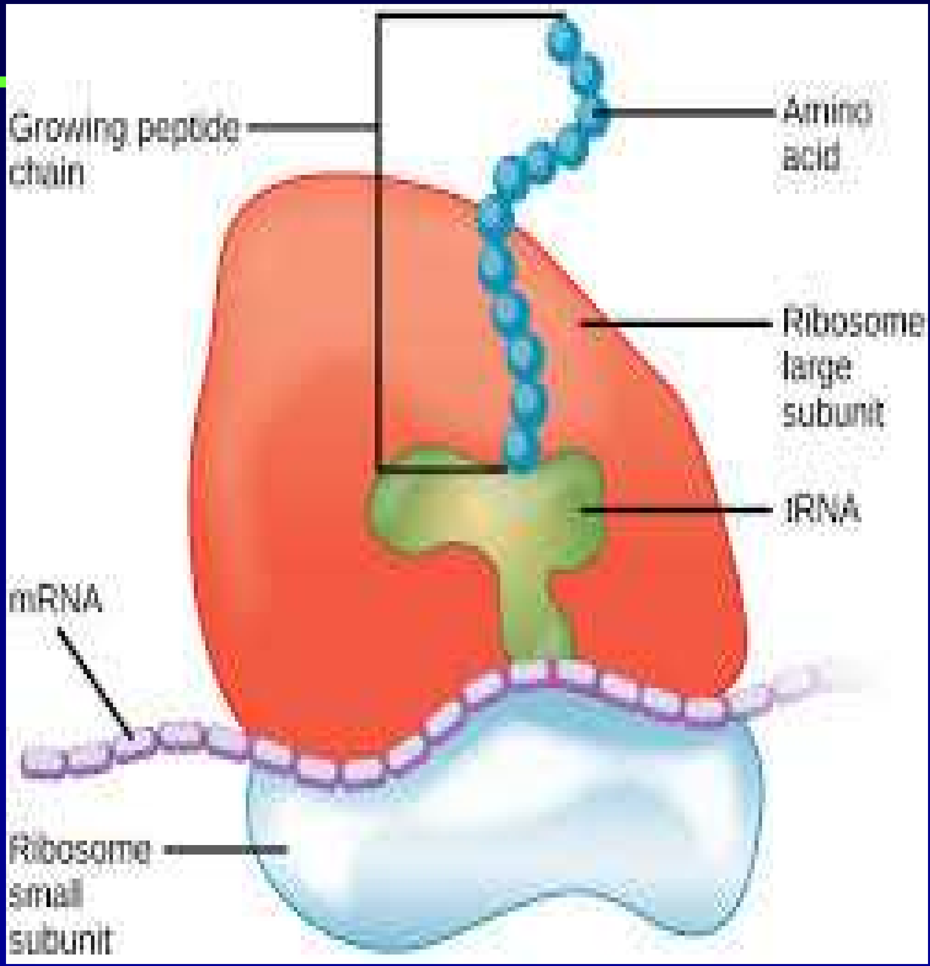
2 centrioles

direct formation of mitotic spindle



Ribosomes

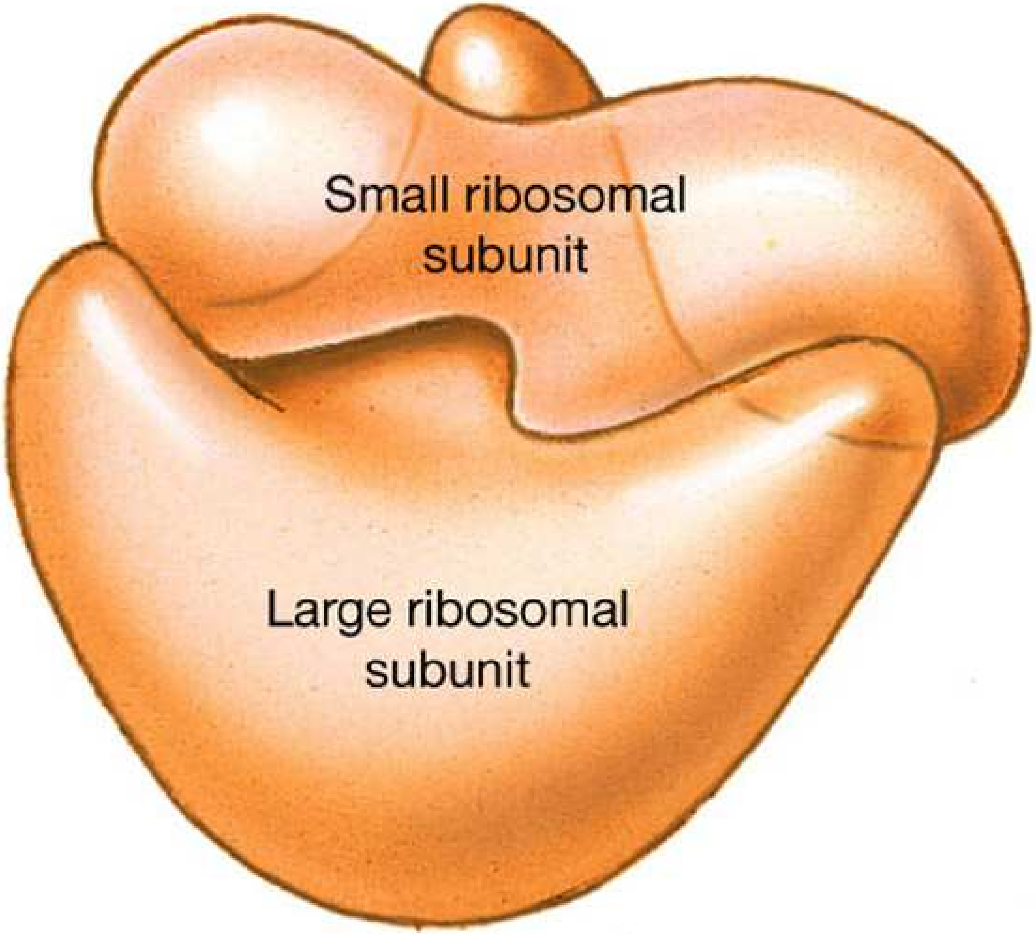
- These are small particles (15x2.5 nm in diam) composed of large amd small subunits
- The large subunit consists of 3 molecules of rER while the small subunit has 1 rER

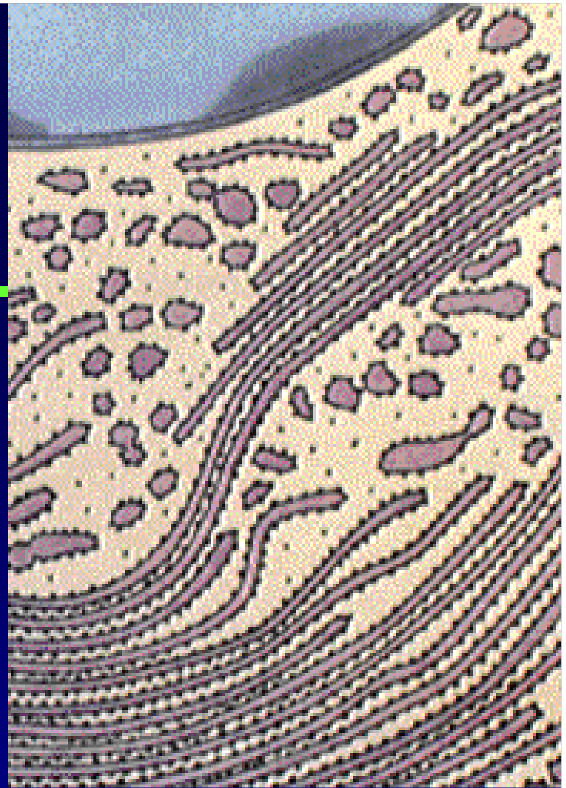


Functions

- Useful in protein synthesis in conjunction with rER

Ribosomes

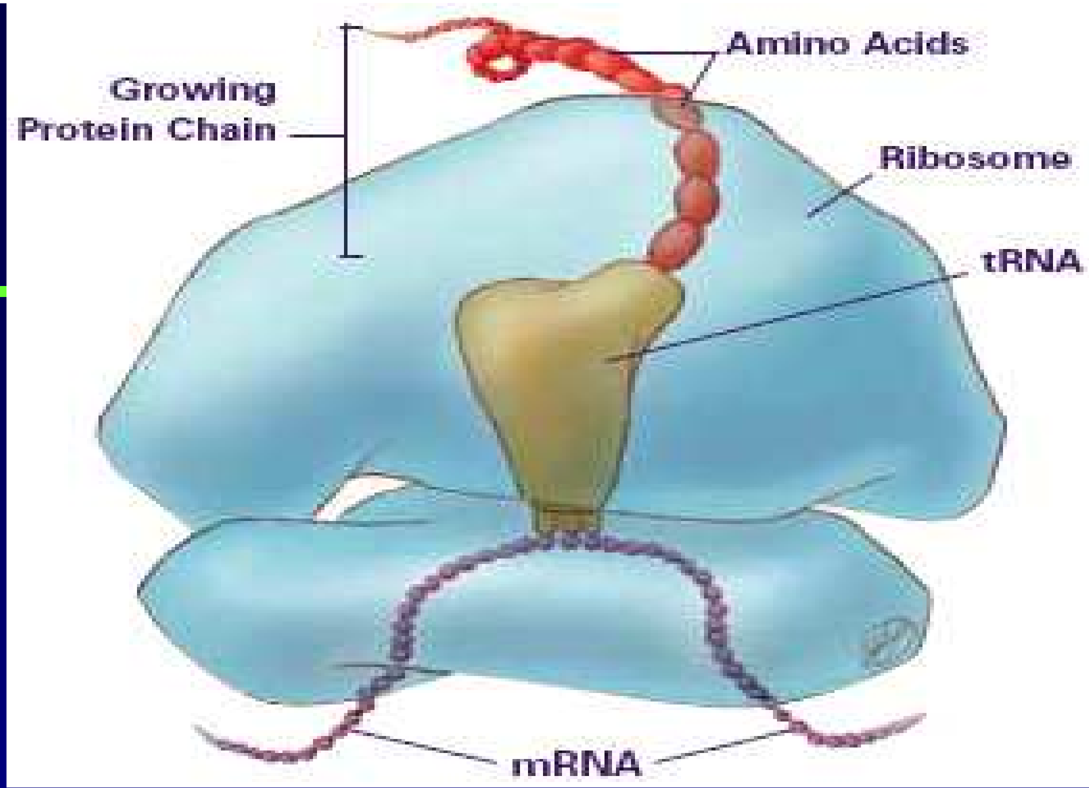


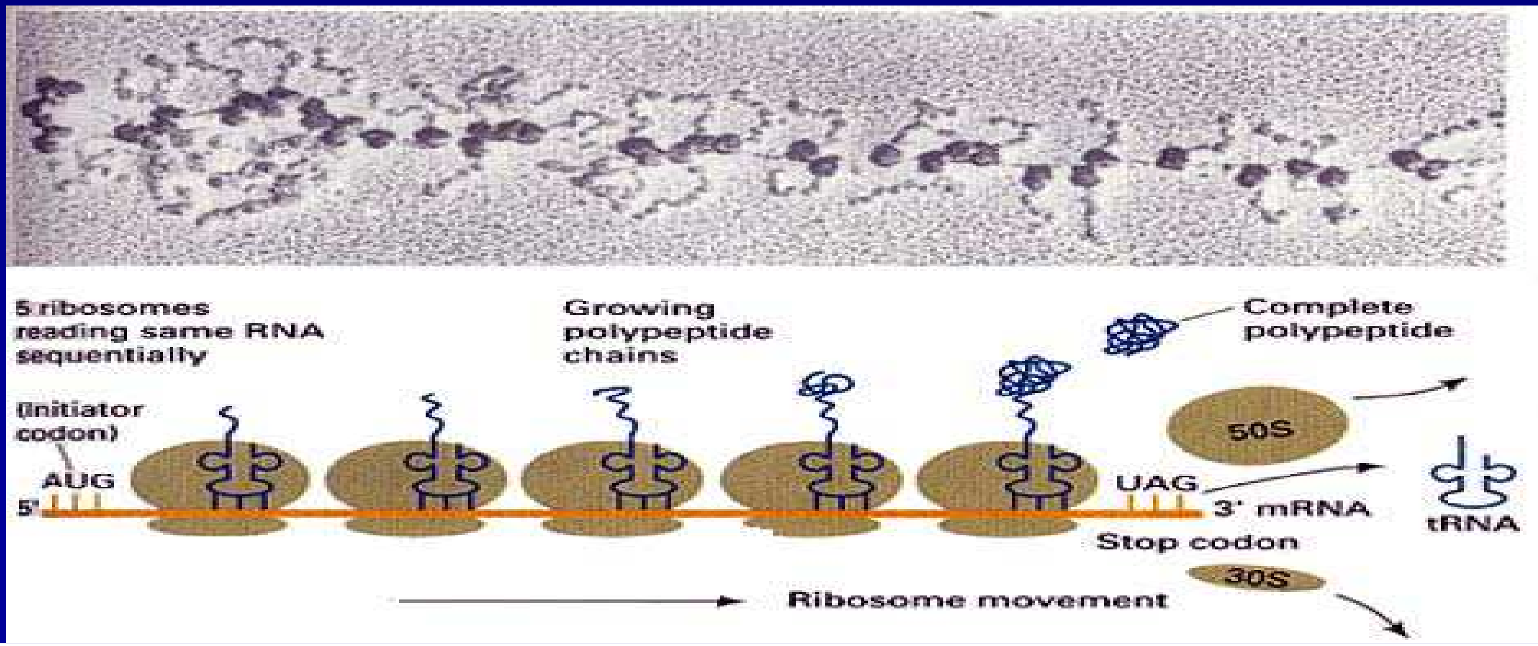


60% RNA + 40% ________

workbench for __________

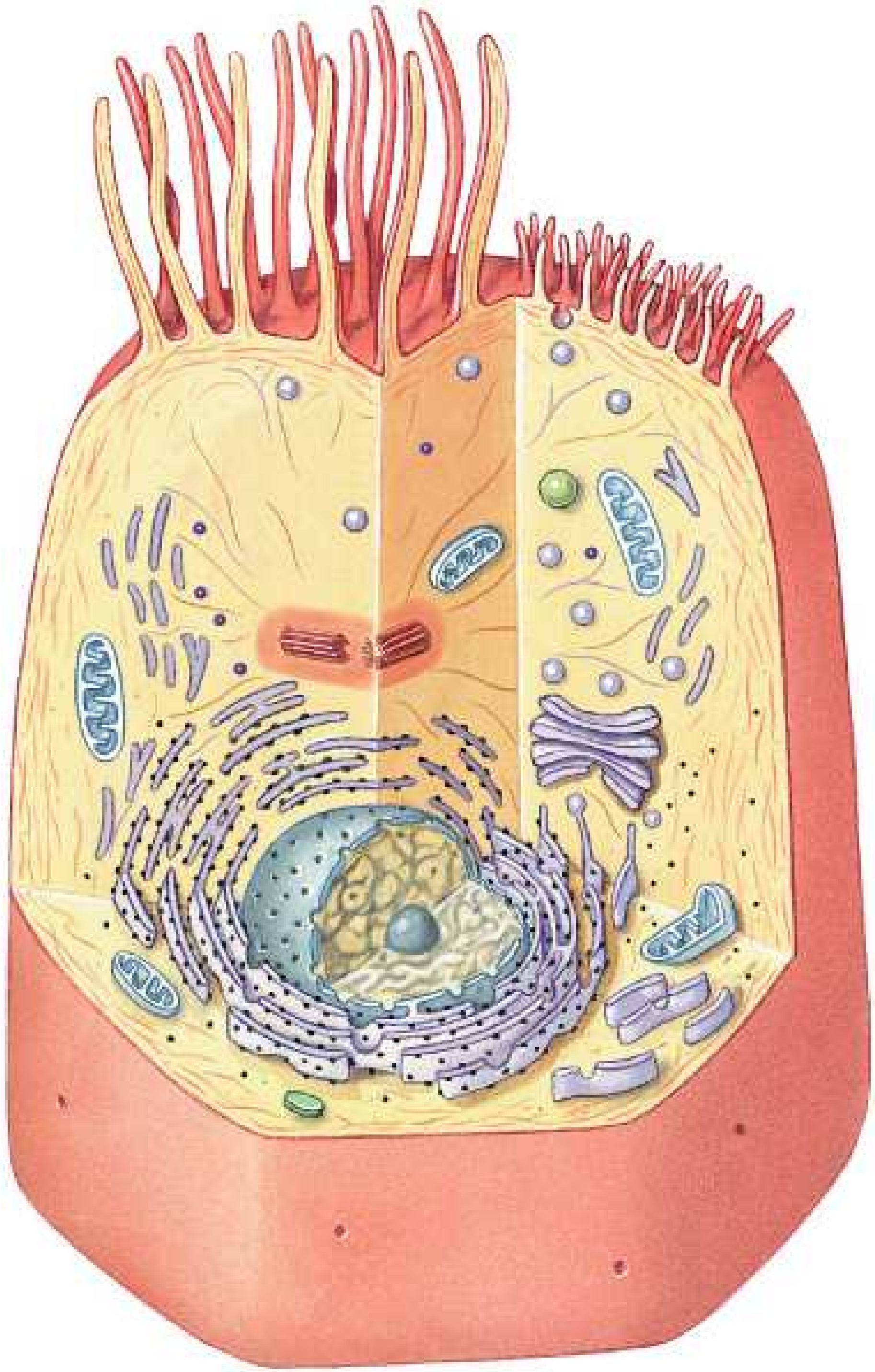
Fixed vs, free ribosomes


Growing
Protein Chain
Amino Acids
Ribosome
tRNA
mRNA


5 ribosomes
reading same RNA
sequentially
Growing
polypeptide
chains
Complete
polypeptide
(initiator
codon)
AUG
5'
50S
UAG
3' mRNA
tRNA
Stop codon
30S
Ribosome movement

Membranous Organelles

Names and functions ?



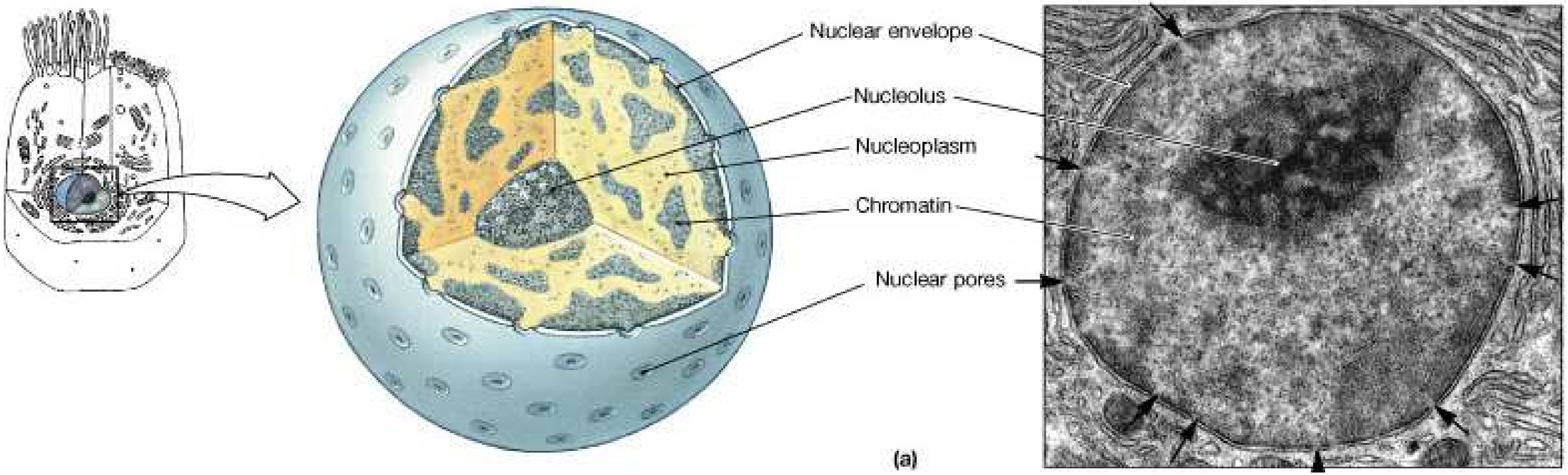
Components of nucleus:

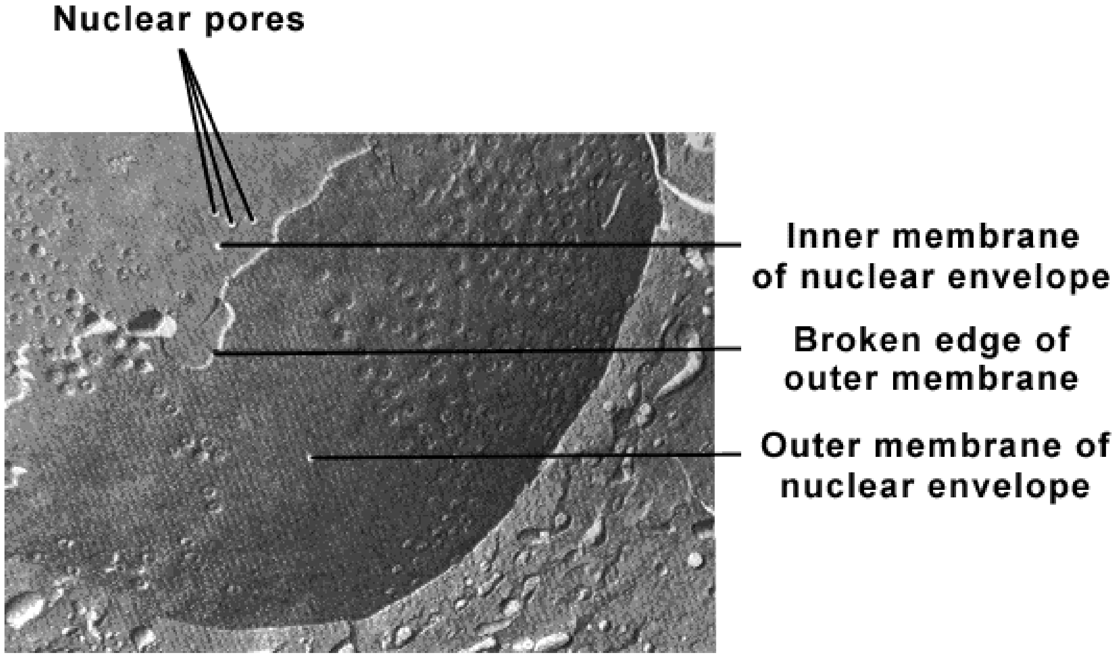
- Nucleolemma (cariolemma)
- Carioplasma
- Nucleolus
- Cromatin or chromosomes

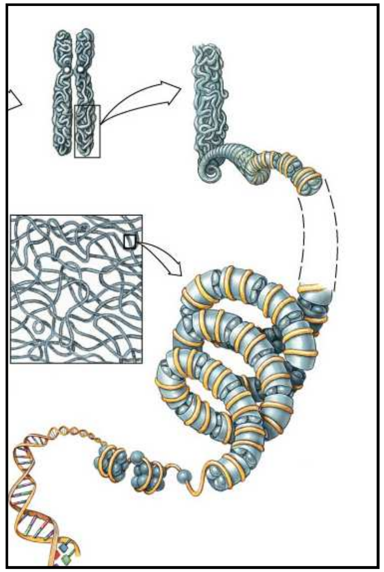
Function:

1. Storage and passihg genetic information
2. Control of protein synthesis (realization of genetic information)

Nucleus


Nuclear envelope
Nucleolus
Nucleoplasm
Chromatin
Nuclear pores
(a)


Nuclear pores
Inner membrane of nuclear envelope
Broken edge of outer membrane
Outer membrane of nuclear envelope



Mitochondria

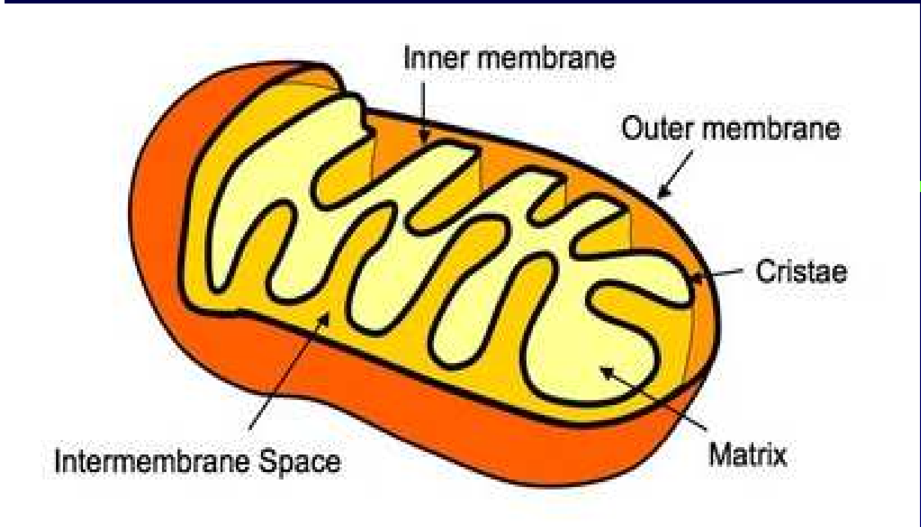
- These are small rods or spheres approx. 0.2µm in diam. and up to 12µm long.
- They are the chief source of energy the cell and therefore numerous in cells with high metabolic activity
- At EM, a mitochondrion is bound by 2 membranes;

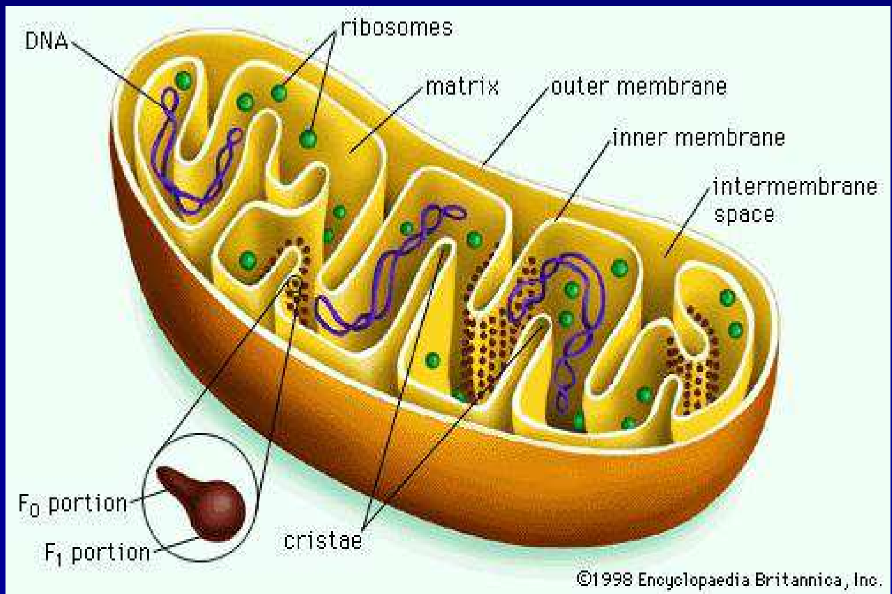
  1) Outer membrane – smooth and sac-like

  2) Inner membrane – thrown into folds that form cristae mitochondriales.

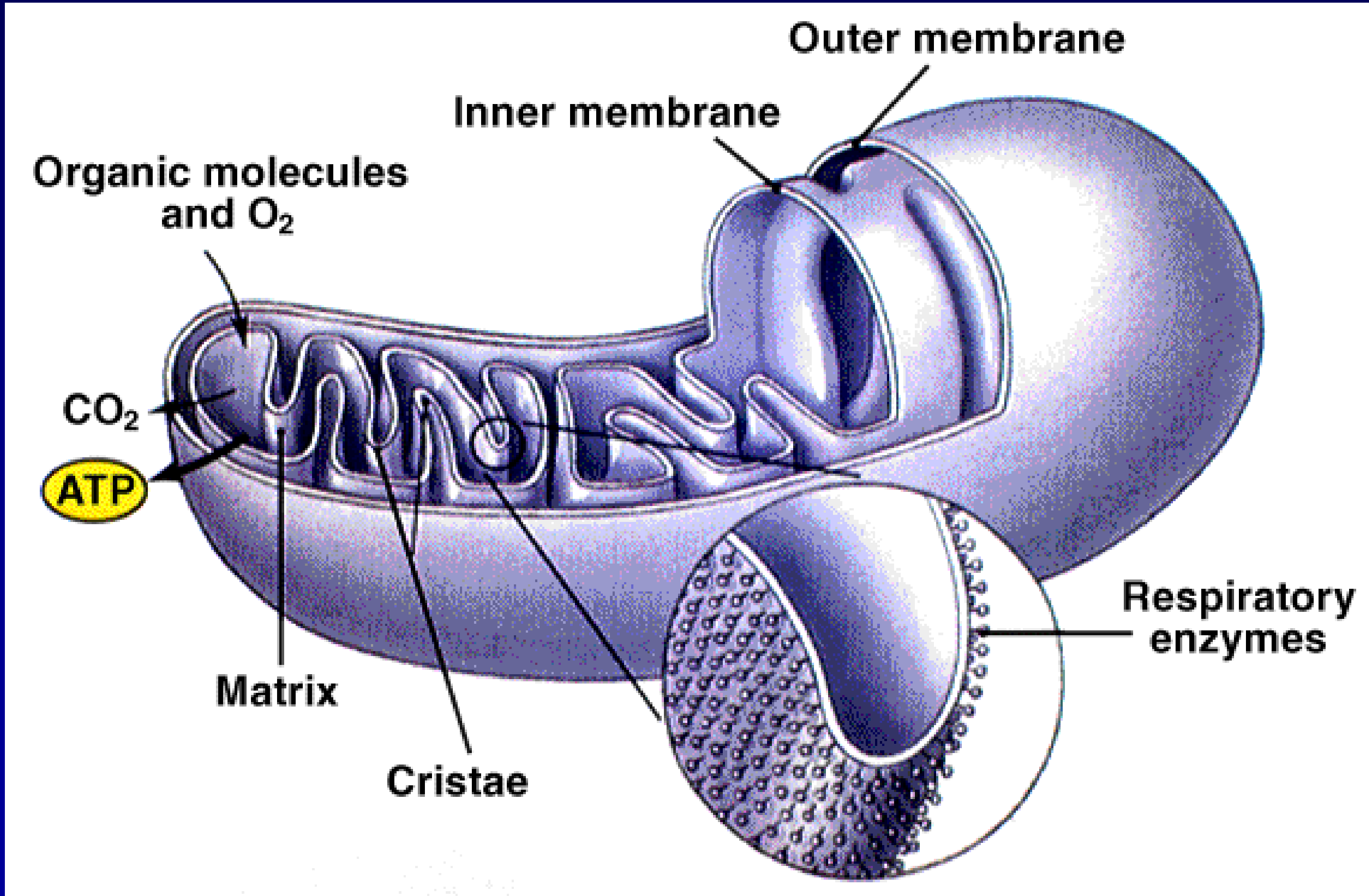
  -On the inner surface of the inner membrane are particles that form transmembrane proteins.

  -3 major respiratory enzyme complexes are located in the inner membrane
- The inner membrane encloses the matrix which contains occasional granules that serve as the binding sites for Ca^{2+} and other divalent cations.
- The matrix also contains DNA (viral) of the circular type and r, t, and mRNA
- Mitochondria do not replicate by *de novo* synthesis but grow and divide


Inner membrane
Outer membrane
Cristae
Intermembrane Space
Matrix


DNA
ribosomes
matrix
outer membrane
inner membrane
intermembrane space
F0 portion
F1 portion
cristae
©1998 Encyclopaedia Britannica, Inc.

Mitochondrion / -a



Endoplasmic reticulum

- There are 2 functionally and structurally distinct forms

  1) Rough endoplasmic reticulum (rER)

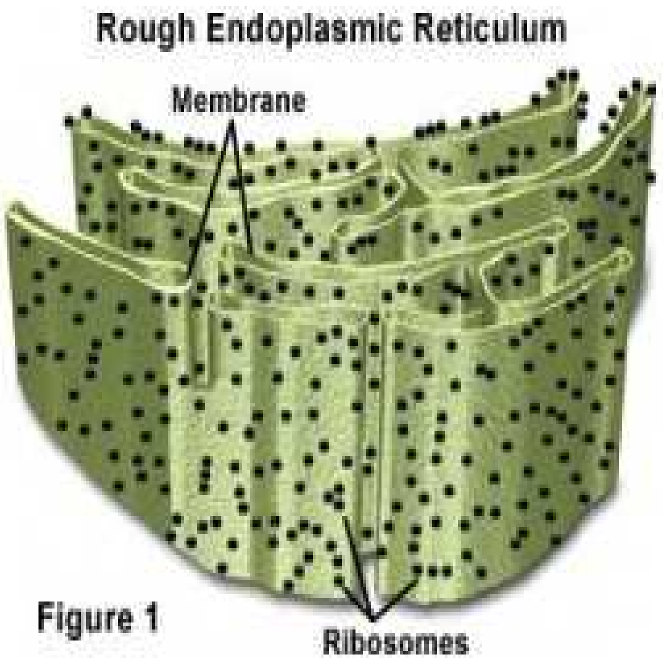
  2) Smooth endoplasmic reticulum (sER)

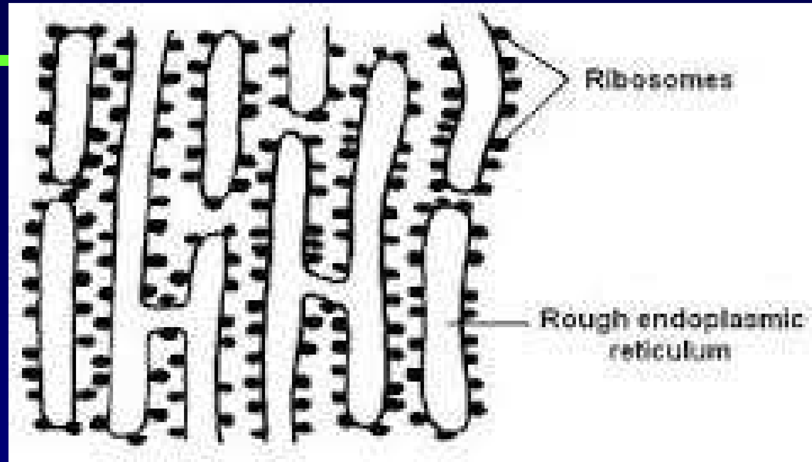
Rough endoplasmic reticulum (rER)

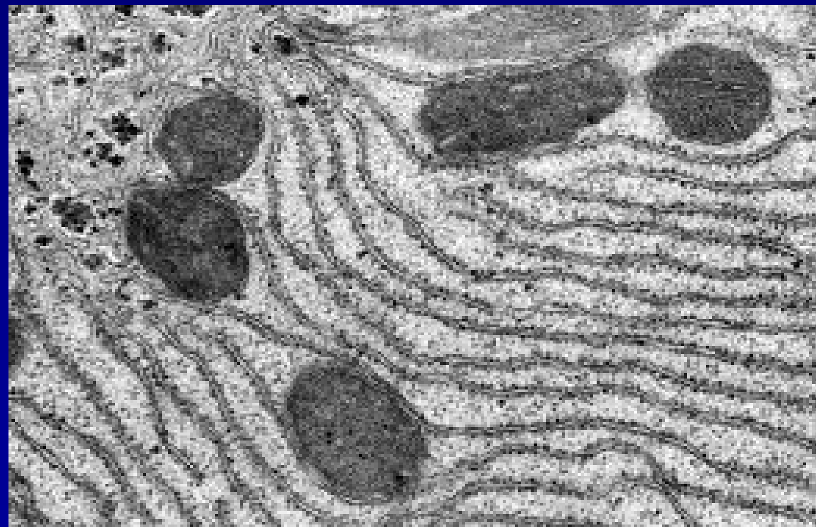
- Consists of a network of flat and wide sacs referred to as cisternae.
- The cytoplasmic surface is studded with ribosomes (hence "rough")
- Aggregates of rER appear as basophilic regions called ergastoplasm or chromidial substance

Functions of rER

- Synthesis of proteins for extracellular or intracellular use (e.g secretory prots., lysosomal prots., membrane prots. etc)
- Glycosylation of proteins to form glycoproteins. This takes place at the luminal site of the rER.


Rough Endoplasmic Reticulum
Membrane
Ribosomes
Figure 1


Ribosomes
Rough endoplasmic reticulum

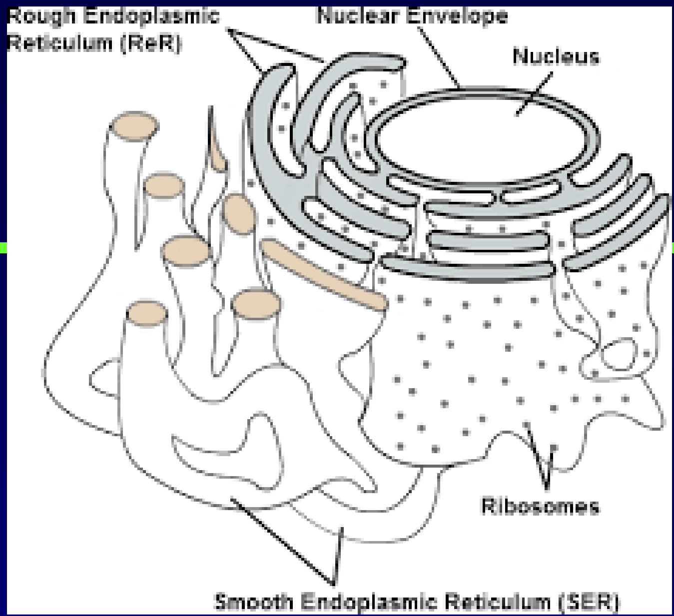


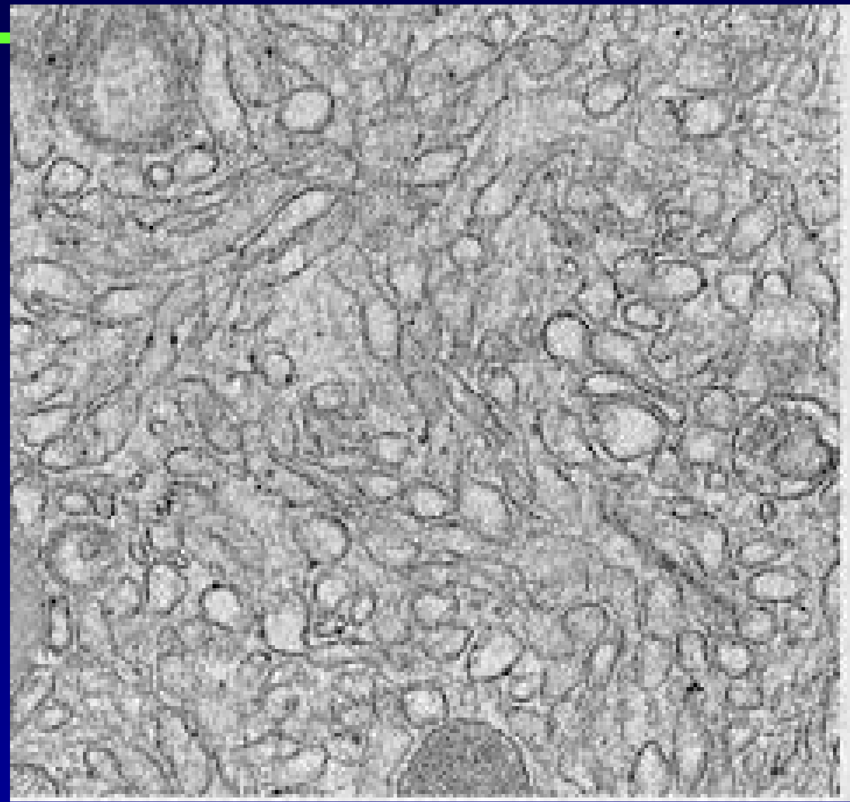
Smooth endoplasmic reticulum

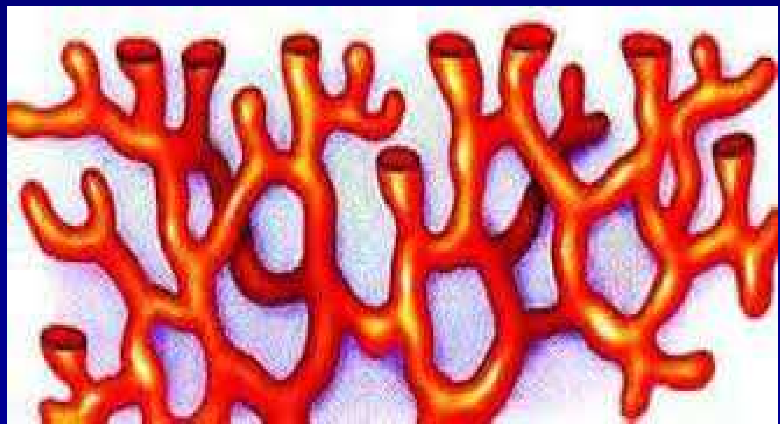
- Consists of a network of tubules that, in most cells, are the ribosome-free terminal portions of rER.
- In steroid hormone synthesizing cells and striated cells, sER are well developed and consists of single vesicles and anastomosing network of tubules of uniform sizes.

Functions

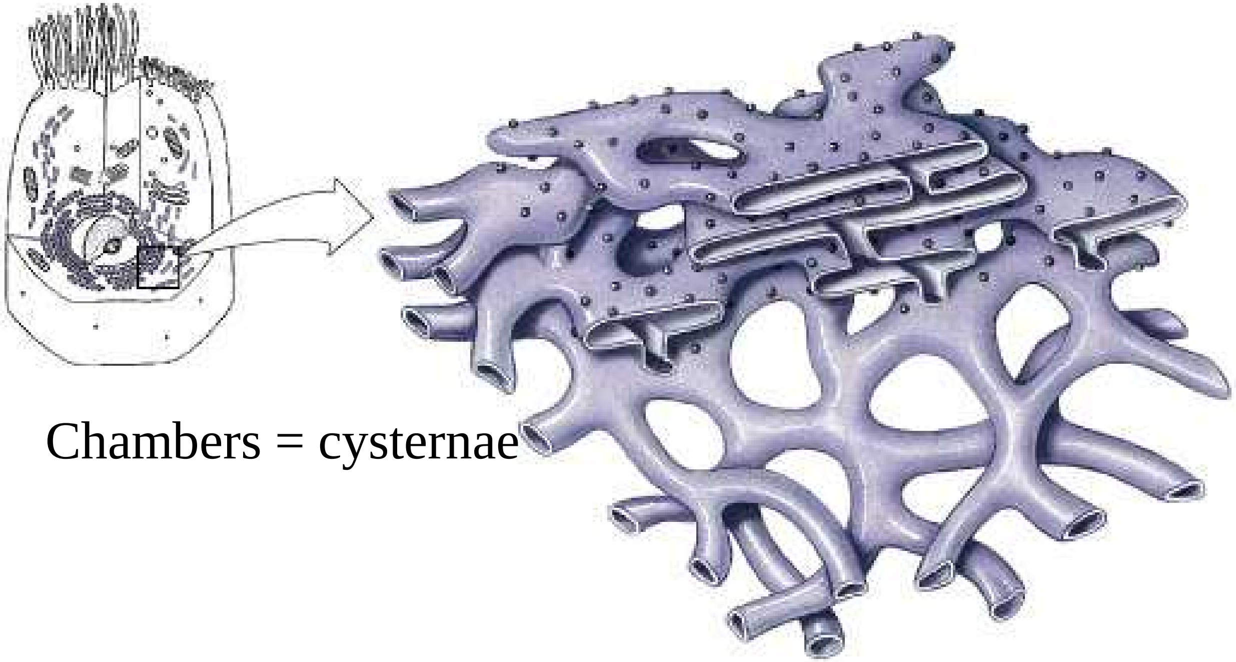
- Steroid hormone synthesis e.g in testicular interstitial cells, corpus luteum and adrenal cortex
- Synthesis of complex lipids
- Drug detoxification in hepatocytes
- Lipid re-synthesis in the interstitial absorptive cells
- Release and capture of Ca^{2+} in striated muscles
- Concentration of Cl^{-} in gastric parietal cells.


Rough Endoplasmic Reticulum (ReR)
Nuclear Envelope
Nucleus
Ribosomes
Smooth Endoplasmic Reticulum (SER)

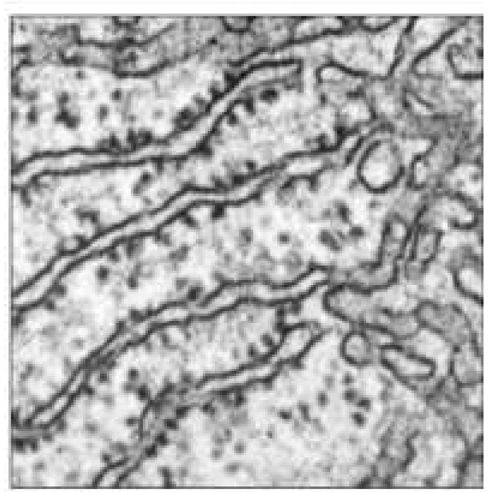




smooth & rough ER



Chambers = cysternae



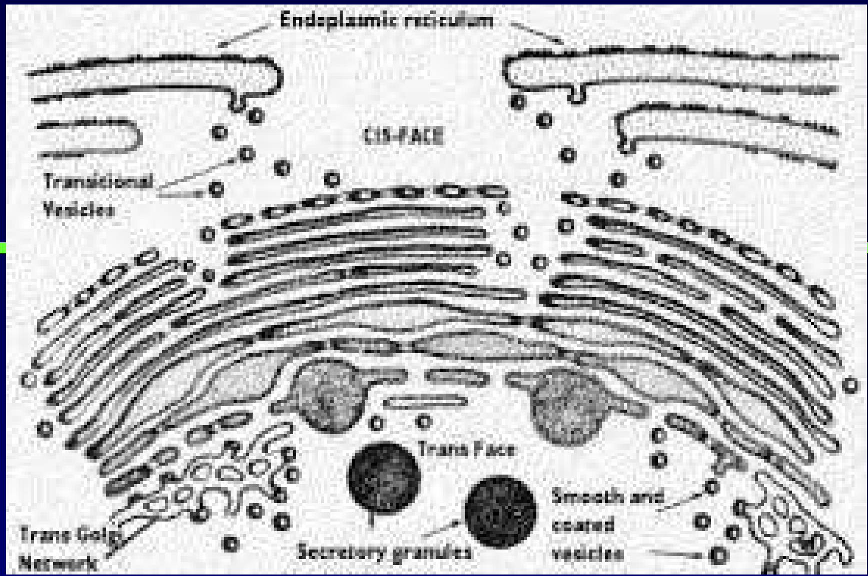
Function: Synthesis — Storage — Transport

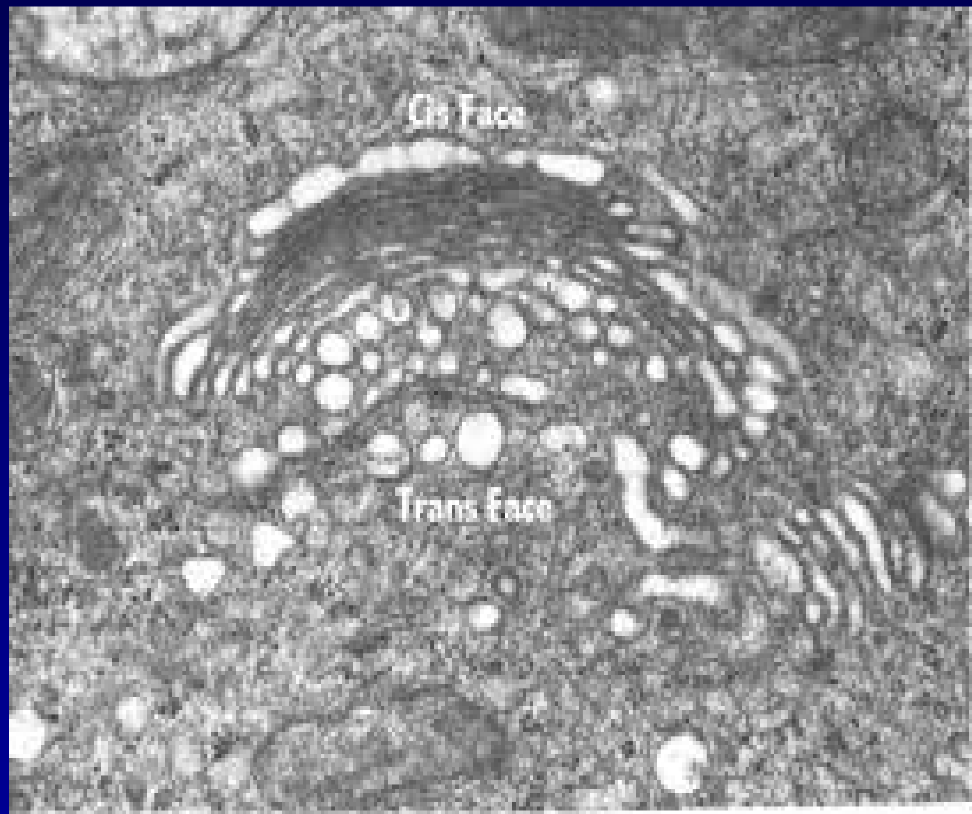
Golgi complex

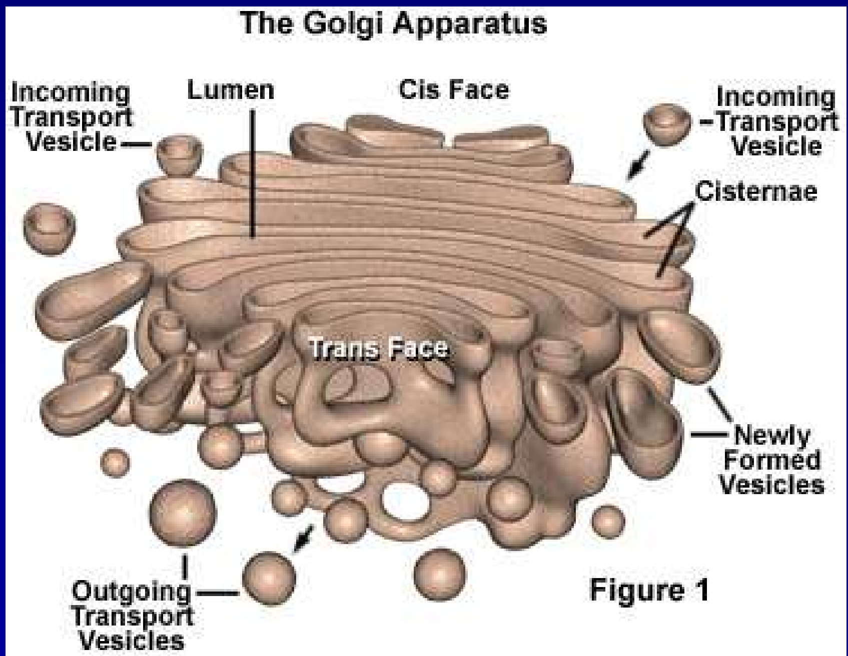
- Consists of one or several stacks of parallel membrane-bound cisternae and associated vesicles and tubules at the lateral surfaces and at either face of the stack
- The face consisting of a network of tubules is called the cis-face while the maturing face of the complex composed of a tubular and cisternal network connected to the stack is called the trans-face

Functions

- Covalent modification of oligosaccharides coupled to proteins in the ER, glycosylation, sulfation and phosphorylation
- Initiation of the process of proteolytic conversion of protein prohormones
- Protein concentration and eventual “packing” into vesicles

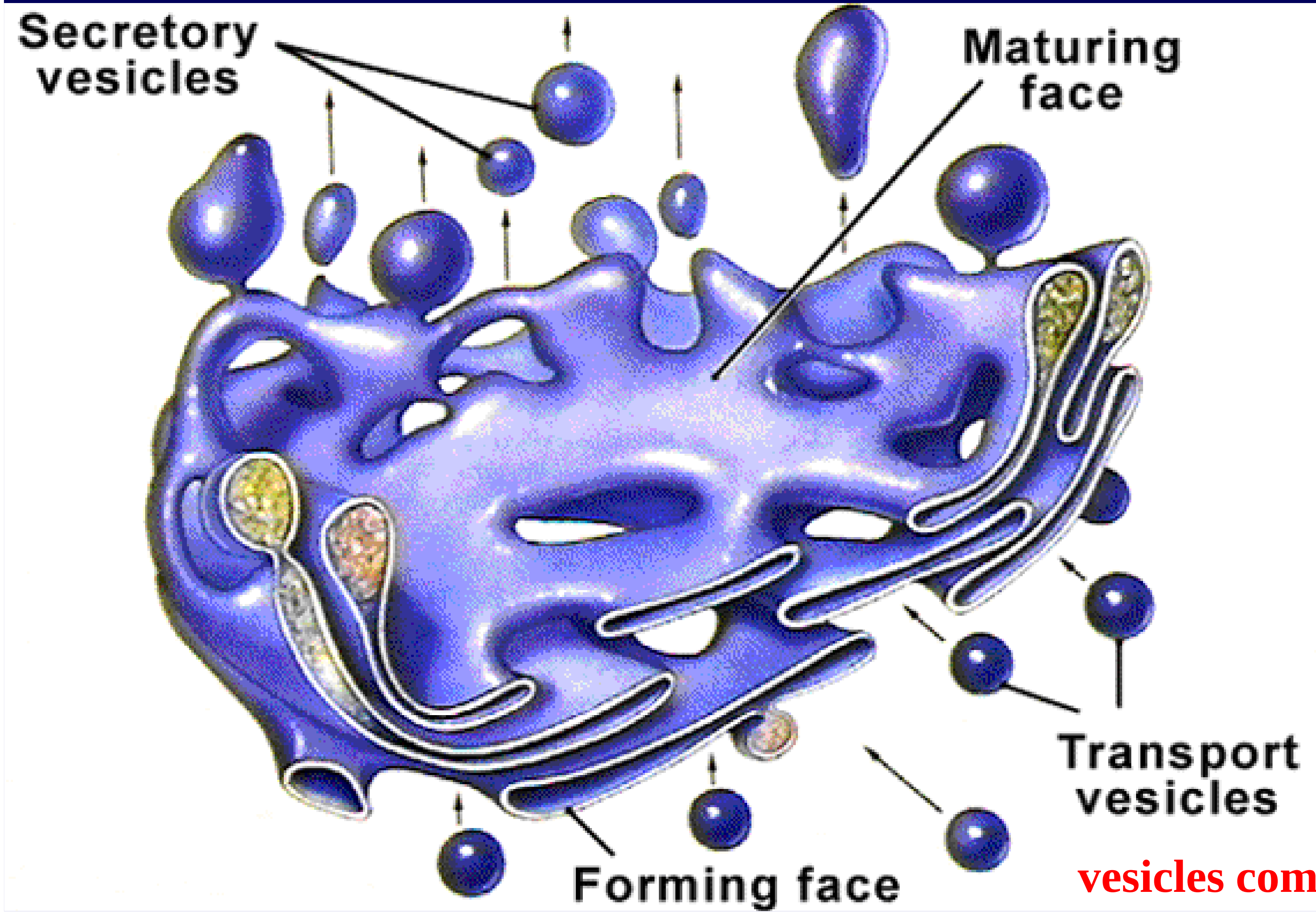

Endoplasmic reticulum
CIS-FACE
Transicional Vesicles
Trans Face
Smooth and coated vesicles
Trans Golgi Network
Secretory granules


Cis Face
Trans Face


The Golgi Apparatus
Incoming Transport Vesicle
Lumen
Cis Face
Incoming Transport Vesicle
Cisternae
Trans Face
Newly Formed Vesicles
Outgoing Transport Vesicles
Figure 1

Golgi Apparatus

Packaging and shipping of proteins



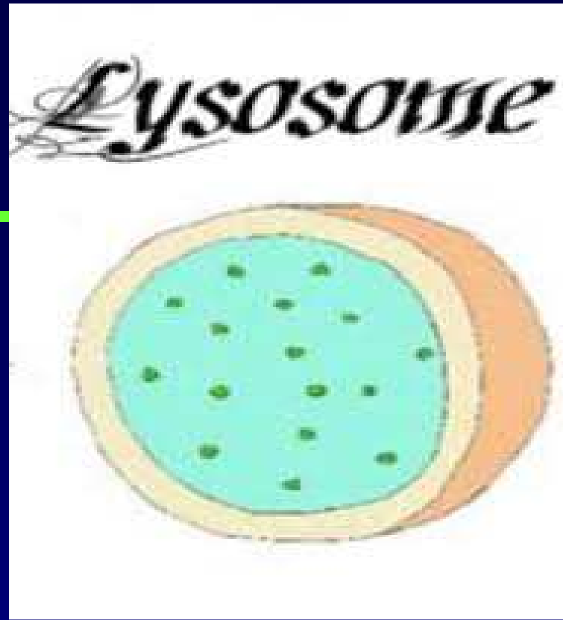
Cell membrane renewal

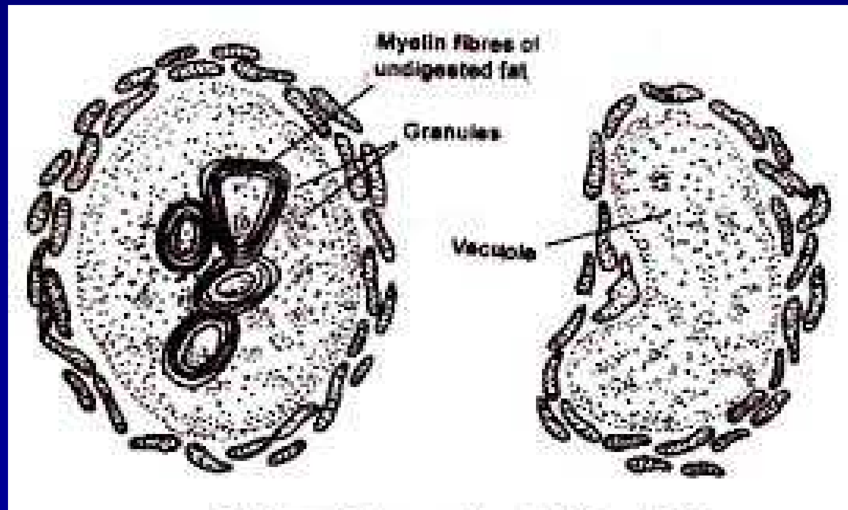
vesicles come from ?

Lysosomes

- There are 2 types of lysosomes;
  1) Primary lysosomes
  2) Secondary lysosomes
- *Primary lysosomes* contain hydrolytic enzymes
- *Secondary lysosomes* are the result of the fusion of primary lysosome with a variety of membrane-bound substrates e.g heterophagosomes, autophagosomes, secretory vesicles and endocytotic vesicles
- When elements of rER, mitochondria and other cytoplasmic organelles lose their ability to function, they become segregated within sER to form autophagosomes which then fuse with primary lysosomes to form autophagic vacuoles.
- Crinophagic vacuoles are formed when aged, damaged or excess secretory vesicles fuse with primary lysosomes
- Multivesicular bodies are large membrane-bound sacs containing varying nos. of small vesicles surrounded by lysosomal enzymes

- In advanced stages of degradation, lamellated concentric membrane-bound structures represent the indigestible residues called dense lamellar bodies, myelinated bodies or residual bodies. They may also occur as vacuolated dense bodies
- The contents of these bodies may either be released from the cell or remain within permanently as lipofuchsin granules





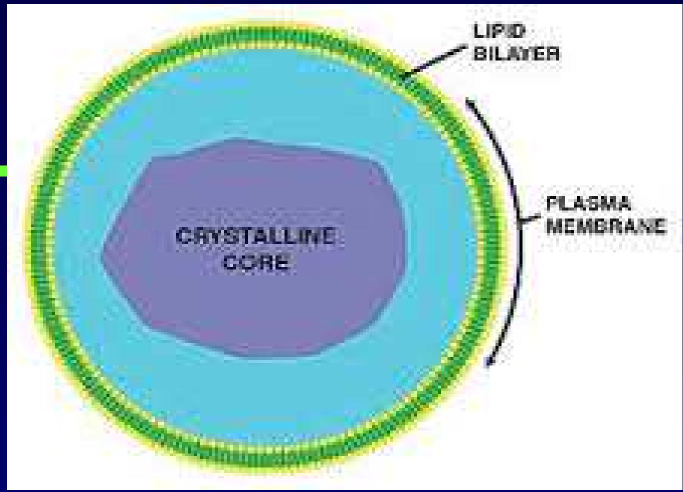
Two types of Lysosomes from the kidney cells of rat

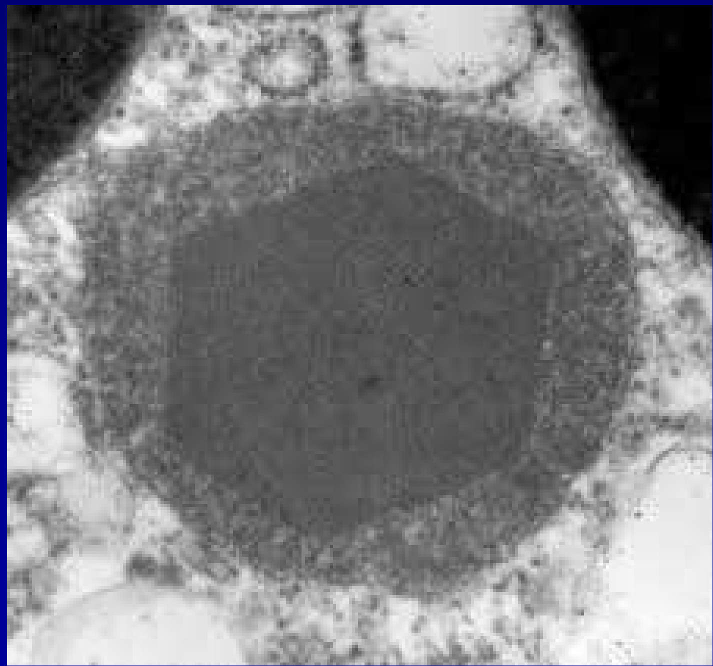
Peroxisomes

- These are membrane-bound spherical organelles with finely granular materials and crystalline electron-dense inclusions abundant in hepatocytes and epithelial cells of proximal convoluted tubules.
- They are the major site of oxygen utilization in the cell and are rich in catalase and hydrogen peroxide

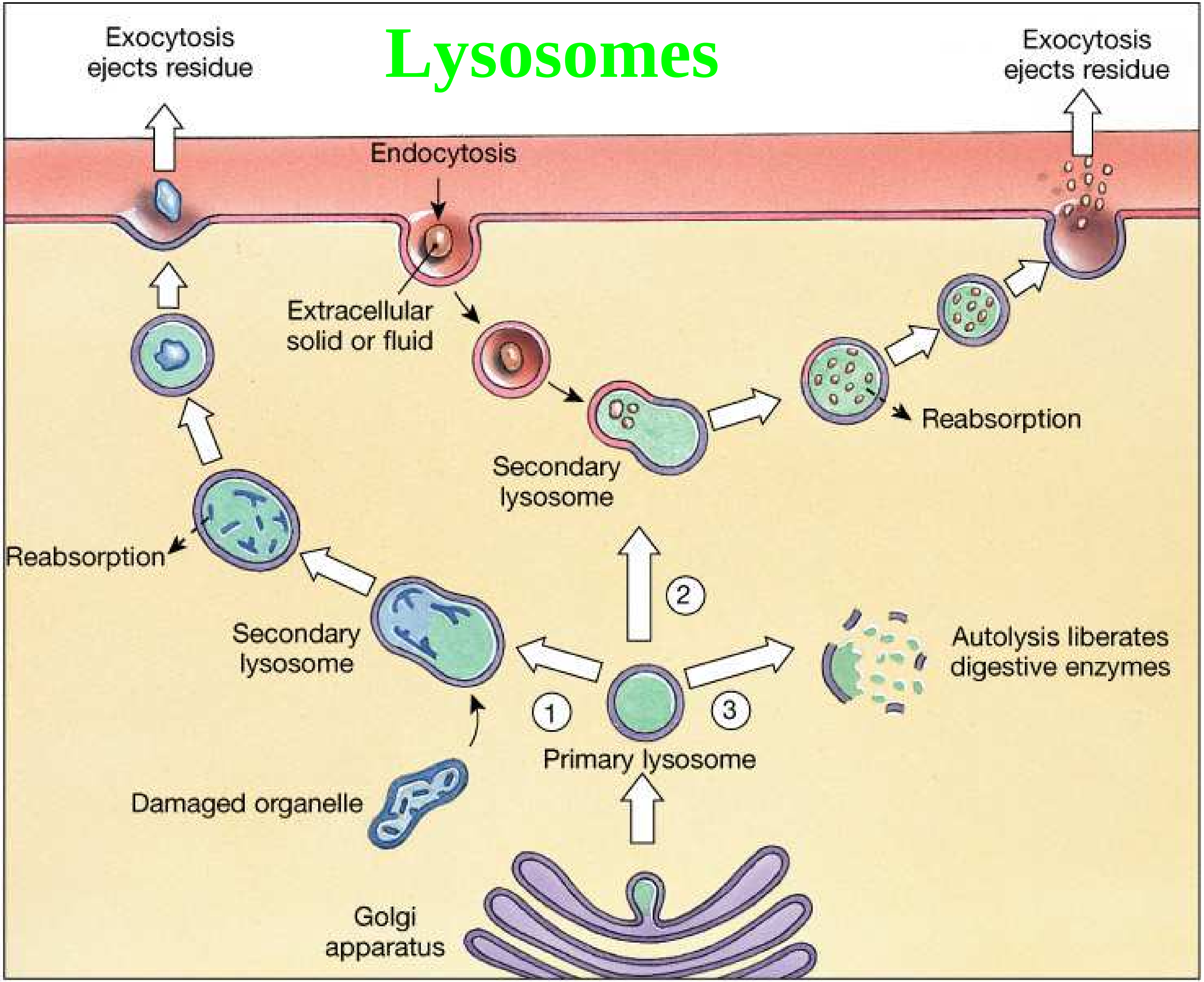
Functions

- Detoxification reactions and breakdown of fatty acids to acetyl CoA.





Lysosomes



Exocytosis ejects residue
Exocytosis ejects residue
Endocytosis
Extracellular solid or fluid
Secondary lysosome
Reabsorption
Reabsorption
Secondary lysosome
2
Autolysis liberates digestive enzymes
1
3
Primary lysosome
Damaged organelle
Golgi apparatus

Cytoplasmic inclusions

- *Glycogen:-* This is the major storage form of carbohydrates and is abundant in liver cells
- *Lipid:-* Fats are primarily stored in fat cells. At EM, lipids appear as droplets
- They are demonstrated by osmic acid fixation or Sudan III staining.
- *Melanin:-* Dark-brown to brown pigment which occurs in the eye and integuments and is synthesized by melanocytes and secreted as granules

- *Hemosiderin:-* This results from Hb degradation following phagocytosis of erythrocytes by macrophages of spleen, liver, bone marrow and hemal lymph nodes. The pigment contains iron
- *Lipofuscin:-* These are golden-brown in colour occurring in aggregates. Commonly found in cardiac muscle, liver and nerve cells. They are referred to as “wear-and tear“ pigments because the amount increases with age

Nucleus

- The nucleus carries information about the functions of the cell, hence, the organism in deoxyribonucleic acid (DNA)
- Most commonly, nuclei are spherical to ovoid although they may also be spindle-shaped, bean-shaped or kidney-shaped (monocytes), or multilobulated (neutrophilic leucocytes)
- The interphase nucleus contains chromatin and one or several nucleoli

Nuclear envelop

- Consists of 2 concentric membranes separated by a perinuclear space 25nm wide.

- The outer nuclear membrane may be studded with ribosomes and continuous with the membranes of both rER and sER. Hence, it is part of the secretory machinery of the cell
- At the inner surface of the inner membrane, polypeptides that bind to membrane protiens and to which specific sites of chromatin (hetero-) are attached form a granular laminar
- The nuclear envelop is interrupted with numerous pores through which the nucleus communicates to the cytoplasm

Chromatin

Chromatin occurs in 2 forms;

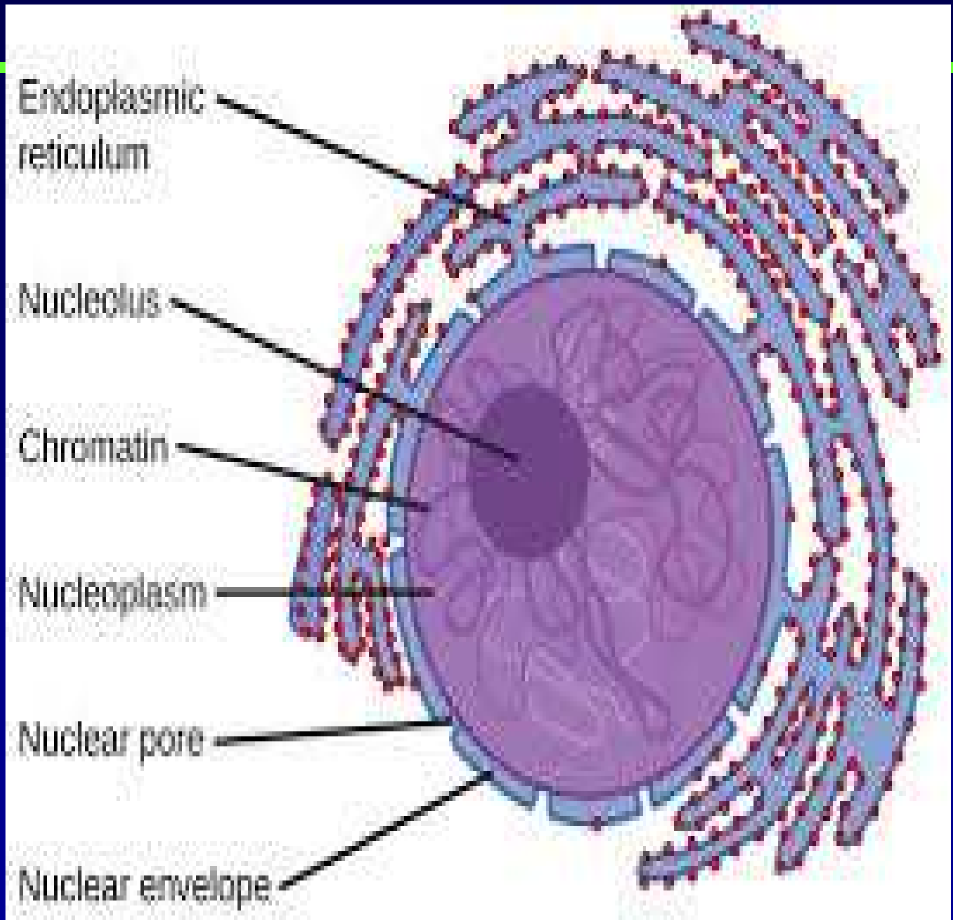
- Heterochromatin
- Euchromatin

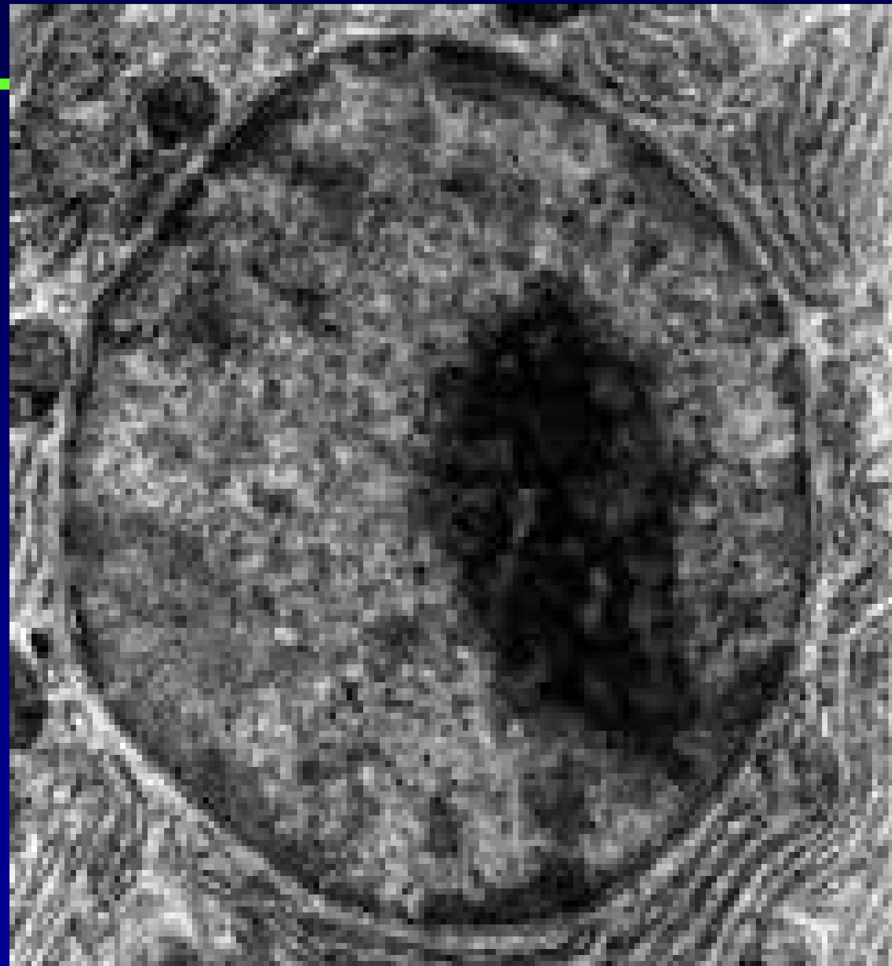
Heterochromatin appear as irregular clumps or threads of basophilic material located at the nuclear periphery or scattered throughout the nucleus or in association with the nucleolus. It consists of tightly coiled portions of chromosomes. They are mainly found in inactive cells

Euchromatin usually remains unstained and are abundant in relatively active cells. In females, sex chromatin or Barr body appears as an appendage in neutrophilic leucocytes

Nucleolus

- This is a conspicuous, spherical basophilic organelle within which the subunits of ribosomes (rRNA) are synthesized
- Under EM, nucleolus consists of pars granulosa (granular part) and pars fibrosa (fibrous part)


Endoplasmic reticulum
Nucleolus
Chromatin
Nucleoplasm
Nuclear pore
Nuclear envelope



Cell division

- Cell division occurs in order to maintain cell populations of mature organisms
- The life cycle of somatic cells is divide into 2 phases;

  -Interphase

  -Mitosis

Interphase:- This is the phase during which replication of genetic material occurs. It is subdivided into 3 phases;

1) G_1 (gap 1) or preduplication phase- The period between the previous mitosis and the beginning of DNA duplication

2) S or synthesis phase – DNA replication occurs resulting in 2 daughter chromosomes each consisting of 50% of the original and 50% new DNA. Daughter chromosomes are referred to as chromatids

3) G_2 (gap 2) or postduplication phase – duplication of the centriole which begins at S-phase is completed

Mitosis:- In this phase, DNA is equally distributed among the daughter cells. It is further divided into 4 phases

- *Prophase:-* Chromosomes become visible, shorten, thickens and coils and is seen consist of 2 chromatids.

  -Centrioles move to the opposite poles and nuclear envelope disintegrate

  - Nucleolus disappears
- *Metaphase:-* Chromosomes become arranged the equatorial plane with their centromeres in the same plane
- *Anaphase:-* Centromeres split separated chromatids of each chromosome move to the opposite pole
- *Telophase:-* There is elongation and unwinding of chromosomes with the ultimate return to the interphase. Nuclear envelope reassemble and nucleolus is reconstituted. Cleavage furrow deepens and eventually breaks completing cytokinesis

In reproductive cells where there are haploid no. of chromosomes, the cells undergo meiosis

Meiosis:- Here the nucleus undergoes 2 successive divisions resulting in a reduction of the no. of chromosomes from diploid (2N) to haploid (N)

- The reproductive cells go through the 1st maturation division characterized by;

- Prophase – divided into;

1) *Leptotene* – chromosomes replicate during interphase

2) *Zygotene* – homologus chromatids pair

3)*Pachytene* – Completion of pairing and cross-over occurs

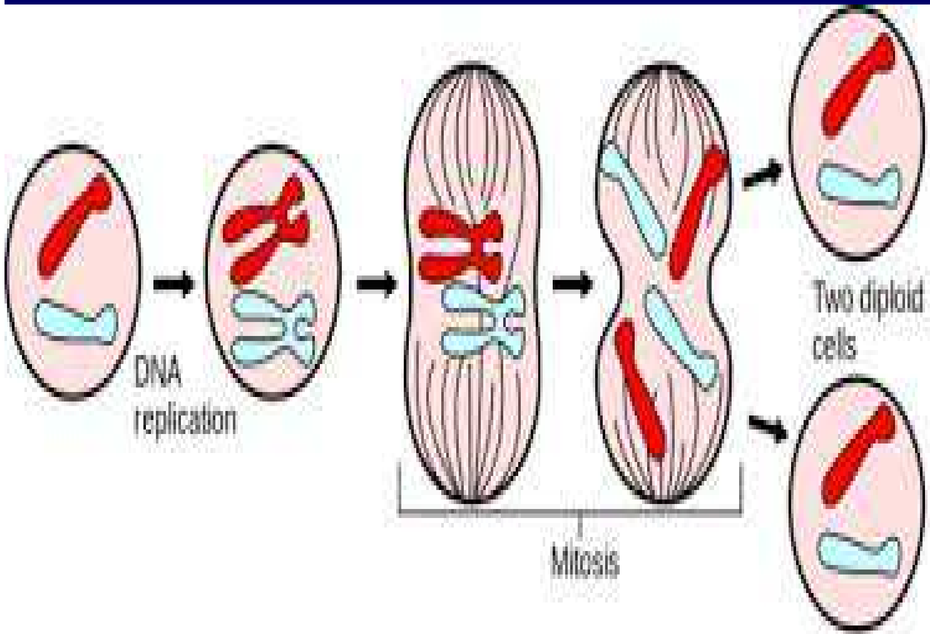
4) *Diplotene* – Paired chromosomes pull away from each other but remain attached at chiasmata

5) *Diakinesis* - Chromosomes shorten and broaden

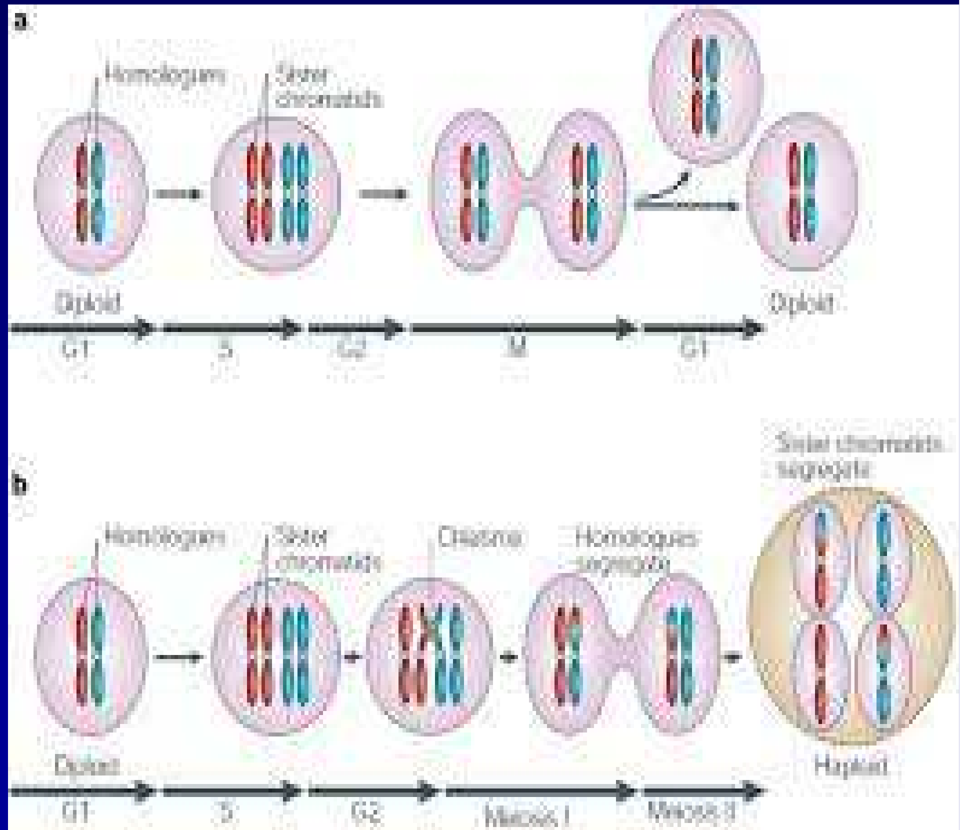
- Metaphase, anaphase and telophase

  These are fairly rapid and the chromosomes are arranged in the equatorial sites, then homologous chromosomes separate and move towards the poles, uncoil and lengthen
- After a short interphase, the 2nd maturation division occurs
- Prophase, metaphase and telophase occur as before but this time the centromere divide, sister chromatids separate and are distributed to each of the resulting mature cells.
- The resulting daughter cells have haploid no. of chromosomes

Mitosis



Meiosis



Functional morphology of the cell

1. Specialization for cell attachment and communication

These can be classified as;

- Adhering junctions
- Impermeable junctions
- Communicating junctions

Adhering junctions:- There are 3 types;

Belt desmosomes (zonula adherens) – surrounds epithelial cells in a belt-like fashion

-the 2 plasma membs. are separated by a space of 20nm wide filled with filamentous intercellular material

- Spot desmosomes (macula adherens) – This is a disk-like structure approx. 200-400nm in diam. It has an intercellular space of about 20nm wide and contains intermediate filaments

– Hemidesmosomes - consists of only ½ of the desmosome. They are means of attaching epithelial cells to the basal lamina

Impermeable junctions:- The only impermeable junction is tight junction (zonula occludens)

- It seals neighbouring cells together forming a barrier preventing passage of substances from lumen to the intercellular space. It may be selectively permeable

– The zonula occludens, zonula adherens and macula adherens found in intestinal epithelial cells together form the junctional complex

Communicating junctions (*gap junctions*) – Here the intercellular space is narrowed to approx. 2nm wide

-Gap junctions allow direct passage of ions and small molecules from cell to cell

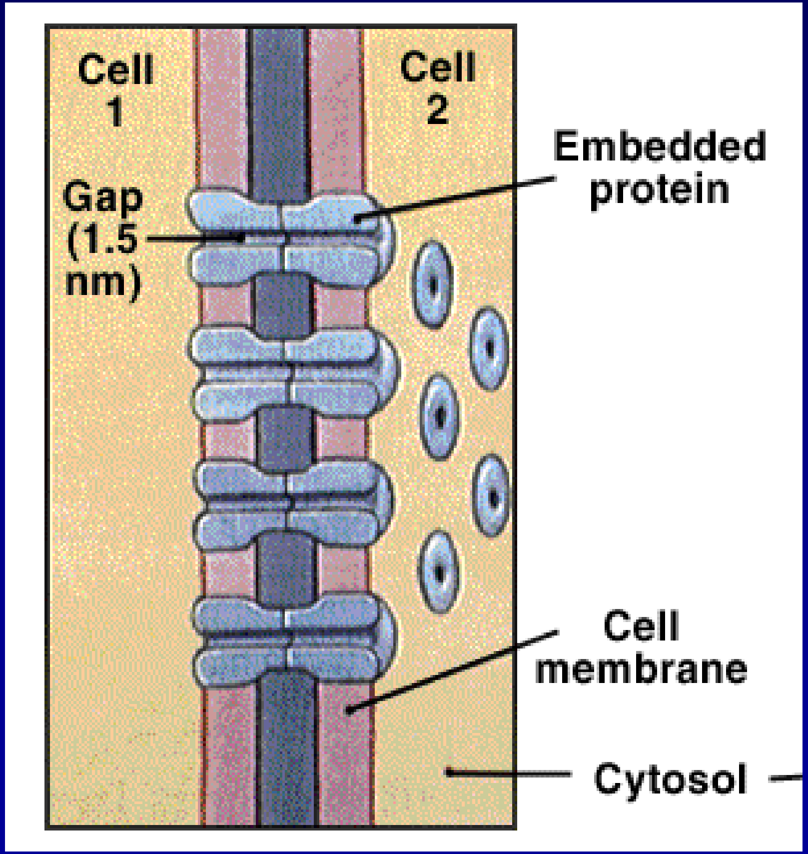
- Commonly found in all tissues (e.g heart muscles) but absent in skeletal muscles, spermatozoa and circulating blood cells

Intercellular Attachments

1) Gap Junctions

channel proteins (connexons) interlock and form pores

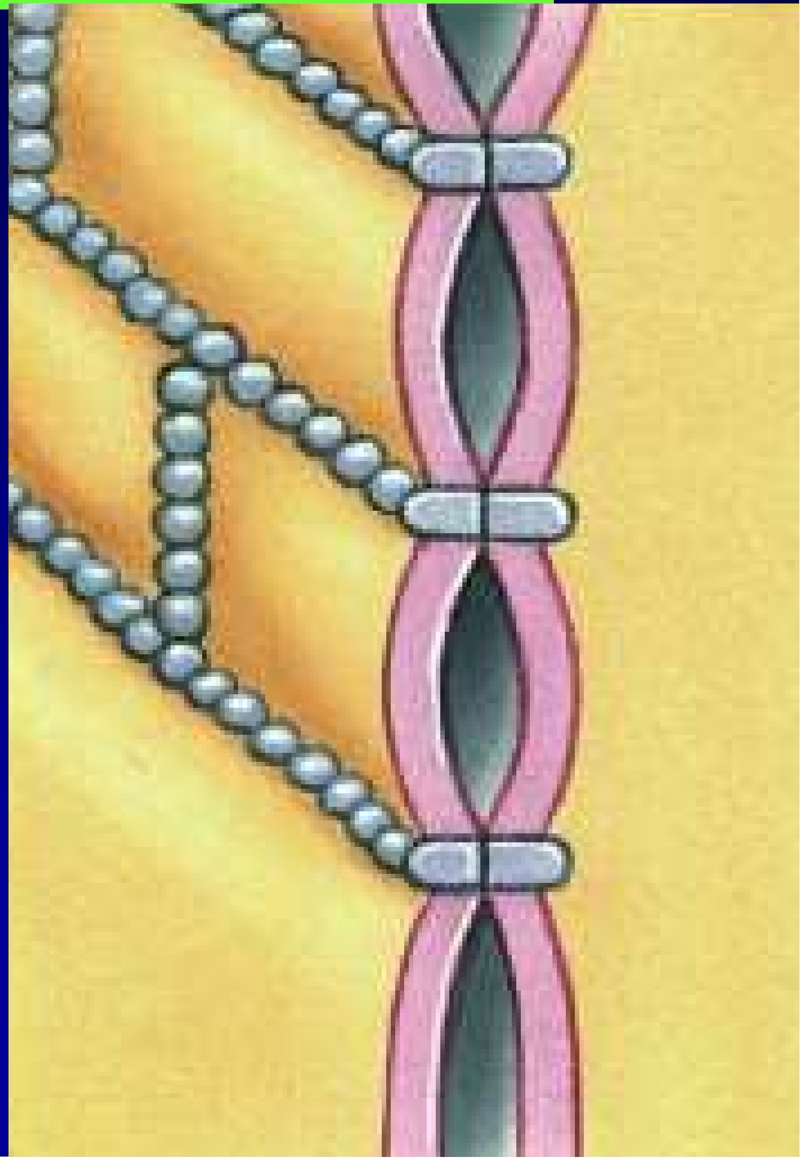
abundant in cardiac and smooth muscle



2) Tight Junctions

Interlocking membrane proteins

Found near surface of cells lining the digestive tract. *Explain!*

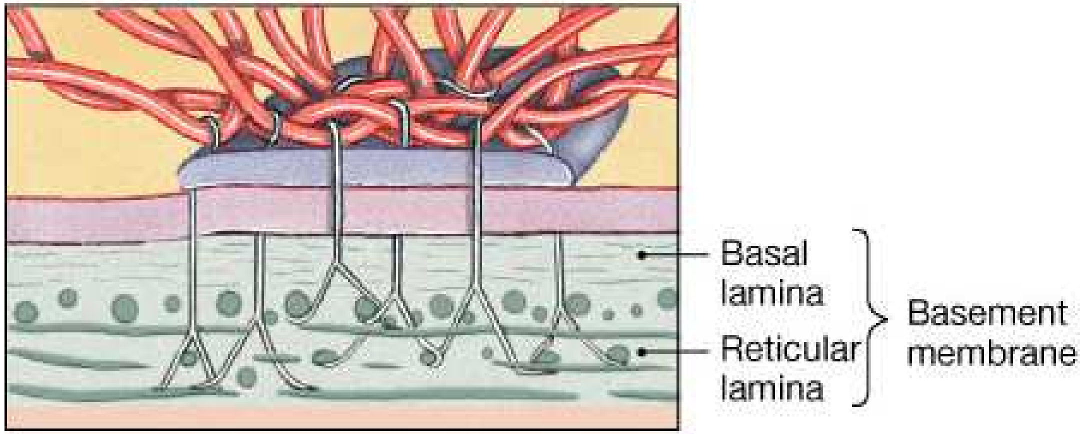


3) Desmosomes

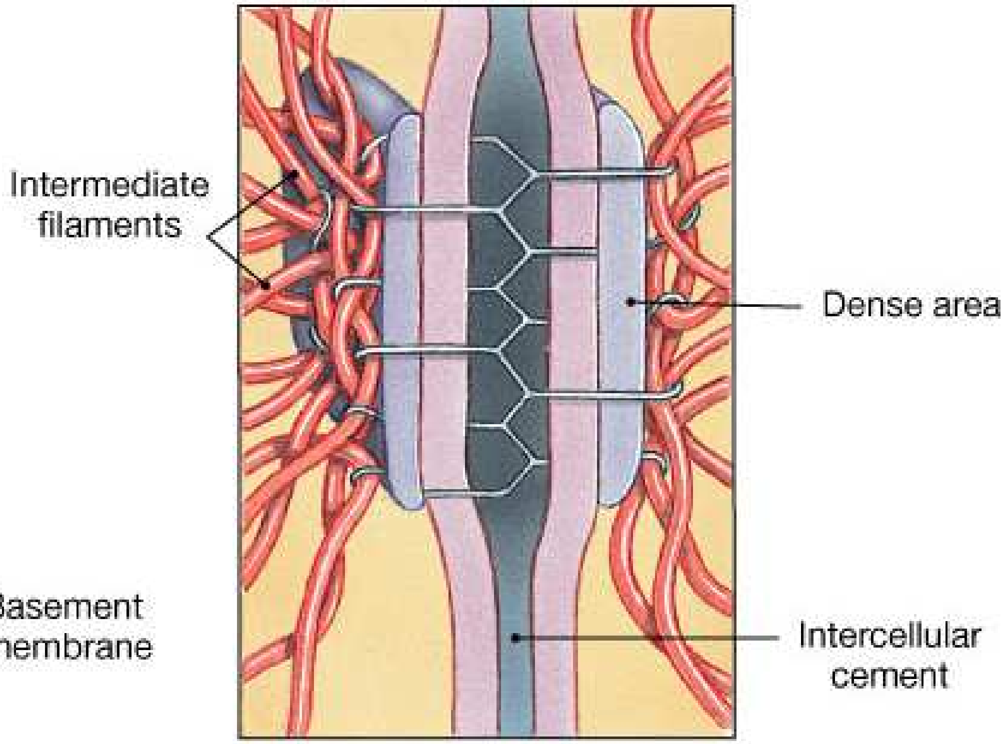
Proteoglycan layer reinforced by transmembrane proteins (cell adhesion molecules or CAMs)

Belt, button and hemidesmosomes

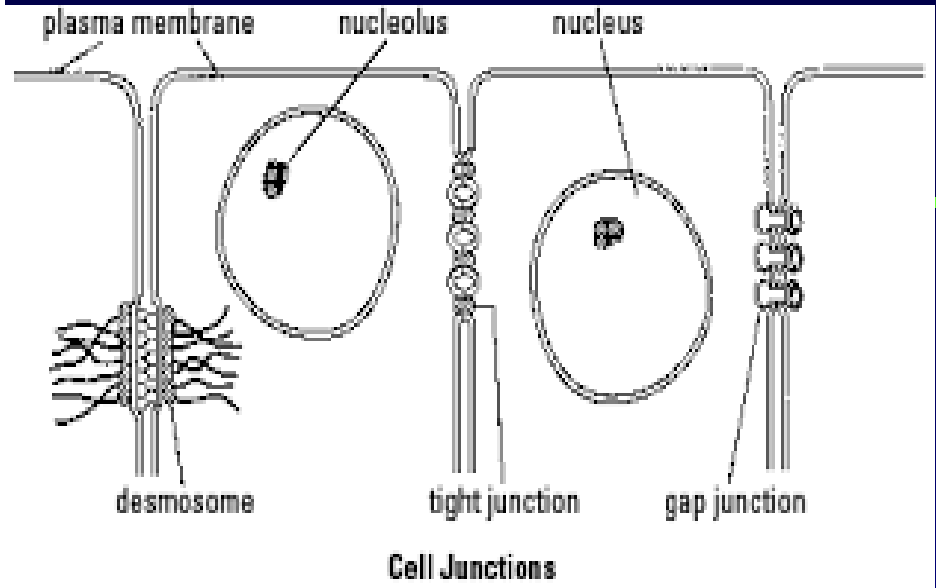
Found in superficial layers of skin

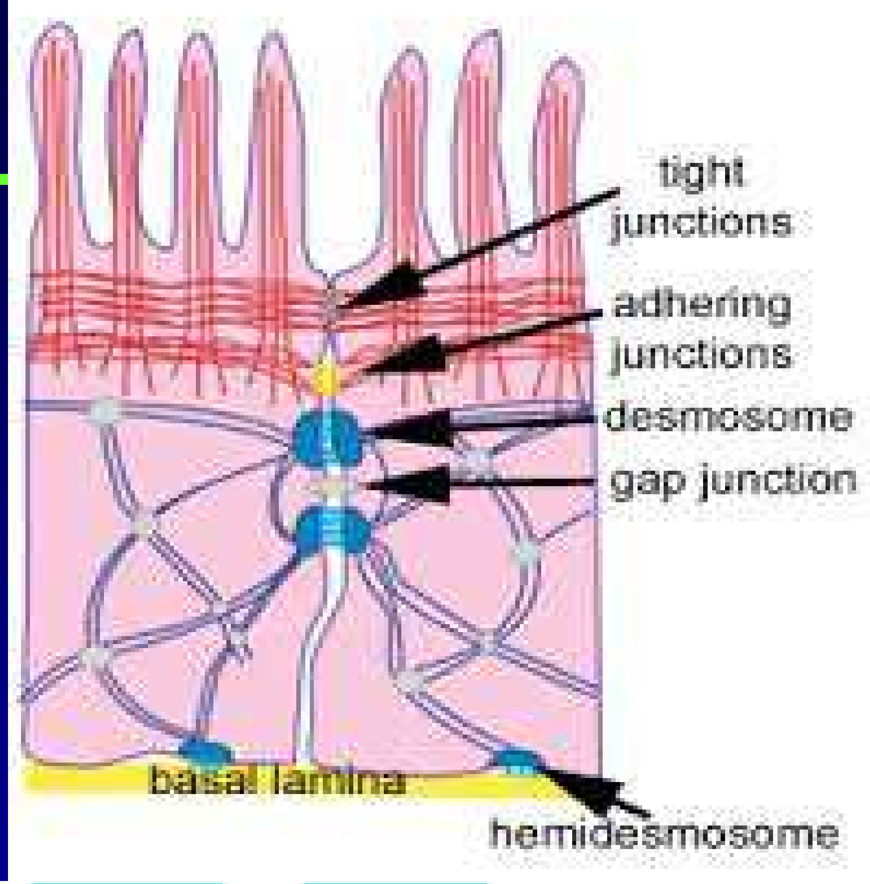


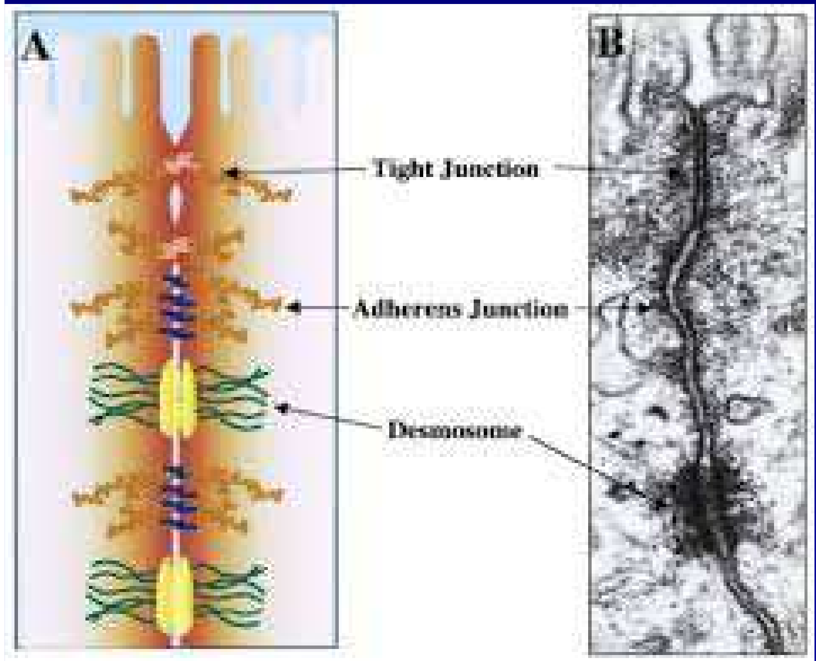
(e) Hemidesmosome

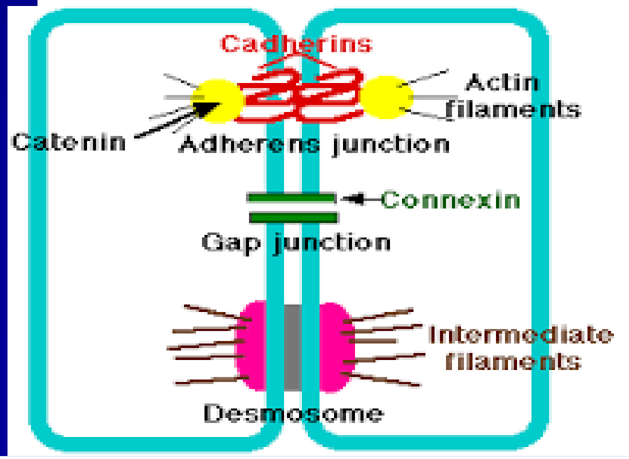


(d) Desmosome


plasma membrane
nucleolus
nucleus
desmosome
tight junction
gap junction
Cell Junctions


tight junctions
adhering junctions
desmosome
gap junction
basal lamina
hemidesmosome


A
B
Tight Junction
Adherens Junction
Desmosome


Cadherins
Actin filaments
Catenin
Adherens junction
Connexin
Gap junction
Intermediate filaments
Desmosome

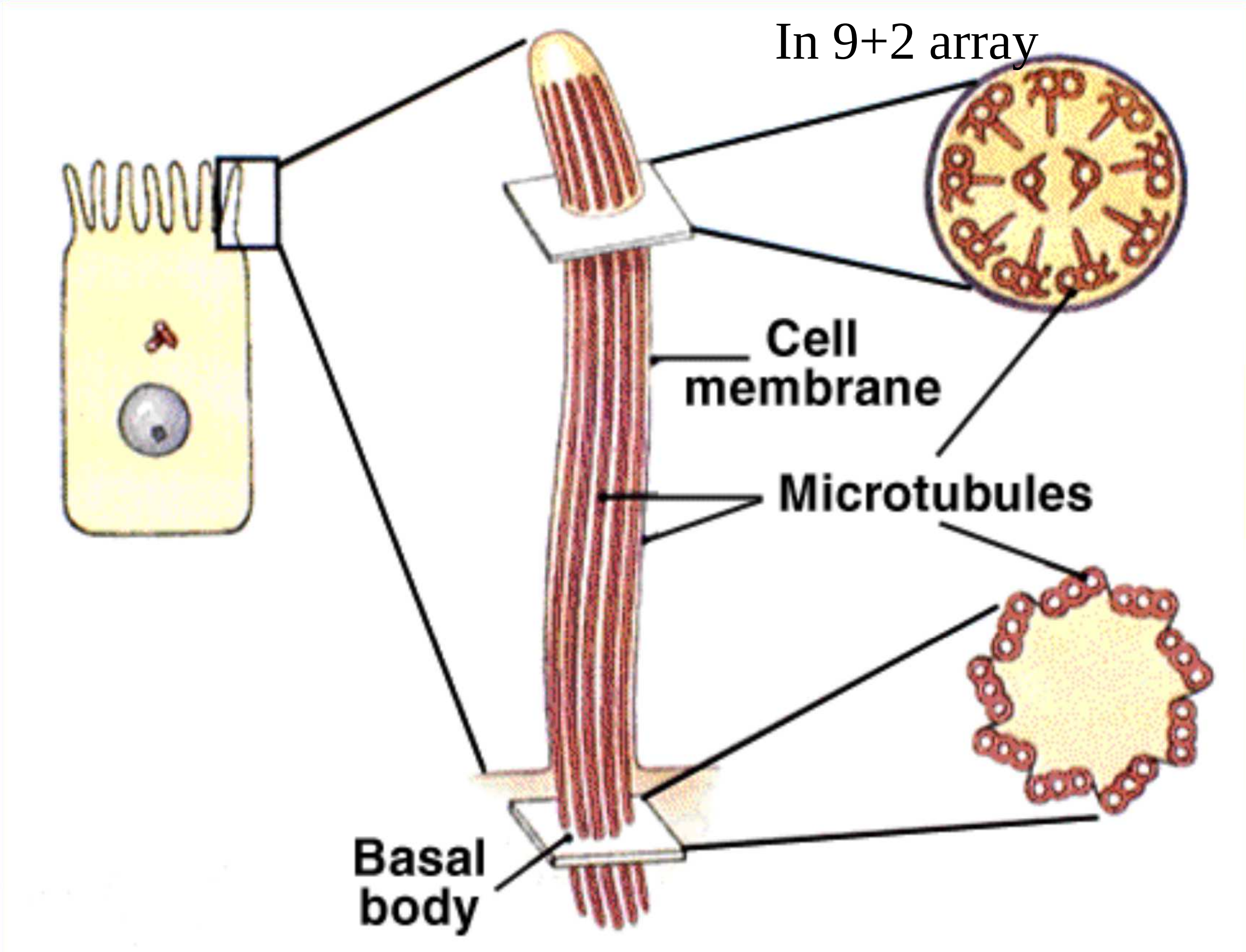
2. Specializations of the free surface

Cilia and flagella

-Cilia measures about 0.2µm in diam and 5-15µm long. It consists of an axoneme with "9+2" arrangement (9 peripheral doublets and 2 central pair of microtubules). Adjacent doublets are linked by a protein called nexin. From each doublet, radial spokes extend towards the central pair.

-Flagellum is a single long cilium. A typical example is in spermatozoon

Cilium - Cilia



Compare to microvilli and flagellum

Microvilli:- These are found in cells whose main function is absorption

-At EM, they are slender and cylindrical measuring 0.1µm in diam. but vary in length

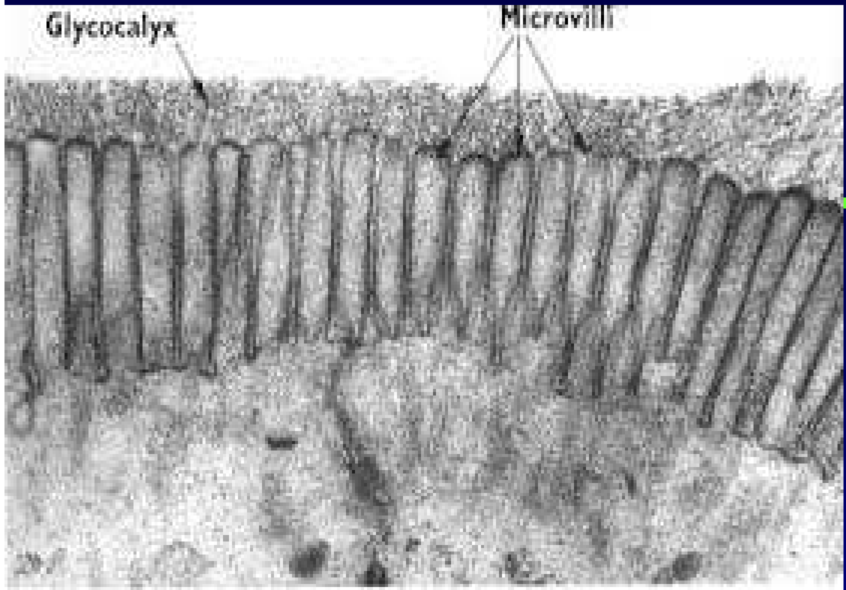
-They contain a core of actin filament

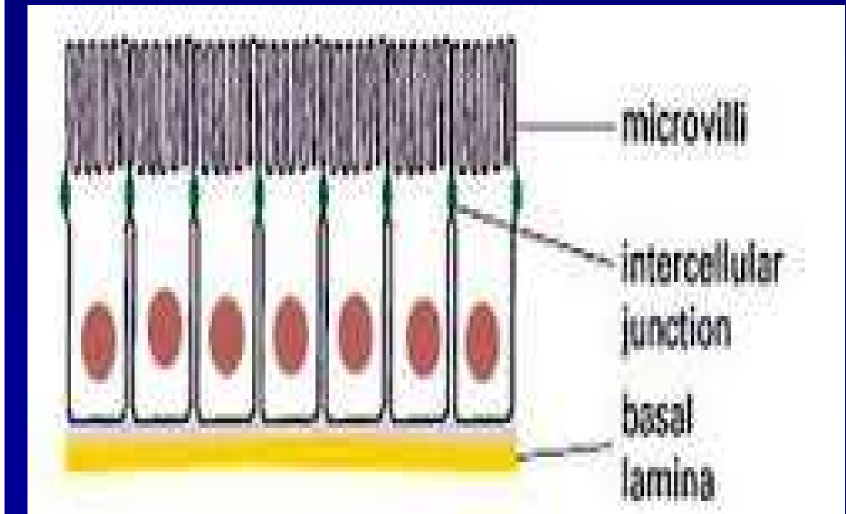
-Another variety of microvilli occur at the luminal surface of the epithelial lining of the epididymis. They are slender and branched

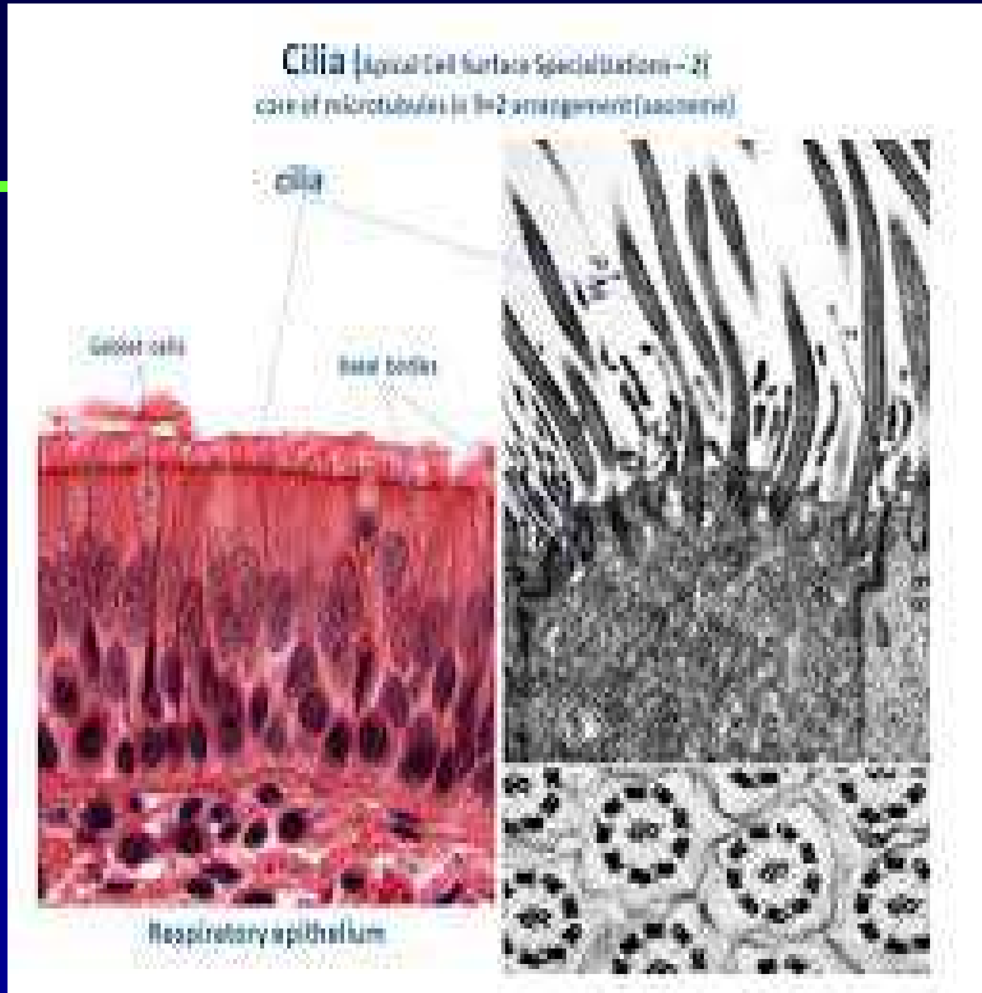
Stereocilia:- These occur in the hair cells of the spiral organ of Corti and receptor cells in the vestibular sensory cells.

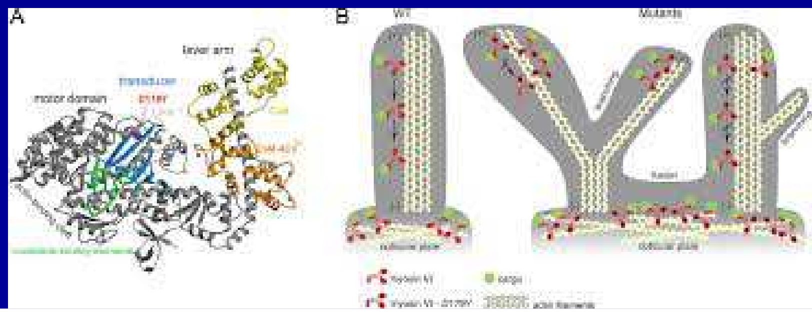
-They contain a core of actin filaments giving them their rigidity

-They are capable of detecting minute movements of the fluid environment


Glycocalyx
Microvilli


microvilli
intercellular
junction
basal
lamina


Cilia
cilia
Respiratory epithelium


A
B