Cell Biology

- Cell Membranes- fluid mosaic model and its functions. Membrane transport, Na-K Pump
- Structure, various models, its function. Cellular transport
- Structure and Function of cells and intracellular organelles (of both prokaryotes and eukaryotes)
- Organelles bounded by double membrane, viz. nucleus, mitochondria, chloroplast etc., endo symbiont theory
- Organelles bounded by single membrane viz. peroxisomes, lysosome, endoplasmic reticulum, Golgi apparatus, vacuoles etc.
- Cytoskeleton- Introduction to microfilaments, microtubules, and intermediate filaments, Nucleation
- Mechanism of cell division including (mitosis and meiosis) and concept of motors

-Dr Gursimran Kaur Uppal

Classification

Five kingdom system:

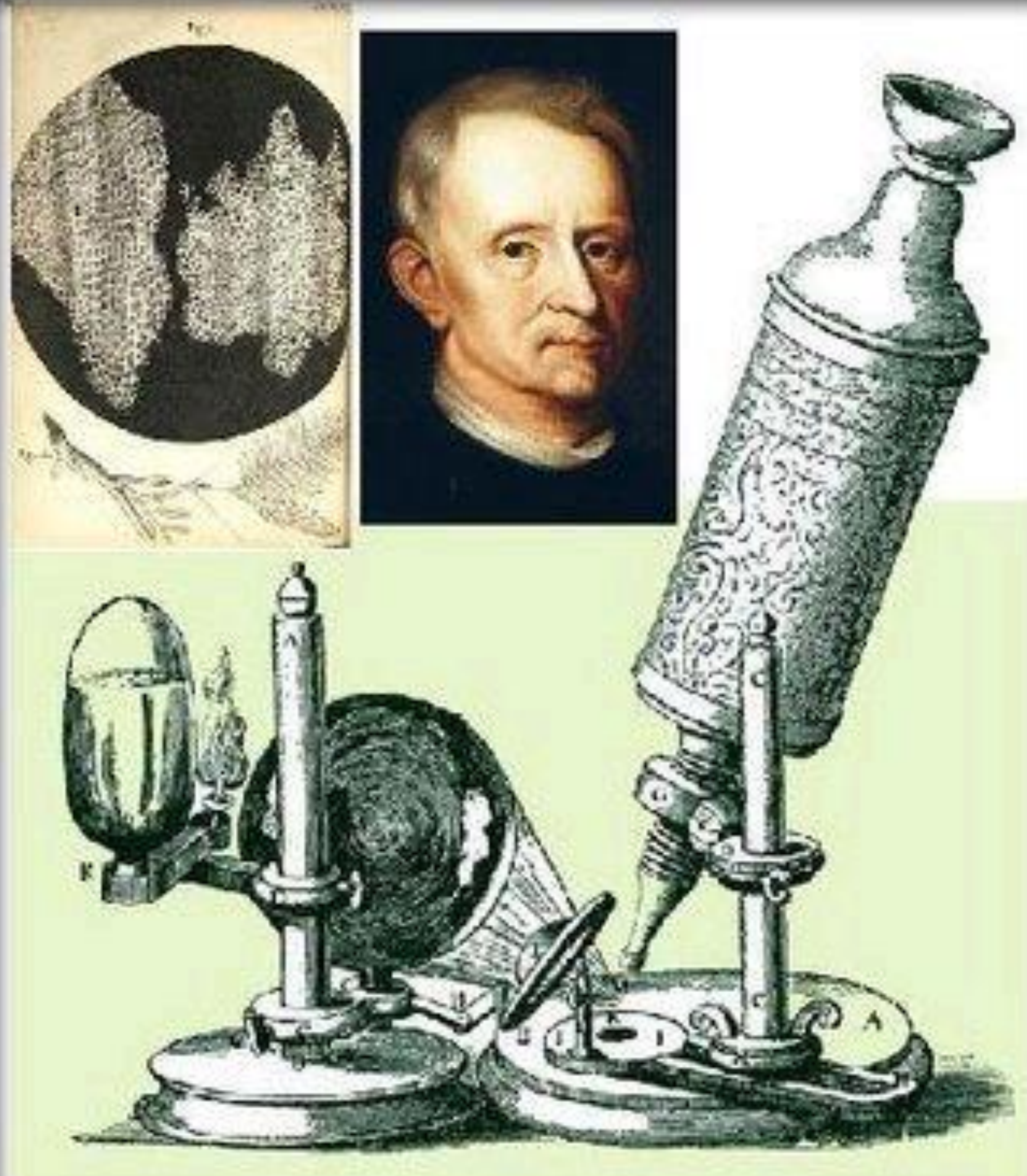
Monera | Protista | Plantae | Fungi | Animalia

Six kingdom system:

Eu-bacteria | **Archae-bacteria** | Protista | Plantae | Fungi | Animalia

Three domain system:

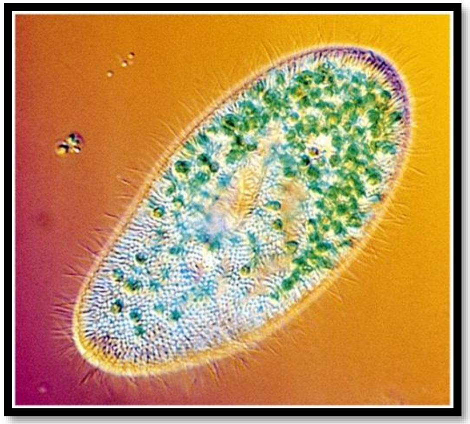
Eu-bacteria | **Archae-bacteria** | E U K A R Y A



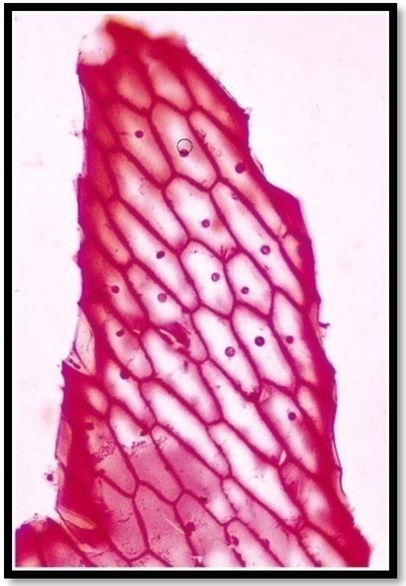
Robert Hooke (1665)

Cells

- Smallest living unit



- Most are microscopic
- Robert Hooke (mid-1600s)
  - Observed sliver of cork
  - Saw “row of empty boxes”
  - Coined the term cell



Cell theory

- (1839)Theodor Schwann & Matthias Schleiden

  " all living things are made of cells"

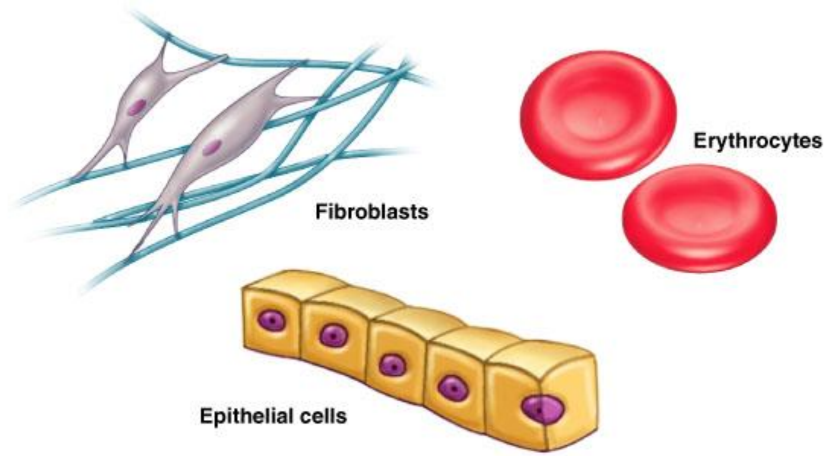
- (50 yrs. later) Rudolf Virchow

  "all cells come from cells"

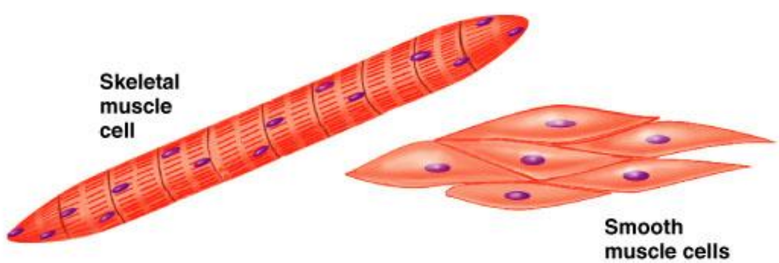
Principles of Cell Theory

- All living things are made of cells
- Smallest living unit of structure and function of all organisms is the cell
- All cells arise from preexisting cells (this principle discarded the idea of spontaneous generation)

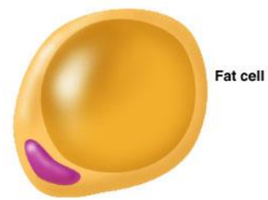
Cell Diversity



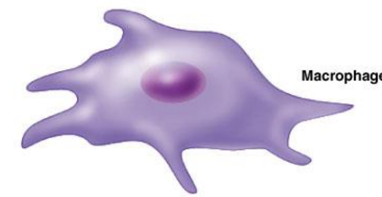
(a) Cells that connect body parts or cover and line organs



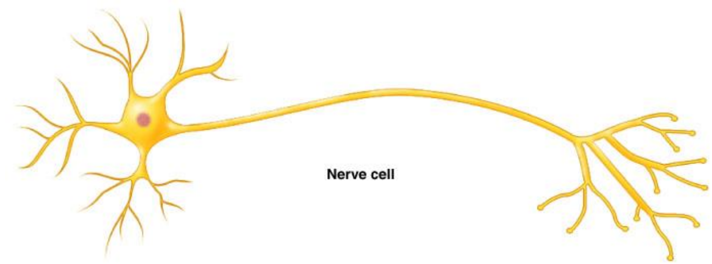
(b) Cells that move organs and body parts



(c) Cell that stores nutrients



(d) Cell that fights disease



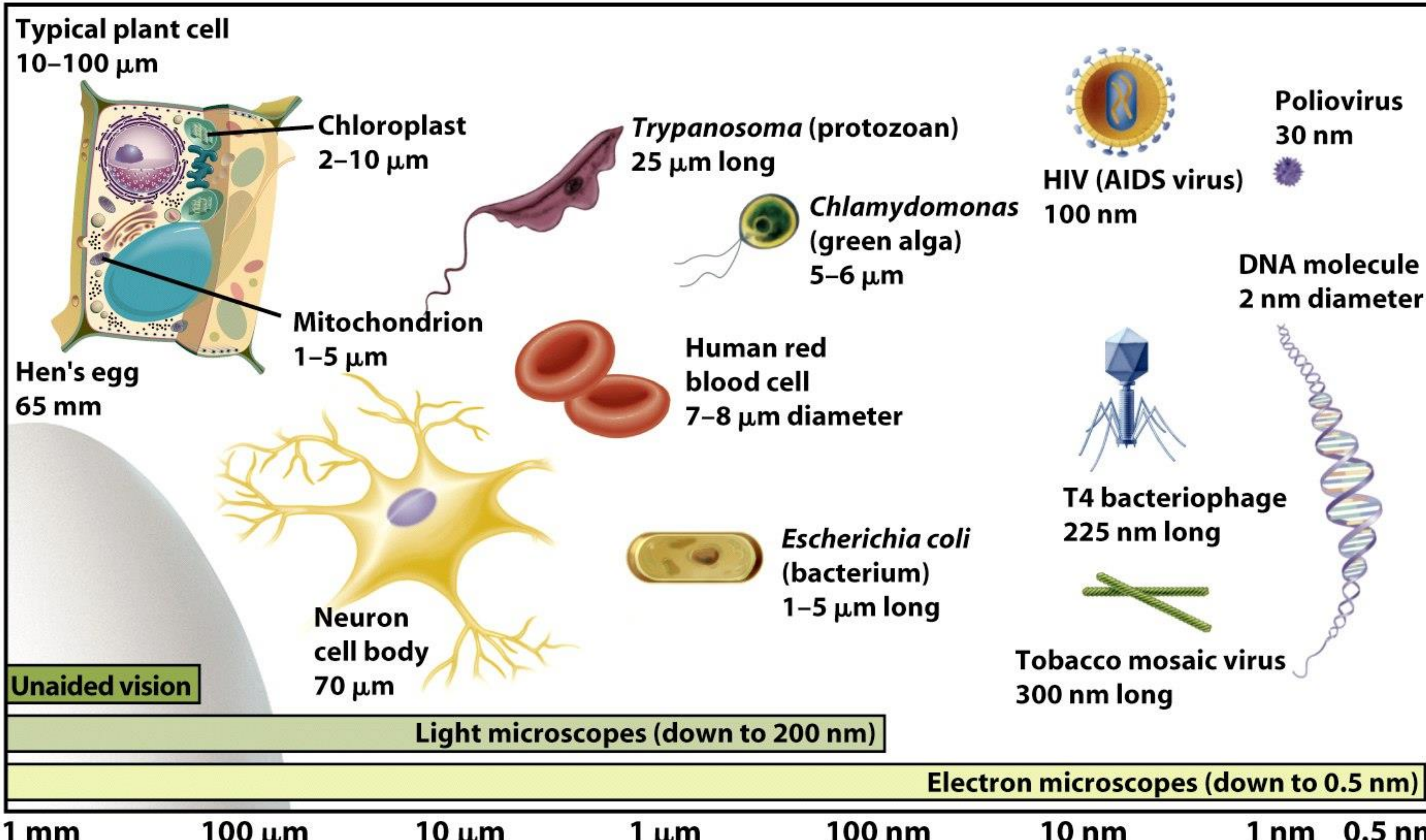
(e) Cell that gathers information and controls body functions

(f) Cell of reproduction

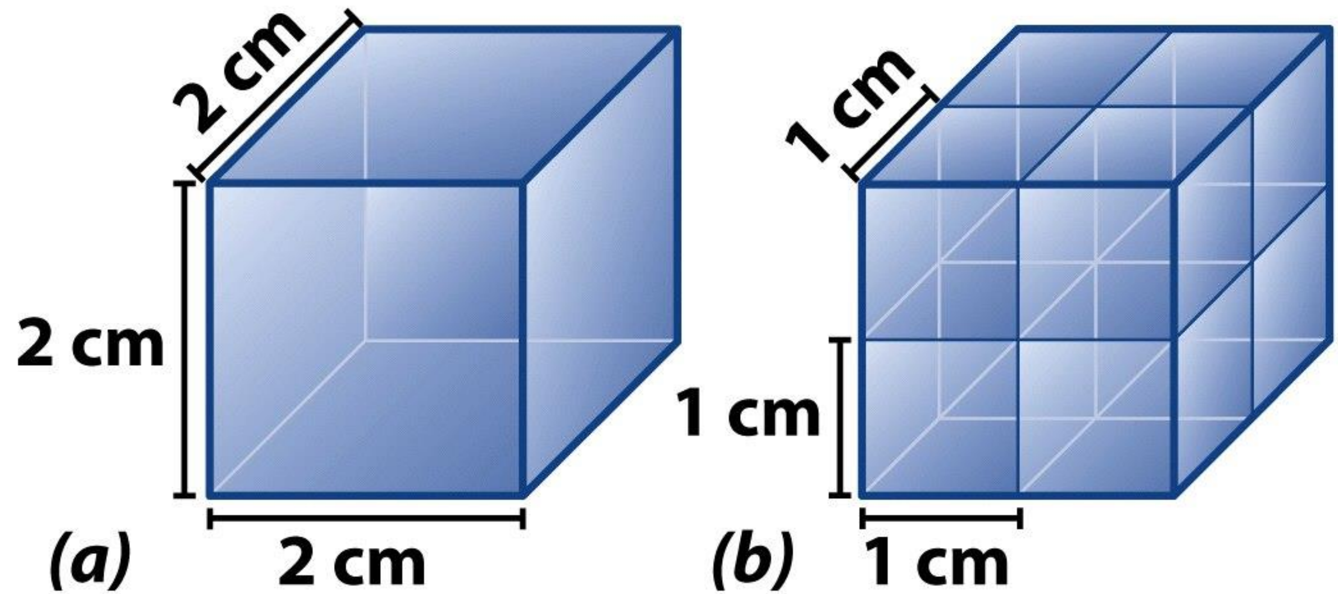
Characteristics of a Cell

- Contain highly organized molecular and biochemical systems and are used to store information
- Use energy
- Capable of movement
- Sense environmental changes
- Can duplicate (transfer genetic information to offspring)
- Capable of self-regulation

Cell Size


Typical plant cell
10–100 µm
Chloroplast
2–10 µm
Mitochondrion
1–5 µm
Hen's egg
65 mm
Trypanosoma (protozoan)
25 µm long
Chlamydomonas
(green alga)
5–6 µm
Human red
blood cell
7–8 µm diameter
Neuron
cell body
70 µm
Escherichia coli
(bacterium)
1–5 µm long
HIV (AIDS virus)
100 nm
Poliovirus
30 nm
DNA molecule
2 nm diameter
T4 bacteriophage
225 nm long
Tobacco mosaic virus
300 nm long
Unaided vision
Light microscopes (down to 200 nm)
Electron microscopes (down to 0.5 nm)
1 mm
100 µm
10 µm
1 µm
100 nm
10 nm
1 nm
0.5 nm

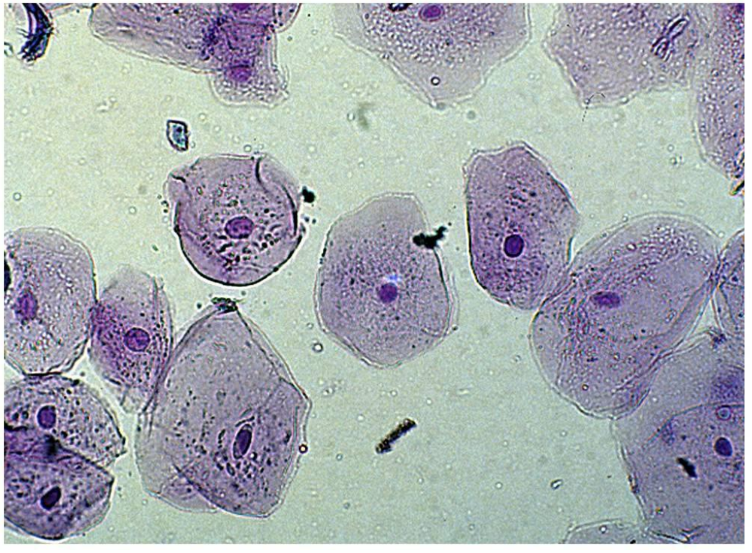
Cells Have Large Surface Area-to-Volume Ratio



Number of cells	**1**	**8**
Total surface area	**24 cm^2**	**48 cm^2**
Total volume	**8 cm^3**	**8 cm^3**
Surface area/volume	**24/8 = 3:1**	**48/8 = 6:1**

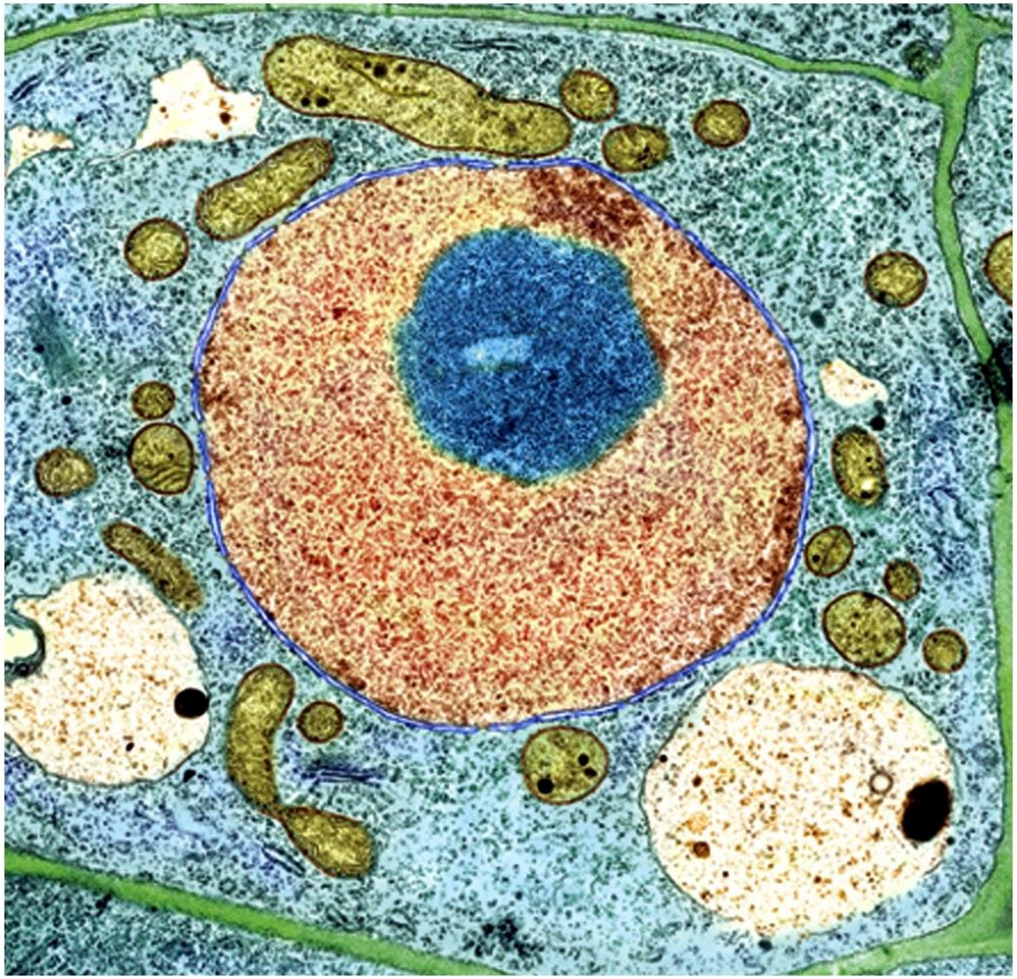
Characteristics of All Cells

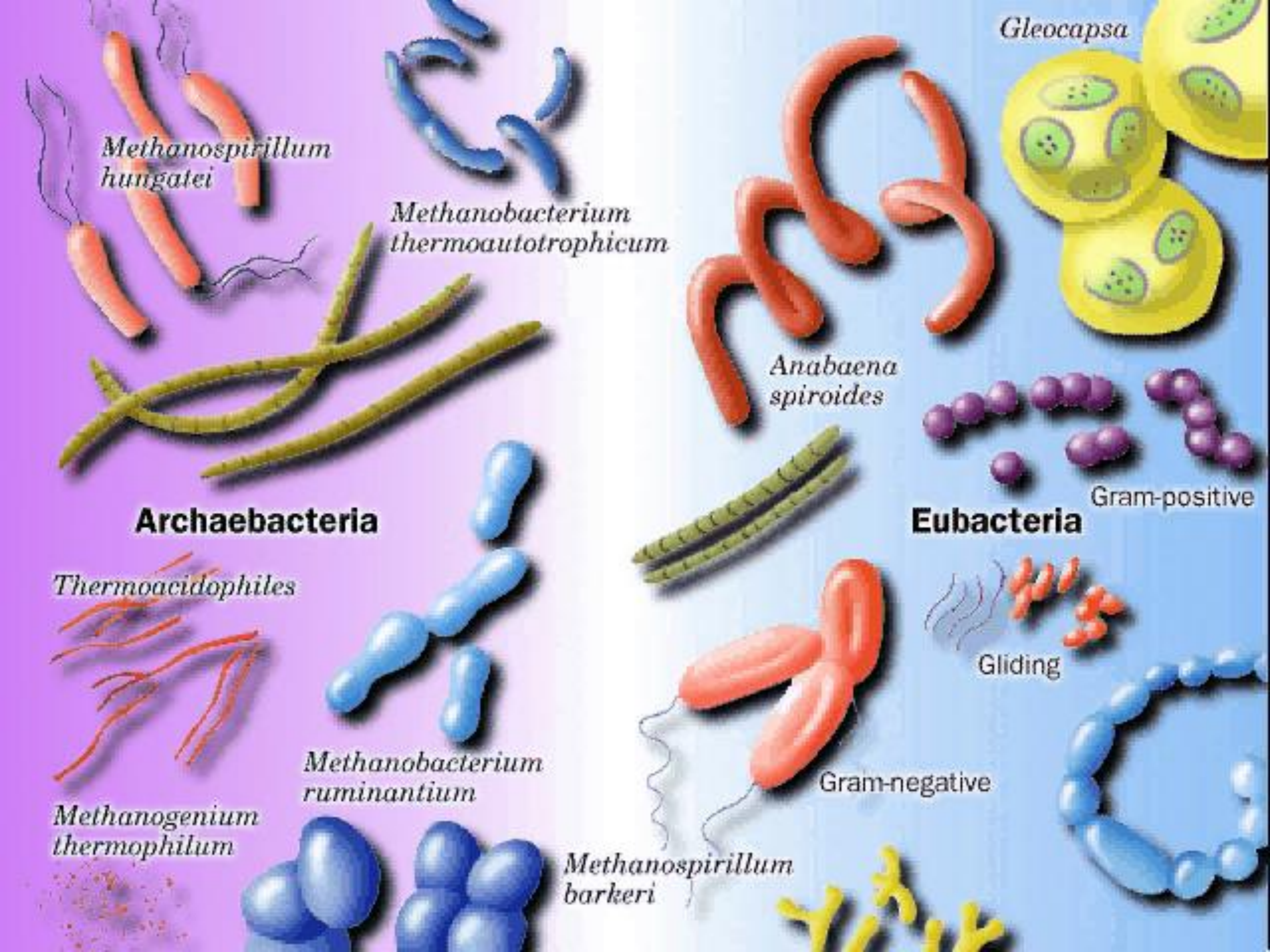
- A surrounding membrane
- Protoplasm – cell contents in thick fluid
- Organelles – structures for cell function
- Control center with DNA



Cell Types

- Prokaryotic
- Eukaryotic



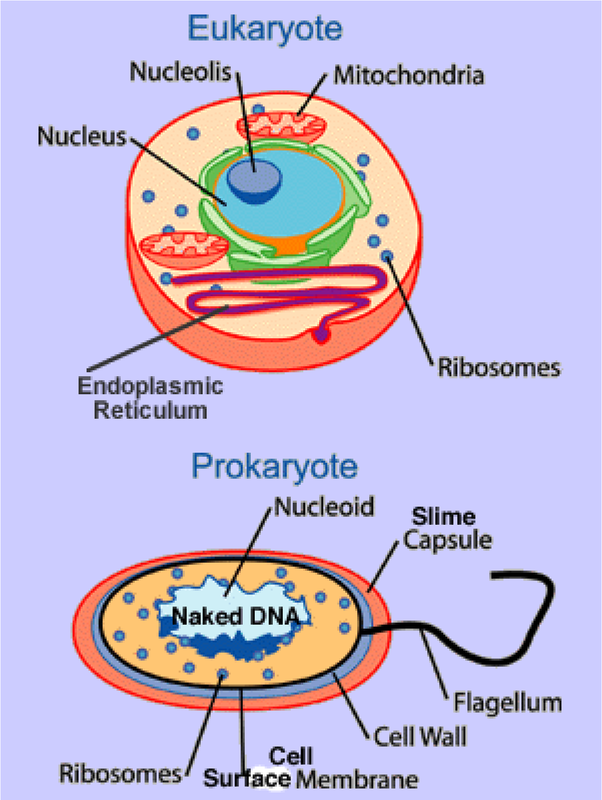


Gleocapsa
Methanospirillum
hungatei
Methanobacterium
thermoautotrophicum
Anabaena
spiroides
Archaebacteria
Eubacteria
Gram-positive
Thermoacidophiles
Gliding
Methanobacterium
ruminantium
Gram-negative
Methanogenium
thermophilum
Methanospirillum
barkeri

Prokaryotic vs. Eukaryotic

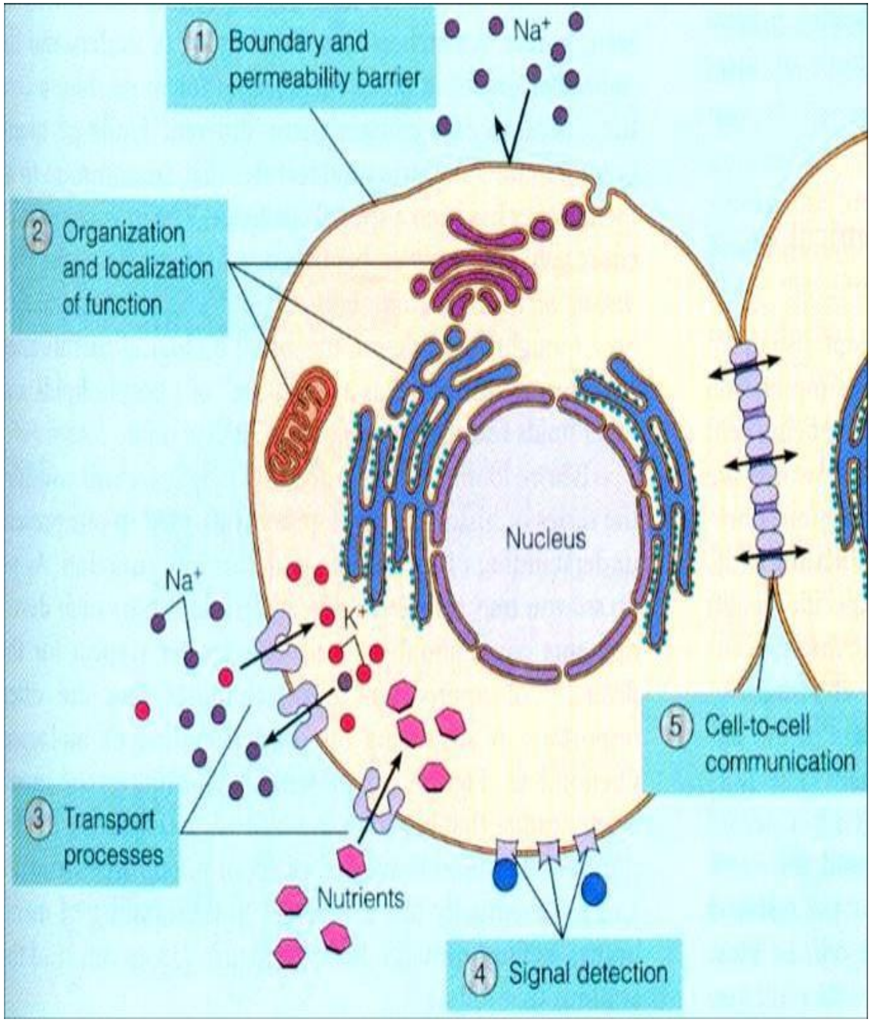
- **Prokaryotic – single cell with nuclear material but no nuclear membrane or membrane bound organelles**

- **Eukaryotic – most cells – with organized nucleus and membrane bound organelles**



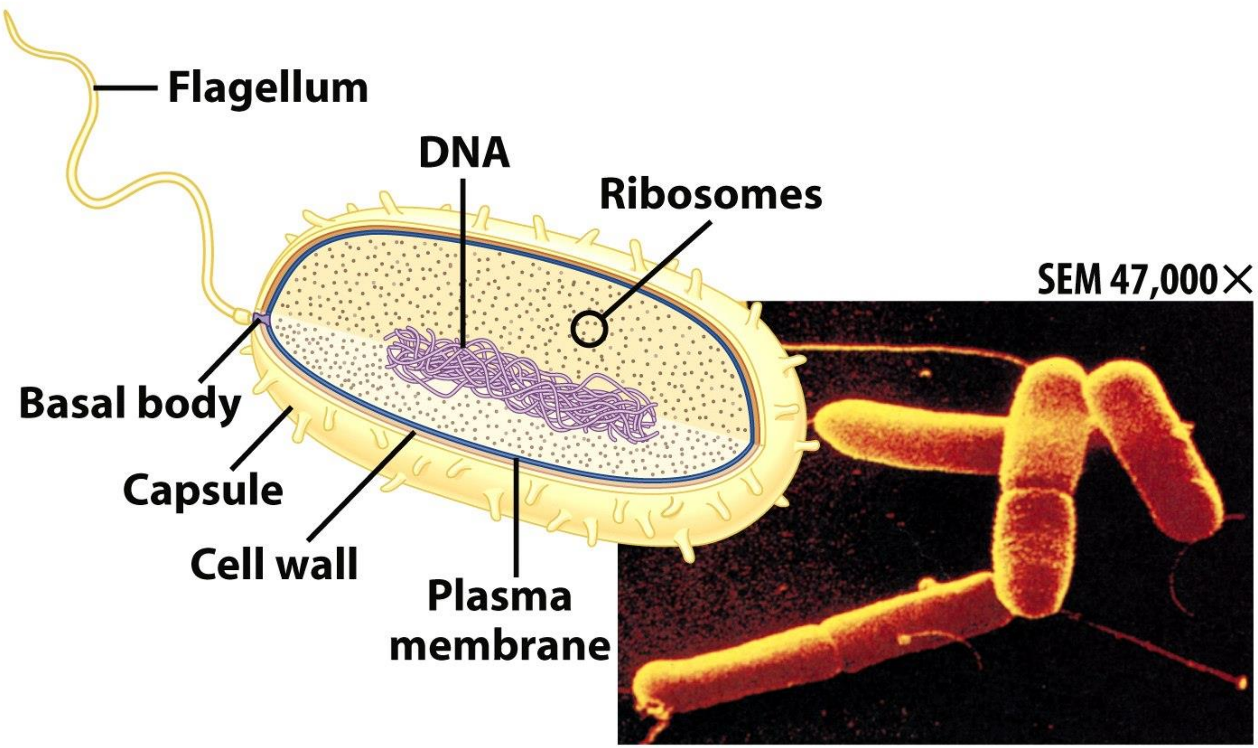
REGIONS OF THE EUKARYOTIC CELL

- Surface of the cell – protection, communication, movement
- Cytoplasm – machinery of cell
- Nucleus – control center



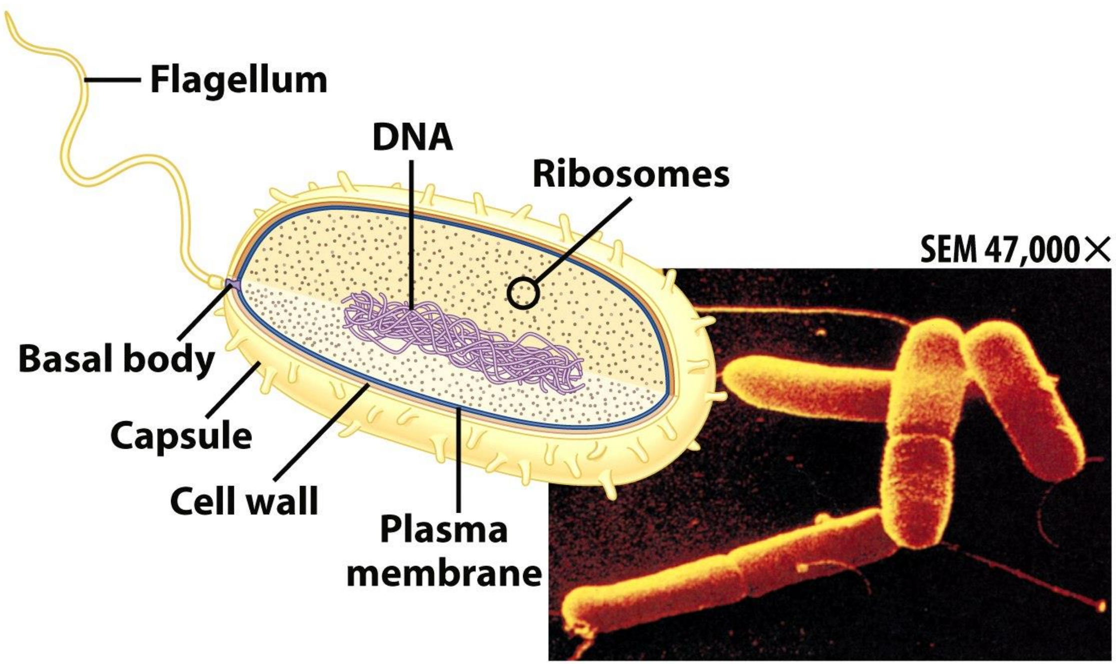
Prokaryotic Cells

- First cell type on earth
- Cell type of Bacteria and Archaea



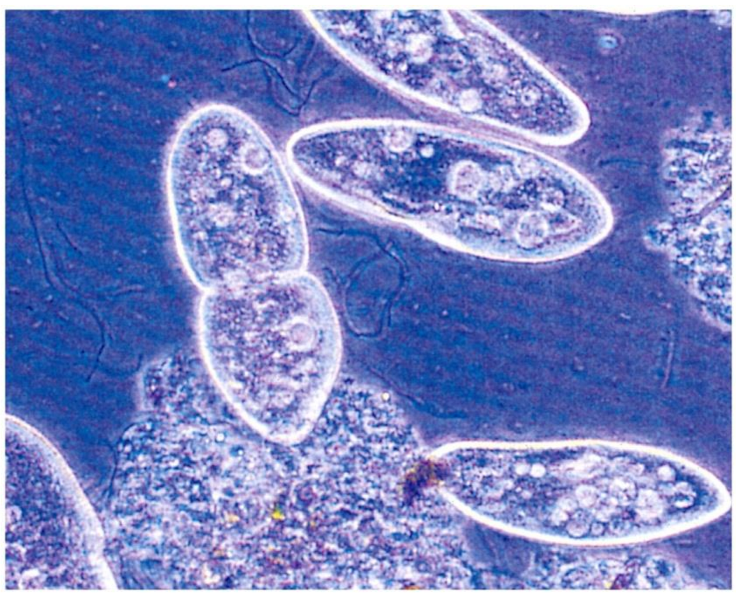
Prokaryotic Cells

- No membrane bound nucleus
- Nucleoid = region of DNA concentration
- Organelles not bound by membranes



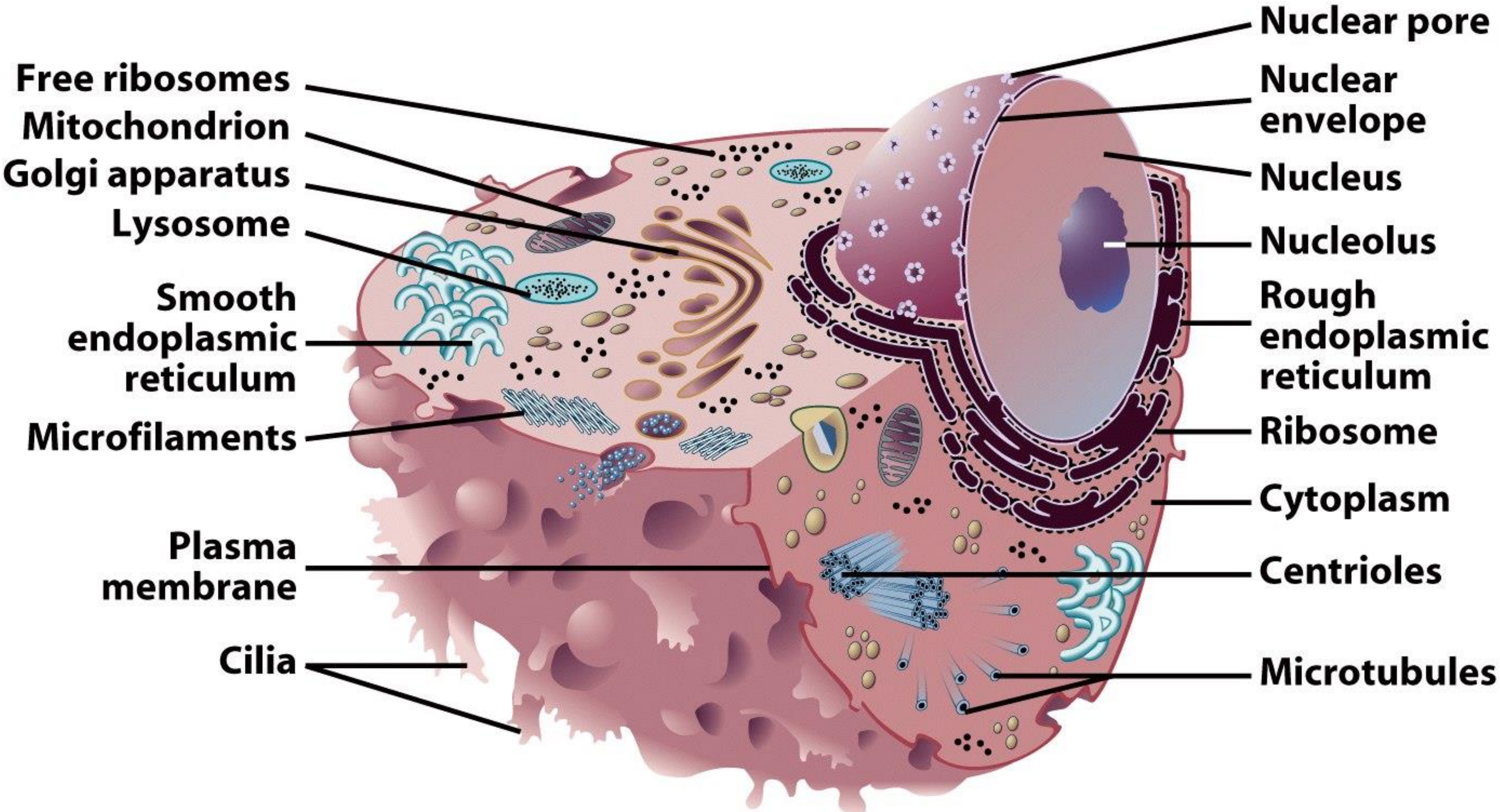
Eukaryotic Cells

- Nucleus bound by membrane
- Include fungi, protists, plant, and animal cells
- Possess many organelles

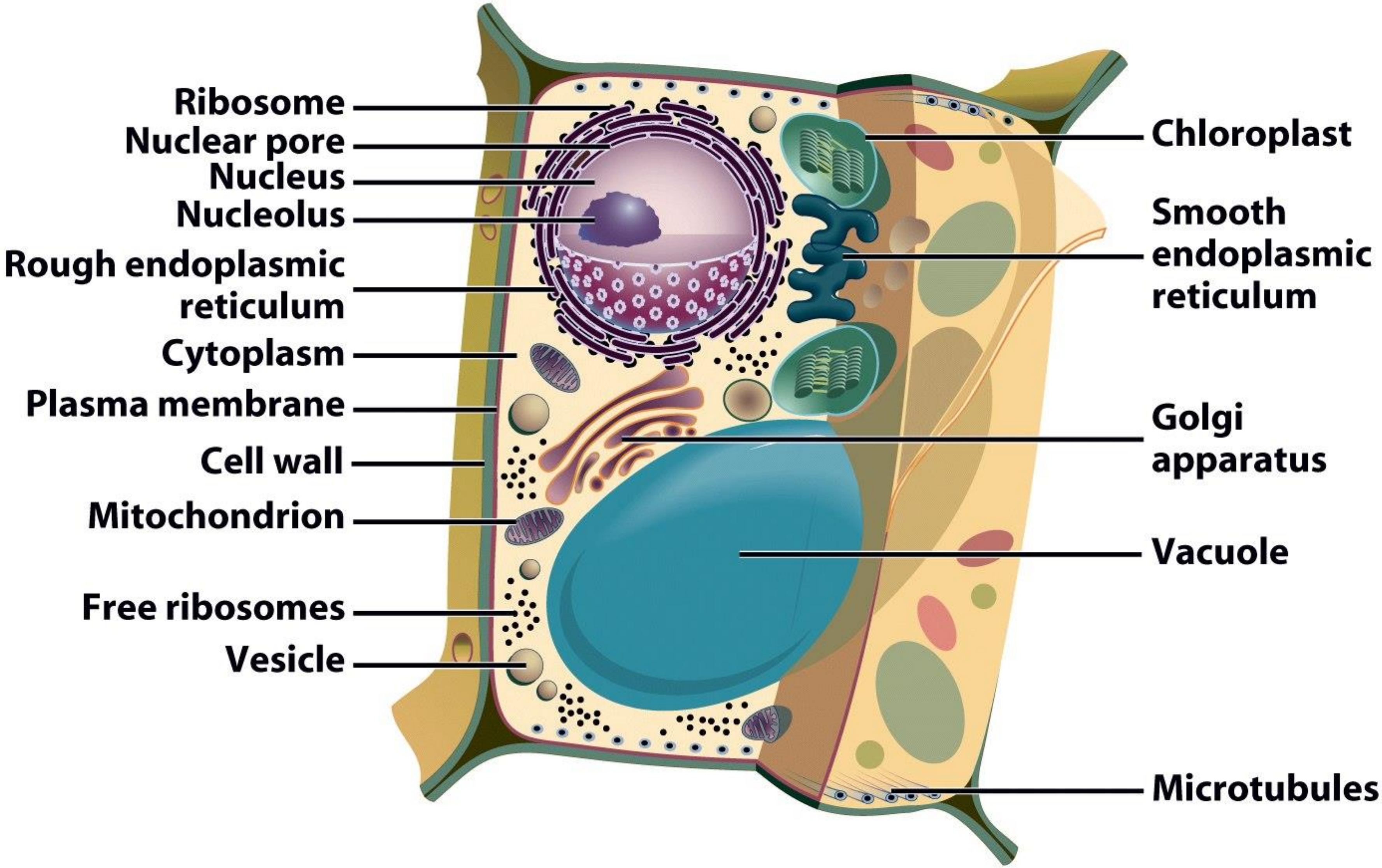


Protozoan

Representative Animal Cell

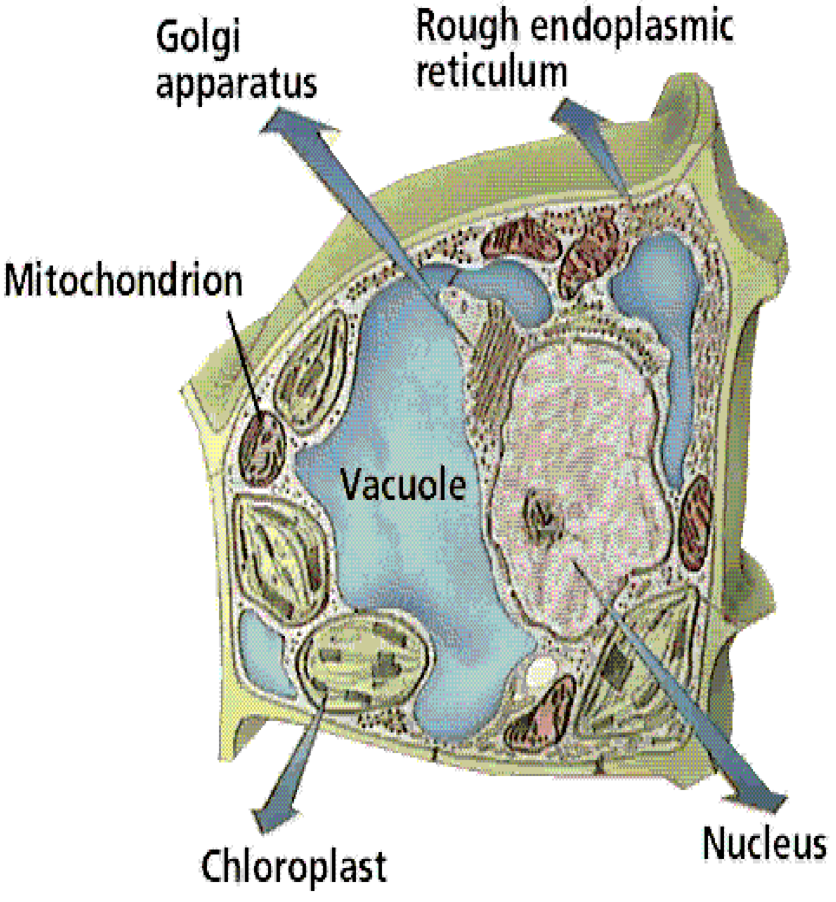


Representative Plant Cell



Plant Cell – Special Features

- Cell wall – protection and support
- Chloroplast - for photosynthesis
- Large central vacuole- for storage and increase surface area



Cell Walls

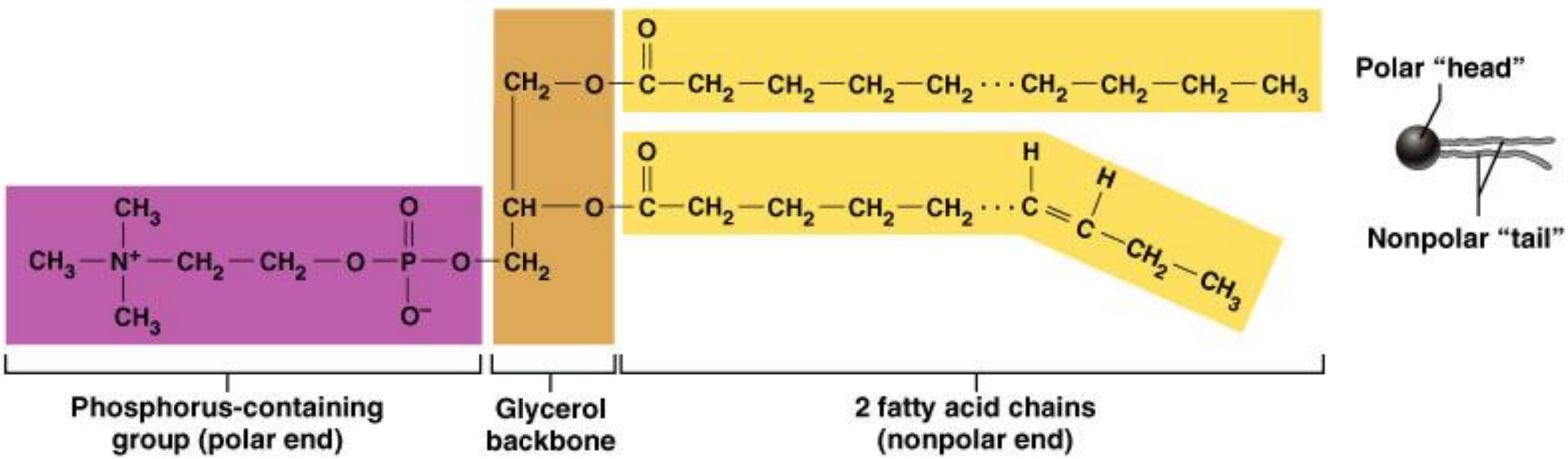
- Found in plants, fungi, & many protists
- Surrounds plasma membrane

- Plants – mostly cellulose
- Fungi – contain chitin

Structure of the Cell Membrane

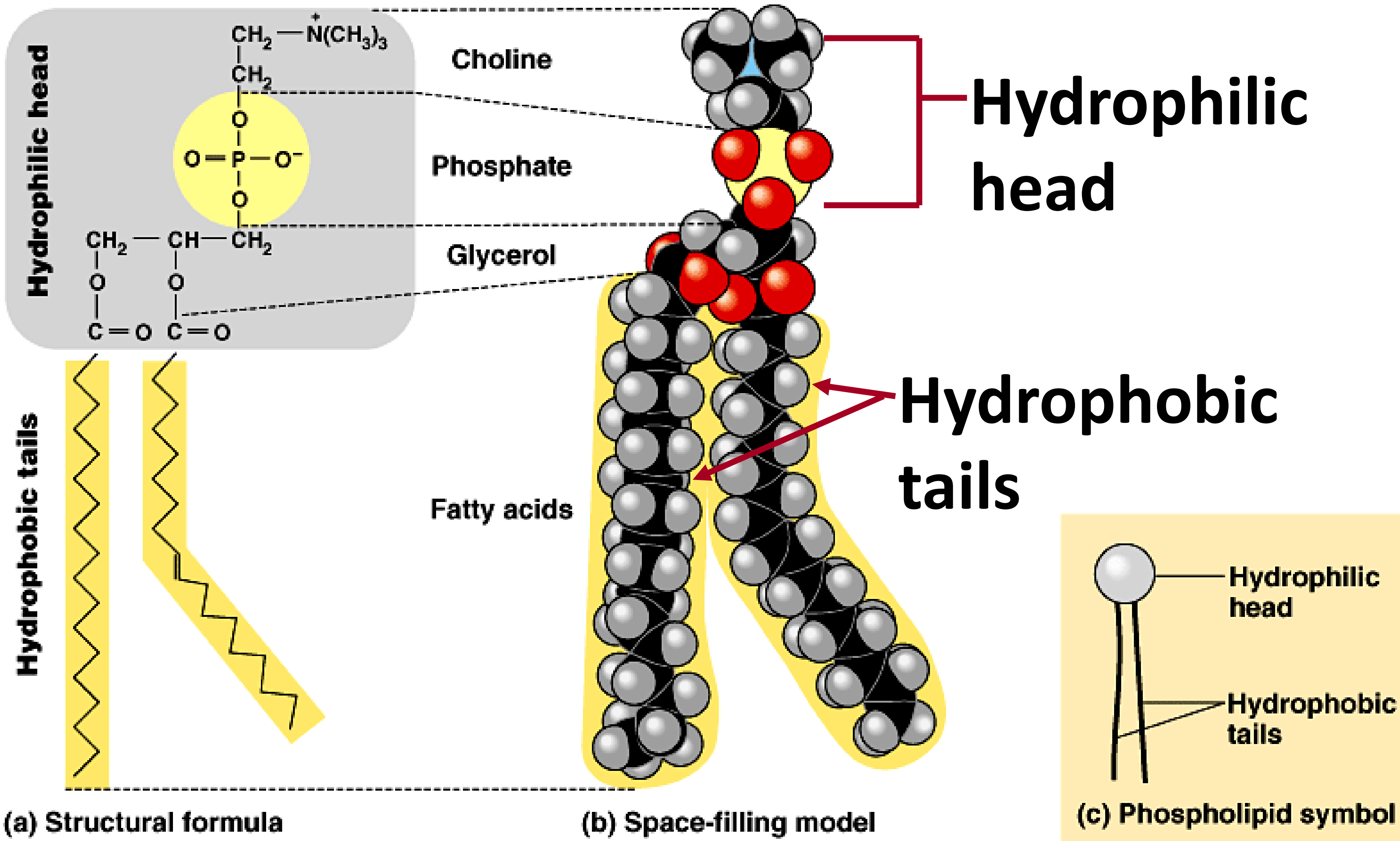
Phospholipids

- Most abundant lipid
- Polar/hydrophilic head(attracted to water)
- Pair of nonpolar/hydrophobic tails(repelled by water)



(b) Phospholipid molecule (phosphatidylcholine)

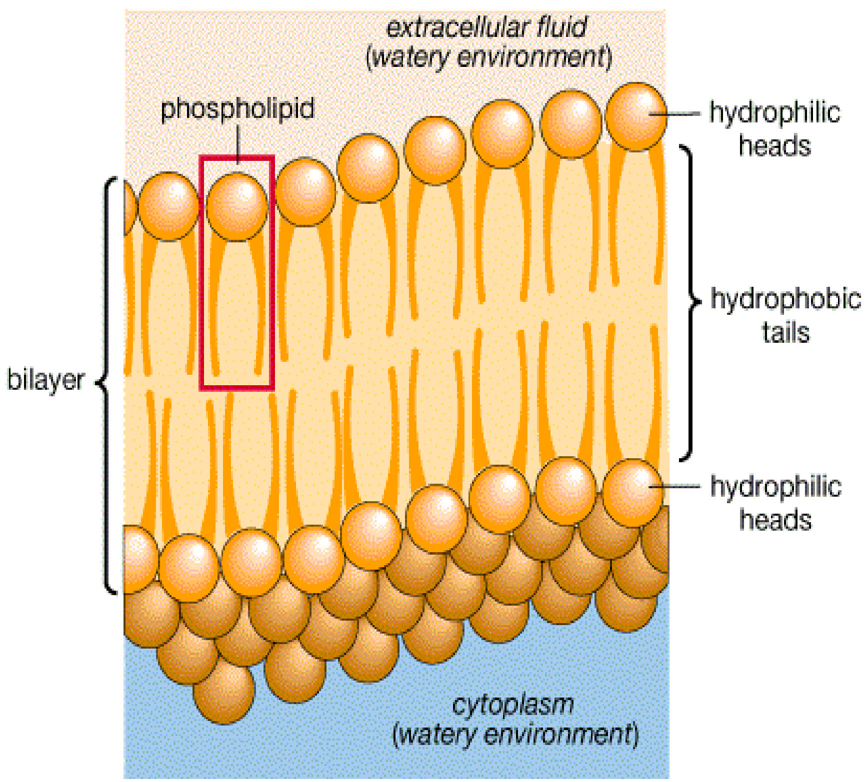
Phospholipids



(a) Structural formula (b) Space-filling model

Phospholipid bilayer:

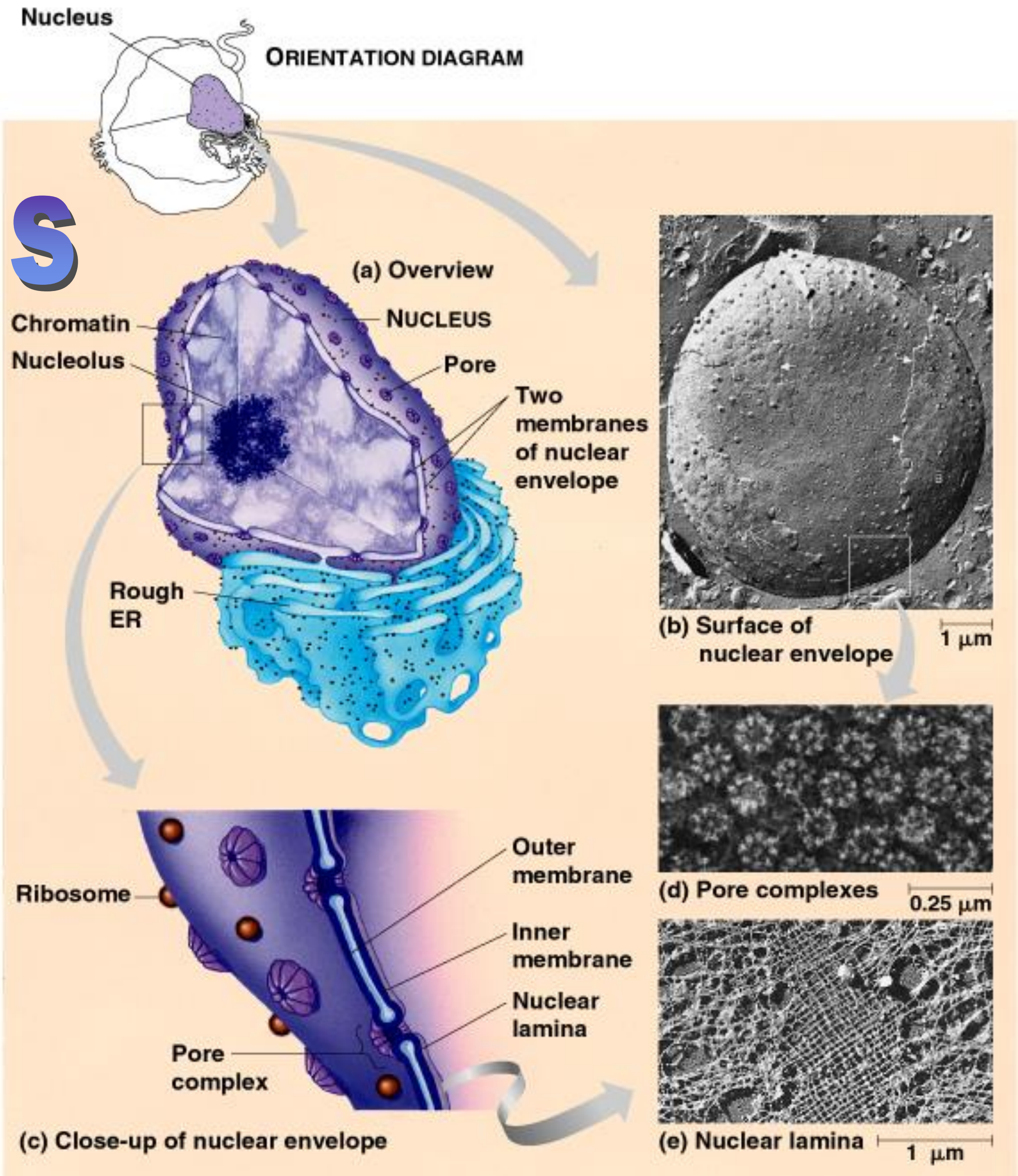
- Polar heads, outside & inside
- Nonpolar tails in the interior
- Cell Membranes



Organelles – "factory components with function"

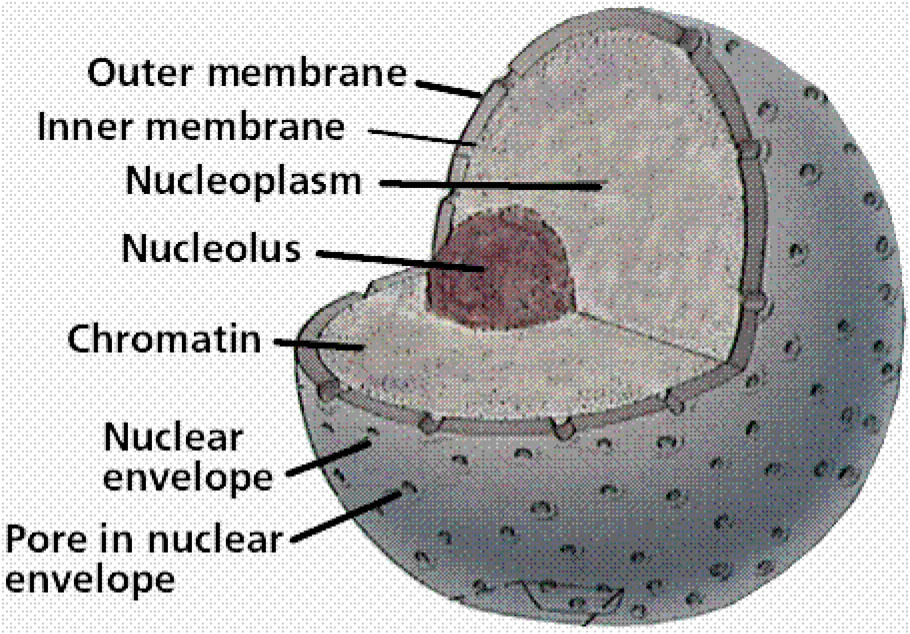
Support - Cell wall , cell membrane cytoskeleton, microtubles	
Controls material entering and leaving - Cell membrane, pores	
Internal transport system – Endoplasmic reticulum	
Powerhouse - mitochondria	
Control center – nucleus, organelle DNA for mitochondria and chloroplast	
Production of key products – ribosomes, endoplastic reticulum, chloroplasts	
Packaging center for shipment of products – Golgi Apparatus, ER	
Shipment of materials out of cell - Golgi Apparatus, vesicles	
Storage of liquids and solids – Vacuole, vesicles, plastids,	
Recycling center – Lysosomes and perixosomes	
Convert light energy to chemical energy - chloroplasts	
Allows new cell factories to be produced – nuclear DNA, centrioles, cell wall	

Nucleus


Nucleus
ORIENTATION DIAGRAM
(a) Overview
Chromatin
NUCLEUS
Nucleolus
Pore
Two membranes of nuclear envelope
Rough ER
(b) Surface of nuclear envelope
1 µm
(d) Pore complexes
0.25 µm
Ribosome
Outer membrane
Inner membrane
Nuclear lamina
Pore complex
(c) Close-up of nuclear envelope
(e) Nuclear lamina
1 µm

Nucleus

- Nuclear envelope – double membrane
- chromatin – DNA
- RNA
- nucleolus – Ribosome sub-units



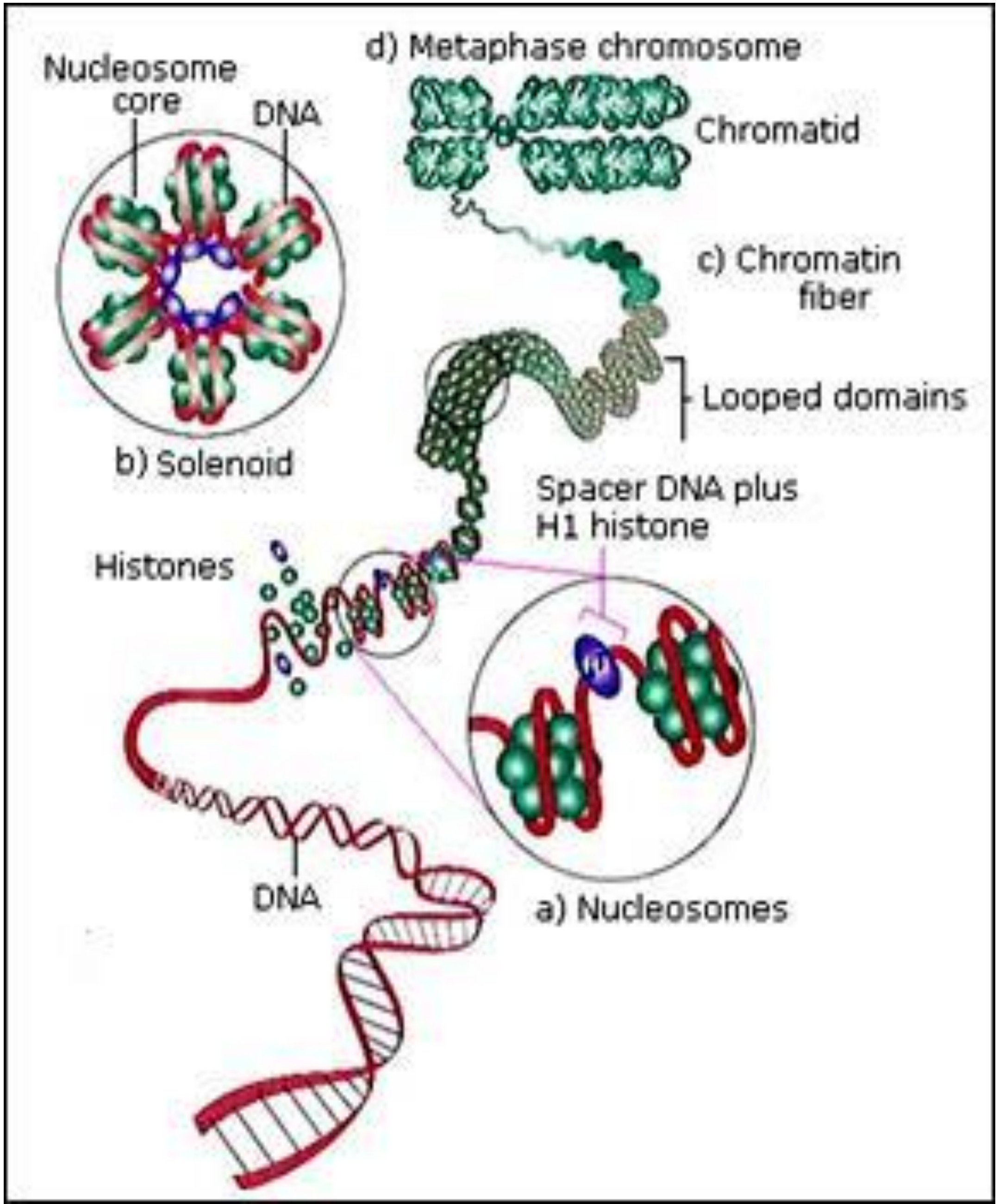
Chromosome Structure

a. Nuclesosomes – Core of DNA wrapped around 8 histone proteins plus linker DNA

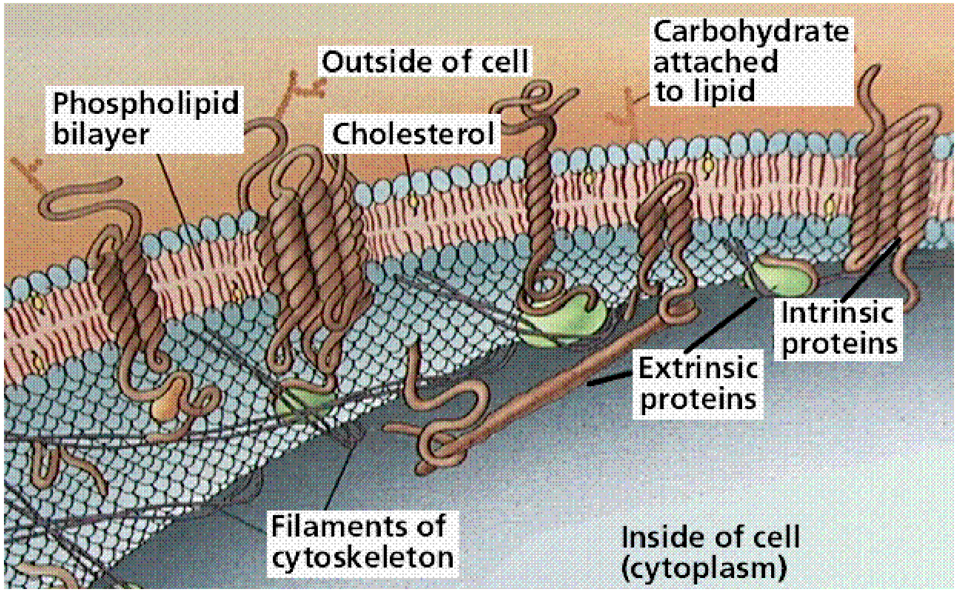
b. Solenoid – coiling of nucleosomes like phone cord

c. Chromatin fiber – series of nucleosomes

d. Metaphase chromosomes



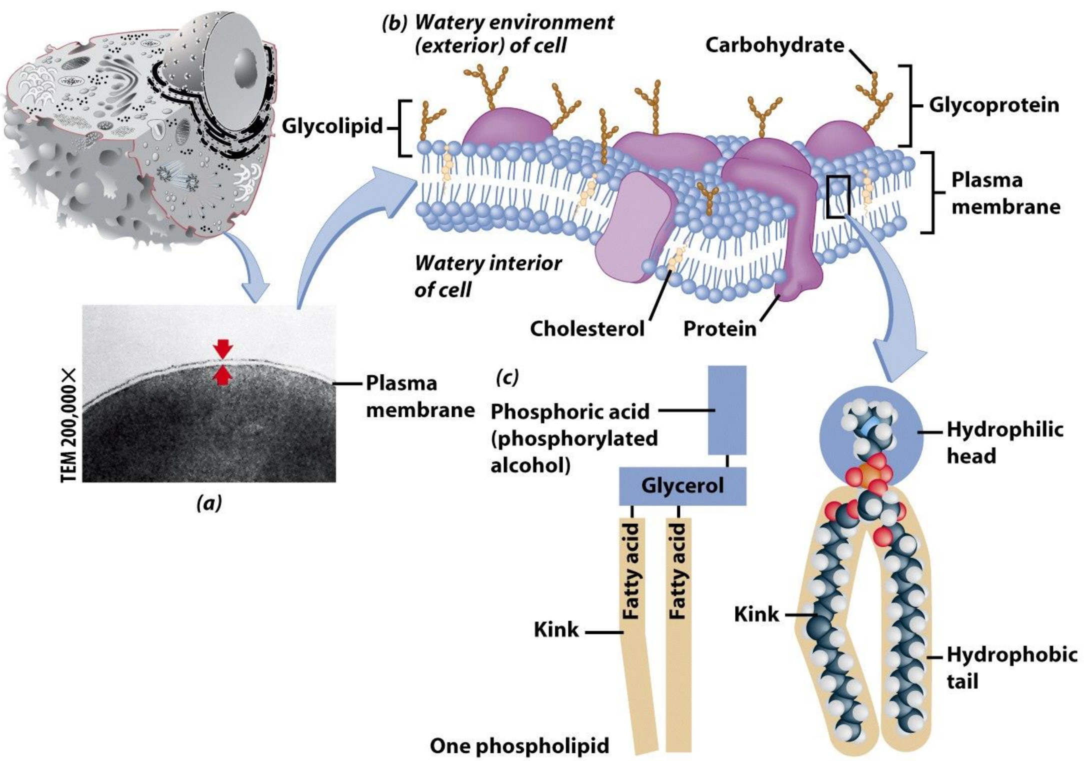
Cell Membrane



- **Composition: mainly protein and phospholipid; some proteins extend thru membrane**
- **Protein function: receptors, transport in and out of cells, structure**
- **Lipids in membrane can move laterally at about 2um/sec**
- **Saturated fatty acids in P-lipids make membrane more rigid; unsaturated fatty acids will increase the fluidity of membrane.**
- **Note: As temp drops, organisms put more unsaturated fatty acids in membrane**

Plasma Membrane

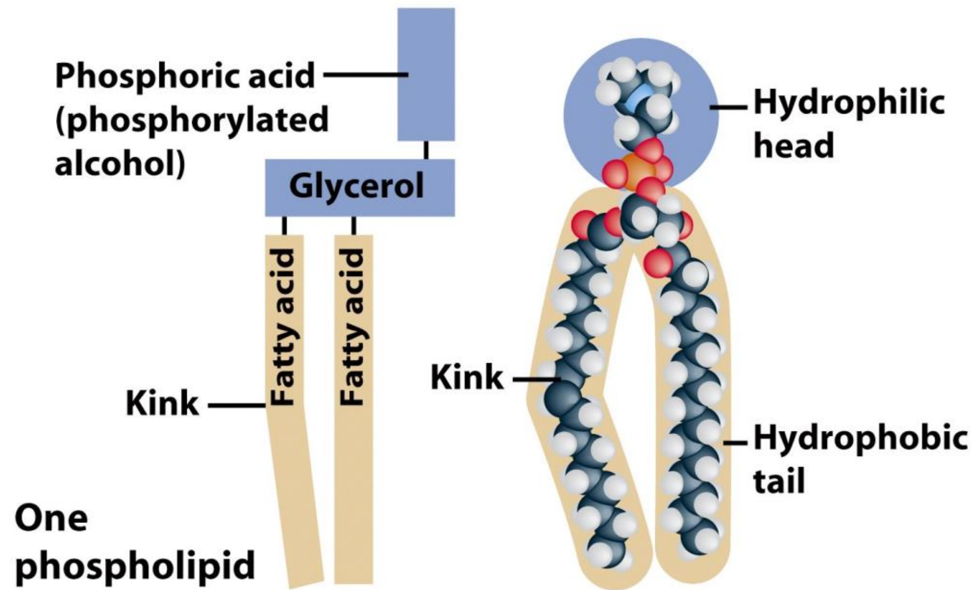
- Contains cell contents
- Double layer of phospholipids & proteins



Phospholipids

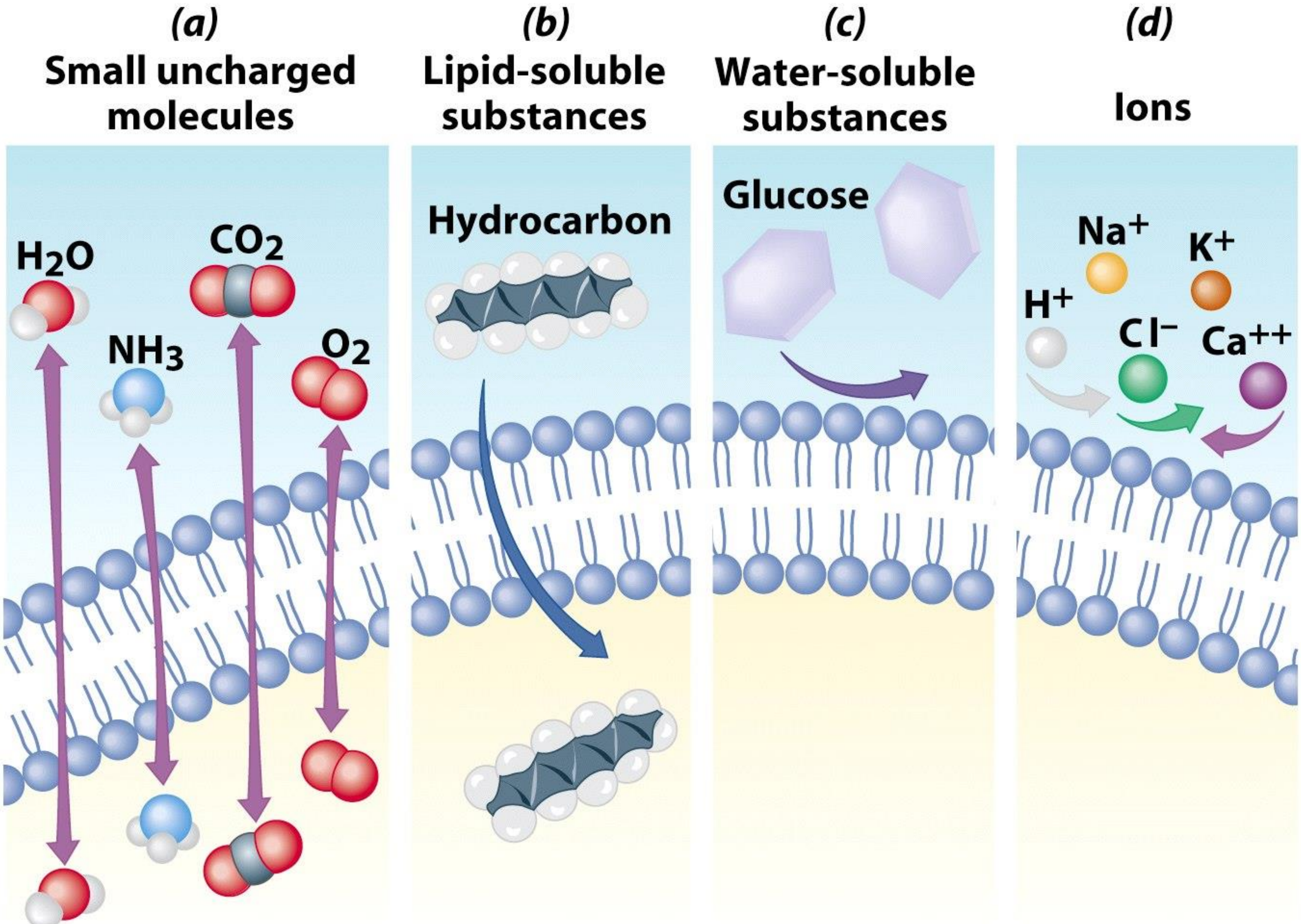
- Polar
  - Hydrophylic head
  - Hydrophobic tail

- Interacts with water



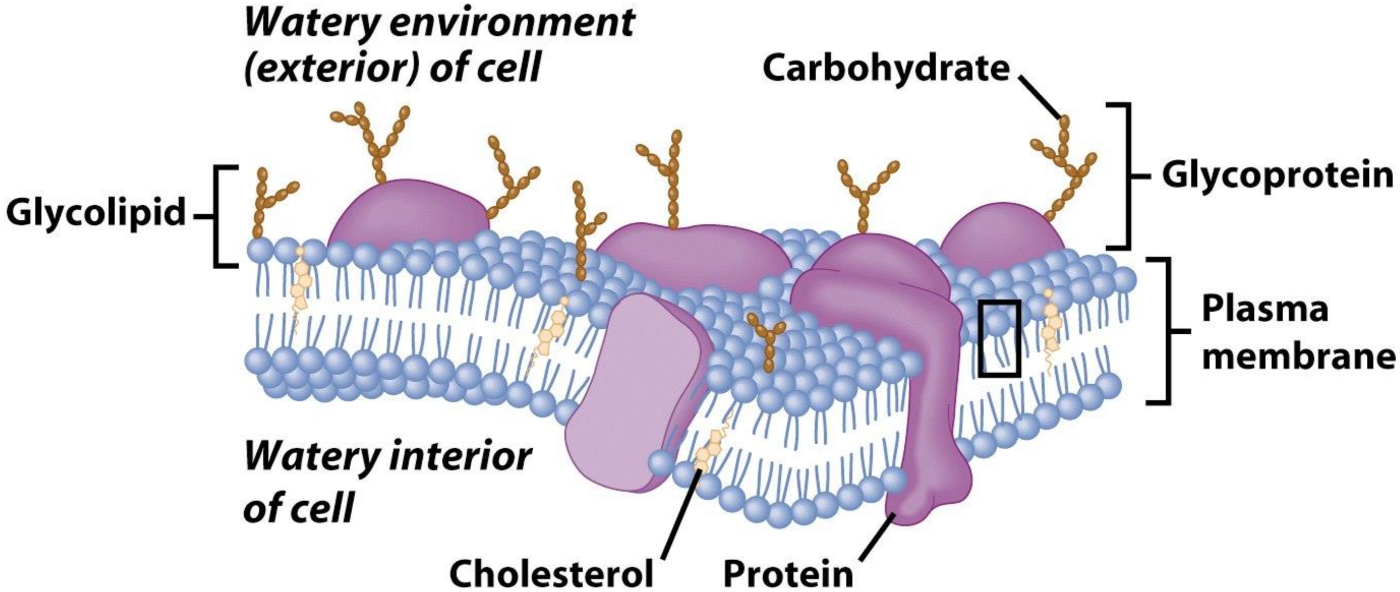
Movement Across the Plasma Membrane

- A few molecules move freely
  - Water, Carbon dioxide, Ammonia, Oxygen
- Carrier proteins transport some molecules
  - Proteins embedded in lipid bilayer
  - Fluid mosaic model – describes fluid nature of a lipid bilayer with proteins


(a)
Small uncharged molecules
H2O
NH3
CO2
O2
(b)
Lipid-soluble substances
Hydrocarbon
(c)
Water-soluble substances
Glucose
(d)
Ions
Na+
K+
H+
Cl−
Ca++

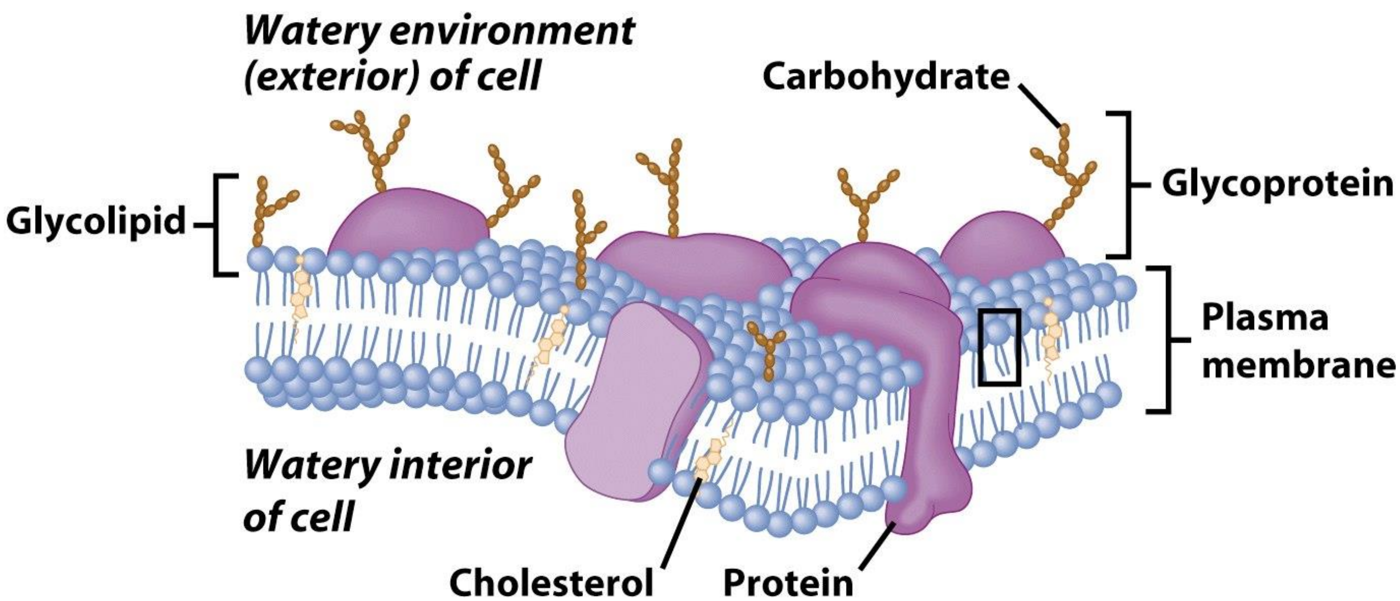
Membrane Proteins

1. Channels or transporters
   – Move molecules in one direction
2. Receptors
   – Recognize certain chemicals

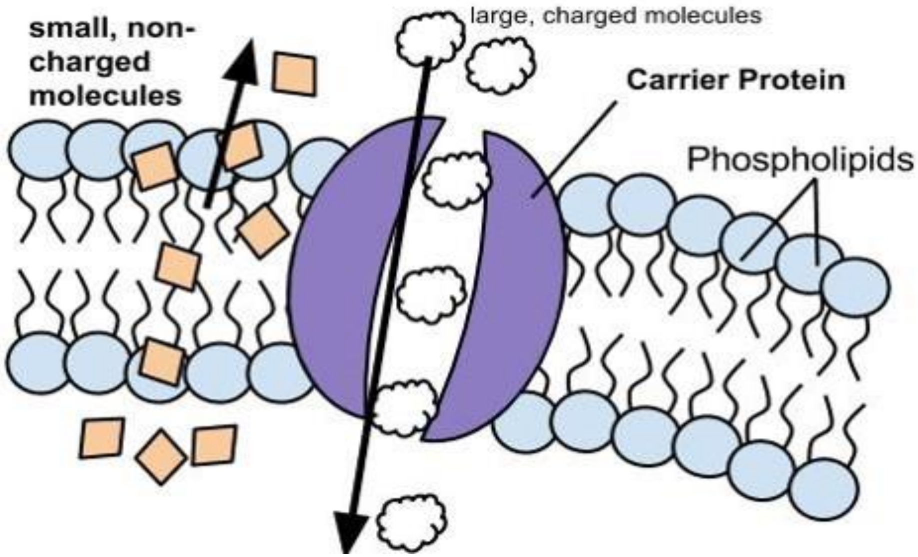


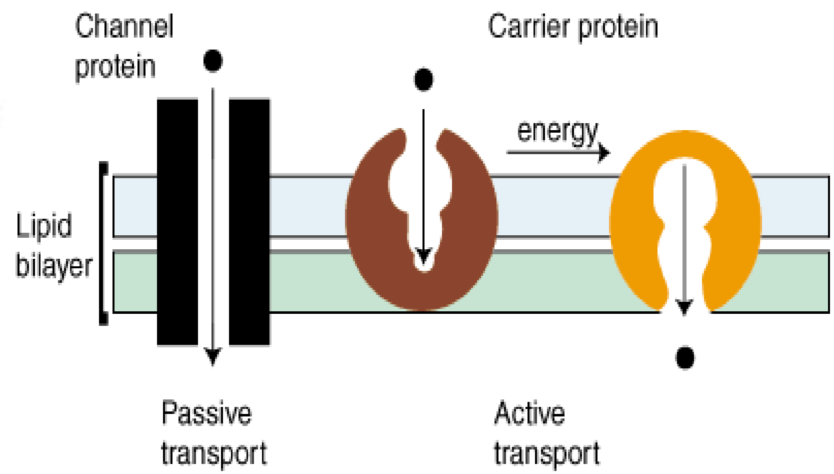
Membrane Proteins

3. Glycoproteins
   – Identify cell type
4. Enzymes
   – Catalyze production of substances



Membrane Proteins





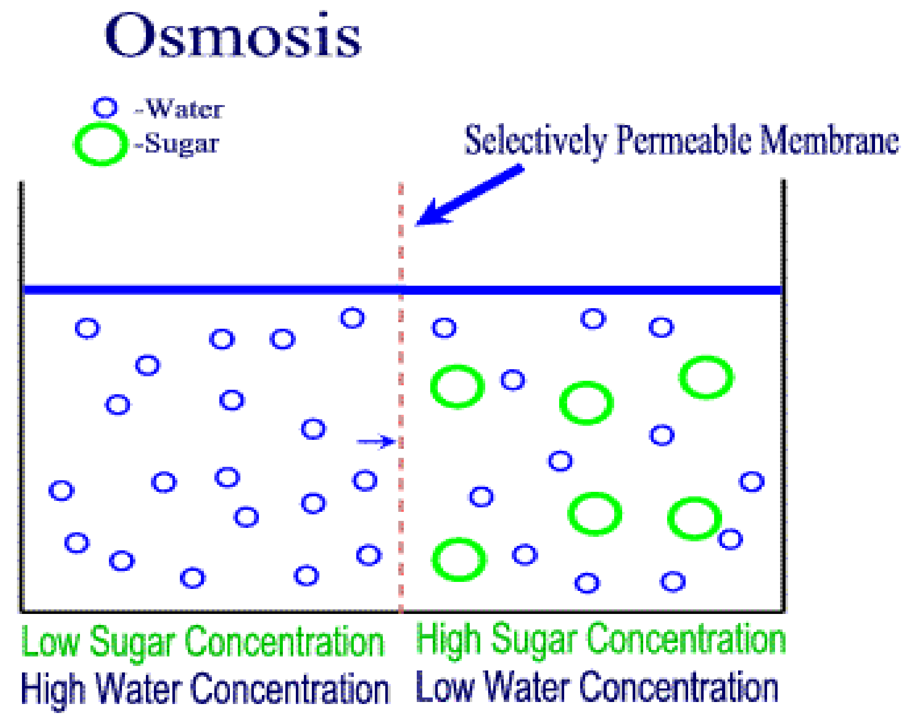
Movement Across Membranes

- **Diffusion:** molecules moving from high to low concentration; concentration = #molecules/volume

- **Osmosis:** diffusion of water across a selective membrane; amount of water is opposite of number molecules-if water is high, solute (molecules) is low.

- **Facilitative diffusion:** just like diffusion (high to low) but a protein carrier is involved Note: diffusion will continue but rate of transport with carrier will level off because carrier becomes saturated

Osmosis

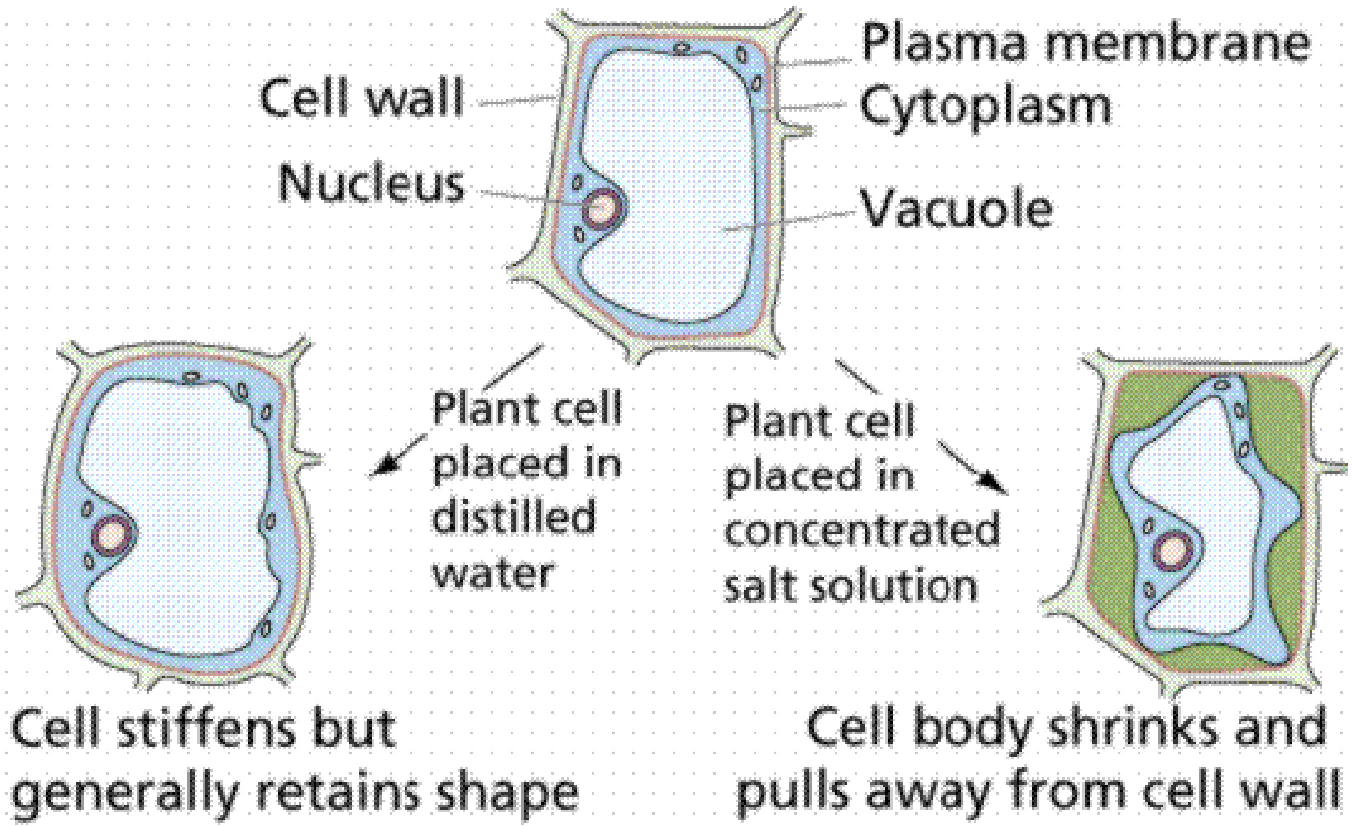


Hypertonic - high solute concentration relative to another solution

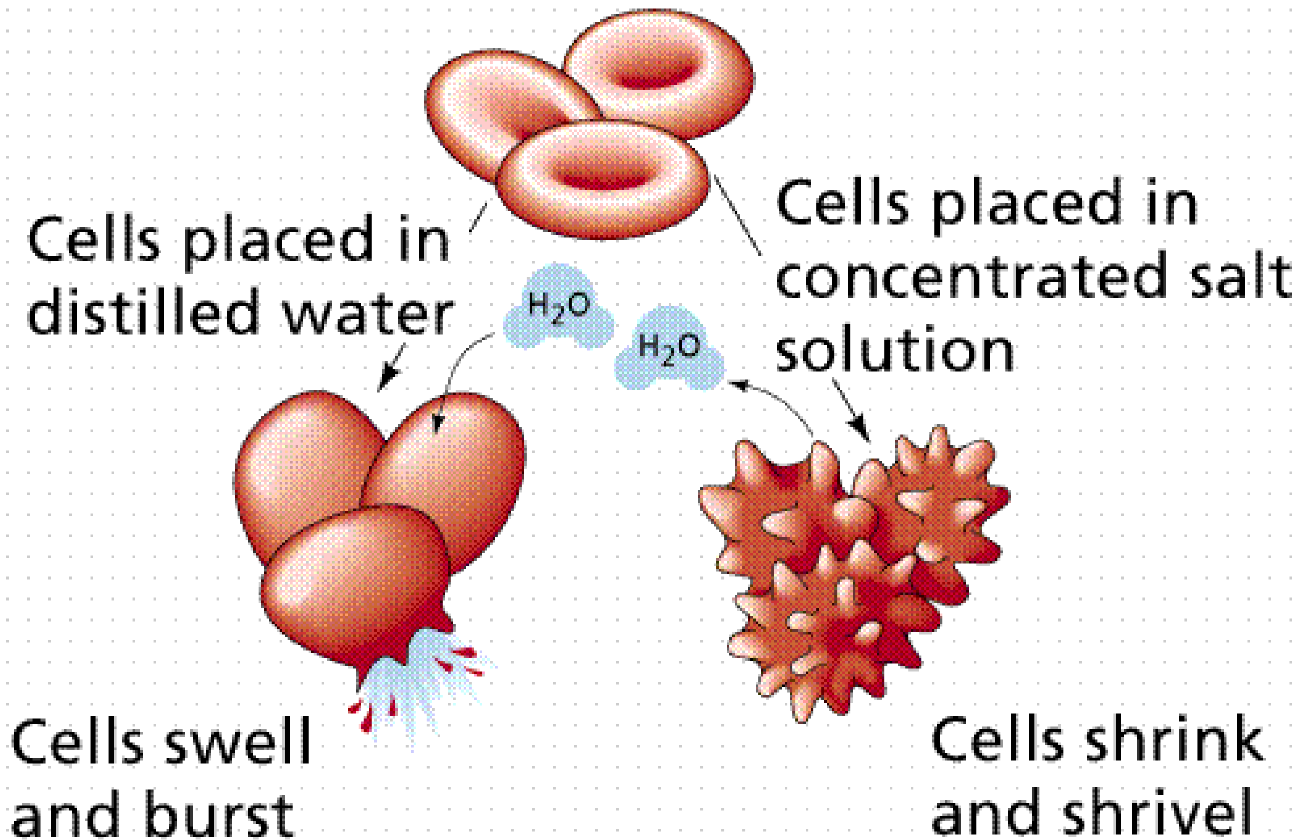
Hypotonic - low solute concentration relative to another solution

Isotonic - solute concentration is the same as that of another solution

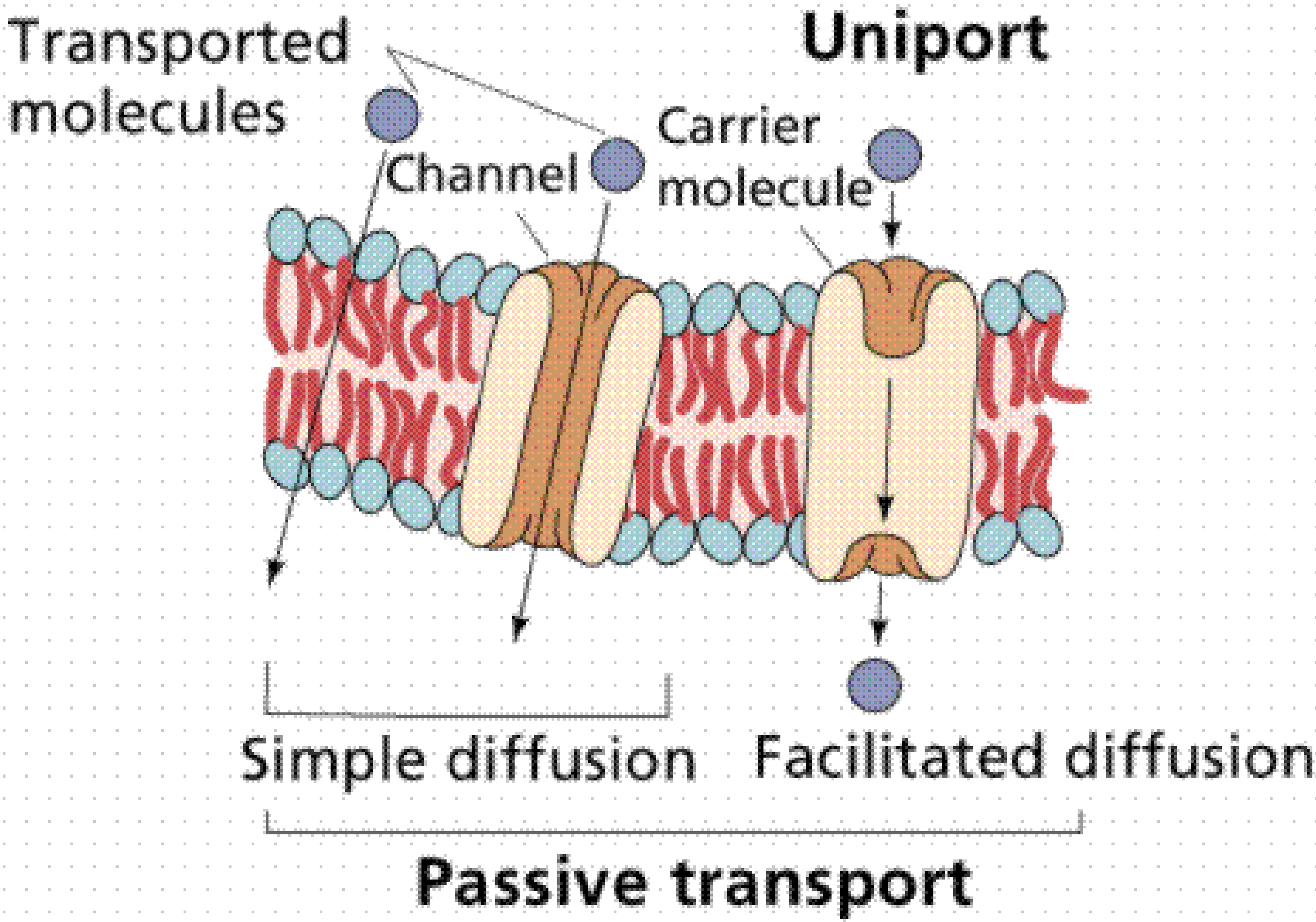
Plant Cells – Turgor Pressure and Plasmolysis



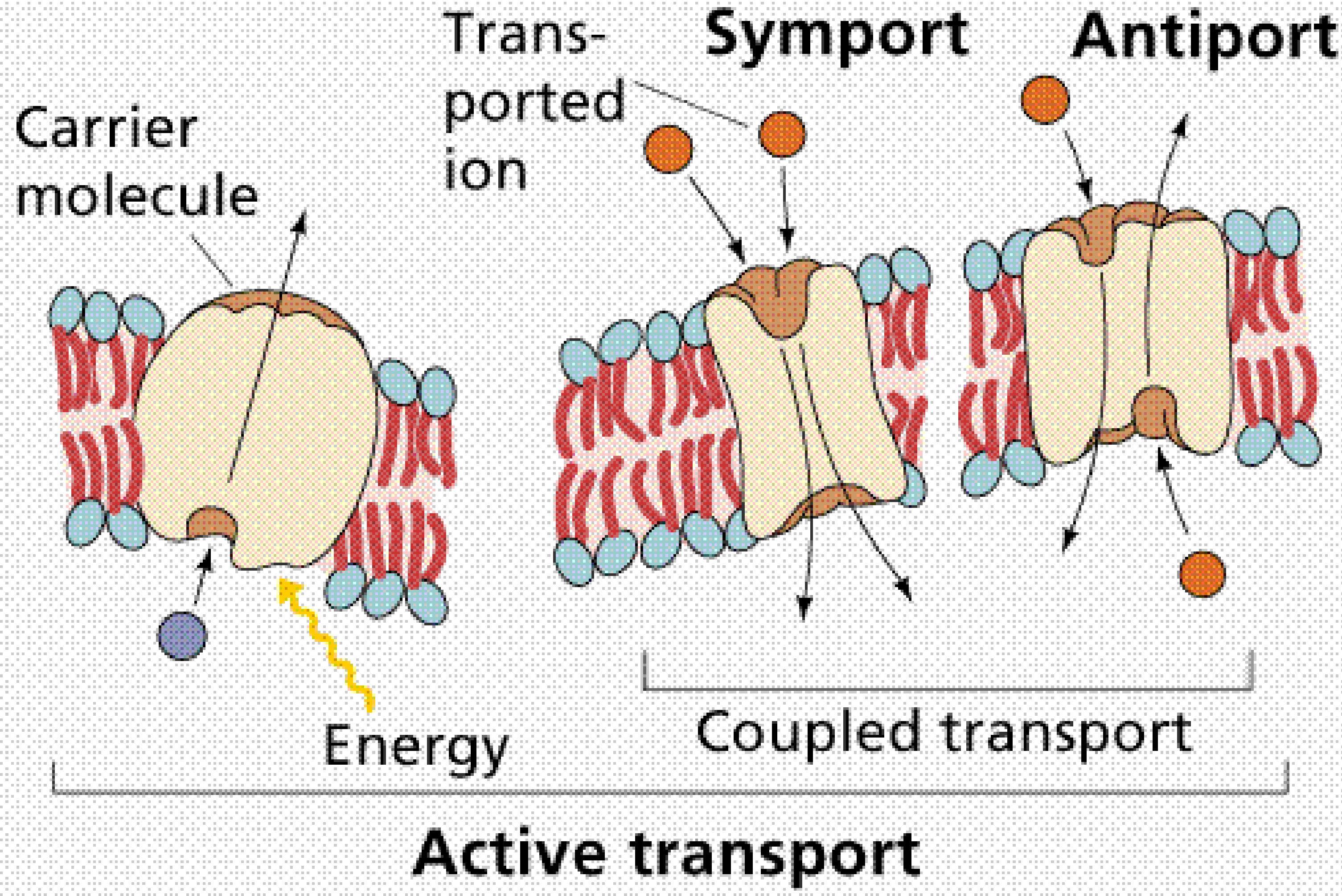
Animal Cells – in different solutions



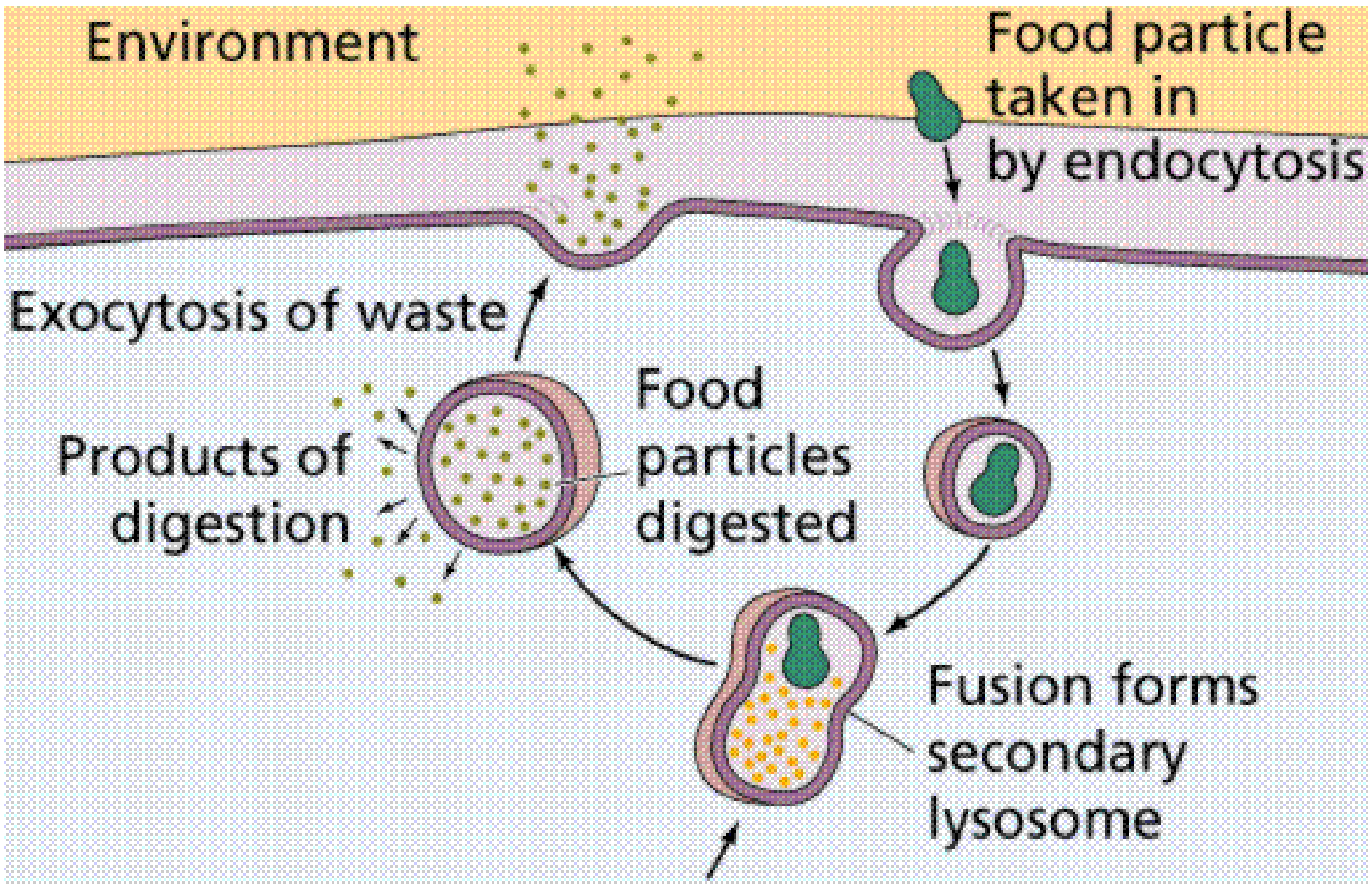
Passive Transport – no energy used

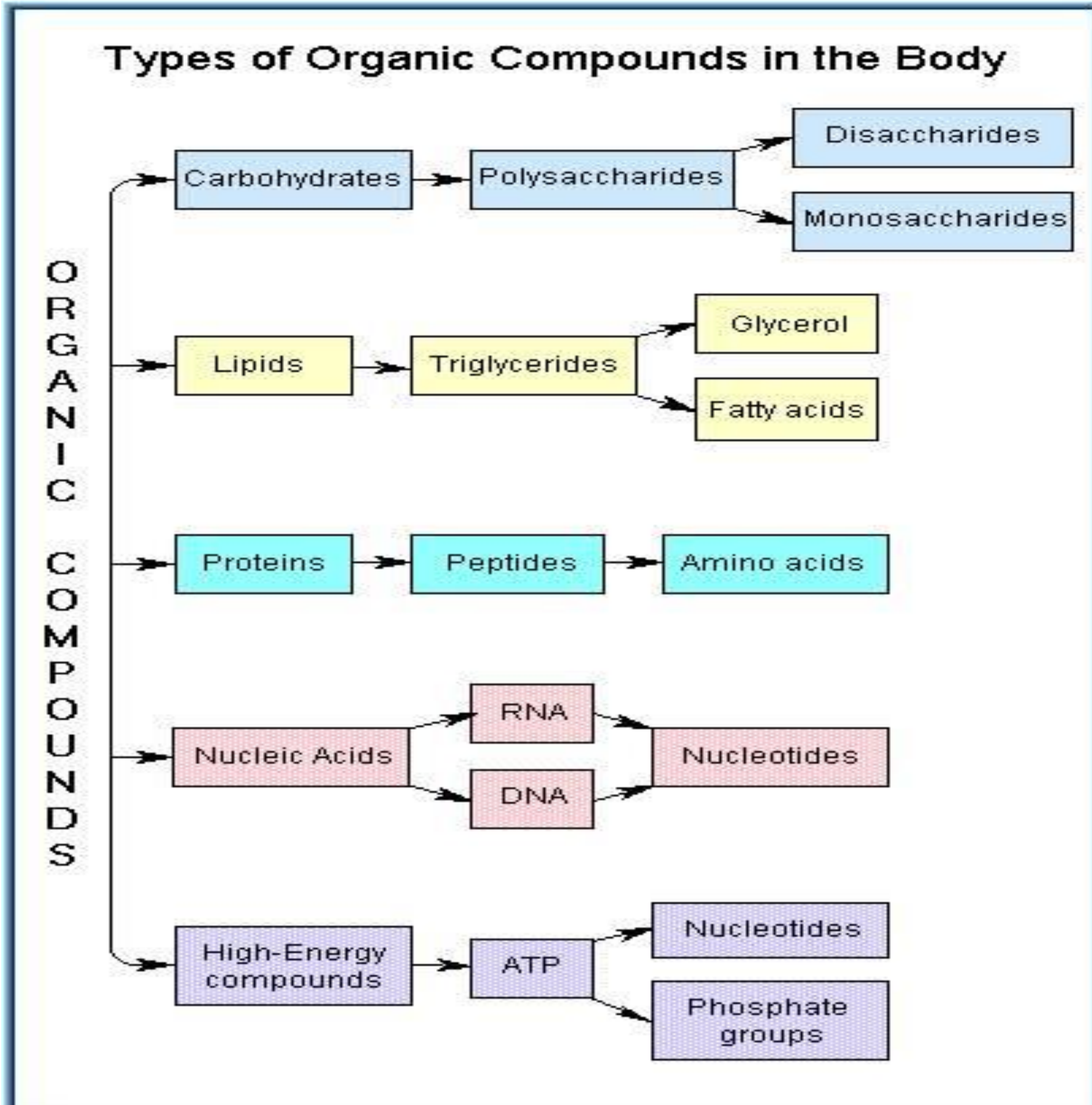


Active Transport – uses energy



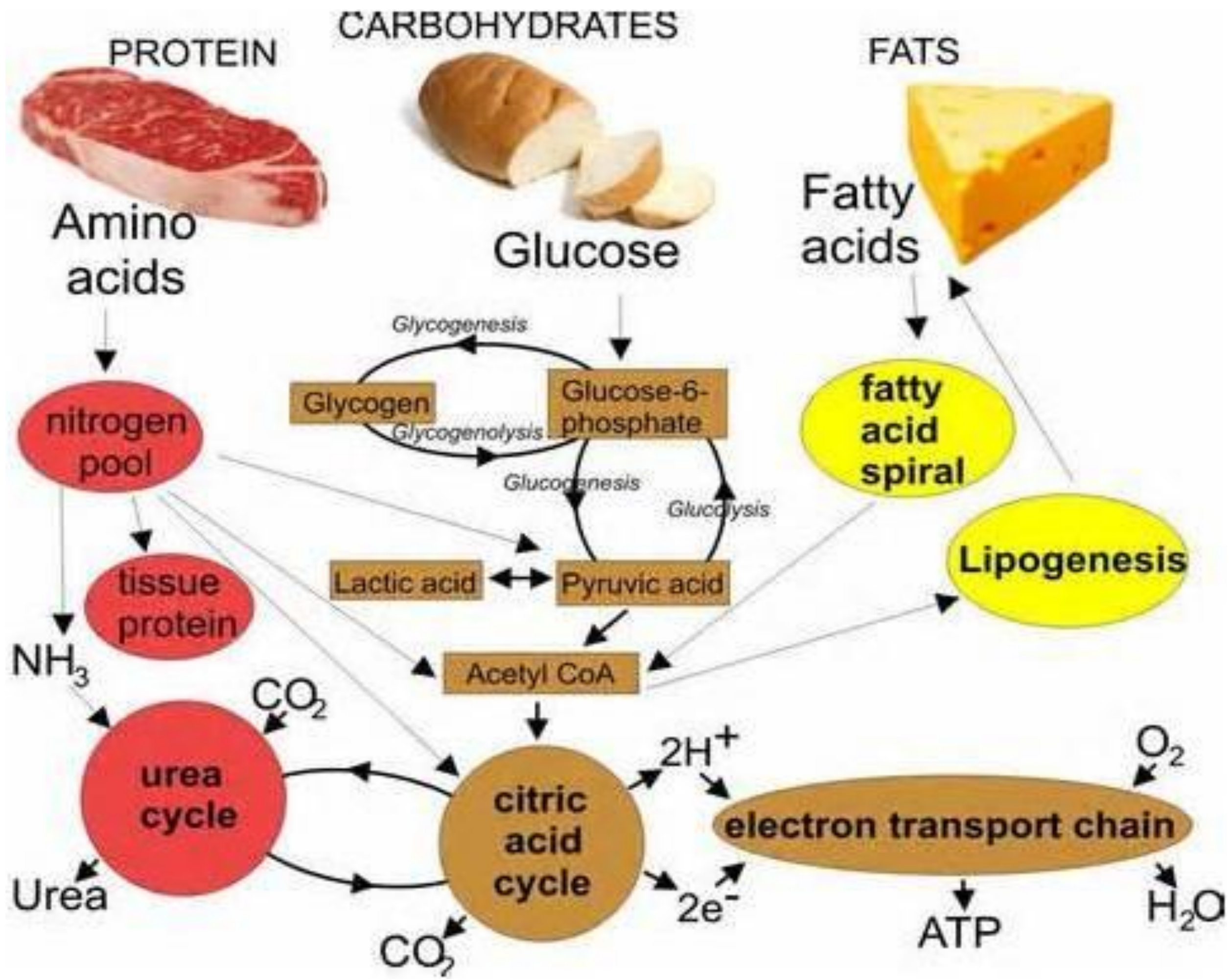
Endocytosis and Exocytosis



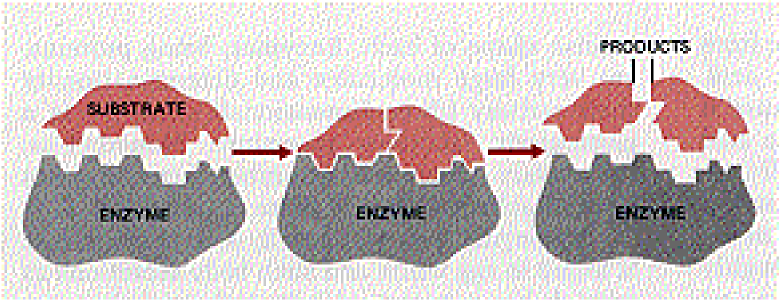


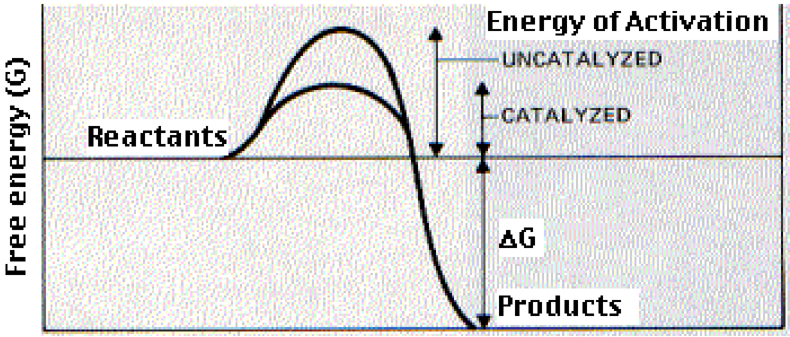
Types of Organic Compounds in the Body
ORGANIC COMPOUNDS
Carbohydrates
Polysaccharides
Disaccharides
Monosaccharides
Lipids
Triglycerides
Glycerol
Fatty acids
Proteins
Peptides
Amino acids
Nucleic Acids
RNA
DNA
Nucleotides
High-Energy compounds
ATP
Nucleotides
Phosphate groups

Chemical Interactions



Enzymes





- Catalysts
- Made of Protein
- May have non-protein parts
- Lower Activation Energy
- Not changed during reaction
- Enzyme-substrate complex
- Inhibition

  Competitive - binding at active site

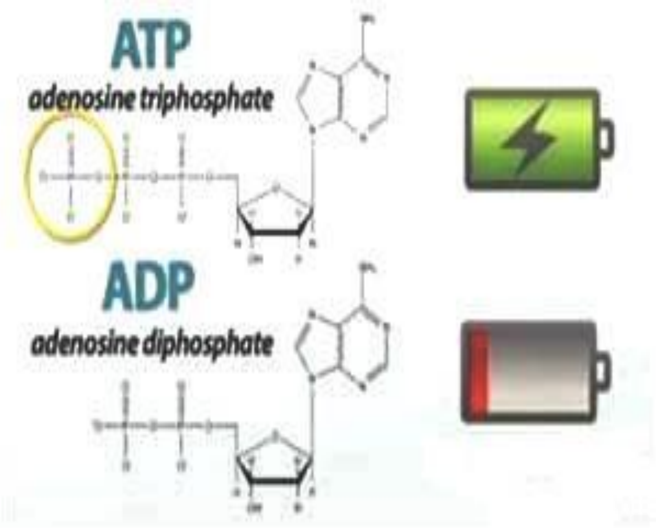
  Noncompetitive-binding at a site other than the active site

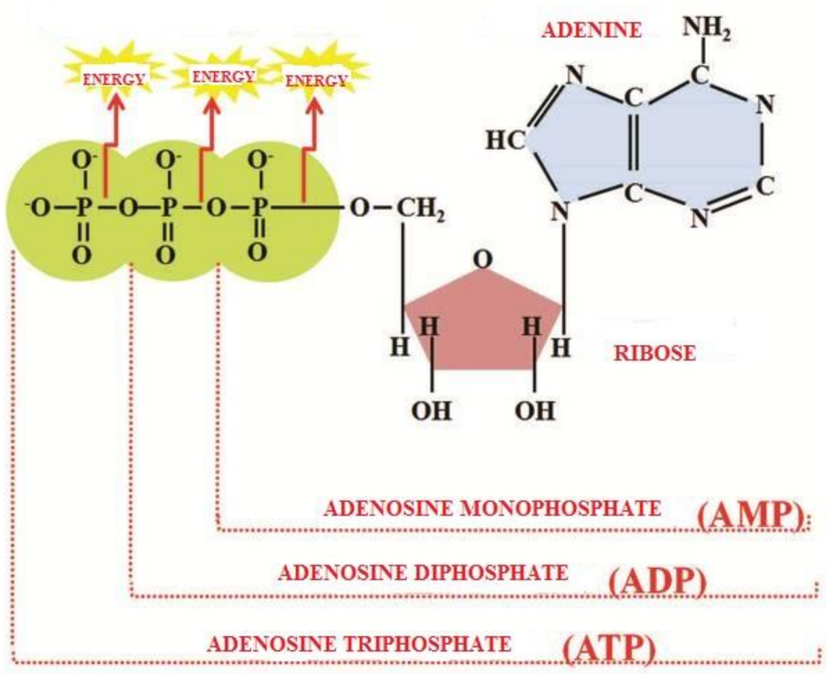
Enzymatic Mechanisms

- Enzymes bring reacting molecules into close proximity
- Enzymes orient reactants into positions to induce favorable interactions
- Enzymes alter the chemical environment of the reactants to promote interaction

Importance of ATP

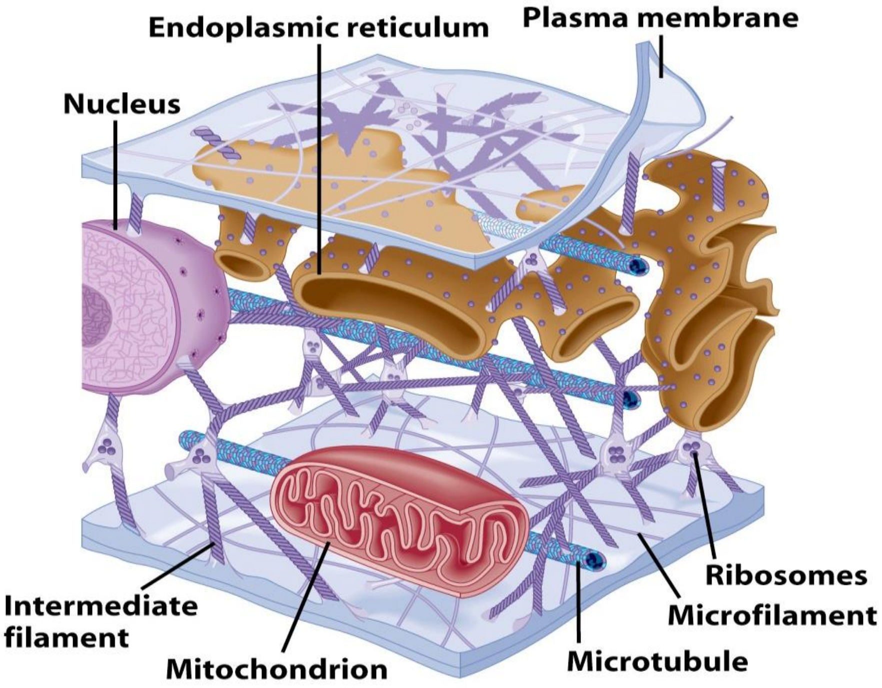
- Energy storage chemical for cell processes
- Most of ATP is produced via electron transport chain
- Main reason that cells need oxygen: to allow them to make lots of ATP
- Involved in both photosynthesis and respiration





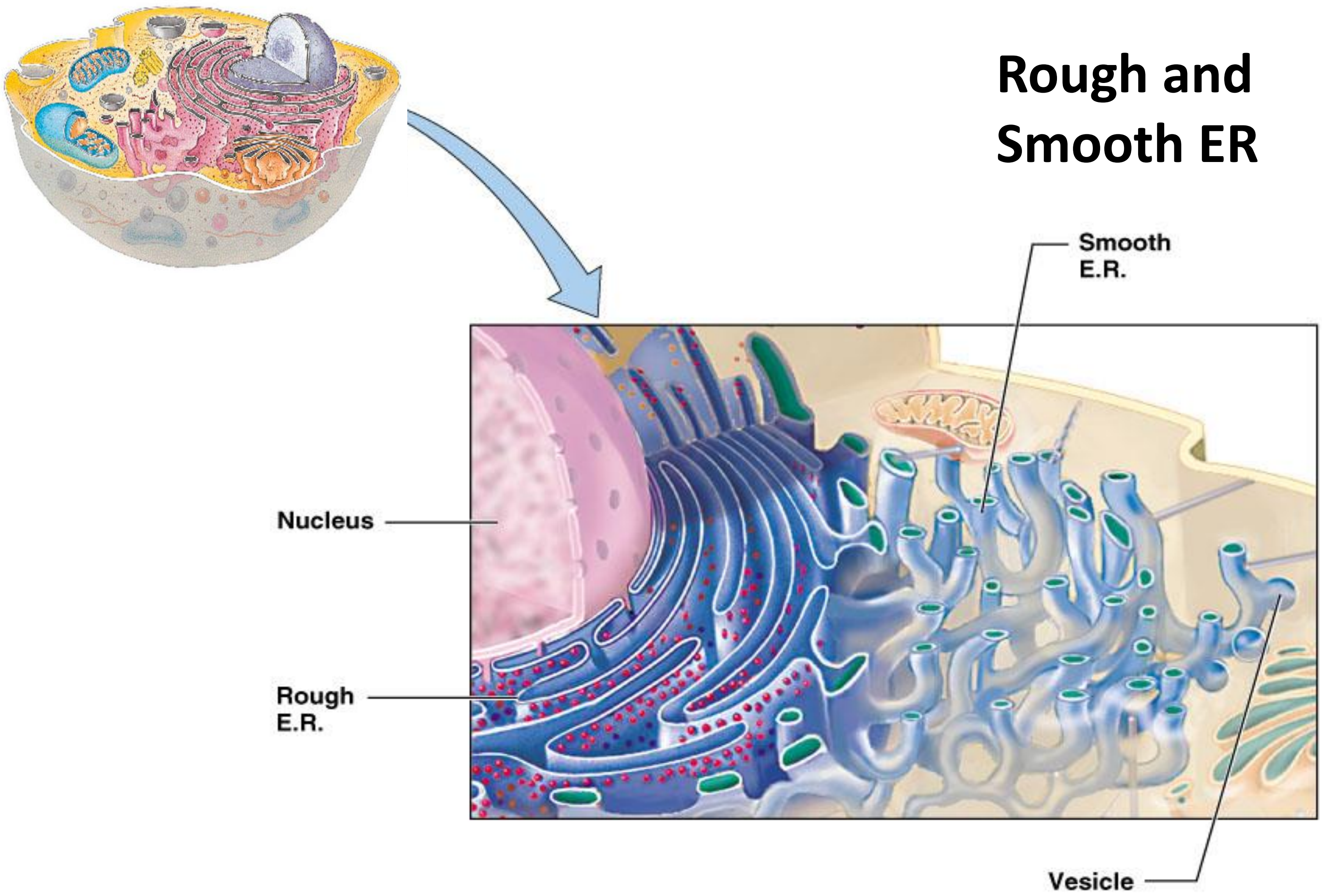
Cytoplasm

- Viscous fluid containing organelles
- components of cytoplasm
  - Interconnected filaments & fibers
  - Fluid = cytosol
  - Organelles (not nucleus)
  - storage substances

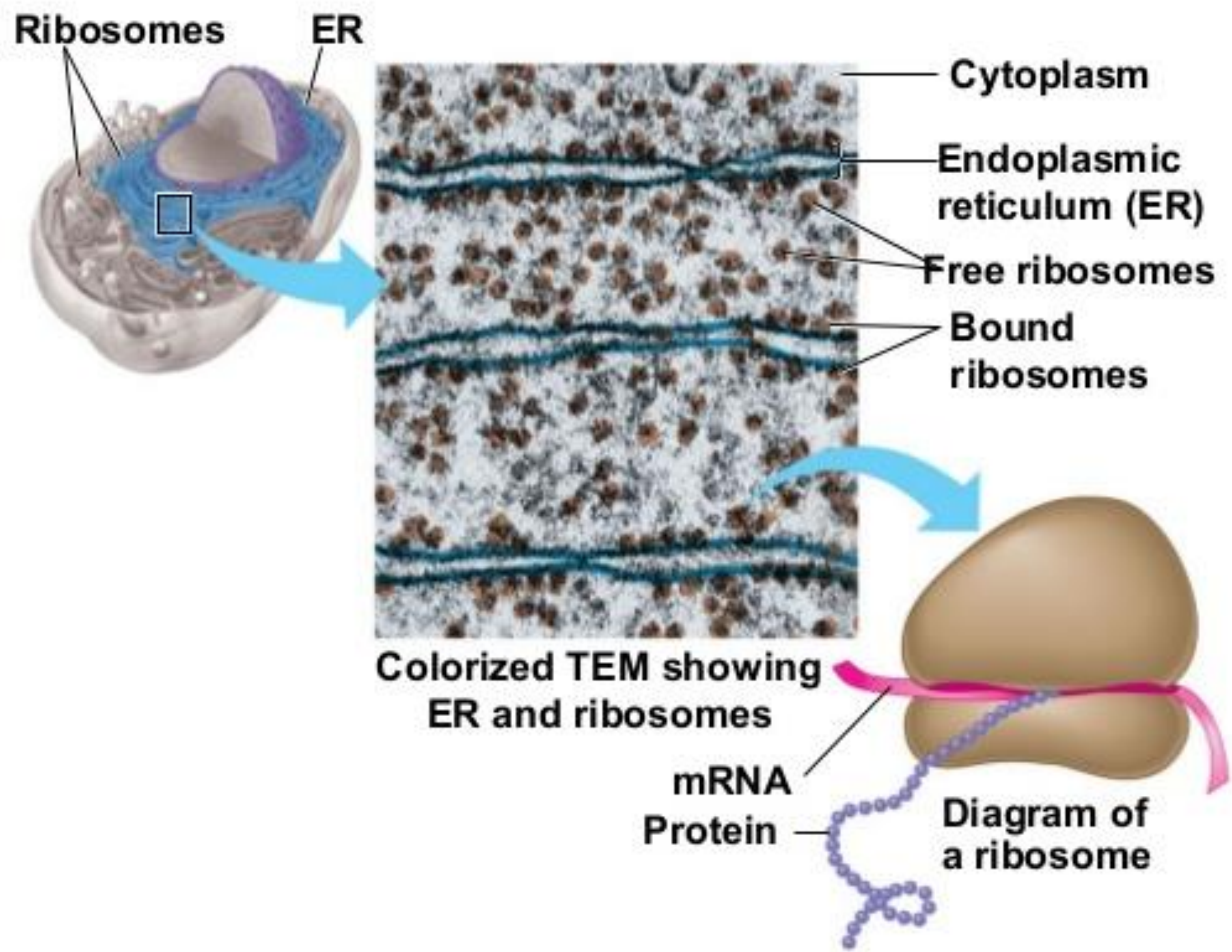


Endoplasmic Reticulum

Rough and Smooth ER

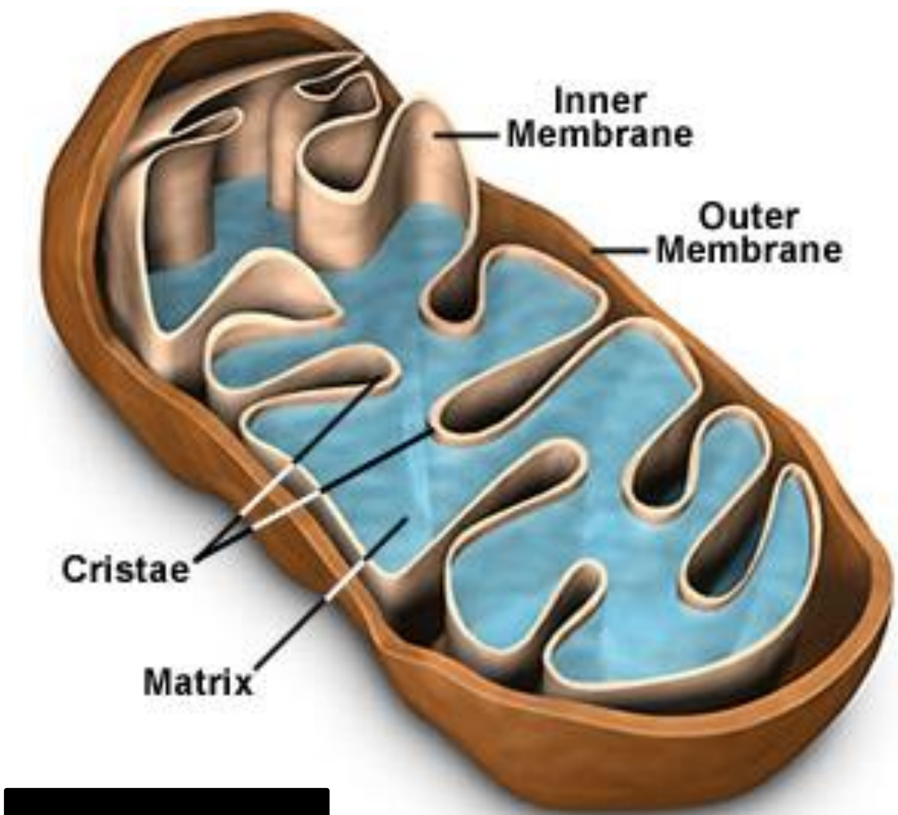


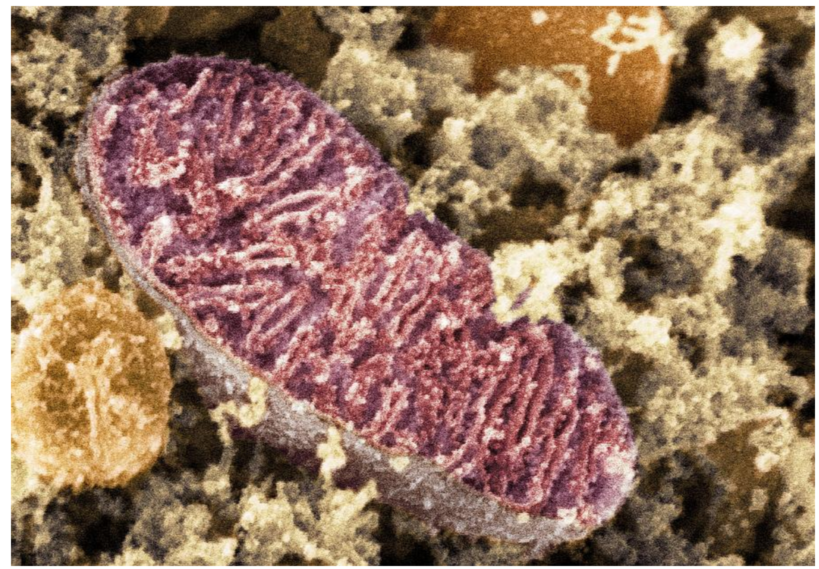
Ribosomes



Ribosomes
ER
Cytoplasm
Endoplasmic reticulum (ER)
Free ribosomes
Bound ribosomes
Colorized TEM showing ER and ribosomes
mRNA
Protein
Diagram of a ribosome

Mitochondria

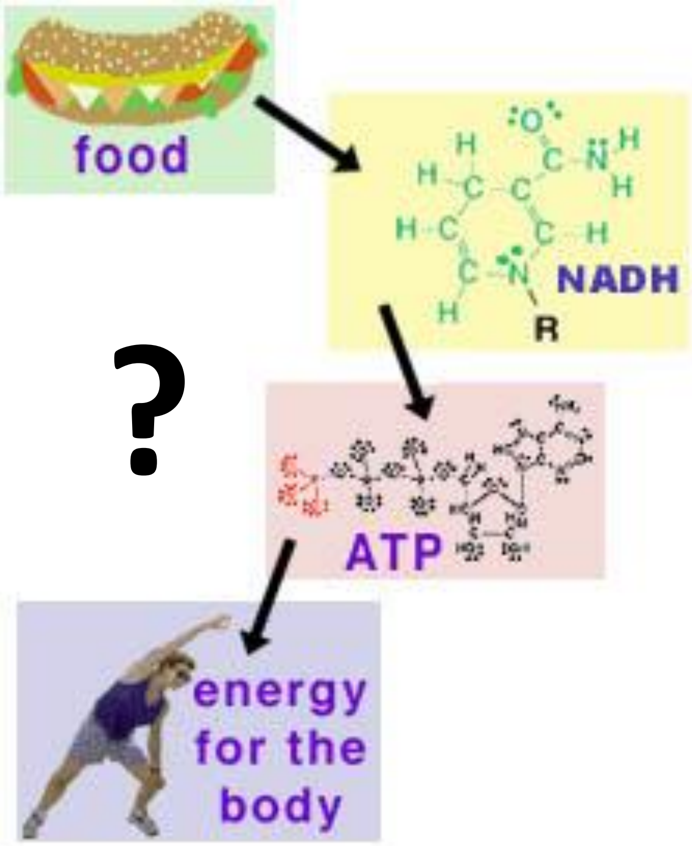




[redacted]

ATP- "the free-energy currency"

- Every day, we build bones, move muscles, think, and perform many other activities with our bodies. All of these activities are based upon **energy .**
- **ATP: The Perfect Energy Currency for the Cell**



Mitochondria-
the power plants of ATP

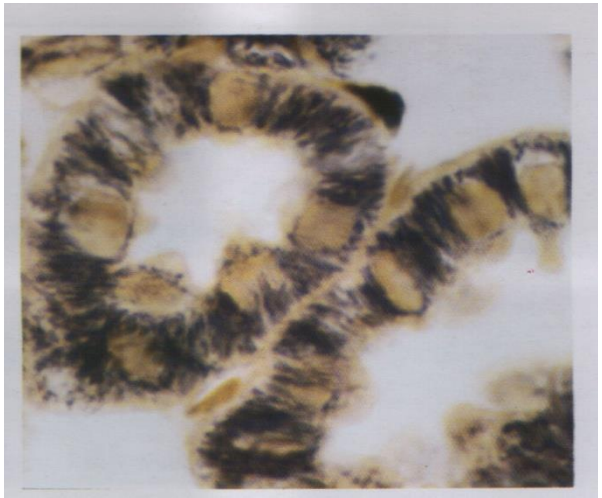
- Mitochondria are double layer membrane-enclosed organelles distributed through the cytosol of most eukaryotic cells.
- Their main function is the conversion of the potential energy of food molecules into ATP. So mitochondria are also called “the powerhouse” of the cell.
- In addition to supplying cellular energy, mitochondria are involved in cell death, as well as the control of the cell cycle and cell growth.

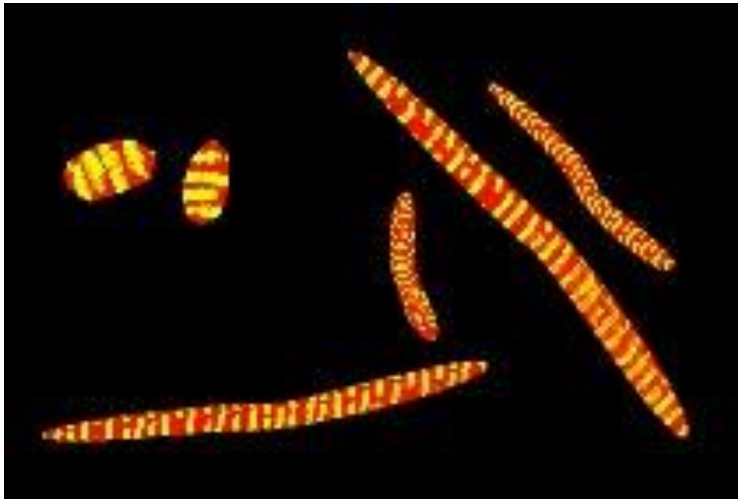
Brief History of Mitochondria studies

- **Richard Altmannin** 1894, established them as cell organelles and called them "bioblasts".
- The term "mitochondria" was coined by **Carl Benda** in 1898.
- **Leonor Michaelis** discovered Janus green can be used as a supravital stain for mitochondria in 1900.
- In 1913 particles from extracts of guinea-pig liver were linked to respiration by **Otto Heinrich Warburg**, which he called "grana".
- The first high resolution micrographs appeared in 1952, replacing the Janus Green stains .
- The popular term "powerhouse of the cell" was coined by **Philip Siekevitz in 1957.**

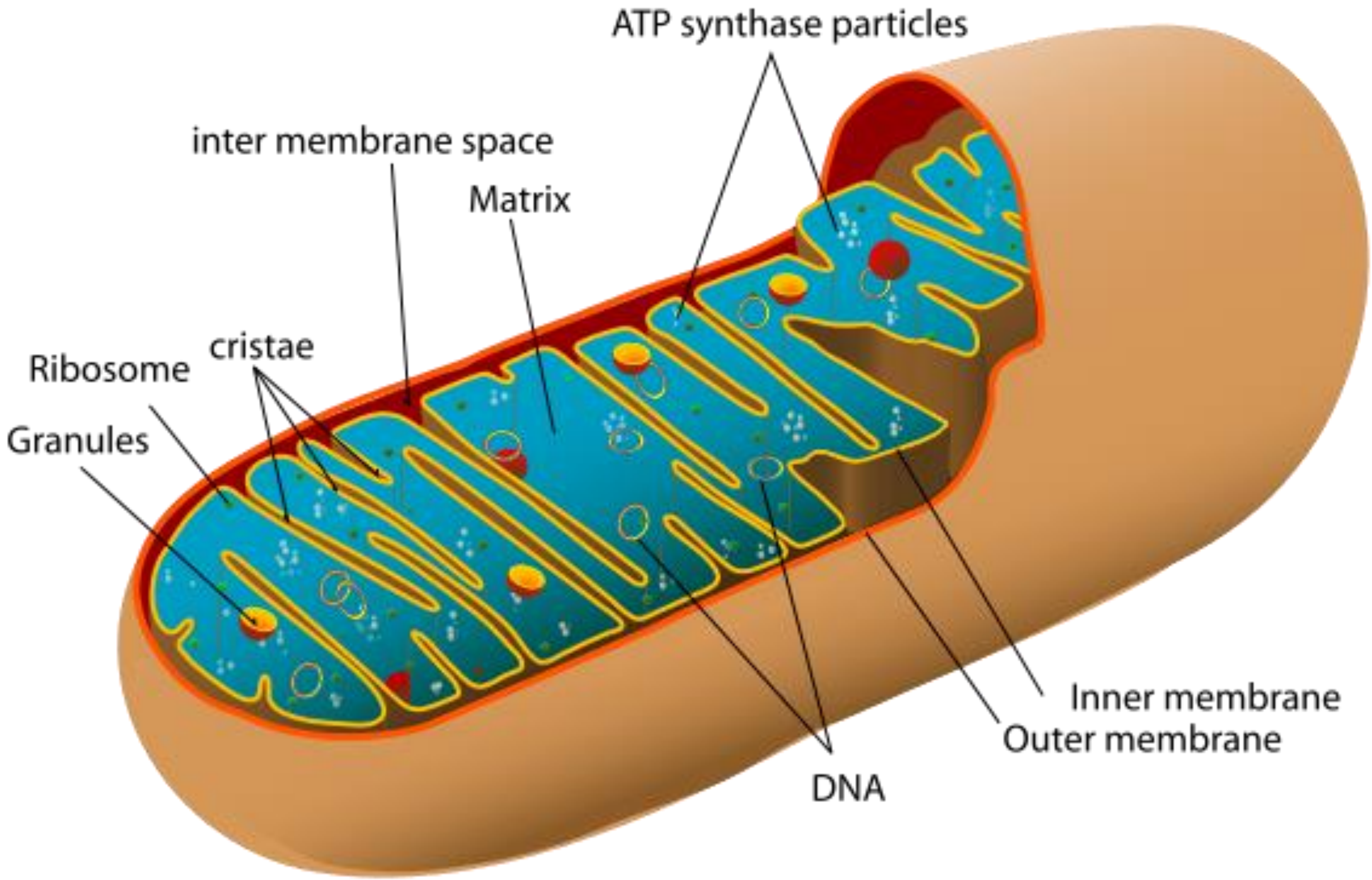
I. Shape, size & number

- Mitochondria are often flexible, rod-shaped organelles that are about 0.5 to 1μm in girth and as much as 7 μ m in length.
- Mitochondria vary considerably in size & shape.
- Their number correlate with the metabolic activities of the cell.



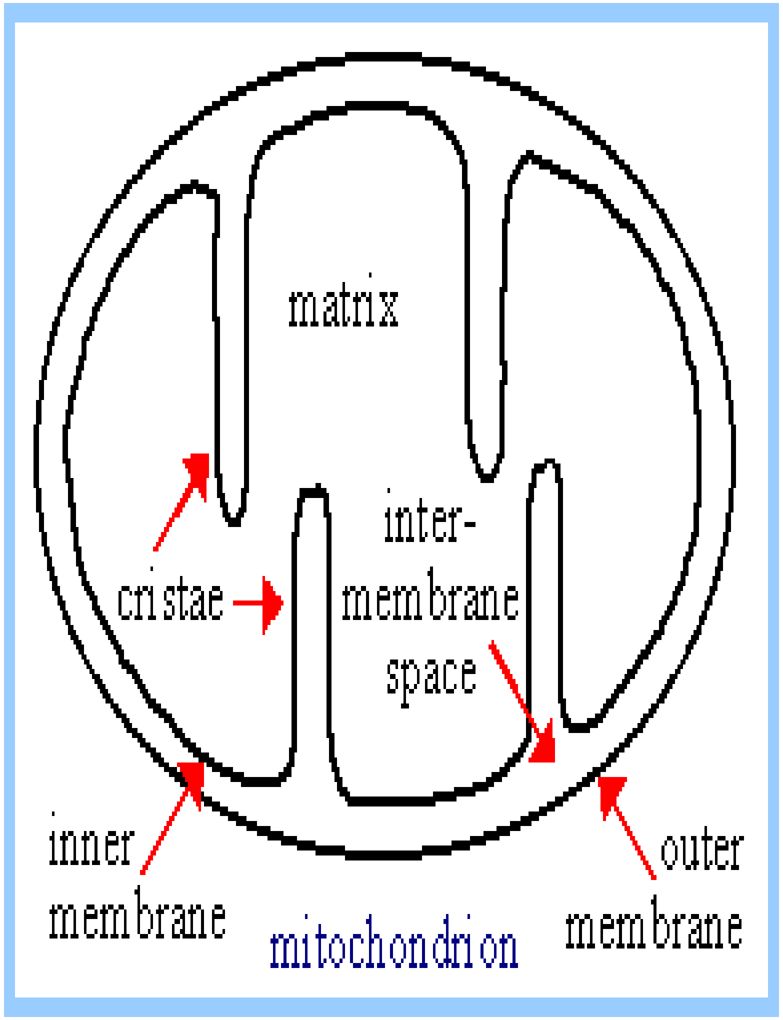


II Ultrastructure and Functional Localization

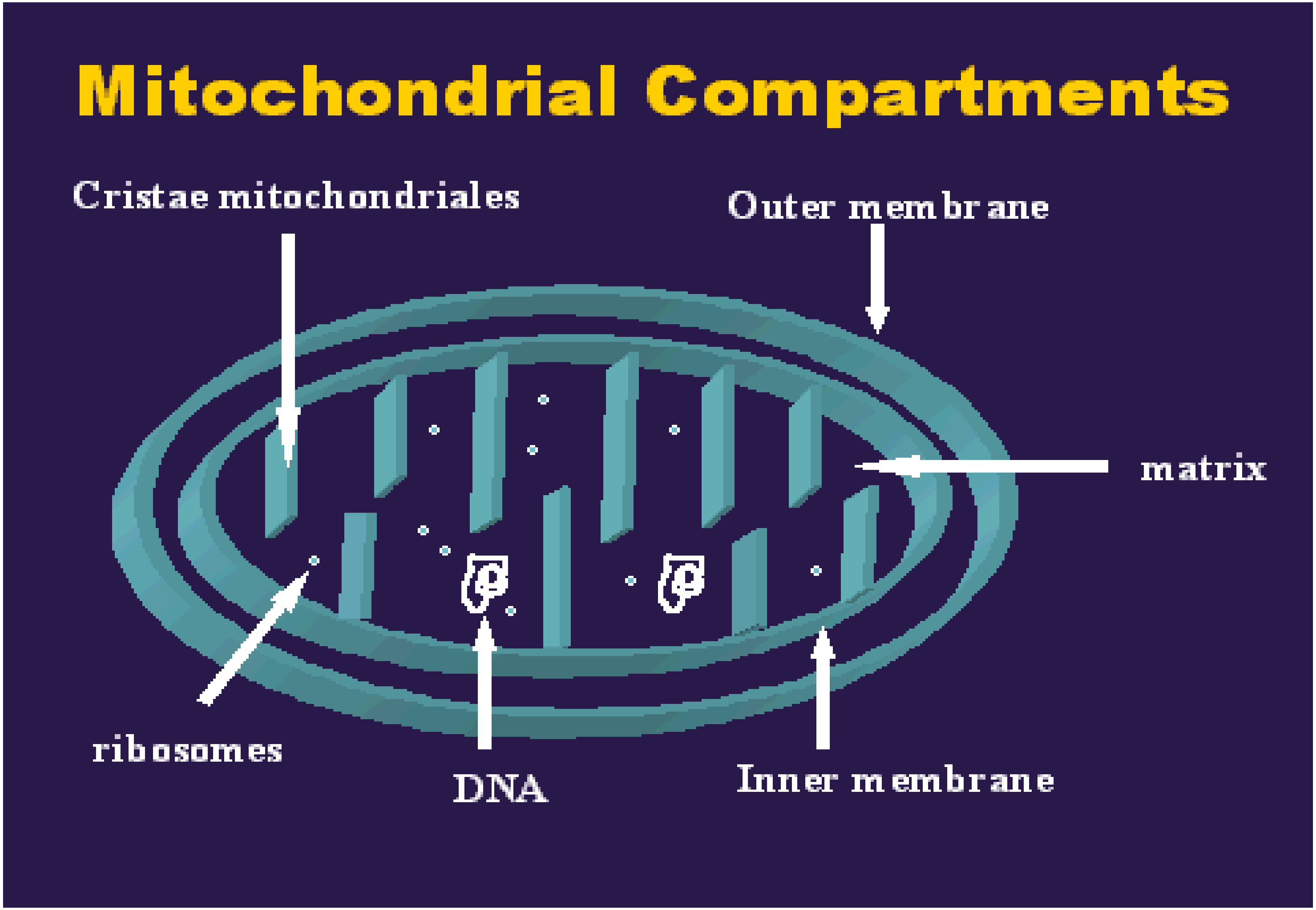


II Ultra structure and Functional Localization

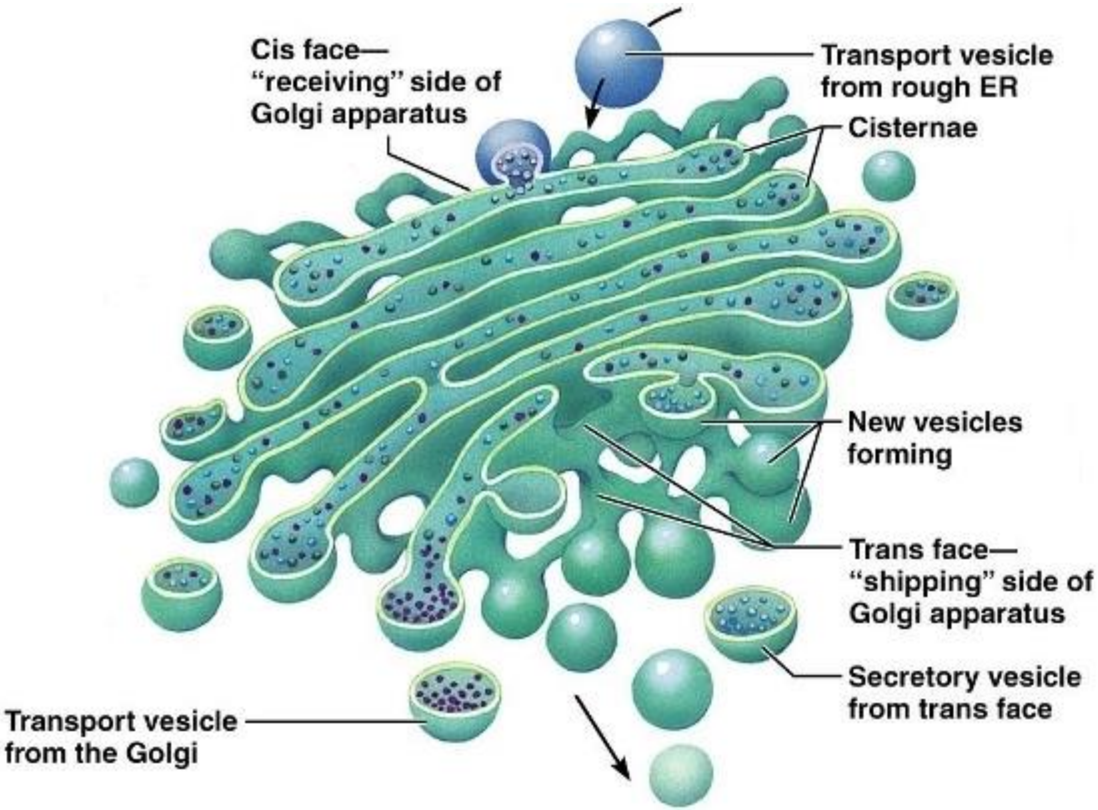
1. **Outer membrane**
2. **Inner membrane**
3. **Inter membrane space**
4. **Translocation contact site**
5. **Matrix**
6. **Cristae**



Diagrame of the mitochondria structure

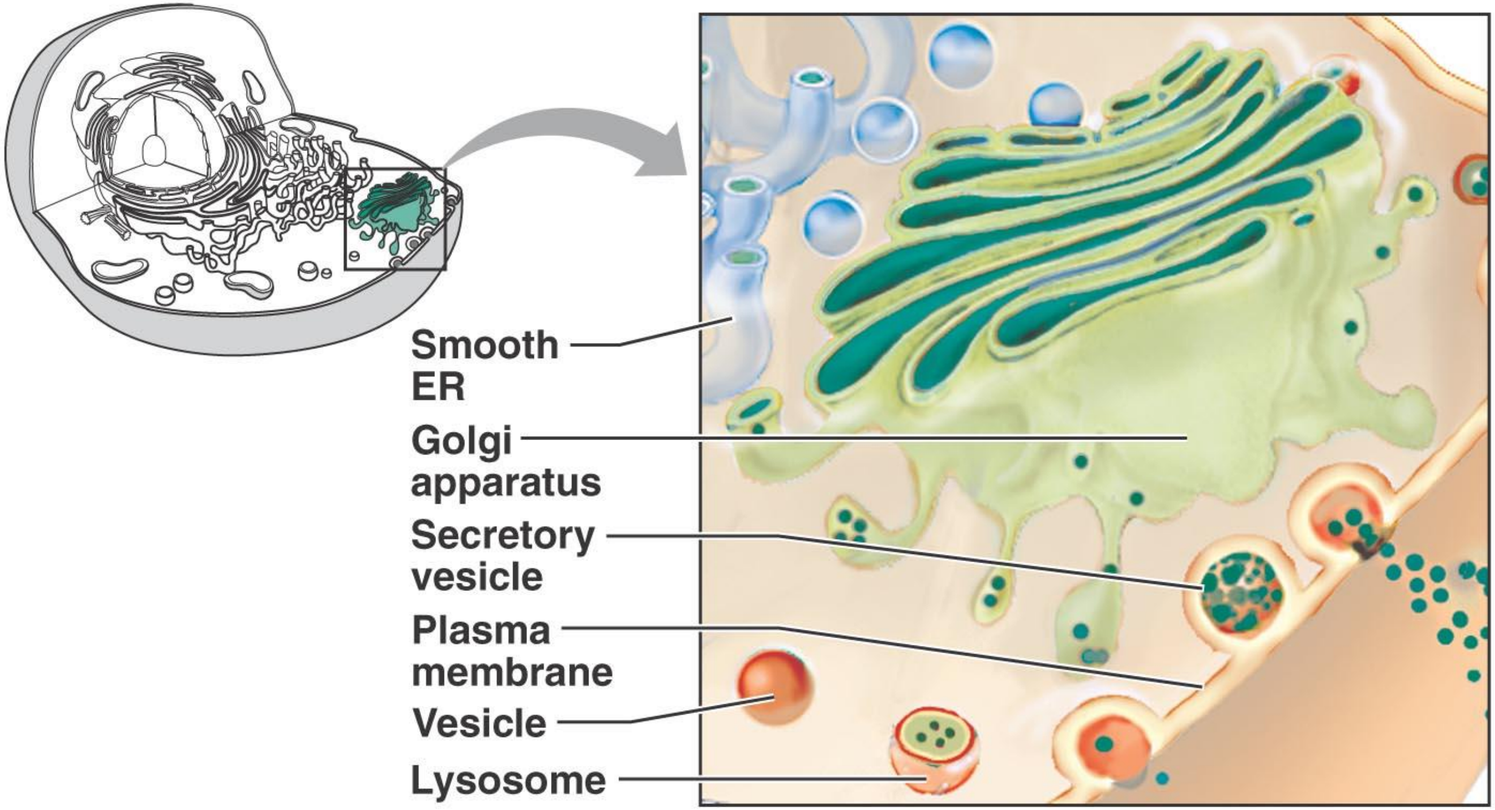


Golgi Complex



Golgi Apparatus

- Receives substances from ER, refines and packages them



INTRODUCTION

- Golgi apparatus was discovered in the year 1898 by an Italian biologist Camillo Golgi.

- The term Golgi apparatus was used in 1910 and in 1913 it first appeared in the scientific literature.

- The newly synthesized proteins, found in the channels of the **rough endoplasmic reticulum** are moved to the **Golgi body** where the carbohydrates are added to them and these molecules are enveloped in a part of the Golgi membrane and then the enveloped molecules leave the cell.
- The Golgi apparatus hence acts as the **assembly factory** of the cell where the raw materials are directed to the Golgi apparatus before being passed out from the cell.

- The Golgi complex is referred to as the **manufacturing and the shipping** center of the eukaryoric cell.

- The Golgi complex is responsible **inside the cell for packaging** of the **protein molecules** before they are **sent to their destination**.

- The major function of the Golgi body is to **modify , sort and package** the macromolecules.

- It also helps in transportation of lipids around the cell and the creation of lysosomes.

Golgi Apparatus Structure

- Observed in eukarytoic cells.

- They are membrane bound organelles, which are **sac-like**.

- They are found in the cytoplasm of plant and animal cells.

- The Golgi complex is composed of **stacks of membrane-bound structures**, these structures are known as the **cisternae.**

- Each cisternae is a **disc enclosed in a membrane**, it possess special enzymes of the Golgi which help to modify and transport of the modified proteins to their destination.

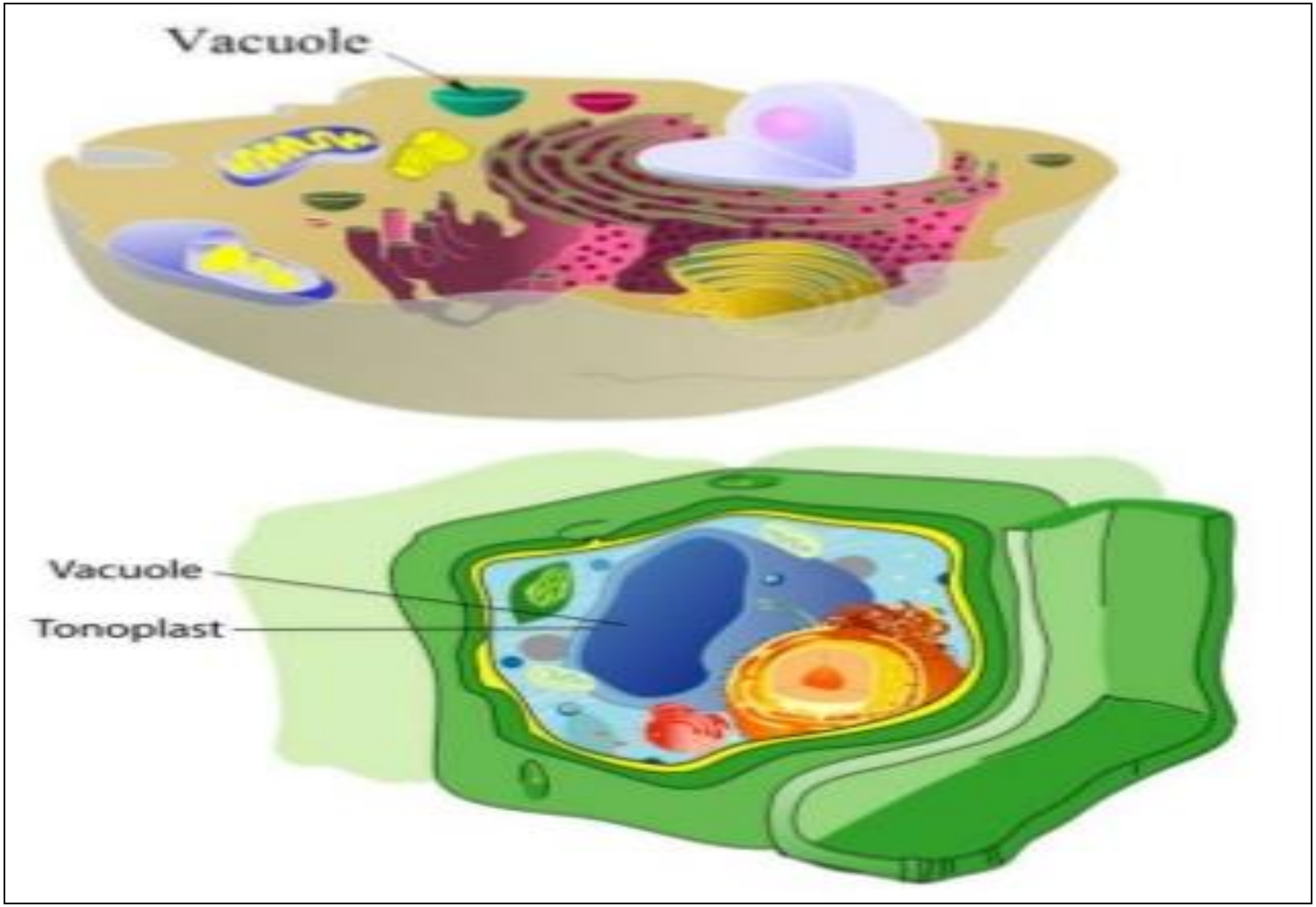
- The interaction in the Golgi membrane in responsible for the unique shape of the apparatus.

Functions

- It mainly modifies the proteins that are prepared by **the rough endoplasmic reticulum.**
- They are also involved in the transport of **lipid molecules** around the cell and creates **lysosomes**.
- The Golgi complex is thus referred **as post office** where the molecules are **packaged, labelled and sent** to different parts of the cell.

- The enzymes in the **cisternae** have the ability to **modify proteins** by the addition of **carbohydrates and phosphate** by the process of **glycosylation and phoshphorylation respectively.**

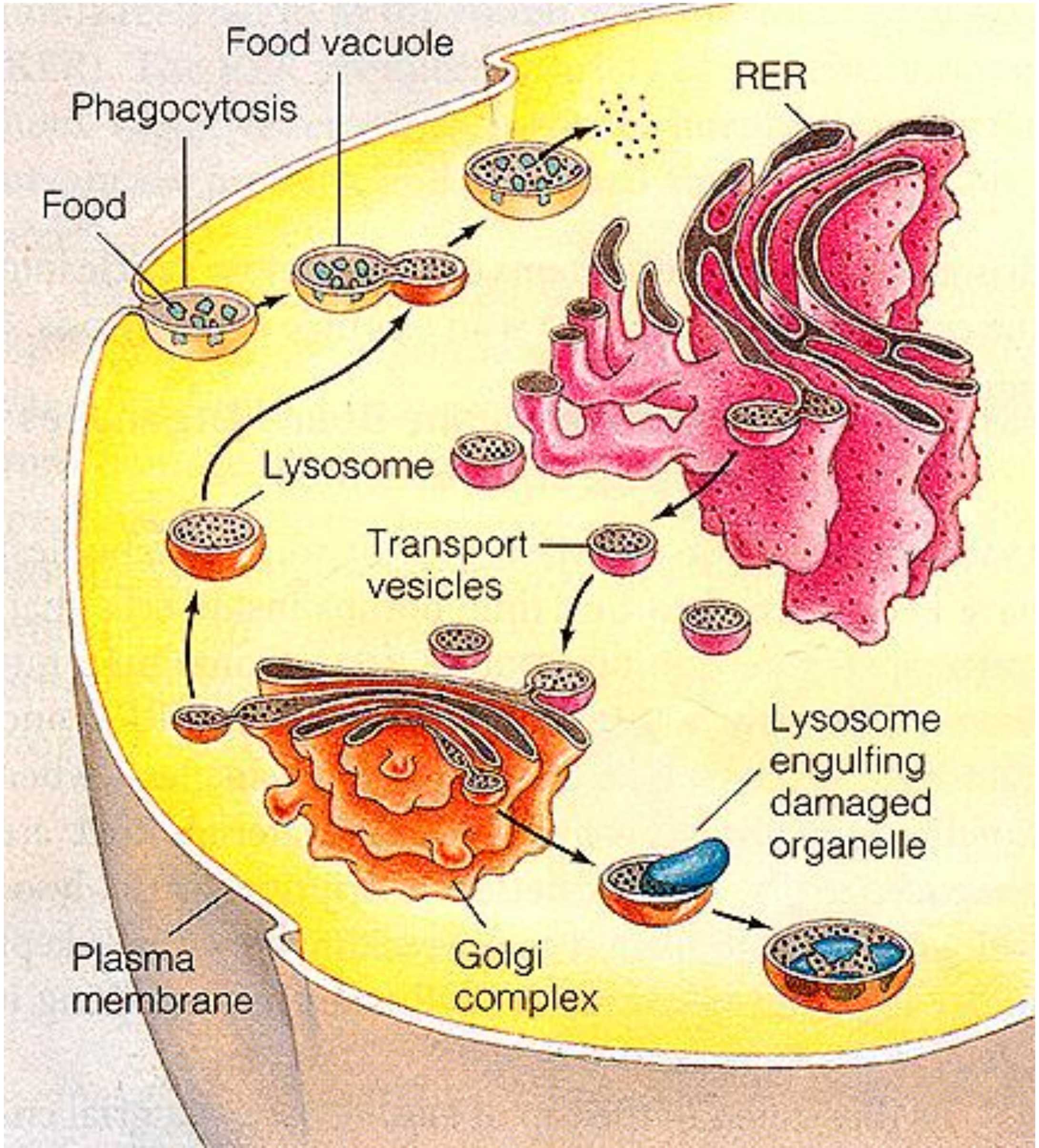
- The Golgi complex also plays an important role in the production of **proteoglycans**.



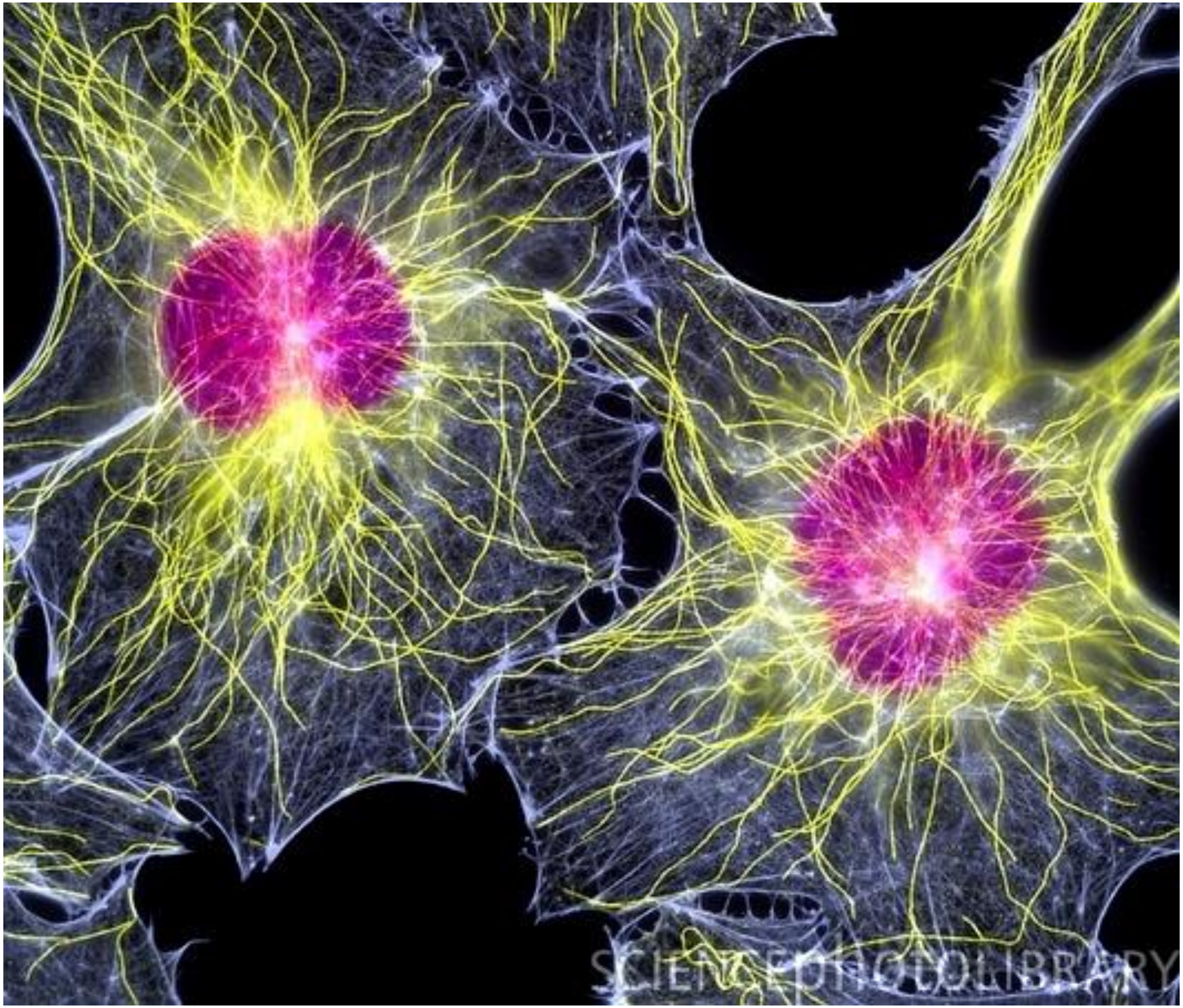
VACUOLES

https://www.youtube.com/watch?v=TxM0wzk5WgY

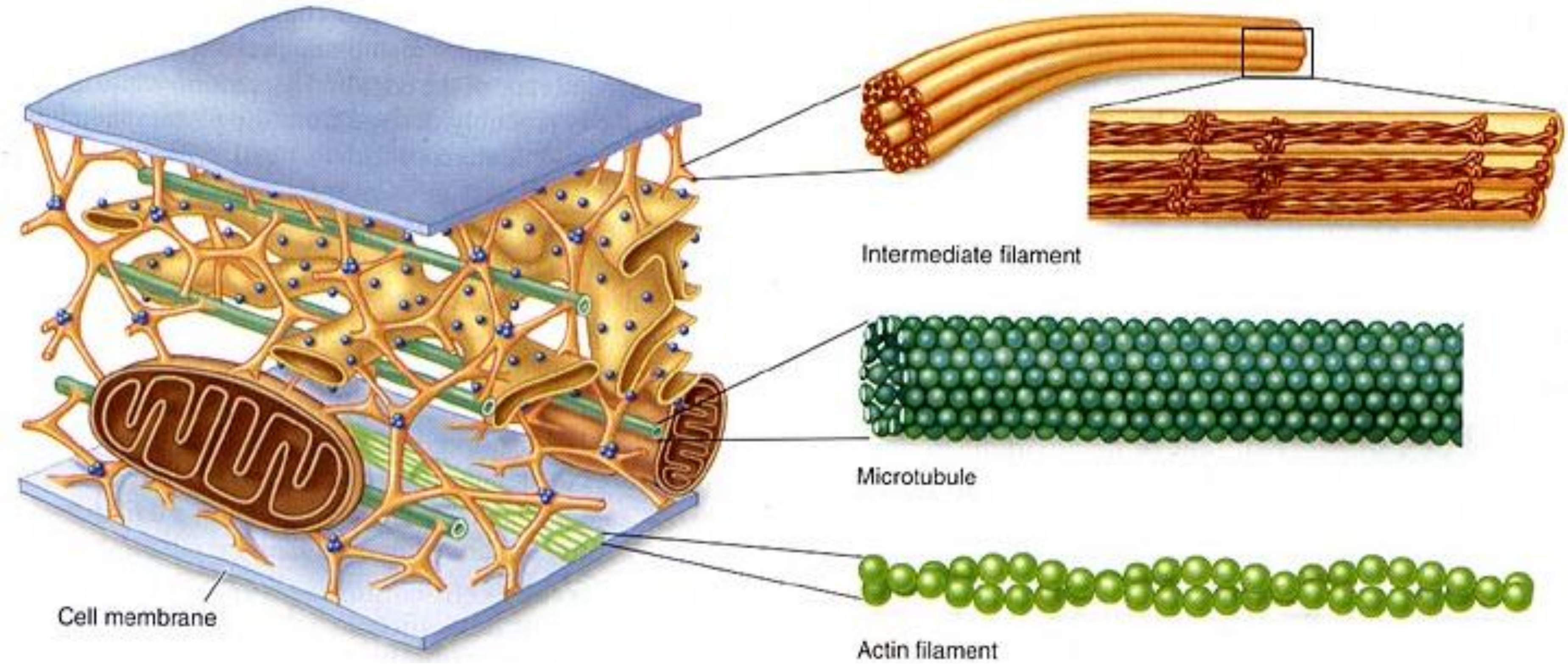
Lysosome Function



Cytoskeleton



Cytoskeleton



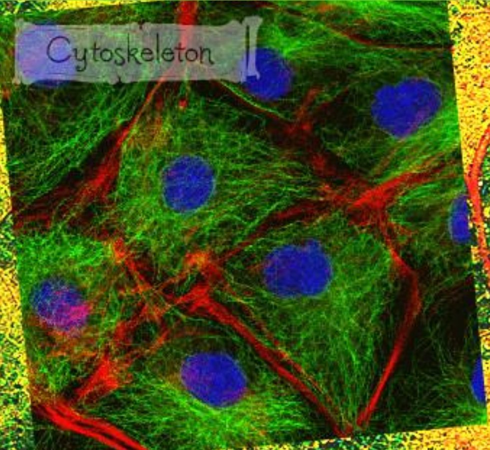
Cytoskeleton (Cell Part)

is the frame of a building. Like a building's frame, the cytoskeleton is the "frame" of the cell, keeping structures in place, providing support, and giving the cell a definite shape.

My cell Functions like the foundation of a building by holding everything together and acting as a base for a cell

My cell looks like a spider web. because the webbing of protiens through it.

The Cytoskeleton
The cytoskeleton is the strucure that holds the cell together. It is the base structure of the cells.



1.) The ctyoskeleton islocated throughout the cytoplasm in a cell.
2.) It is very important to a plant cells function because it helps hold the cell together. it is the base of the plant cell, the thing holding it up.
3.) If the cytoskeleton was missing from a plant cell the whole cell would fall apart and nothing would be able to funtion correctly causing the cell to shut down and no longer funtion at all.
4.)The cytoskeleton is made up of three kinds of protein filaments: Actin filaments, Intermediate filaments and Microtubules.

The Cytoskeleon of the cell funtions similar to a human skeleton because a human skeleton is the base structure of the human body and holds the body up just like the cytoskeleton does in a cell.

My Cell part functions like a hanger because a hanger helps maintain organization within a closet as where the cytoskeleton hels maintain internal organization in a cell.

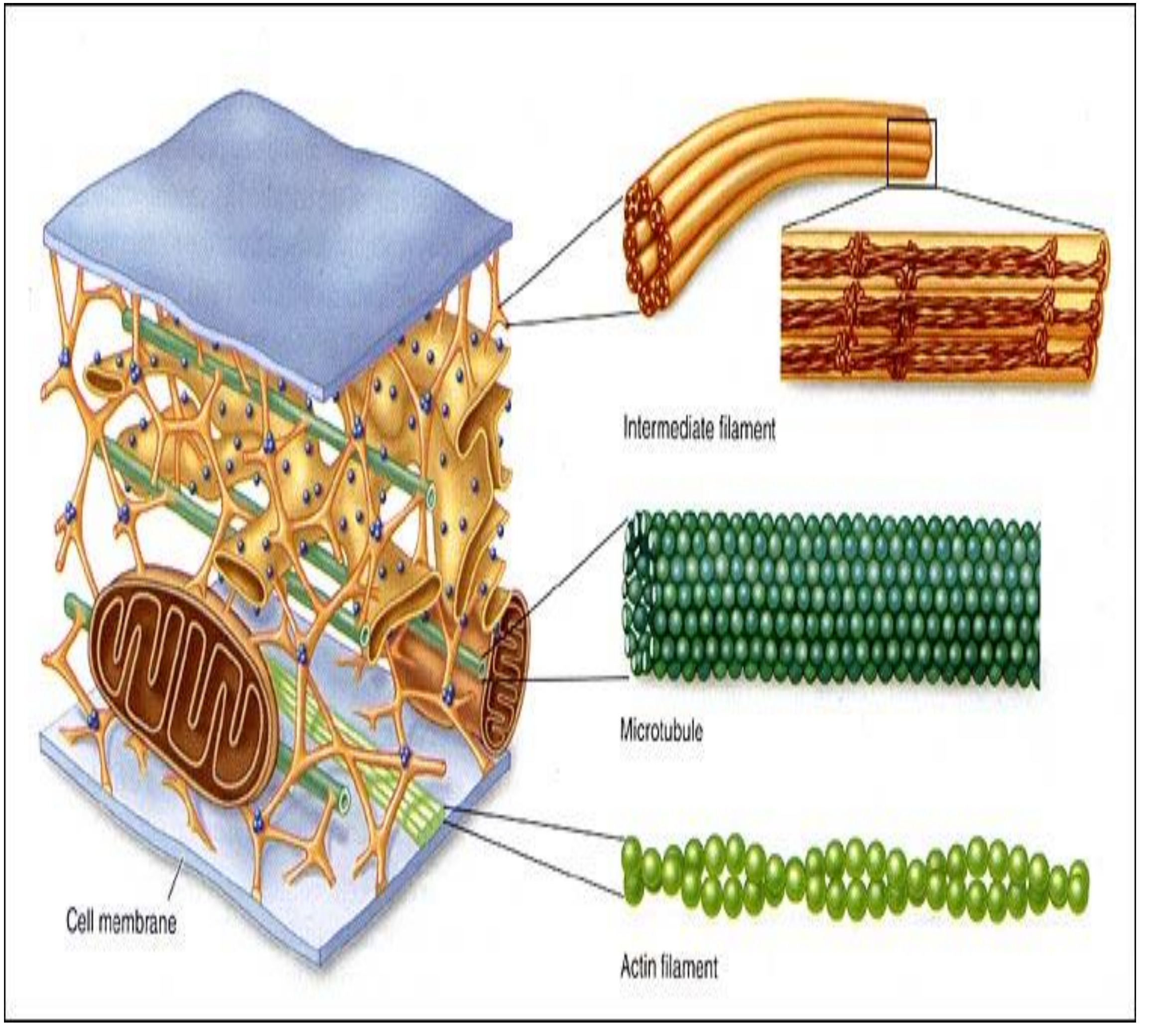
My cell part functions like the frame of a newly built building, because it holds the building up and together as the cytoskeleton does for the cell.

What is Cytoskeleton?

The cytoskeleton is an intracellular matrix that supports cell shape.

A microscopic network of protein filaments and tubules in the cytoplasm of many living cells, giving them shape and coherence.

Cytoskeleton is composed of three well defined filamentous structures-microfilaments, microtubules, and intermediate filaments.



- Eukaryotic cells also possess a “skeletal
- system”—a **cytoskeleton—that has analogous functions.**
- **The cytoskeleton is composed** of three well-defined filamentous structures—microtubules, microfilaments, and intermediate filaments—that together form an elaborate interactive network. Each of
- The three types of cytoskeletal filaments is a polymer of protein subunits held together by weak, noncovalent bonds.
- This type of construction lends itself to rapid assembly and disassembly, which is dependent on complex cellular regulation.
- **Microtubules are long, hollow, unbranched tubes composed** of subunits of the protein tubulin.
- **Microfilaments are solid, thinner structures,** often organized into a branching network and composed of the protein actin.
- Intermediate filaments are tough, ropelike fibers composed of a variety of related proteins

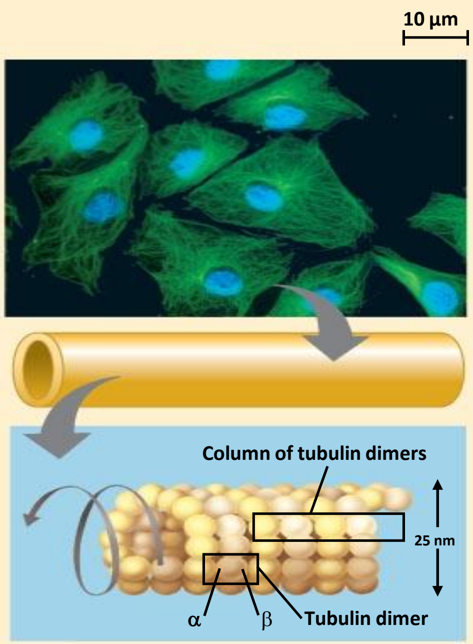
Components of the Cytoskeleton

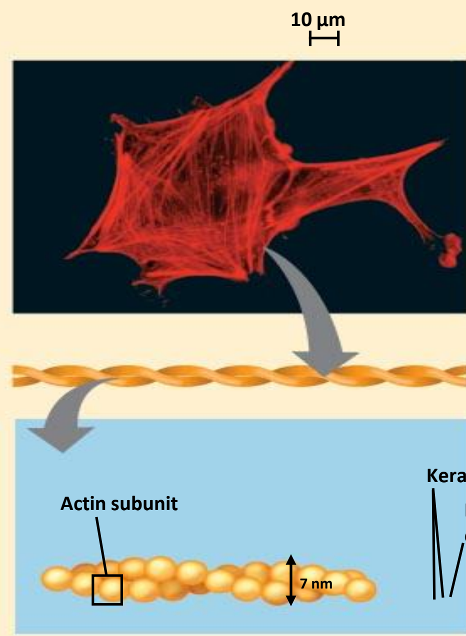
- Three main types of fibers make up the cytoskeleton:
  - *Microtubules* are the thickest of the three components of the cytoskeleton
  - *Microfilaments*, also called actin filaments, are the thinnest components
  - *Intermediate filaments* are fibers with diameters in a middle range

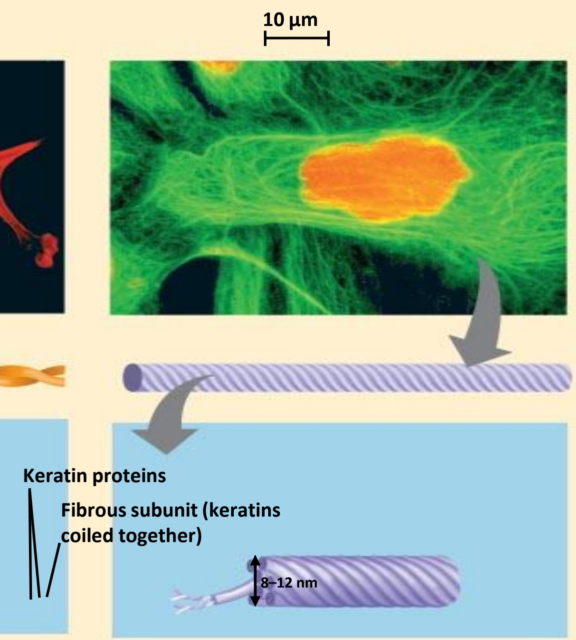
Table 6.1 The Structure and Function of the Cytoskeleton

Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two intertwined strands of actin, each a polymer of actin subunits	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins of the keratin family, depending on cell type
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	Maintenance of cell shape (tension-bearing elements) Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina

Micrographs of fibroblasts, a favorite cell type for cell biology studies. Each has been experimentally treated to fluorescently tag the structure of interest.



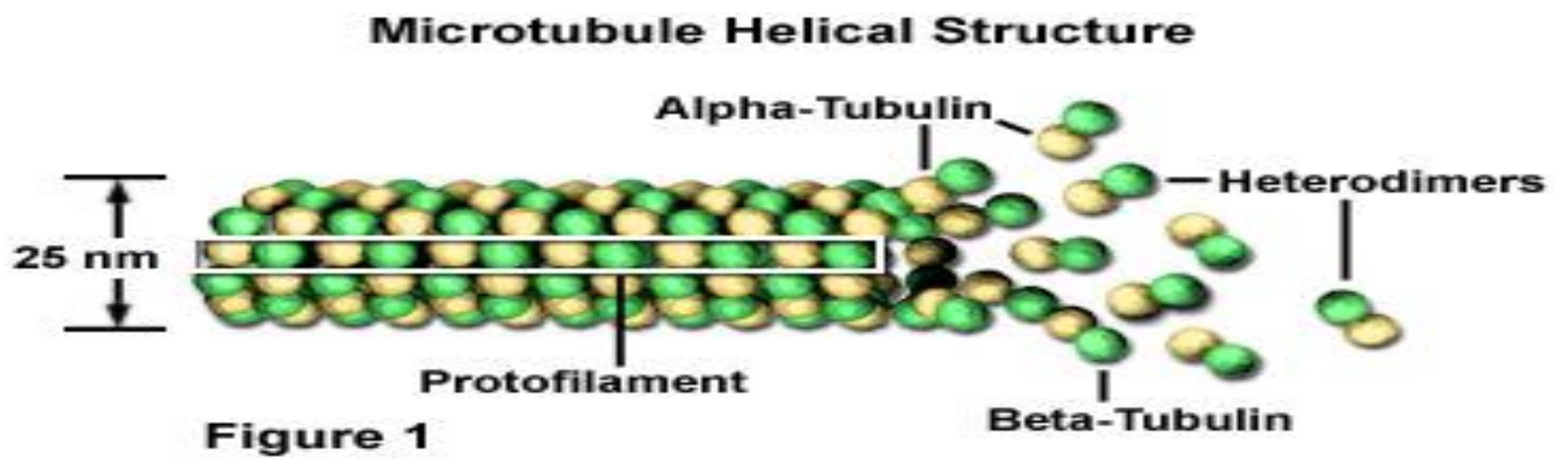




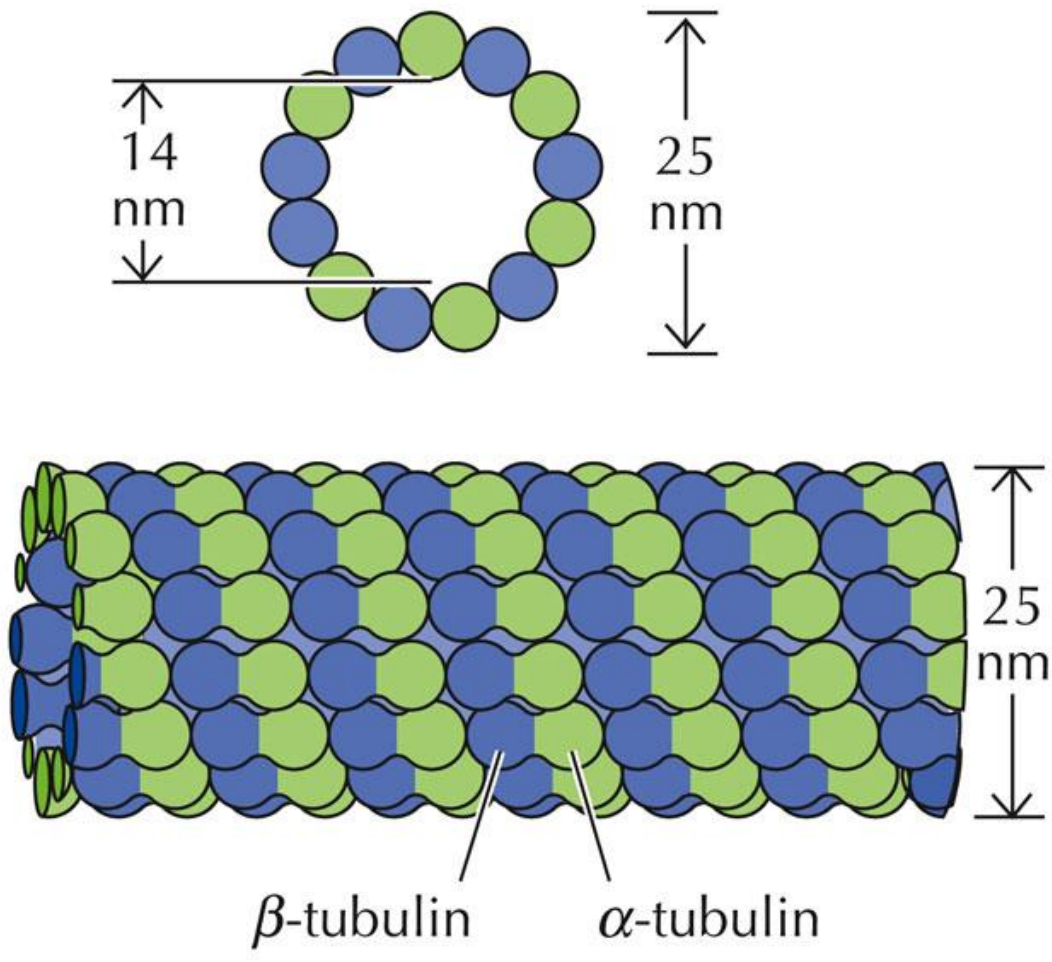
MICROTUBULES

- Microtubules are hollow, relativelyrigid, tubular structures, and they occur in nearly everyeukaryotic cell. Microtubules are components of a diverse array of structures, including the mitotic spindle of dividing cells and the core of cilia and flagella. Microtubules have an outer diameter of 25 nm and a wall thickness of approximately4 nm, and may extend across the length or breadth of a cell.

The wall of a microtubule is composed of globular proteins arranged in longitudinal rows, termed **protofilaments, that** are aligned parallel to the long axis of the tubule



Structure of microtubule



ASSEMBLY

- Microtubules are seen to consist of 13 protofilaments aligned side by side in a circular pattern within the wall .
- *Noncovalent interactions* between adjacent protofilaments are thought to play an important role in maintaining microtubule structure.
- Each protofilament is assembled from dimeric building blocks consisting of one -tubulin and one -tubulin subunit.
- The two types of globular tubulin subunits have a similar three-dimensional structure and fit tightly.
- *The tubulin dimers are organized in a linear* array along the length of each protofilament.
- *Because each assembly unit contains two nonidentical* components (a heterodimer), the protofilament is asymmetric, with an -tubulin at one end and a -tubulin at the other end.
- All of the protofilaments of a microtubule have the same polarity.

- Consequently, the entire polymer has polarity.One end of a microtubule is known as the *plus end and is* terminated by a row of -tubulin subunits
- The opposite end is the *minus end and is terminated by a row of* -tubulin subunits. growth of these structures and their ability to participate in directed mechanical activities.

Microtubule-Associated Proteins (MAP)

- Microtubules prepared from living tissue typically contain additional proteins, called **microtubule-associated proteins (or**
- **MAPs).**
- **MAPs comprise a heterogeneous collection of proteins.**
- The first MAPs to be identified are referred to as “classical MAPs” and typically have one domain that attaches to the side of a microtubule and another domain that projects outward as a filament from the microtubule’s surface.
- The binding of one of these MAPs to the surface of a microtubule thus maintaining their parallel alignment.
- MAPs generally increase the stability of microtubules and promote their assembly.
- The microtubule-binding activity of the various MAPs is controlled primarily by the addition and removal of phosphate groups from particular amino acid residues.

Cytoplasmic Dynein (MOTOR)

- The first microtubule-associated motor was discovered in 1963 as the protein responsible for the movement of cilia and flagella. The protein was named **dynein.**
- **The existence of cytoplasmic forms was almost immediately** suspected, but it took over 20 years before a similar protein was purified and characterized from mammalian brain tissue and called **cytoplasmic dynein.**
- **Cytoplasmic dynein is** present throughout the animal kingdom, but there is controversy as to whether or not it is present in plants.Whereas each of us has many different kinesins (and myosins), each adapted for specific functions, we are able to manage with only two cytoplasmic dyneins, one of which appears responsible for most transport operations.
- Cytoplasmic dynein is a huge protein (molecular mass of approximately 1.5 million daltons) composed of two identical heavy chains and a variety of intermediate and light chains.
- *Each dynein heavy chain consists of a large* globular head with an elongated projection (stalk).
- The dynein head, which is an order of magnitude larger than a kinesin head, acts as a force-generating engine.
- Each stalk contains the all-important microtubule-binding site situated at its tip

- In vitro motility assays indicate that cytoplasmic dynein moves processively along a microtubule toward the polymer's minus end opposite that of kinesin .
- *A body* of evidence suggests at least two well-studied roles for cytoplasmic
- Dynein.:

1. As a force-generating agent in positioning the spindle and moving chromosomes during mitosis
2. As a minus end–directed microtubular motor with a role in positioning the centrosome and Golgi complex and moving organelles, vesicles, and particles through the cytoplasm.

- **Microtubule Nucleation:**
- Regardless of their diverse appearance, all MTOCs play similar roles in all cells: they control the number of microtubules, their polarity, the number of protofilaments that make up their walls, and the time and location of their assembly.
- In addition, all MTOCs share a common protein component—a type of tubulin discovered in the mid-1980s, called **-tubulin.**
- Unlike the tubulins, which make up about 2.5 percent of the protein of a nonneural cell, -tubulin constitutes only about 0.005 percent of the cell's total protein.
- Fluorescent antibodies to tubulin stain all types of MTOCs, including the pericentriolar material of centrosomes *suggesting* that -tubulin is a critical component in microtubule nucleation.
- This conclusion is supported by other studies.
- For example, microinjection of anti--tubulin antibodies into a living cell blocks the reassembly of microtubules following their depolymerization by drugs or cold temperature

- To understand the mechanism of microtubule nucleation, researchers have focused on the structure and composition of the pericentriolar material (PCM) at the periphery of centrosomes.
- The insoluble fibers of the PCM *are* thought to serve as attachment sites for ring-shaped structures that have the same diameter as microtubules (25 nm) and contain -tubulin.
- These ring-shaped structures were discovered when centrosomes were purified and incubated with gold-labeled antibodies that bound to -tubulin.
- *The ends of the microtubules* that are embedded in the PCM of the centrosome where nucleation occurs.

Property	Microtubules (Tubulin Polymers)
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules
Diameter	25 nm with 15-nm lumen
Protein subunits	Tubulin
Main functions	Maintenance of cell shape Cell motility Chromosome movements in cell division Organelle movements

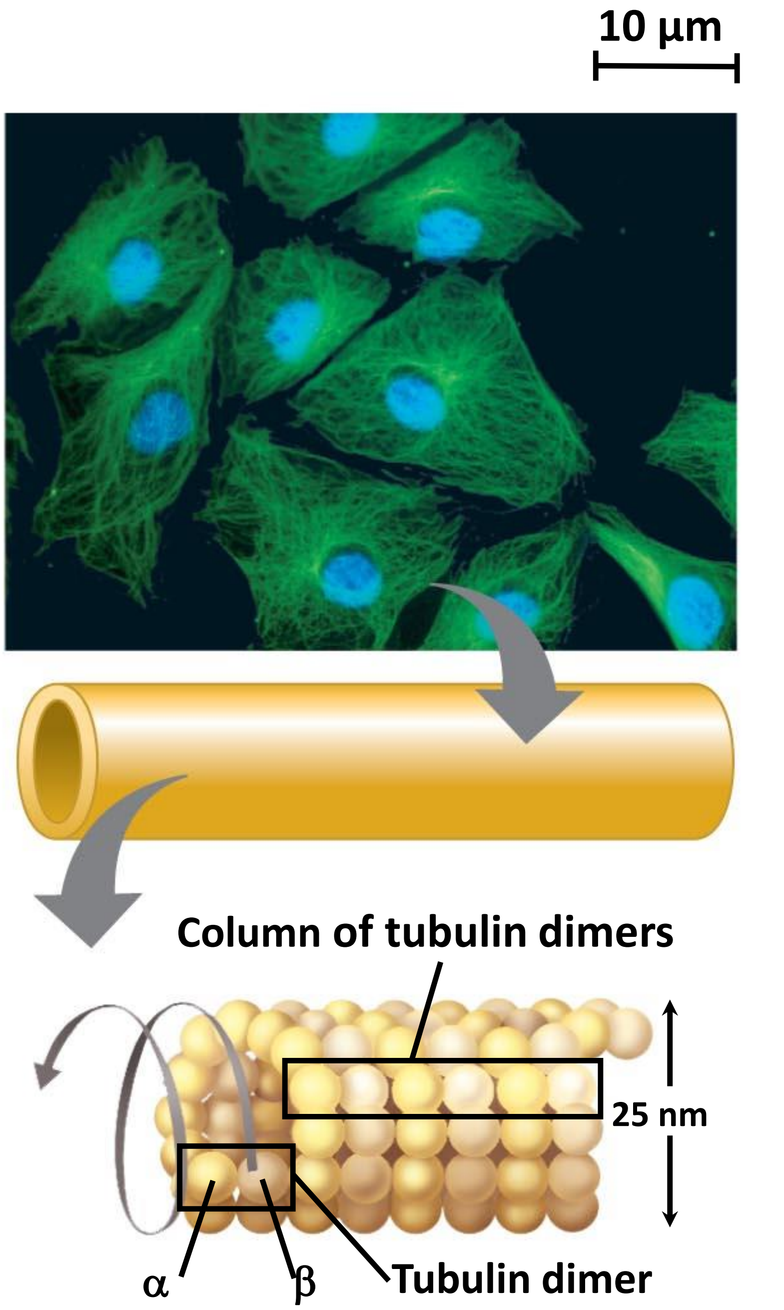


Table 6-1b

Property	Microfilaments (Actin Filaments)
Structure	Two intertwined strands of actin
Diameter	7 nm
Protein subunits	Actin
Main functions	Maintenance of cell shape Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility Cell division

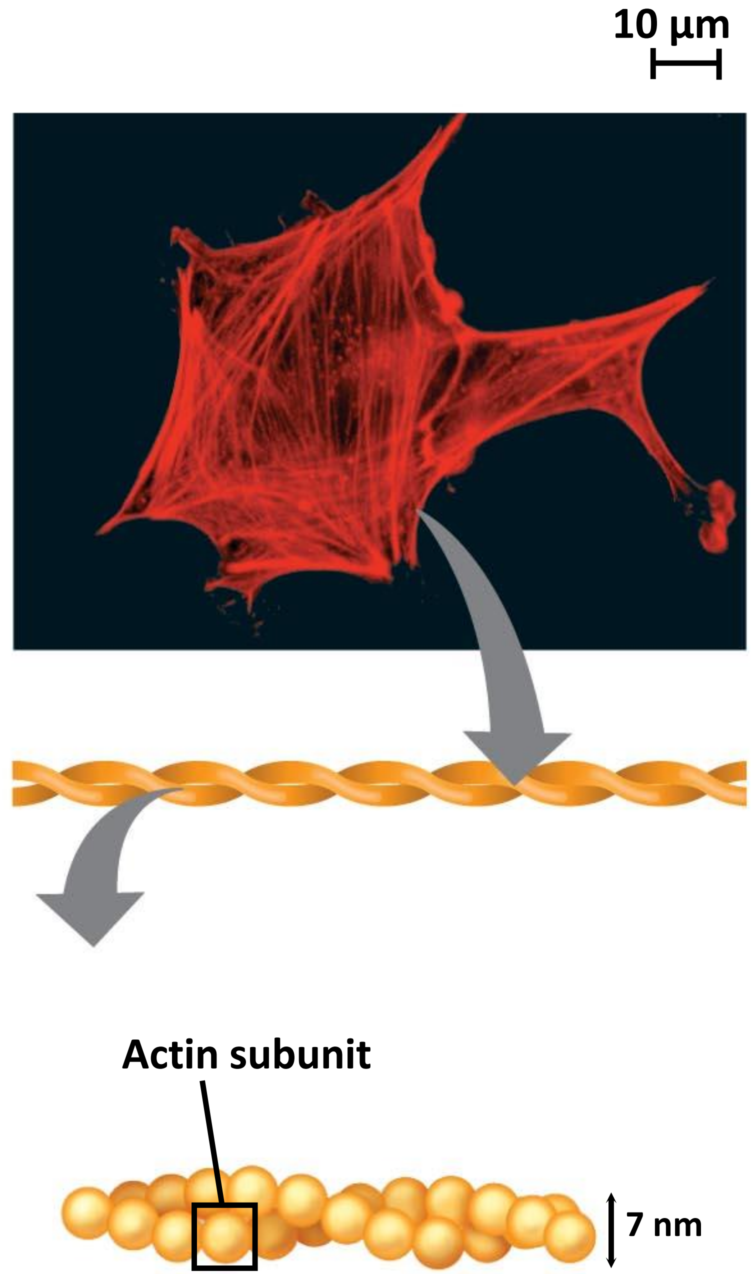
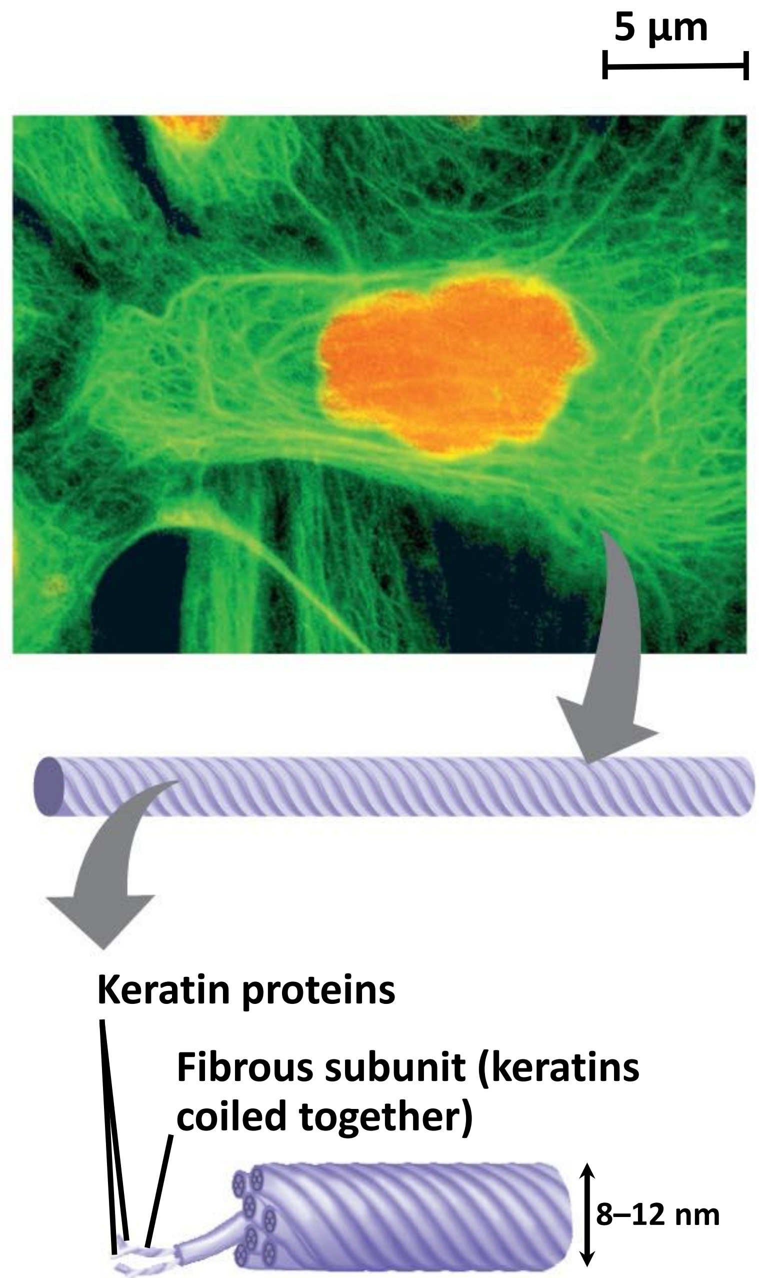


Table 6-1c

Property	Intermediate Filaments
Structure	Fibrous proteins supercoiled into thicker cables
Diameter	8–12 nm
Protein subunits	One of several different proteins of the keratin family
Main functions	Maintenance of cell shape Anchorage of nucleus and certain other organelles Formation of nuclear lamina



Cytoskeleton

- The cytoskeleton is a network of filaments and tubules that extends throughout a cell, through the cytoplasm, which is all of the material within a cell except for the nucleus.

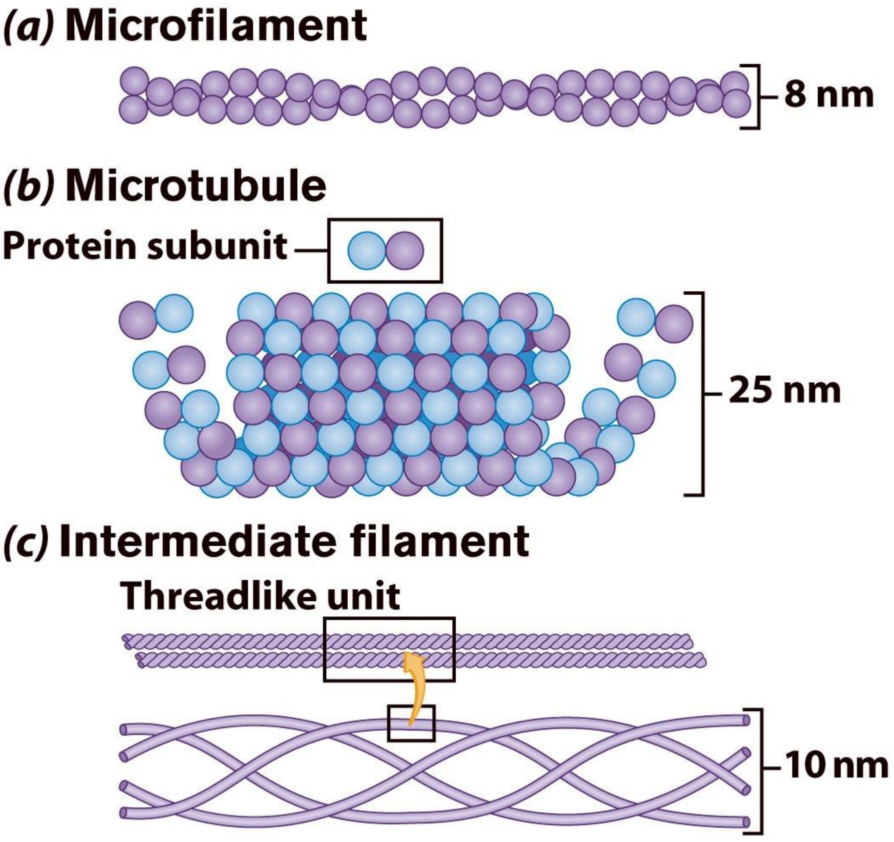
- It is found in all cells, though the proteins that it is made of vary between organisms.

- The cytoskeleton supports the cell, gives it shape, organizes and tethers the organelles, and has roles in molecule transport, cell division and cell signaling.

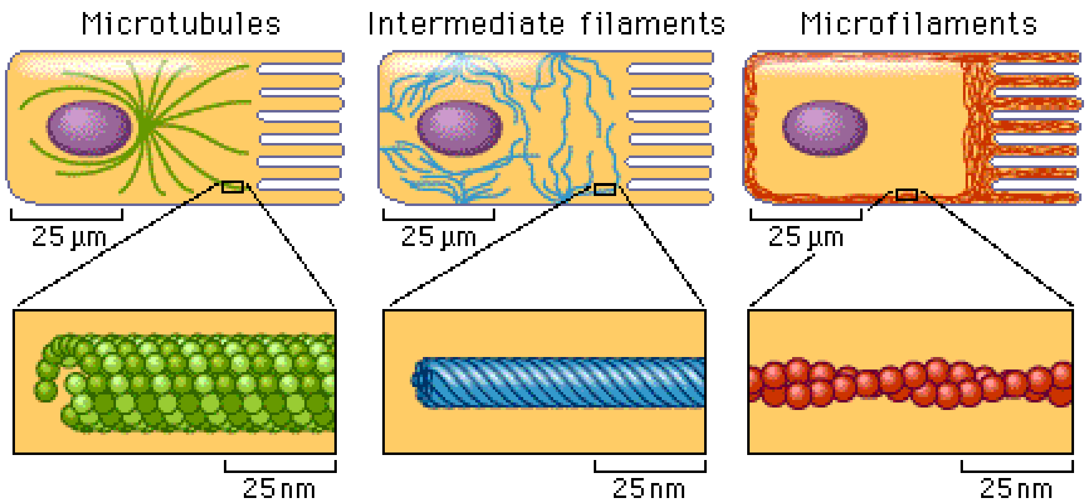
Cytoskeleton

- Filaments & fibers

- Made of 3 fiber types
  - Microfilaments
  - Microtubules
  - Intermediate filaments
- 3 functions:
  - mechanical support
  - anchor organelles
  - help move substances



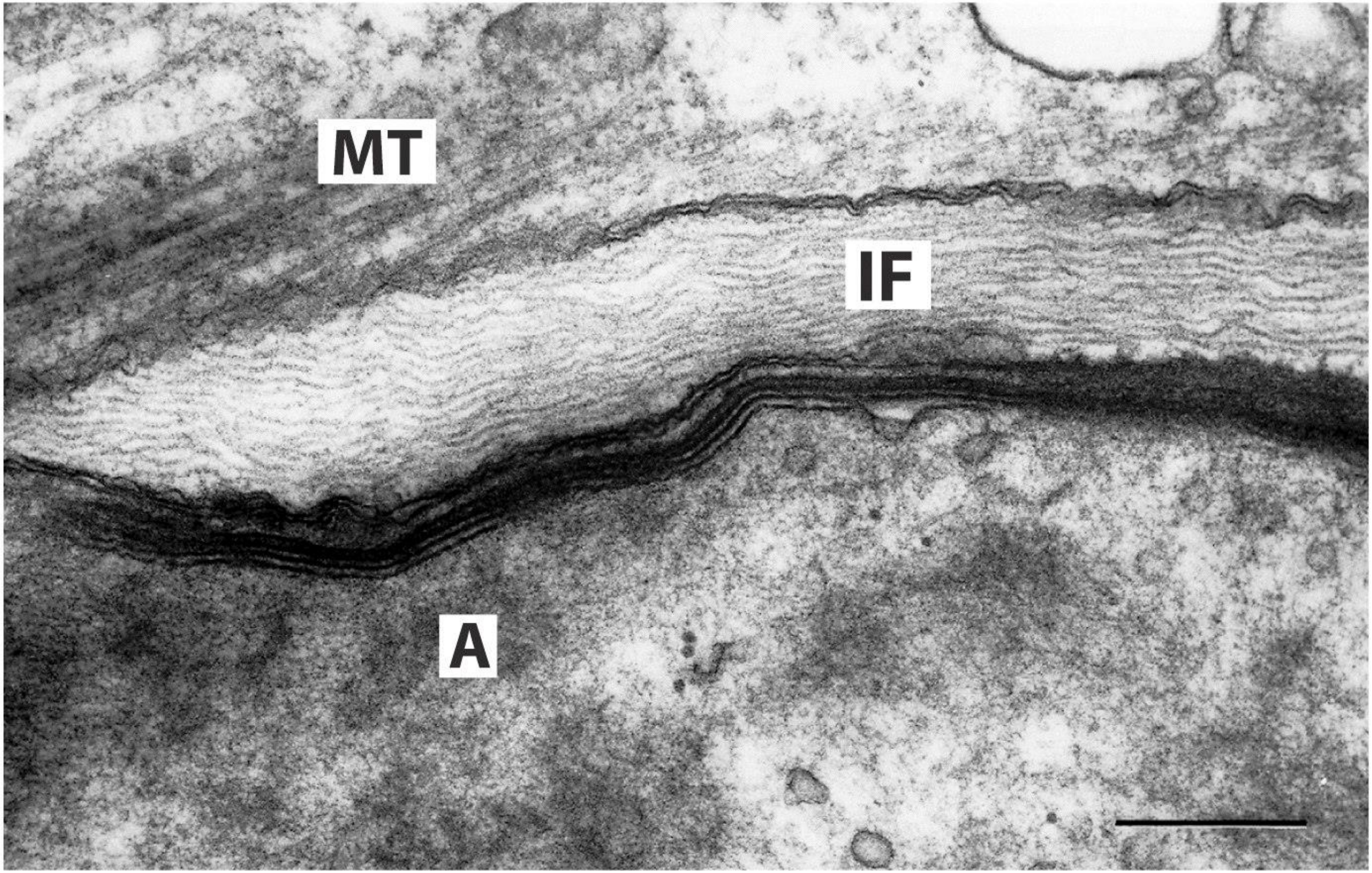
Cytoskeleton



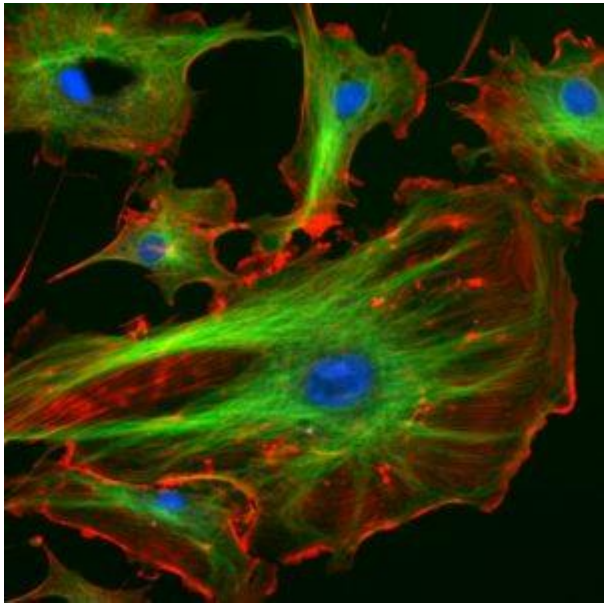
Intermediate filaments are more permanent than microtubules and microfilaments- they provide tensile strength for the cell

Microtubules-composed of tubulin - act as a scaffold to determine cell shape, and provide a set of "tracks" for cell organelles and vesicles to move on. Microtubules also form the spindle fibers for separating chromosomes during mitosis. When arranged in geometric patterns inside flagella and cilia, they are used for locomotion.

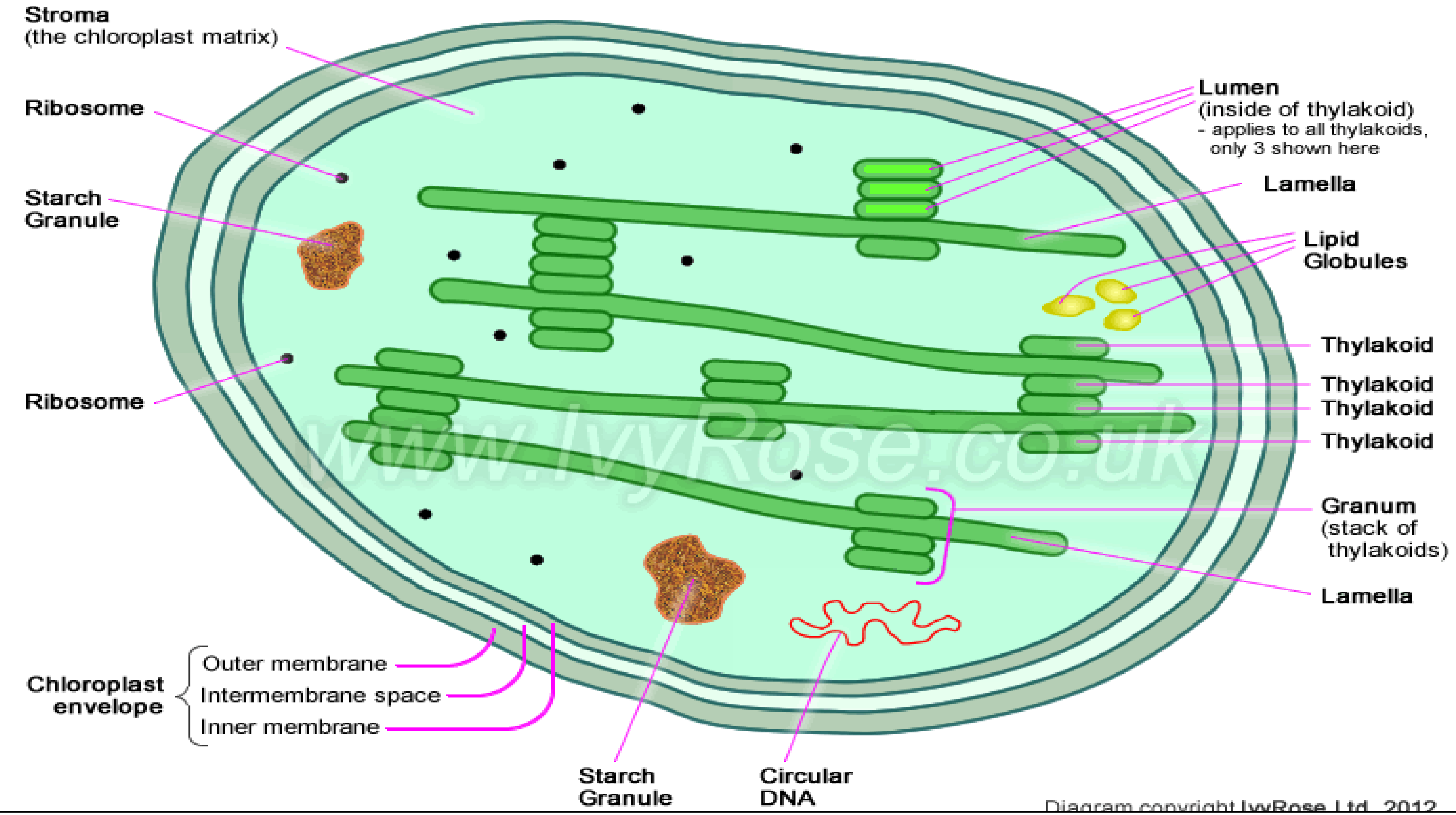
Microfilaments-composed of actin - Microfilaments' association with the protein myosin is responsible for muscle contraction. Microfilaments can also carry out cellular movements including gliding, contraction, and cytokinesis.



A = actin, IF = intermediate filament, MT = microtubule



The microfilaments of this cell are shown in red,
Microtubules are shown in green.
The blue dots are nuclei.



CHLOROPLAST

https://www.youtube.com/watch?v=uJlc8QLawfA

INTRODUCTION

- Chloroplasts are the site of photosynthesis.
- Therefore they are only present in photosynthetic cells e.g. plant cells and algae. There are no chloroplasts in animal cells or bacteria cell.
- Biconvex shape and a maximum dimension of about 5µm .
- Although they exist within cells, chloroplasts (and mitochondria) are sometimes referred to as "**semi-autonomous organelles**" because they contain their own DNA and reproduce independently of the nucleus of the eukaryotic cell in which they are located.
- Each chloroplast is surrounded by a double-layered membrane i.e. it is enclosed by two membranes separated by an intermembrane space.

STRUCTURE

- Chloroplasts are located in the parenchyma cells of plants as well as in autotrophic algae.

- They are oval-shaped organelles having a diameter of 2 - 10 µm and a thickness of 1 - 2 µm.

- Although their dimensions are almost similar in all plants, the algal chloroplasts show a variation in their size as well as shape.

1. **Chloroplast Envelope**:

- Each chloroplast is enclosed (surrounded by) a chloroplast envelope consisting of three layers:

    The **outer membrane** is a phospholipid membrane

    The **intermembrane space**

    The **inner membrane** is a phospholipid membrane

- It is permeable to glucose molecules and certain ions including Fe^{2+} and Mg^{2+}, and oxygen and carbon dioxide.

2.Stroma (chloroplast matrix):-

- The chloroplast matrix is called the stroma and contains enzymes that catalyze the **light-independent** reactions of photosynthesis.

3. Thylakoids:-

- Thylakoids are also referred to as **thylakoid membranes**.
- They are disc-shaped structures that are the sites of light absorption at which the **light-dependent** reactions of photosynthesis take place.
- The region within the membrane forming each thylakoid (by enclosing the contents of the thylakoid) is called the **lumen** of the thylakoid.
- Either on the surface of, or embedded within, thylakoids are:

  chlorophyll molecules - on the surface of thylakoids.

  accessory pigments

  enzymes

  electron transport systems

- Thylakoids are also the sites at which ATP synthesis occurs within chloroplasts.

4. Grana:-

- Thylakoids are arranged in stacks called grana (*plural*).
- A single **granum** is a stack of several thylakoids one on top of another.

5. Lamellae:-

- The stromal **lamellae** connect two or more **grana** to each other.
- In this way the lamellae act as a "skeleton" of the chloroplast, maintaining efficient distances between the **grana**, thereby maximizing the overall efficiency of the chloroplast.

6. Circular DNA:-

- Each chloroplast contains one or more molecules of small circular DNA.

7. **Ribosomes:-**

- Chloroplasts contain the smaller type of ribosomes (i.e. "70S ribosomes"), which is the same type as those freely distributed around the cytoplasm of prokaryotic cells.

FUNCTIONS

- The envelope of the chloroplasts is **semi-permeable**, and it regulates the entry and exit of molecules from the chloroplast.

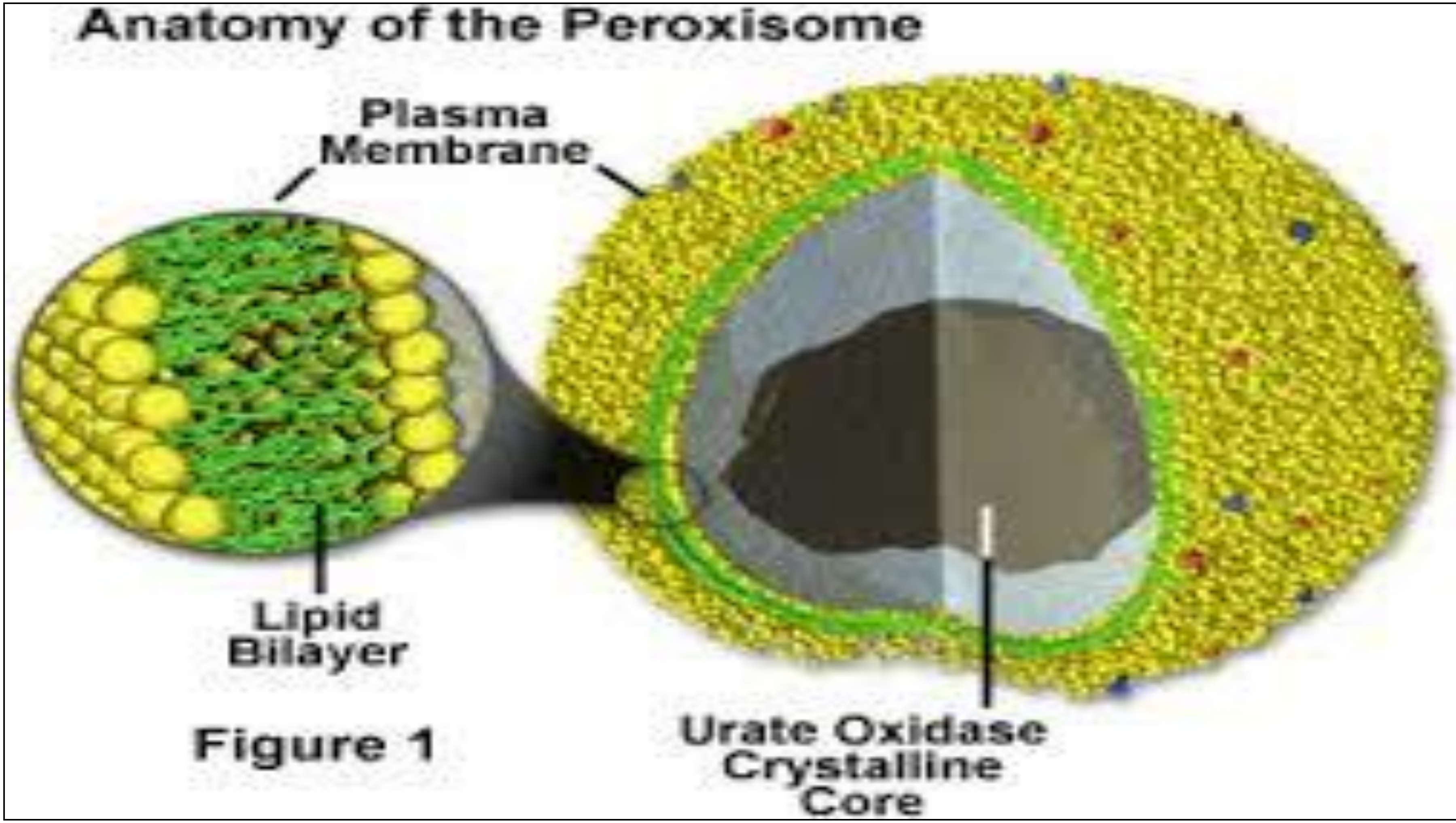
- The outer and inner membranes have **specialized intermembrane proteins** for the transport of **large molecules in and out** of the chloroplasts.

- The light-dependent reactions of **photosynthesis** occur in the **grana** and the associated photosystems.

- The **stroma** of chloroplasts is the site for the **dark** or light-independent reactions of photosynthesis.

- The function of peripheral reticulum of chloroplasts is not yet clearly understood.
- However, it has been suggested that these units are an adaptation for fast transport of metabolites and proteins from the **intermembrane space** into the chloroplasts.
- The enzymes in the stroma utilize carbon dioxide from the atmosphere, as well as the **ATP and NADPH2** molecules released from grana, to synthesize sugar molecules and starch.
- This process is also known as carbon dioxide fixation, and occurs through a series of reactions collectively called Calvin cycle.

ETC……



PEROXISOMES

https://www.youtube.com/watch?v=LOidek5YvOY

INTRODUCTION

- They are small, membrane-enclosed organelles that contain enzymes involved in a variety of metabolic reactions, including several aspects of energy metabolism.
- Although peroxisomes are morphologically similar to lysosomes, they are assembled, like mitochondria and chloroplasts, from proteins that are synthesized on free ribosomes and then imported into peroxisomes as completed polypeptide chains.
- Although peroxisomes do not contain their own genomes, they are similar to mitochondria and chloroplasts in that they replicate by division.

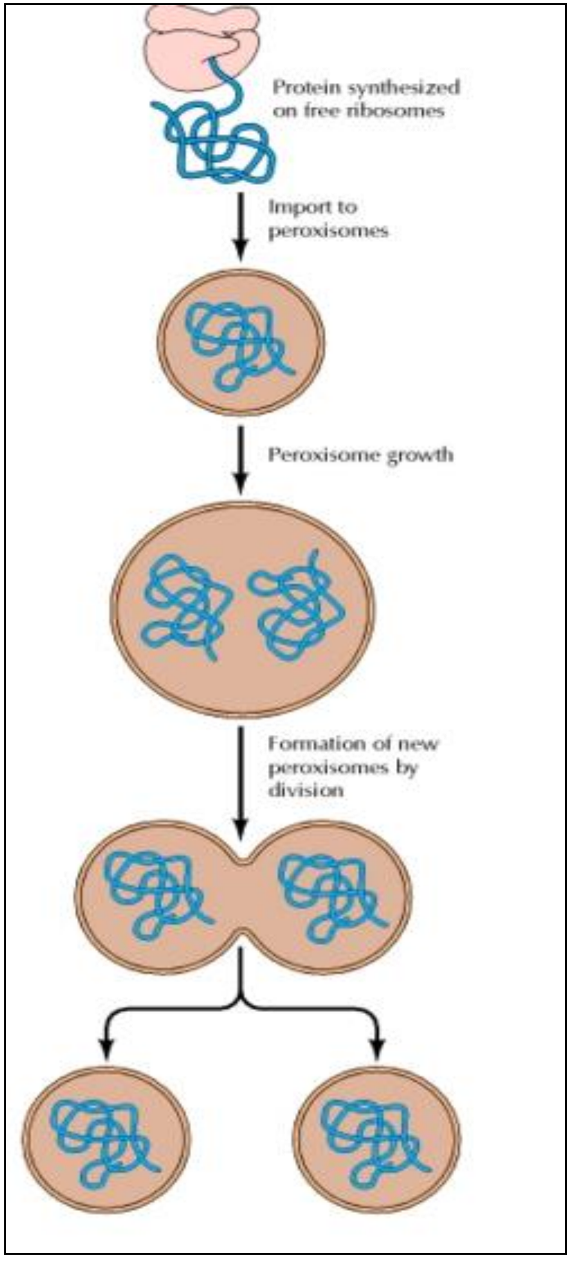
FUNCTIONS

- Peroxisomes contain at least 50 different enzymes, which are involved in a variety of biochemical pathways in different types of cells.
- Peroxisomes originally were defined as organelles that carry out oxidation reactions leading to the production of hydrogen peroxide.
- Because hydrogen peroxide is harmful to the cell, peroxisomes also contain the enzyme catalase, which decomposes hydrogen peroxide either by converting it to water or by using it to oxidize another organic compound.
- A variety of substrates are broken down by such oxidative reactions in peroxisomes, including uric acid, amino acids, and fatty acids.
- The oxidation of fatty acids is a particularly important example, since it provides a major source of metabolic energy.
- In animal cells, fatty acids are oxidized in both peroxisomes and mitochondria, but in yeasts and plants fatty acid oxidation is restricted to peroxisomes.
- In addition to providing a compartment for oxidation reactions, peroxisomes are involved in lipid biosynthesis.

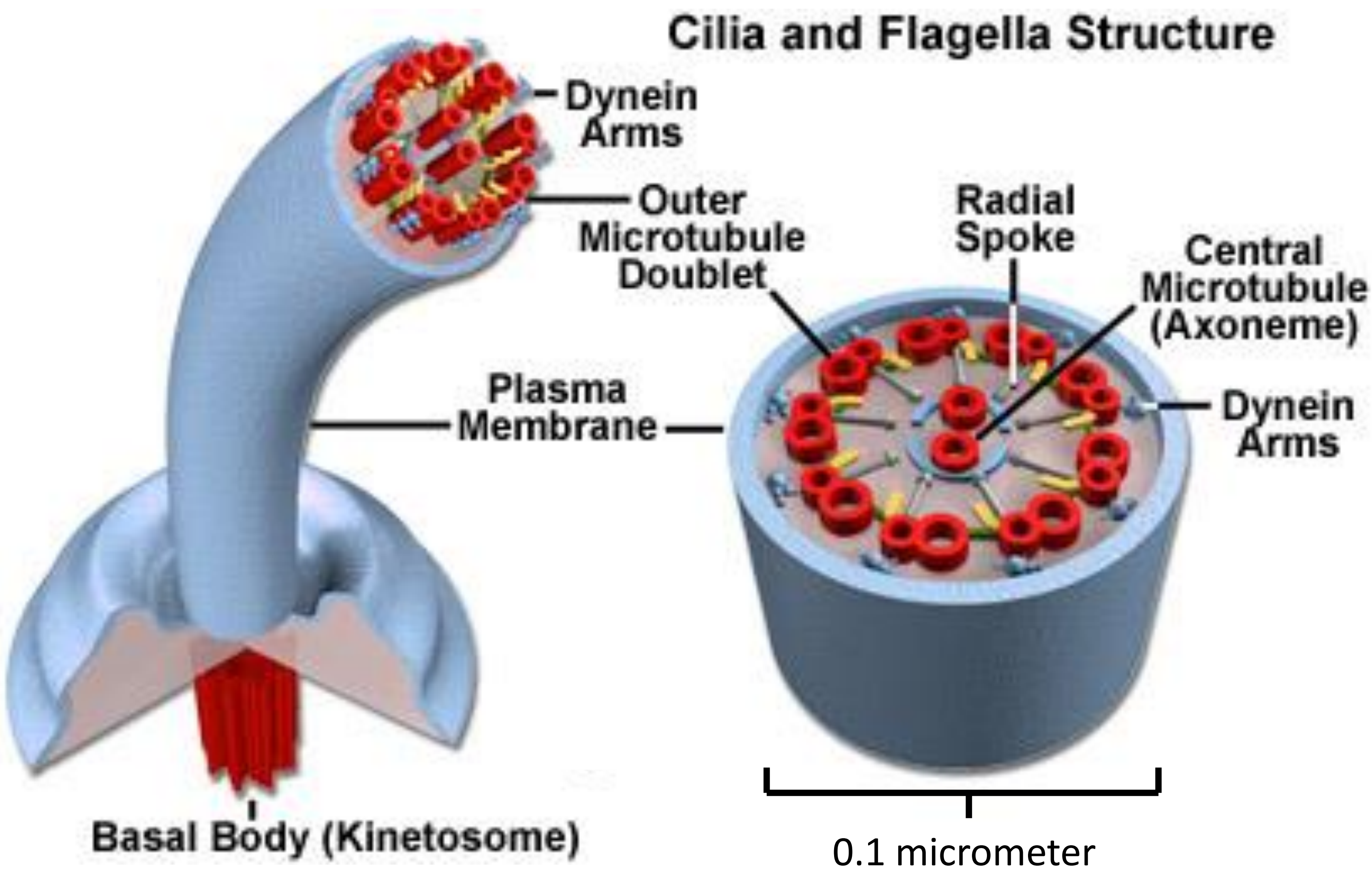
- In animal cells, cholesterol are synthesized in peroxisomes as well as in the ER.
- In the liver, peroxisomes are also involved in the synthesis of bile acids, which are derived from cholesterol. In addition, peroxisomes contain enzymes required for the synthesis of plasmalogens—a family of phospholipids
- Peroxisomes play two particularly important roles in plants. First, peroxisomes in seeds are responsible for the conversion of stored fatty acids to carbohydrates, which is critical to providing energy and raw materials for growth of the germinating plant.
- Second, peroxisomes in leaves are involved in photorespiration, which serves to metabolize a side product formed during photosynthesis .
- CO_2 is converted to carbohydrates during photosynthesis via a series of reactions called the Calvin cycle.

FUNCTIONS

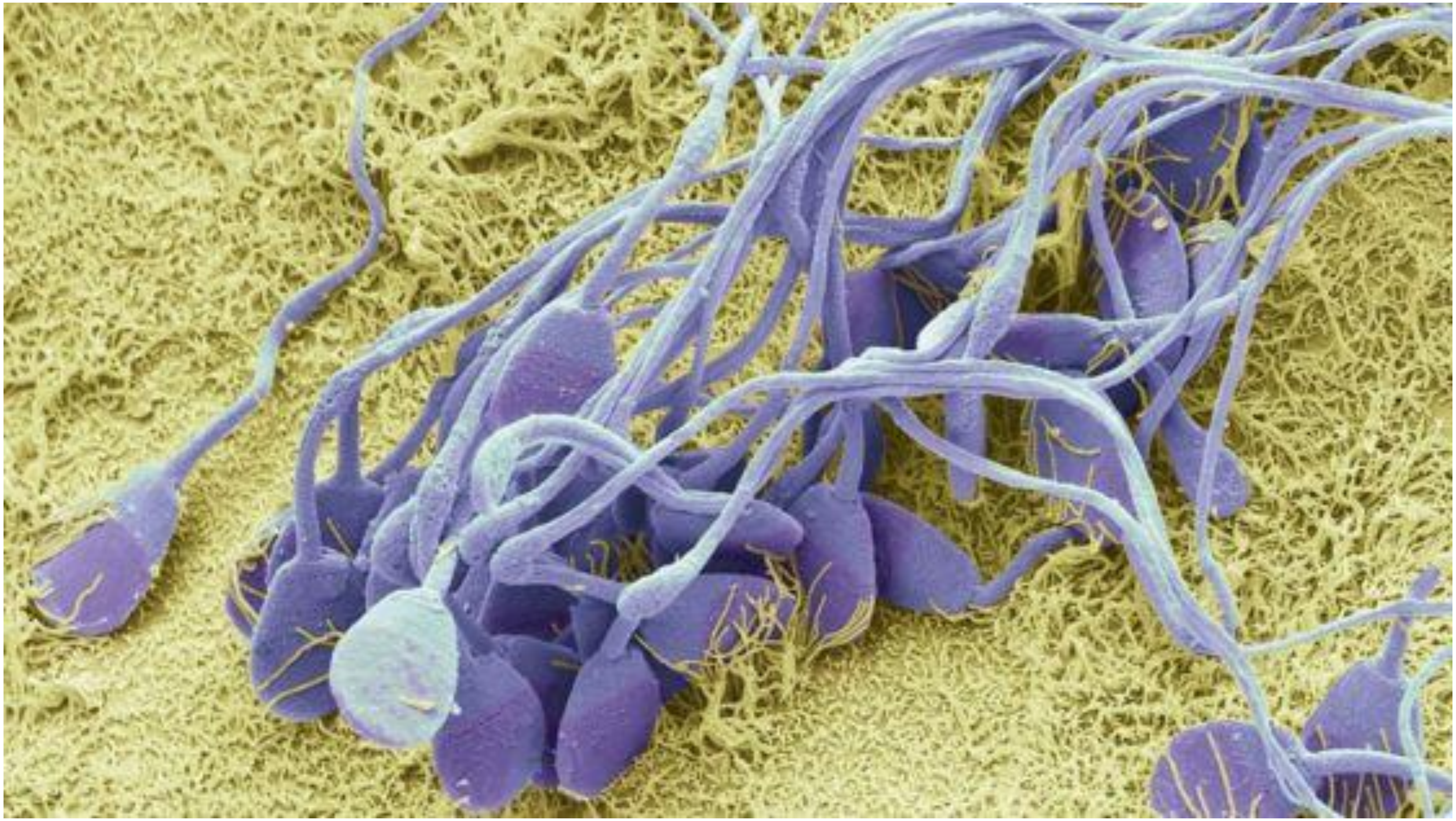
- **PEROXISOMES ASSEMBLY:-**
- Similar to that of mitochondria and chloroplasts, rather than to that of the endoplasmic reticulum, Golgi apparatus, and lysosomes.
- Proteins destined for peroxisomes are translated on free cytosolic ribosomes and then transported into peroxisomes as completed polypeptide chains .
- Phospholipids are also imported to peroxisomes, via phospholipid transfer proteins, from their major site of synthesis in the ER.
- The import of proteins and phospholipids results in peroxisome growth, and new peroxisomes are then formed by division of old ones.



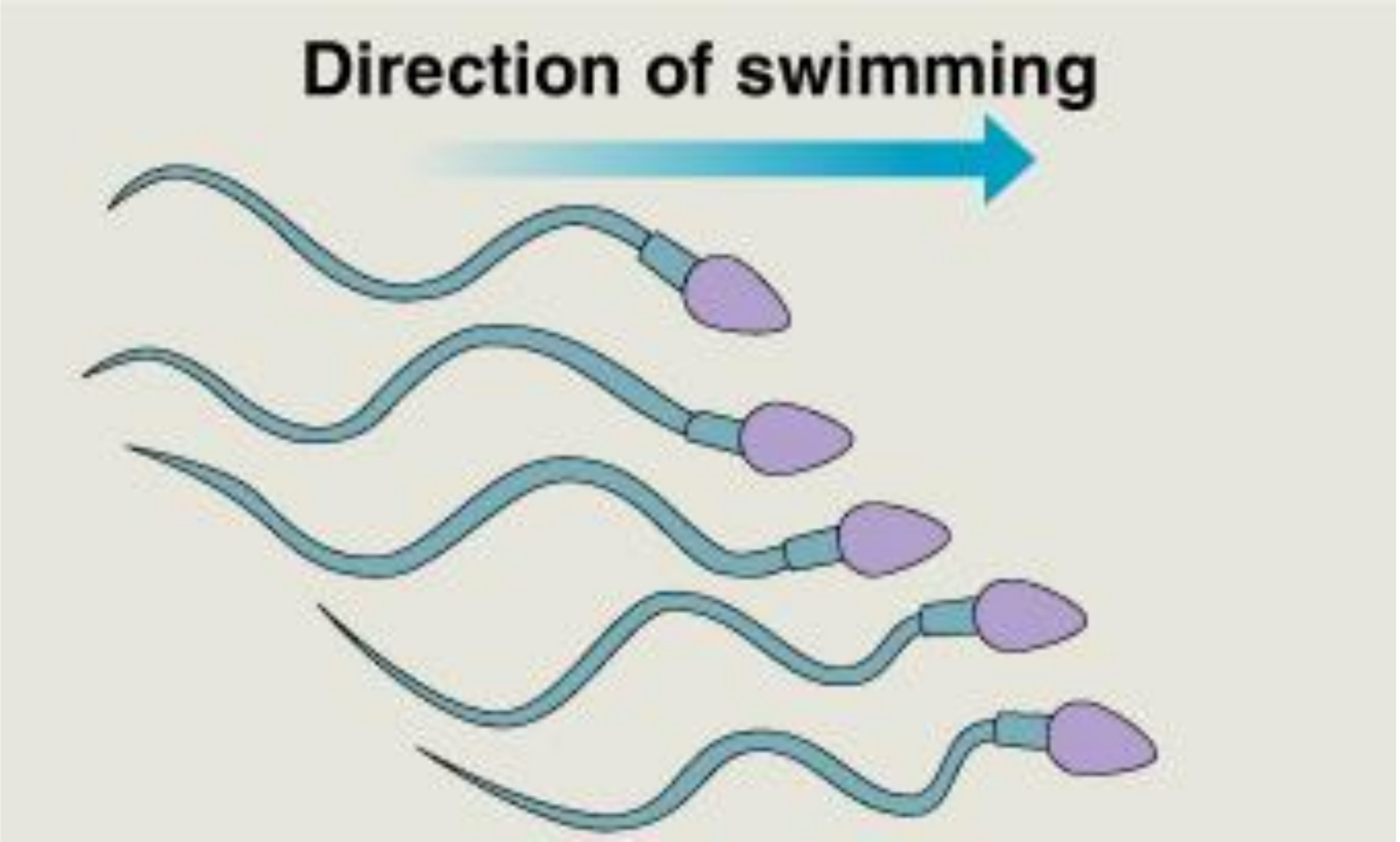
Cillia & Flagella- 9x2 arrangement



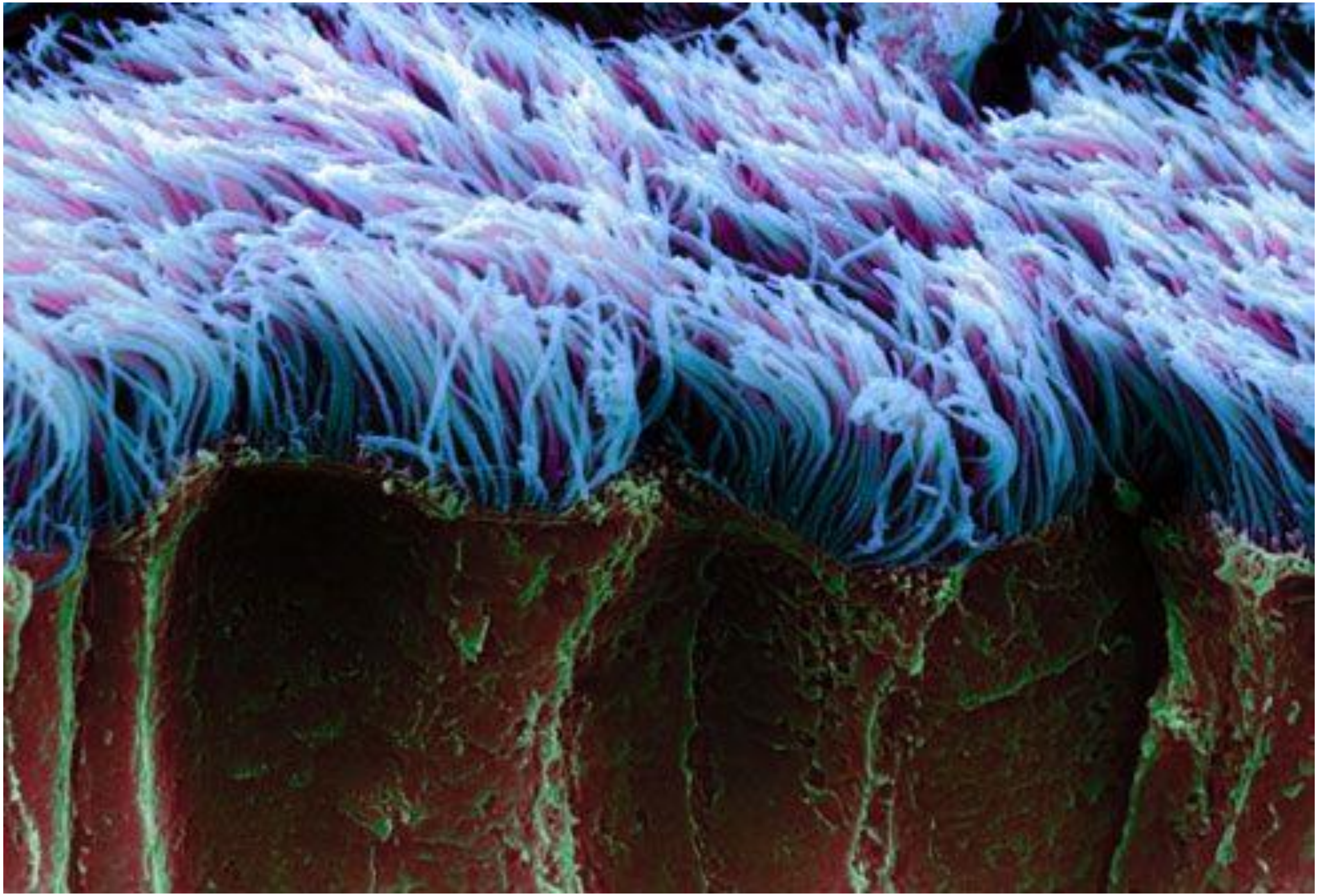
Flagellum



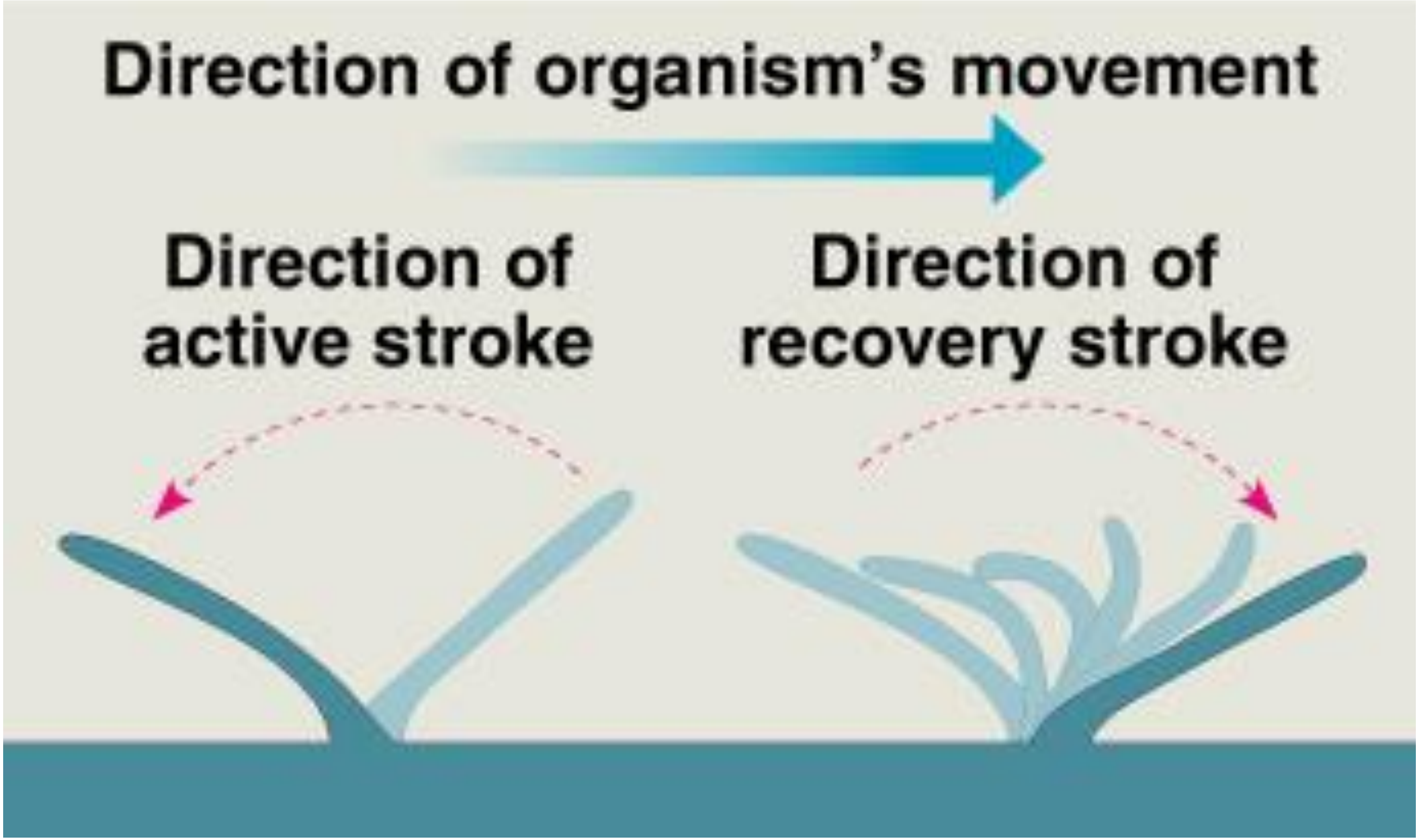
Flagellar Movement



Ciliated Epithelium

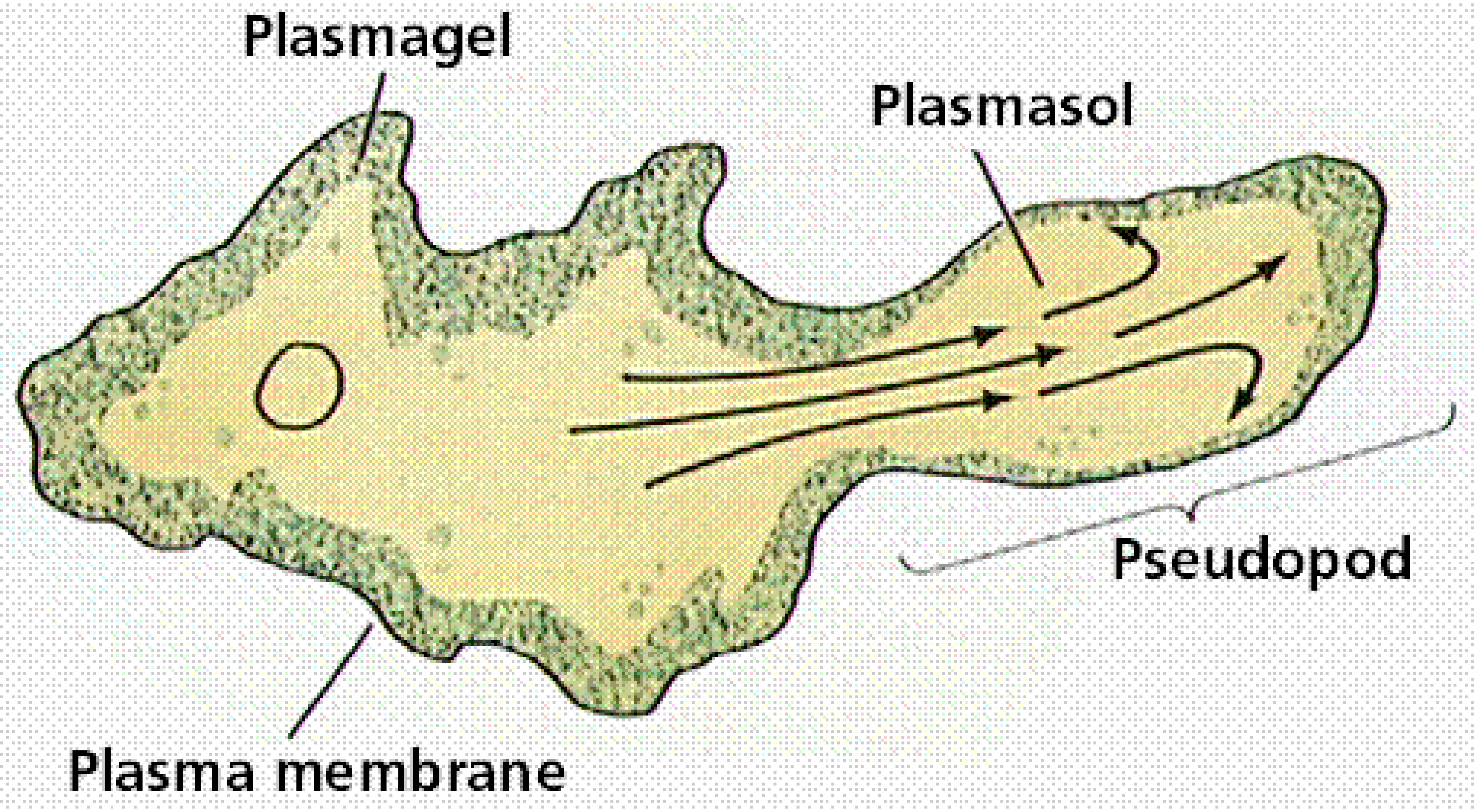


Ciliary Movement

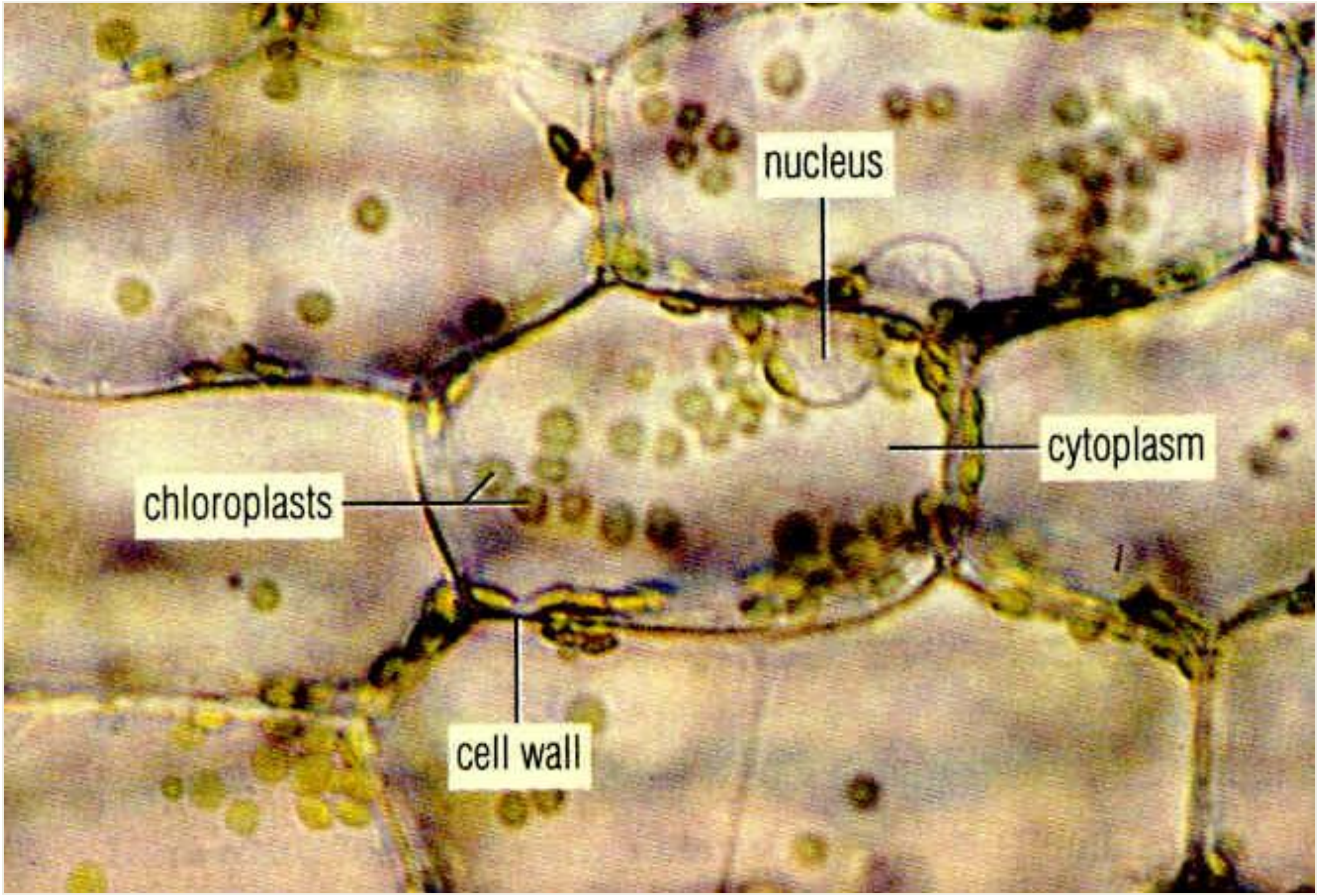


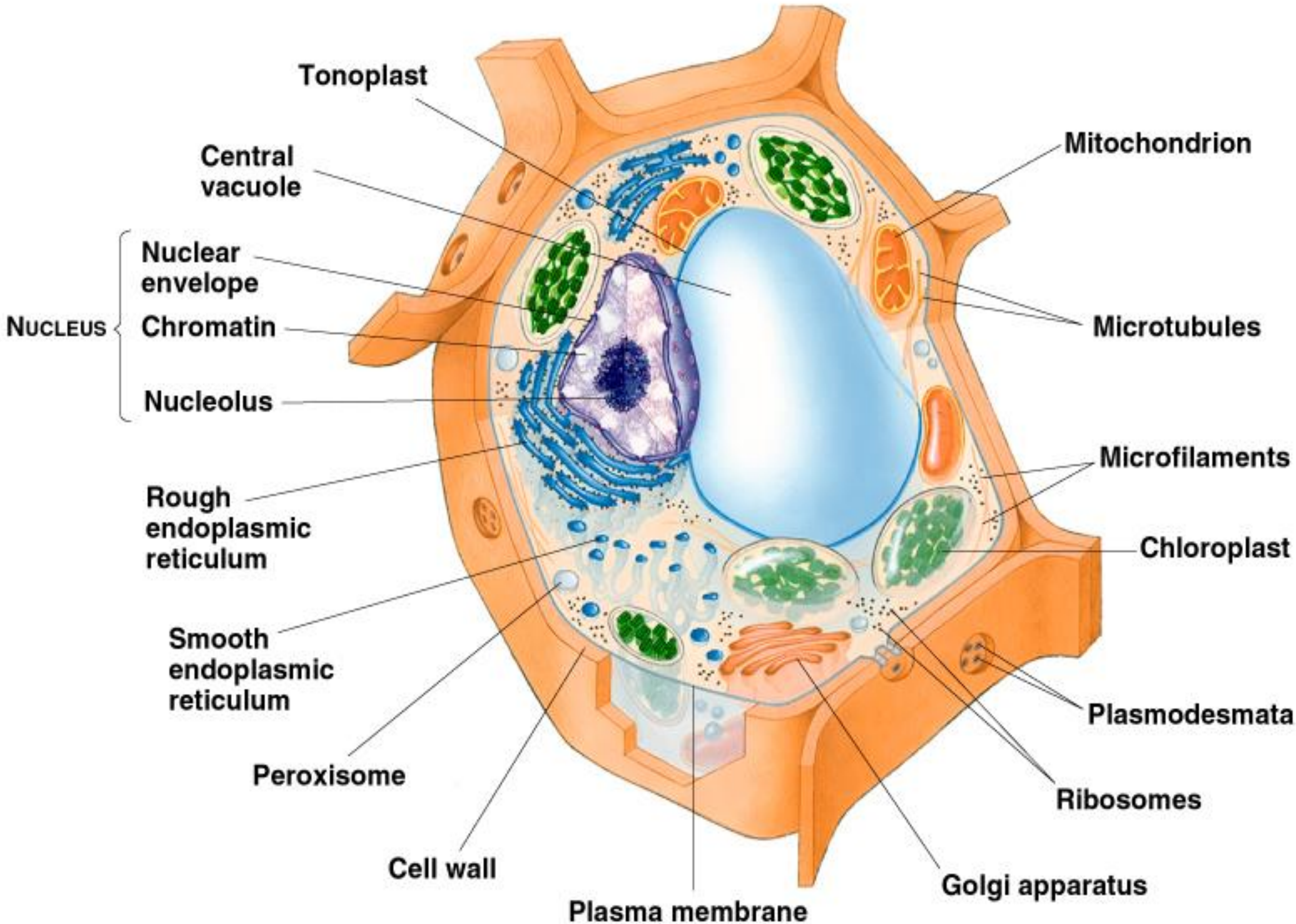
Ameboid Movement

Ex. WBC



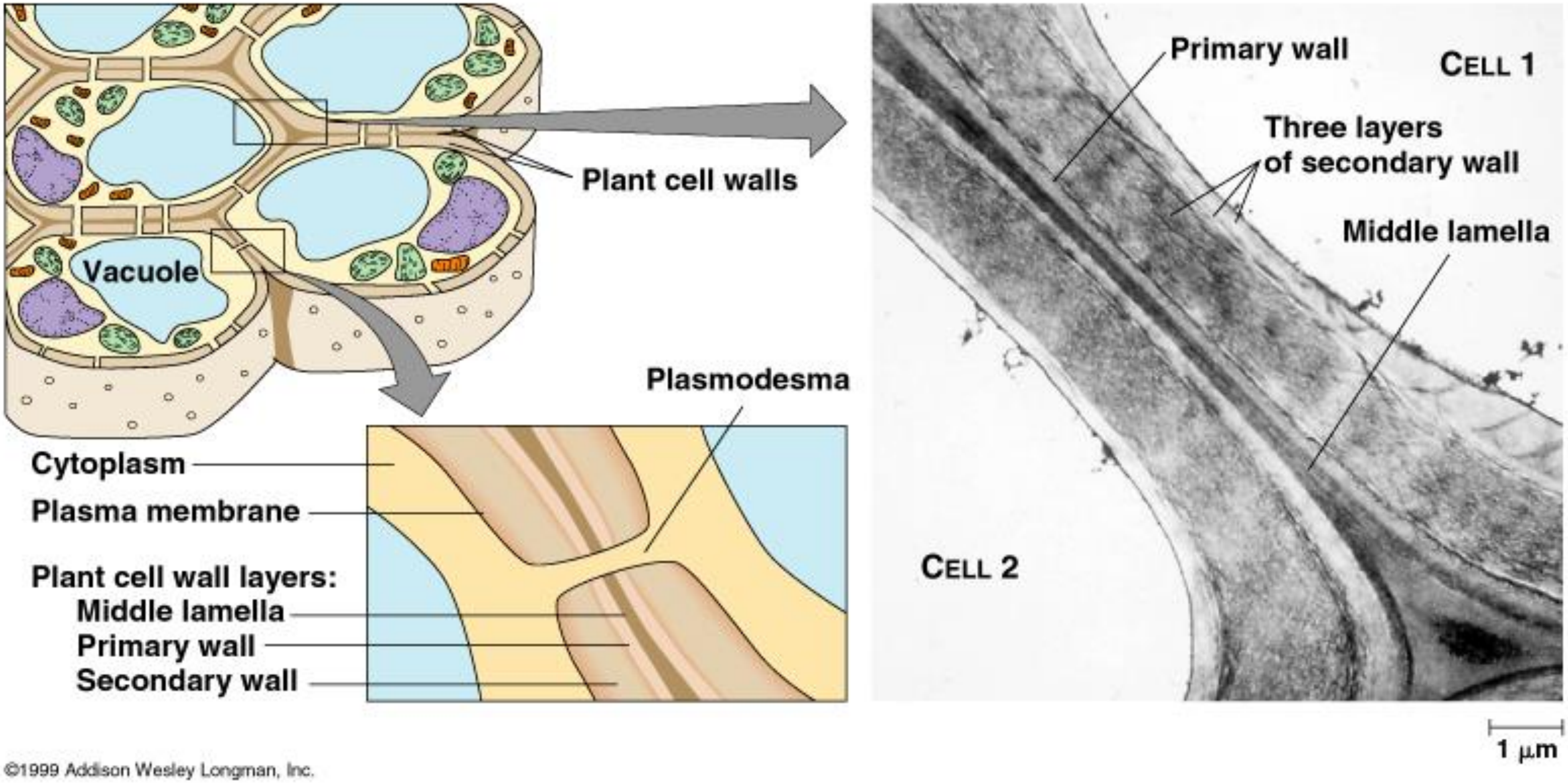
Typical Plant Cell





Tonoplast
Central vacuole
Mitochondrion
Nuclear envelope
NUCLEUS
Chromatin
Microtubules
Nucleolus
Microfilaments
Rough endoplasmic reticulum
Chloroplast
Smooth endoplasmic reticulum
Plasmodesmata
Peroxisome
Ribosomes
Cell wall
Golgi apparatus
Plasma membrane

Cell Walls


Plant cell walls
Vacuole
Plasmodesma
Cytoplasm
Plasma membrane
Plant cell wall layers:
Middle lamella
Primary wall
Secondary wall
Primary wall
CELL 1
Three layers
of secondary wall
Middle lamella
CELL 2
1 µm