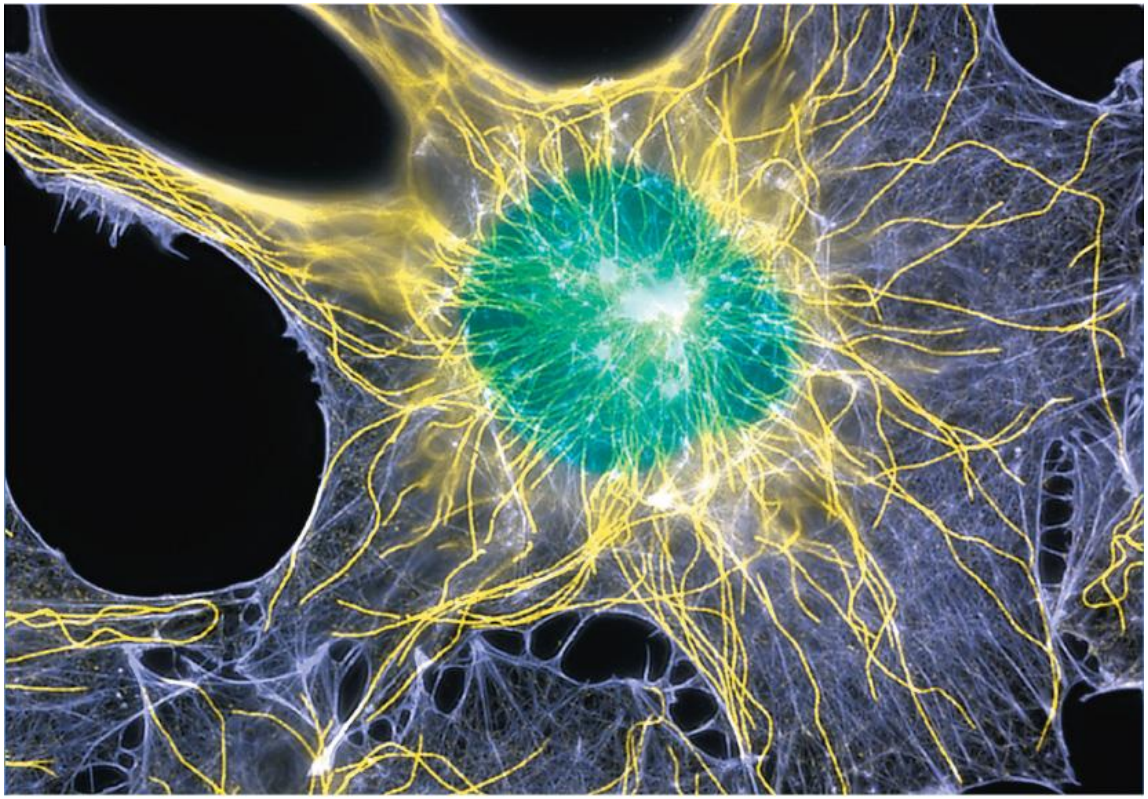
Life on Earth is cellular: the cell is the fundamental structural and functional unit of life (Chapter 7)



“cells are as fundamental to living systems as atoms are to chemistry”
“the simplest collection of matter that can be alive”

Key concepts – cell structure/function

- **There are two basic cell designs: prokaryotic and eukaryotic (Table 7.1)**

- **The structure of individual cell components is closely correlated with their function**
- **Eukaryotic cells contain numerous membrane-bound organelles with specialized, compartmentalized functions**
  - **Nucleus**
  - **Endomembrane system**
  - **Mitochondria**

- **Cytoskeleton = network of fibers - *organises internal structure and activities in cell***
- **Connections between cells (e.g. gap junctions, tight junctions) - *coordinate cell activities***

Cells are very *dynamic*

Prokaryotic vs. eukaryotic cells

Bacteria and archaea = prokaryotes; have "simpler" cell structure (lack a membrane-bound nucleus)

Fig. 7.1

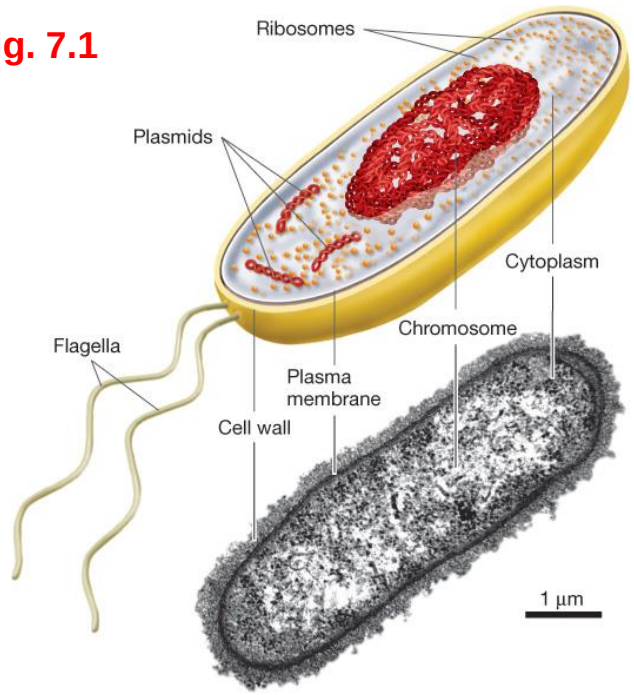
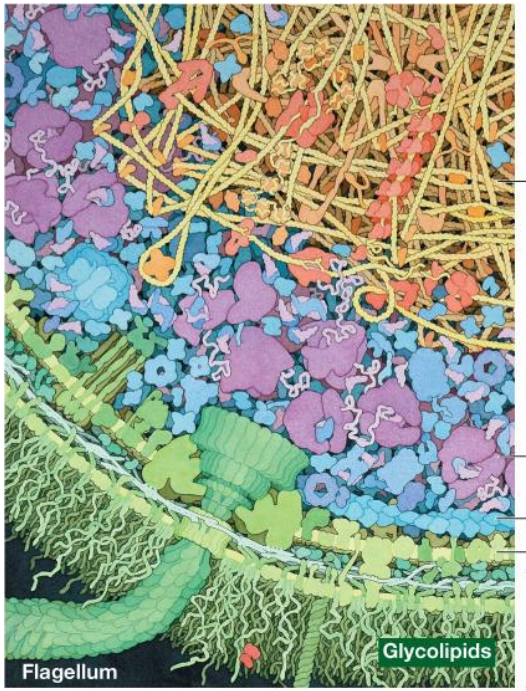


Fig. 7.6



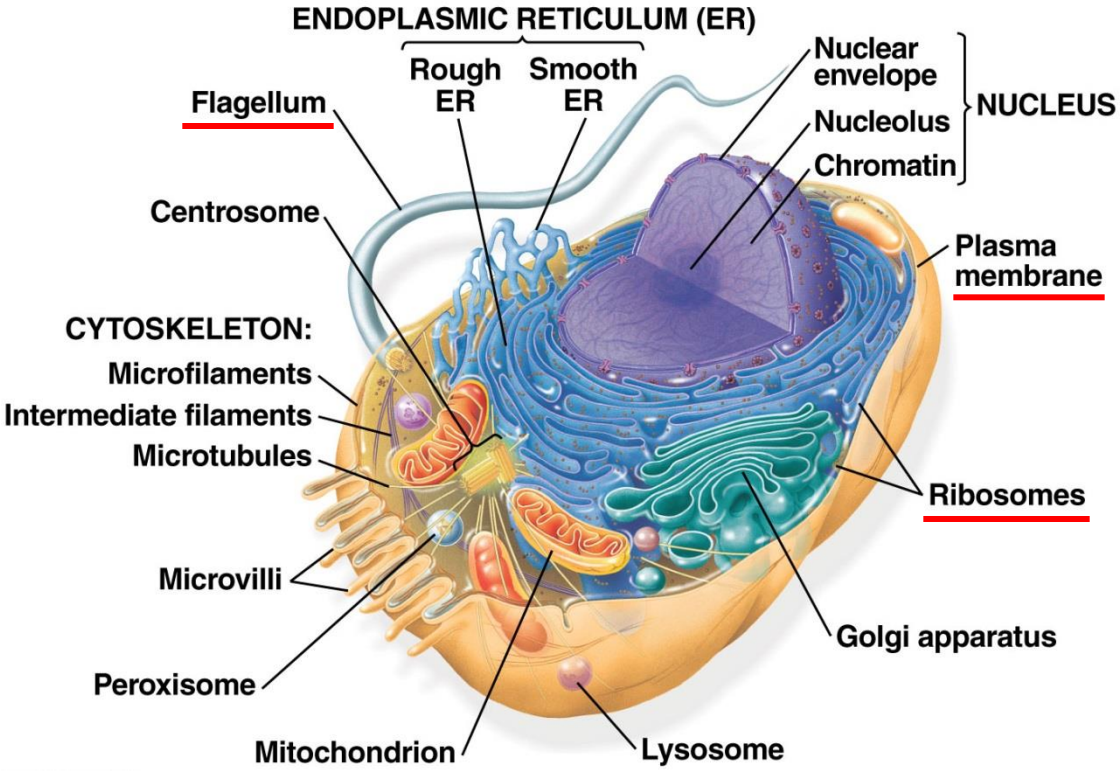
"supercoiled" 500 x longer than cell!

- **All cells have plasma membrane, cytoplasm, genetic material (DNA), ribosomes (cytoskeleton, membrane-bound organelles?)**

- **Prokaryotes: single, circular chromosome (DNA molecule) in non-membrane bound *nucleoid* + 1-100 small DNA molecules (*plasmids*); tough, fibrous *cell wall***

A generalised eukaryotic animal cell (see Fig. 7.7)

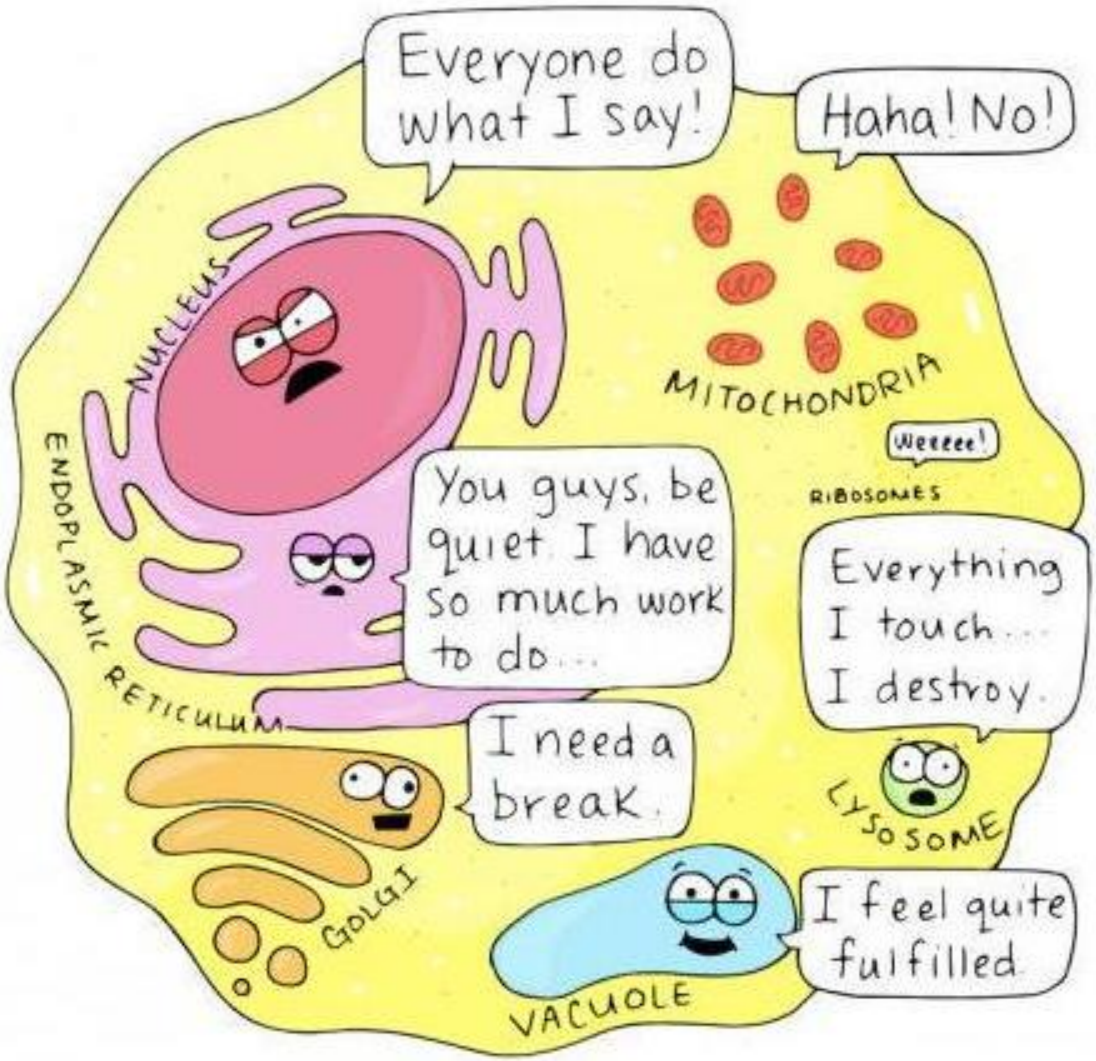
Protists, fungi, plants, animals (Eukarya) all consist of eukaryotic cells



- Chromosomes are found within membrane-bound nucleus
- Extensive membrane-bound compartments and organelles
- Especially diverse and dynamic cytoskeleton
- Larger than prokaryote cells

Why such complex "compartmentalization"?

- Incompatible reactions can be separated
- Chemical reactions become more efficient

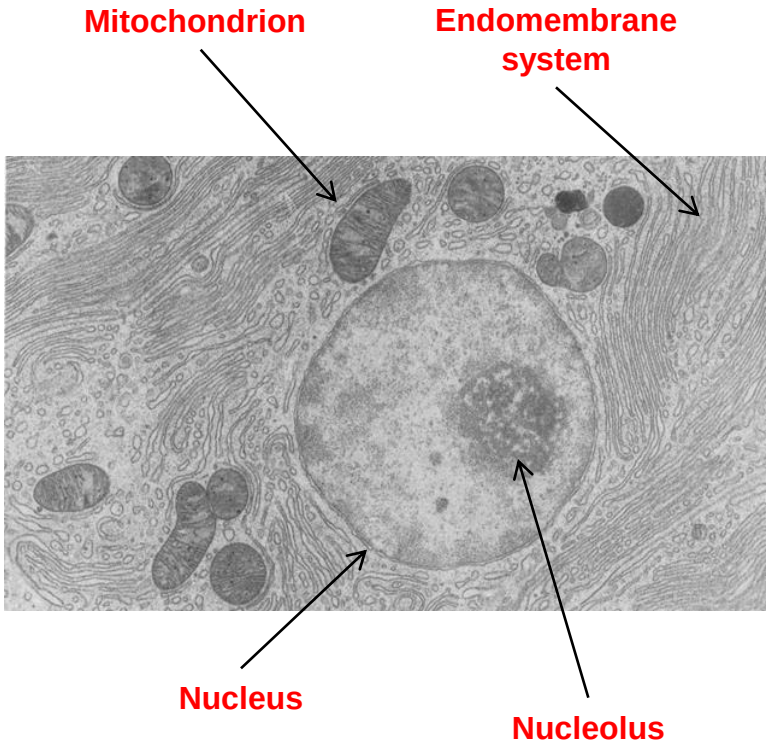


If organelles could talk

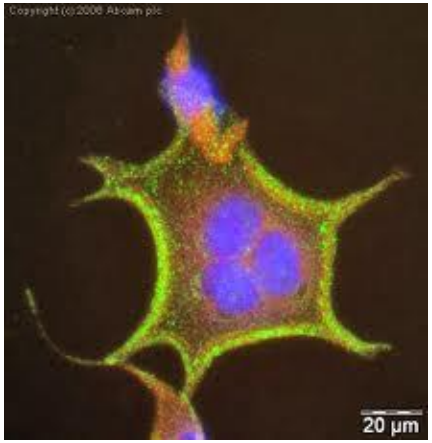
Beatrice the Biologist

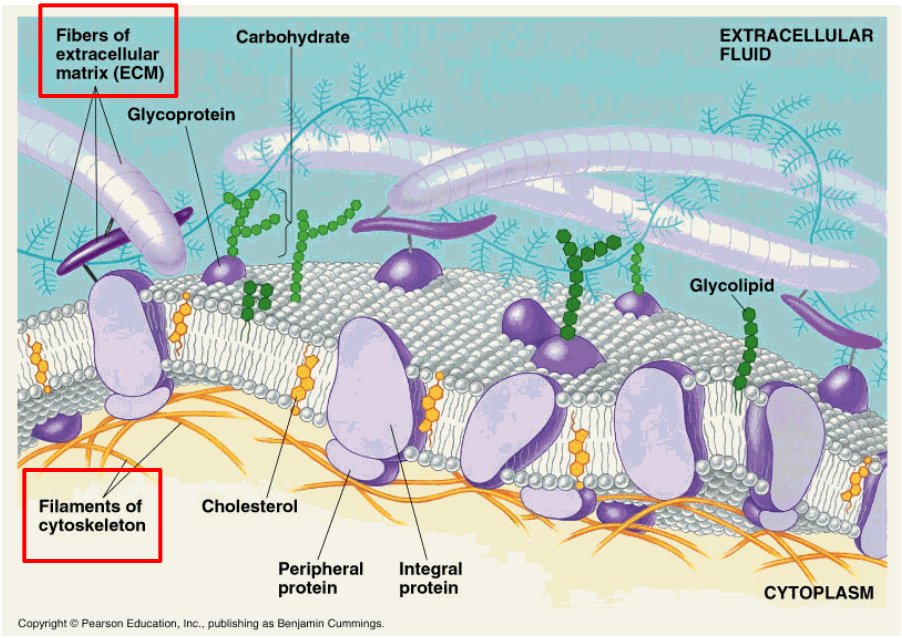
Summary Table 7.2 Eukaryotic Cell Components

Icons not to scale		Structure		
		Membrane	Components	Function
	Nucleus	Double ("envelope"); openings called nuclear pores	Chromosomes Nucleolus Nuclear lamina	Genetic information Assembly of ribosome subunits Structural support
	Ribosomes	None	Complex of RNA and proteins	Protein synthesis
	Endomembrane system ***Rough ER***	Single; contains receptors for entry of selected proteins	Network of branching sacs Ribosomes associated	Protein synthesis and processing
	Golgi apparatus	Single; contains receptors for products of rough ER	Stack of flattened cisternae	Protein processing (e.g., glycosylation)
	Smooth ER	Single; contains enzymes for synthesizing phospholipids	Network of branching sacs Enzymes for synthesizing lipids	Lipid synthesis
	Lysosomes	Single; contains proton pumps	Acid hydrolases (catalyze hydrolysis reactions)	Digestion and recycling
	Peroxisomes	Single; contains transporters for selected macromolecules	Enzymes that catalyze oxidation reactions Catalase (processes peroxide)	Oxidation of fatty acids, ethanol, or other compounds
	Vacuoles	Single; contains transporters for selected molecules	Varies—pigments, oils, carbohydrates, water, or toxins	Varies—colouration, storage of oils, carbohydrates, water, or toxins
	Mitochondria	Double; inner contains enzymes for ATP production	Enzymes that catalyze oxidation-reduction reactions, ATP synthesis	ATP production
	Chloroplasts	Double; plus membrane-bound sacs in interior	Pigments Enzymes that catalyze oxidation-reduction reactions	Production of ATP and sugars via photosynthesis
	Cytoskeleton	None	Actin filaments Intermediate filaments Microtubules	Structural support; movement of materials; in some species, movement of whole cell
	Plasma membrane	Single; contains transport and receptor proteins	Phospholipid bilayer with transport and receptor proteins	Selective permeability—maintains intracellular environment
	Cell wall	None	Carbohydrate fibres running through carbohydrate or protein matrix	Protection, structural support



Plasma membranes consist of a phospholipid bi-layer with various proteins attached/embedded (Fig. 6.22)





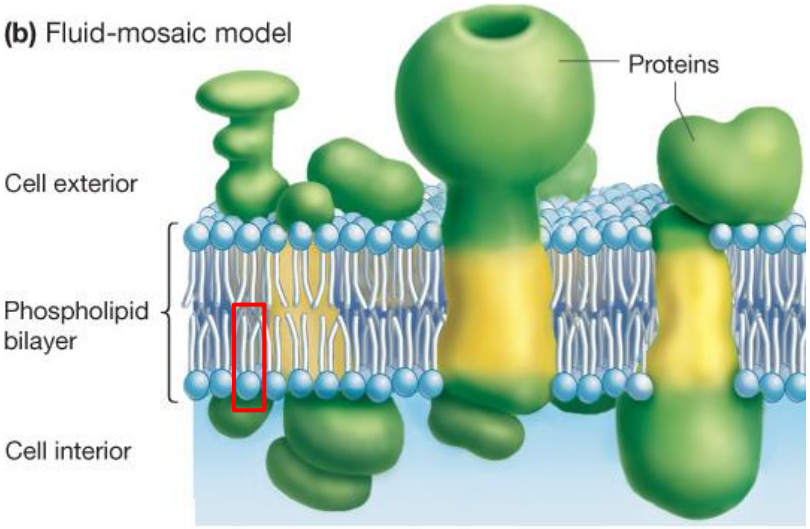
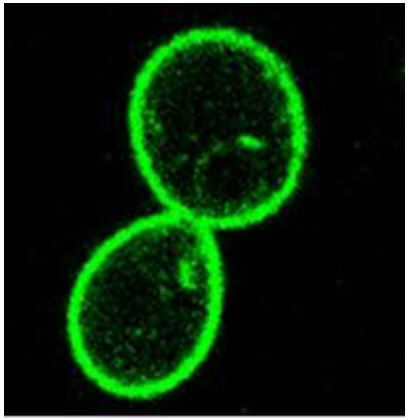


Fig. 6.20b

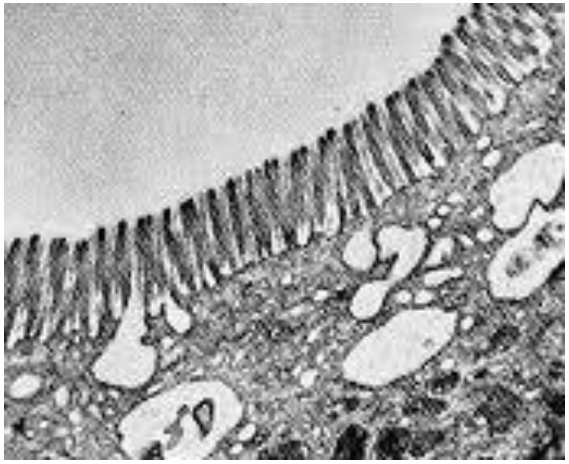


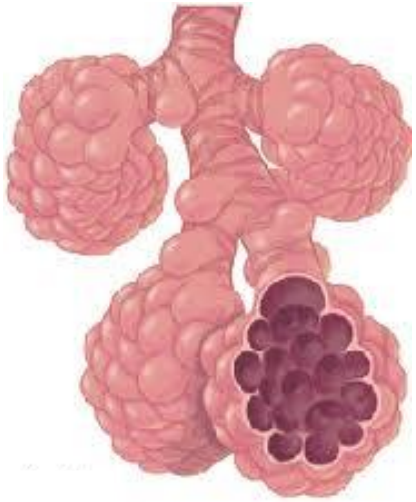
Plasma membrane labelled in budding yeast

Lots of important things happen at biological surfaces e.g. plasma membranes, transport epithelia, skin

So the size (area) of these biological surfaces relative to the volume (or mass) of the cell/organism is of fundamental importance in biology (Fig. 41.9)

Surface Area:Volume ratio SA:Vol

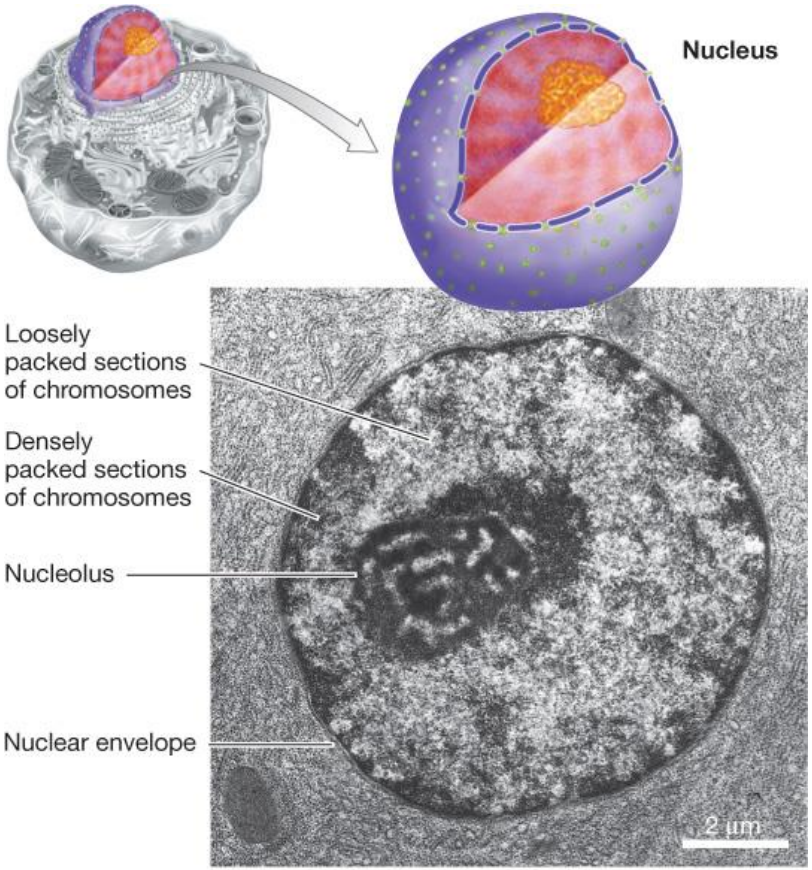




Lake Titicaca frog

Topic of the Week (next week)!

The nucleus is the eukaryotic cell's information storage and retrieval centre (Fig. 7.8)

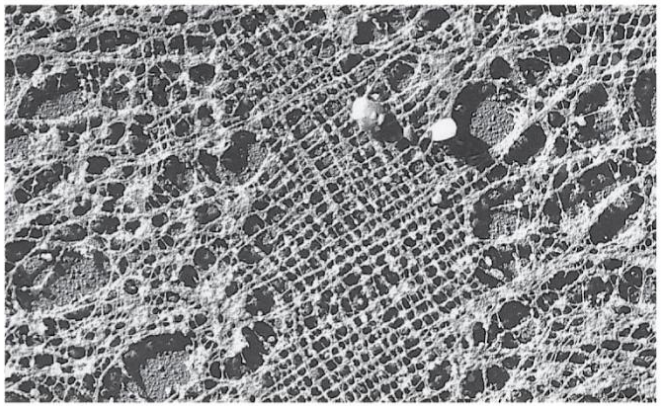


- Contains chromosomes (DNA) that carries genetic information

- Chromatin = complex of DNA and proteins (e.g. some proteins help DNA coil)

- Nucleolus = site of manufacture of ribosomal RNA (rRNA) and assembly of ribosomal sub-units

- Nuclear envelope = double lipid bilayer supported by a lattice-like sheet called the nuclear lamina



Nuclear envelope of the nucleus is continuous with the endomembrane system

- But it is also perforated by a large number of nuclear pores between nucleus and cytoplasm

- Each surrounded by protein nuclear pore complexes
- Regulate entry and exit of proteins, ribosomal sub-units, mRNA. etc

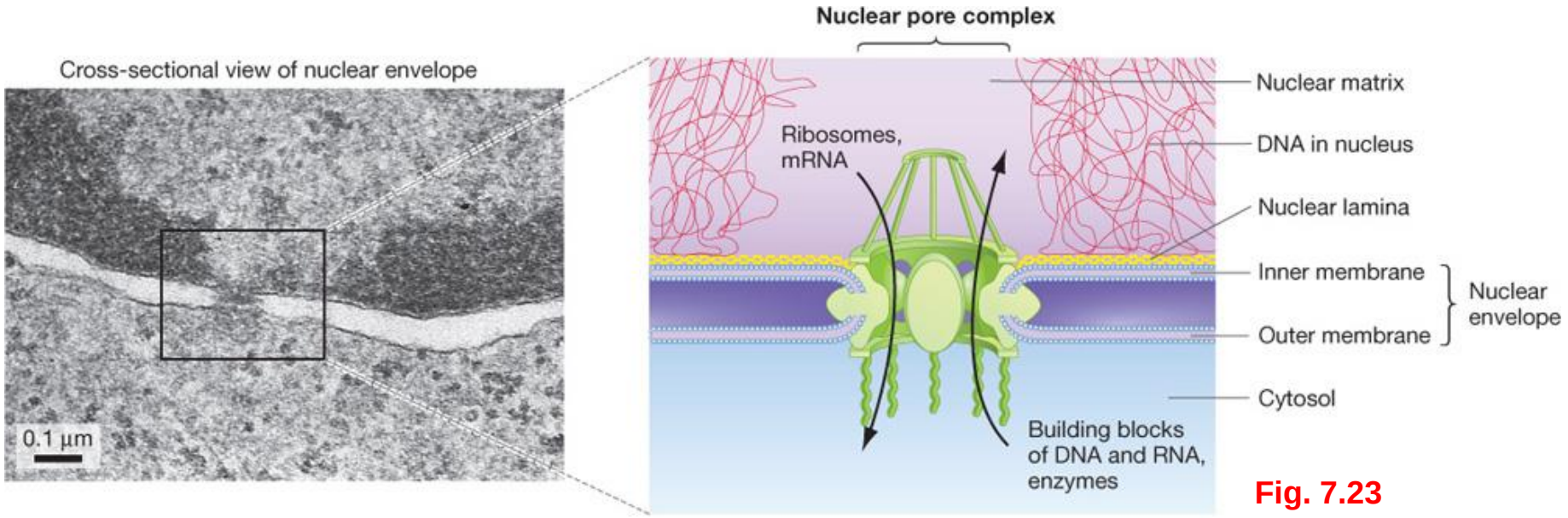
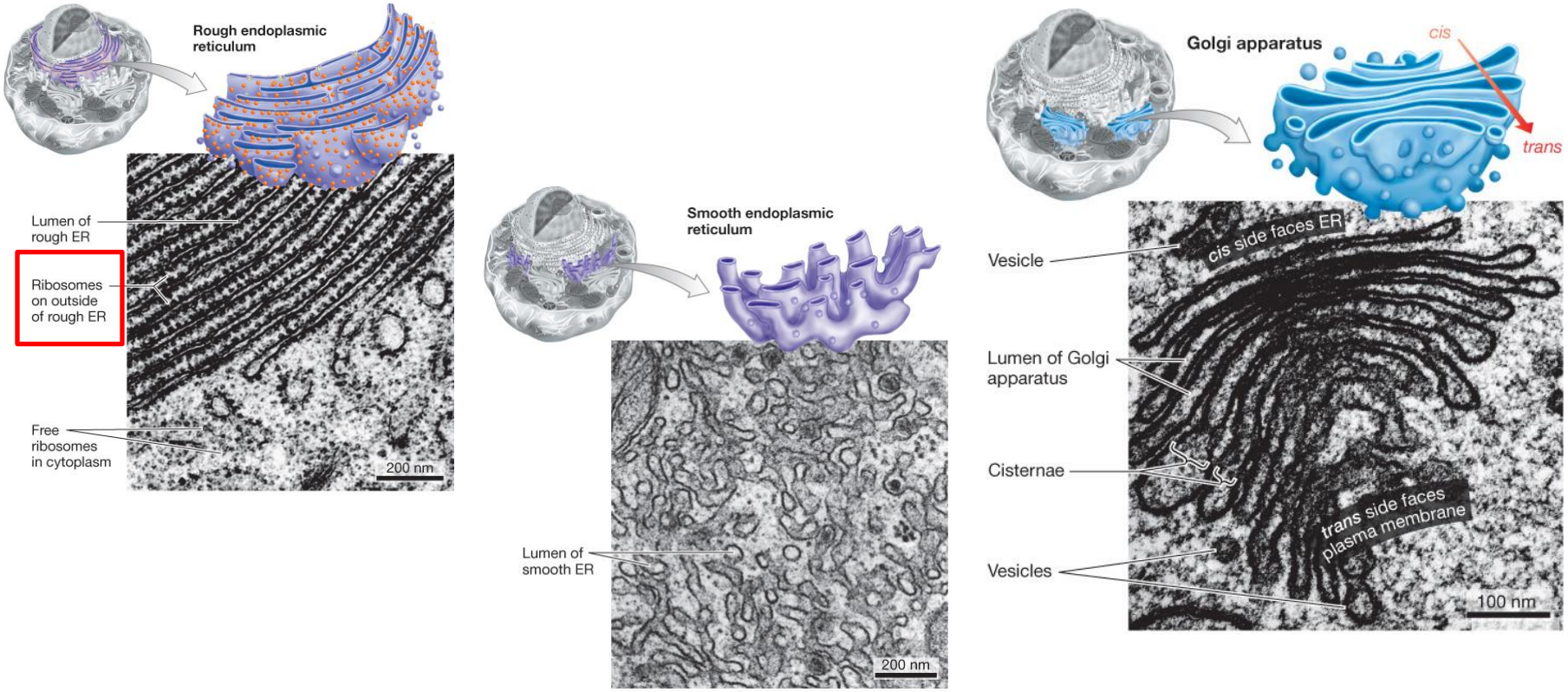


Fig. 7.23

500 molecules pass through 3000-4000 pores every second (1.75 million/sec!)

The endomembrane system regulates protein traffic and performs metabolic functions (Fig. 7.10-7.11)

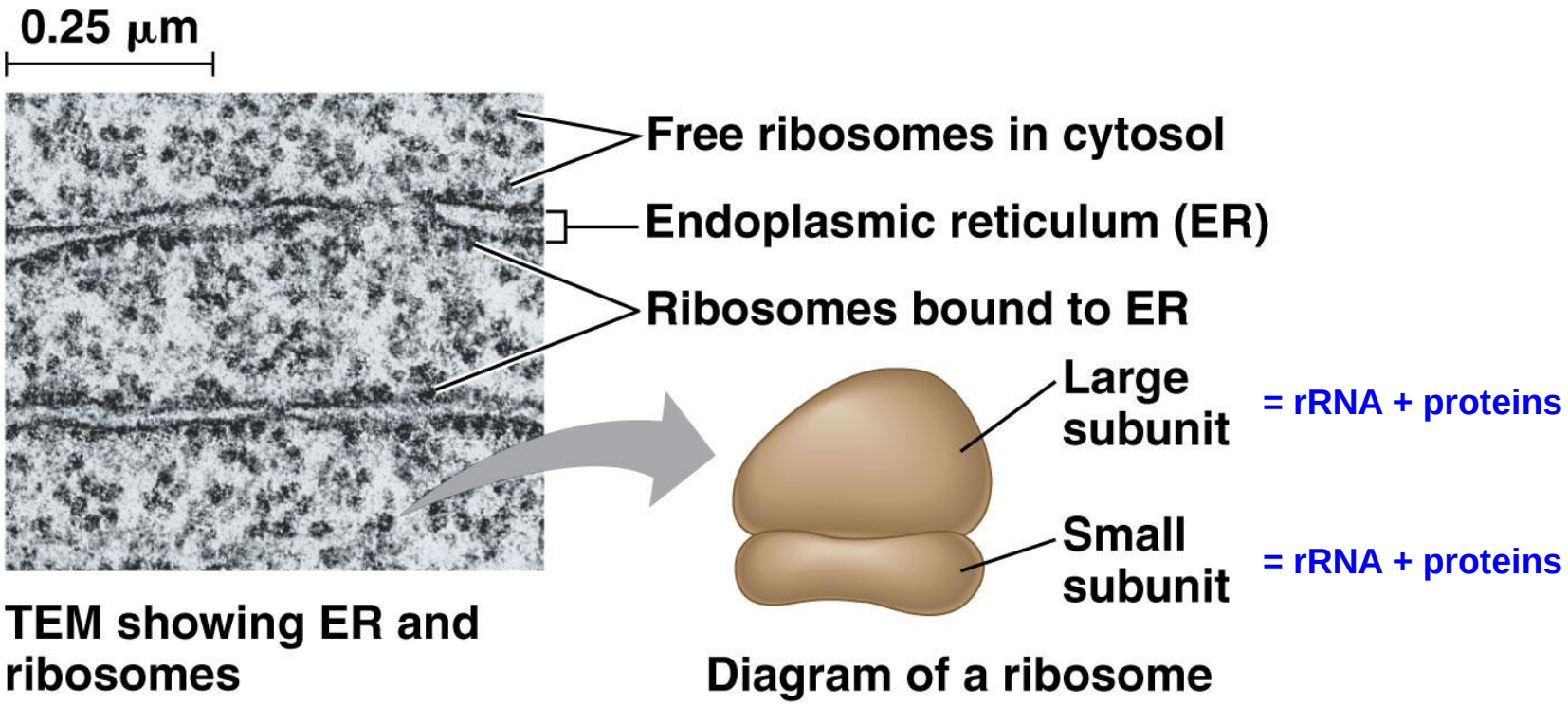


Rough ER: protein processing, folding, modification and packaging

Smooth ER: lipid/steroid synthesis, detoxification of drugs, calcium storage

Golgi apparatus: receives, modifies, stores and ships products from ER

Ribosomes are the site of protein synthesis (Fig. 7.12)



- **attached to endoplasmic reticulum** (ER = rough ER) makes proteins for export in membrane bound vesicles e.g. secretion
- **free in cytosol** make proteins that function in cell, e.g. enzymes

Link: we'll revisit the role of ribosomes in protein synthesis in a later lecture

Ribosomes make proteins and the endomembrane modifies and ships them – movement of proteins is energy demanding and tightly regulated

Translation

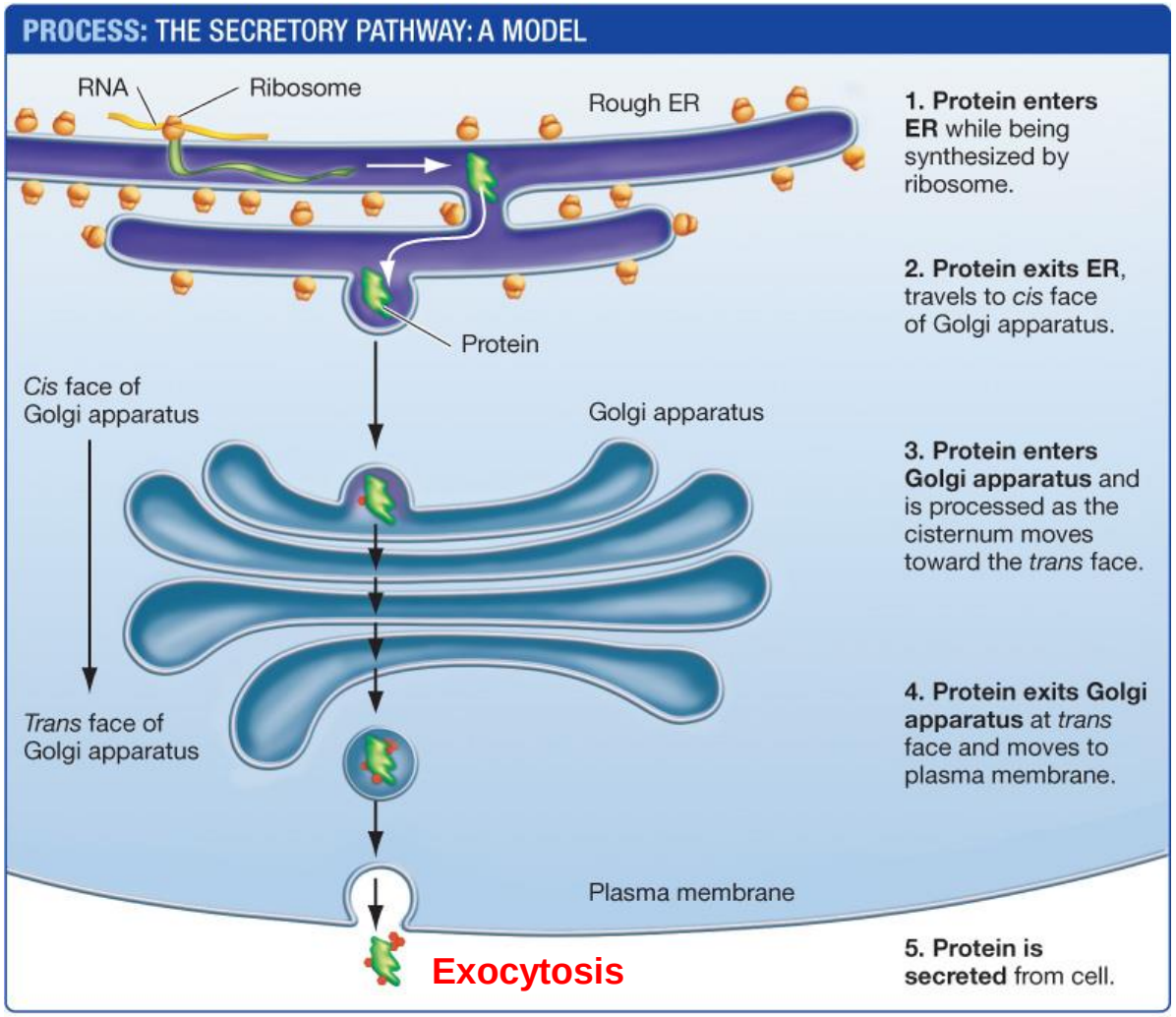
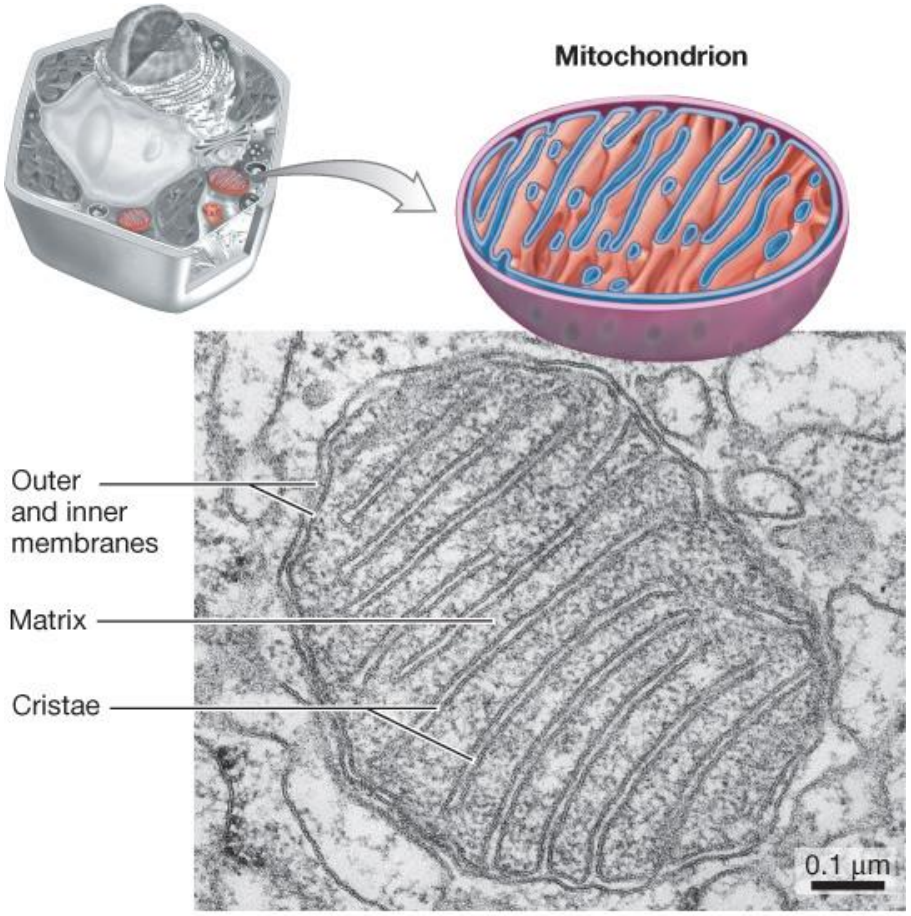


Fig. 7.25

Mitochondria are power-generating stations: sites of cellular respiration (Fig. 7.18)



- **Mitochondria have a double membrane (2 bi-layers)**

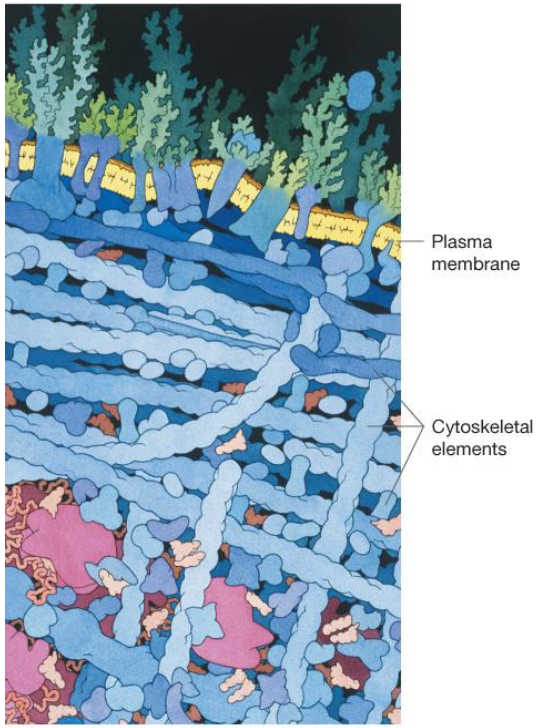
- **Outer membrane is smooth**
- **Inner membrane is folded into cristae (increases surface area)**

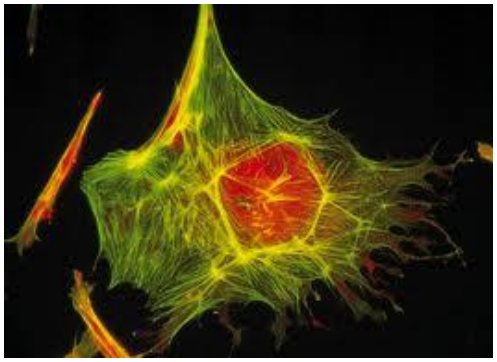
- **Enzymes that run cellular respiration are embedded in inner membrane or suspended in the mitochondrial matrix**

- **Mitochondria have their own small chromosome and ribosomes – WHY?**

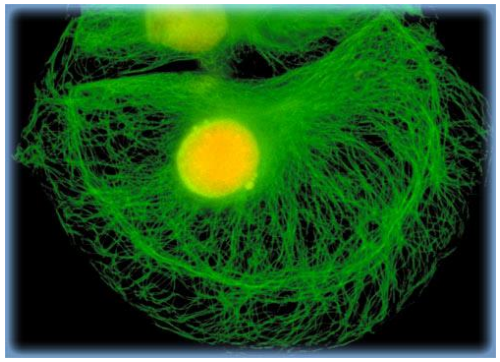
Link: cell respiration produces ATP which provides the energy to build things (like organelles) and to do other cellular work

The cytoskeleton: a network of fibers that organizes the structure and activity of cell (see Summary Table 7.3)



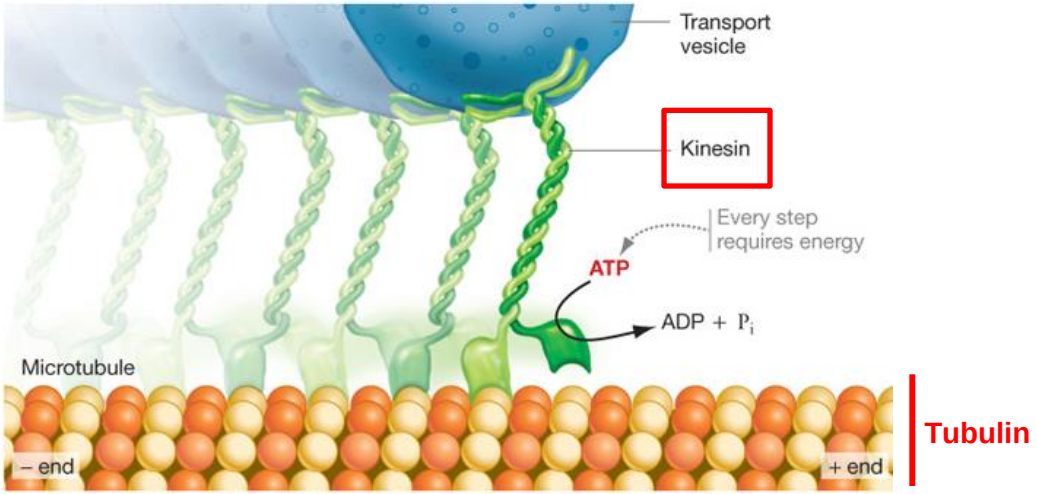


Microfilaments
(actin polymer)



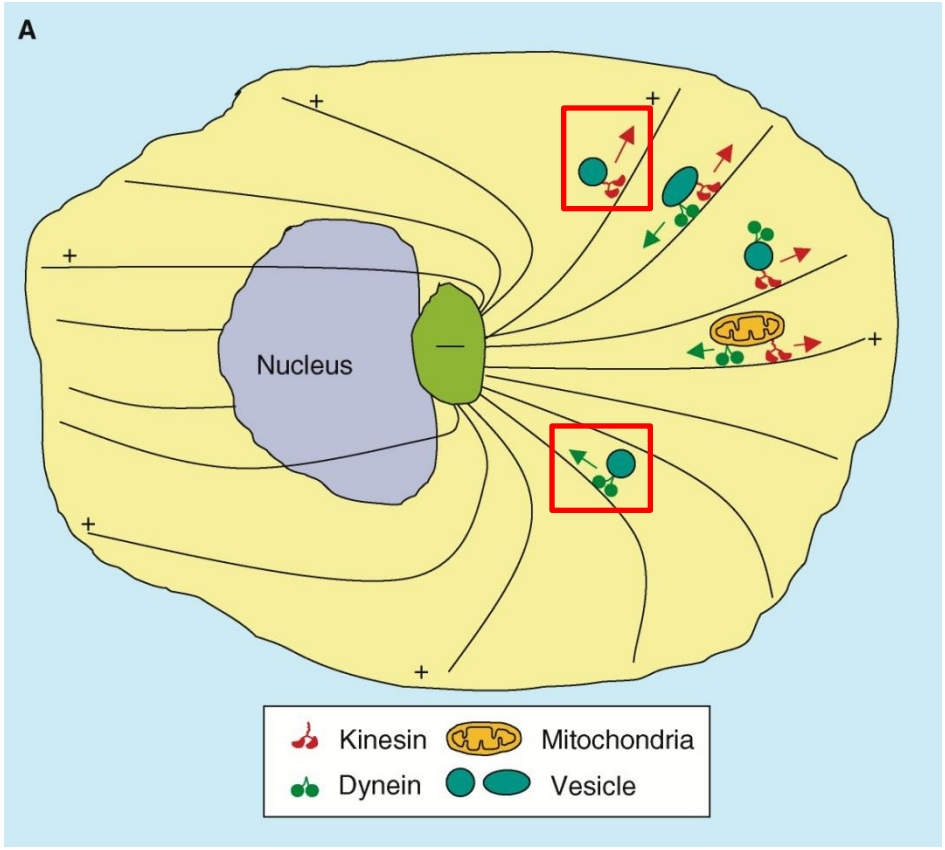
Microtubules
(tubulin polymer)

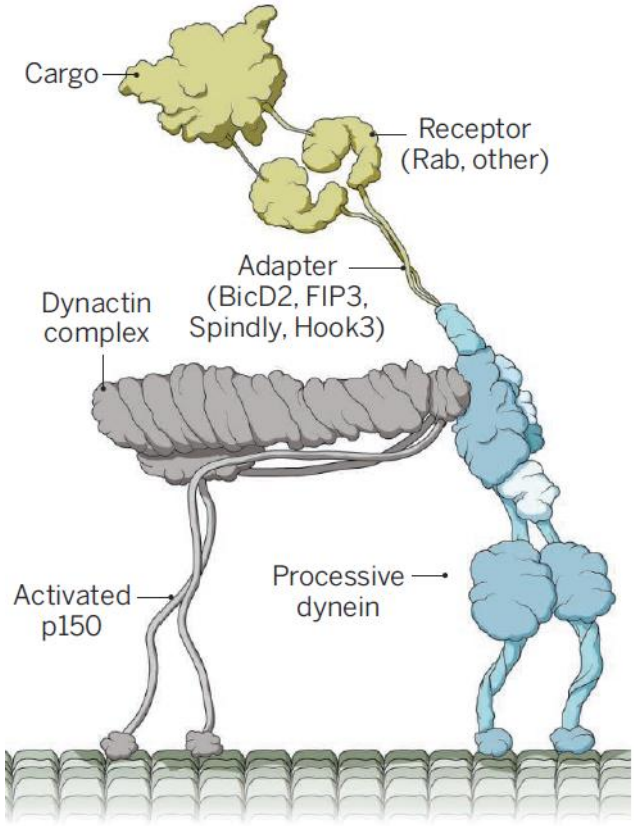
Microtubules provide tracks for "motor proteins" (e.g. kinesin) to carry cargo (transport vesicles) around the cell (Fig. 7.35)



Cell motility: organization of microtubules in a eukaryotic cell with kinesin and dynein motor proteins

provides tracks for "motor proteins" to carry cargo around the cell

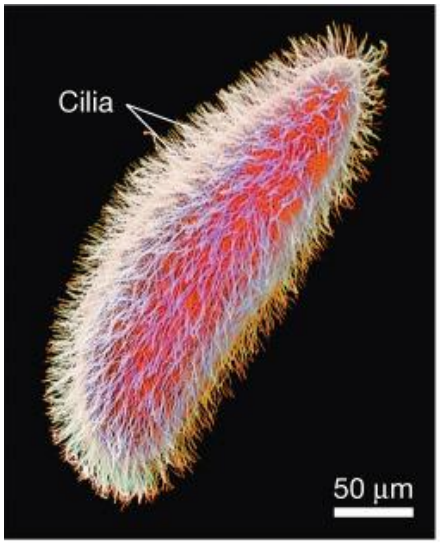


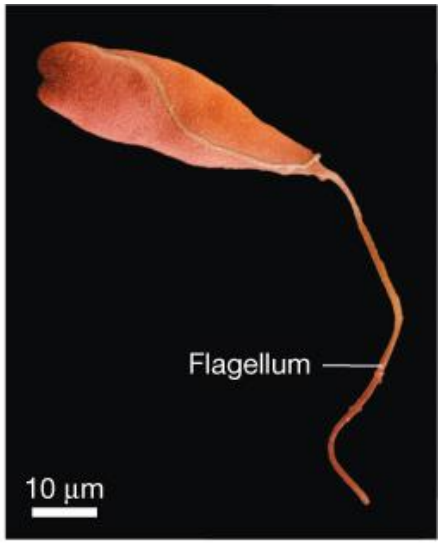


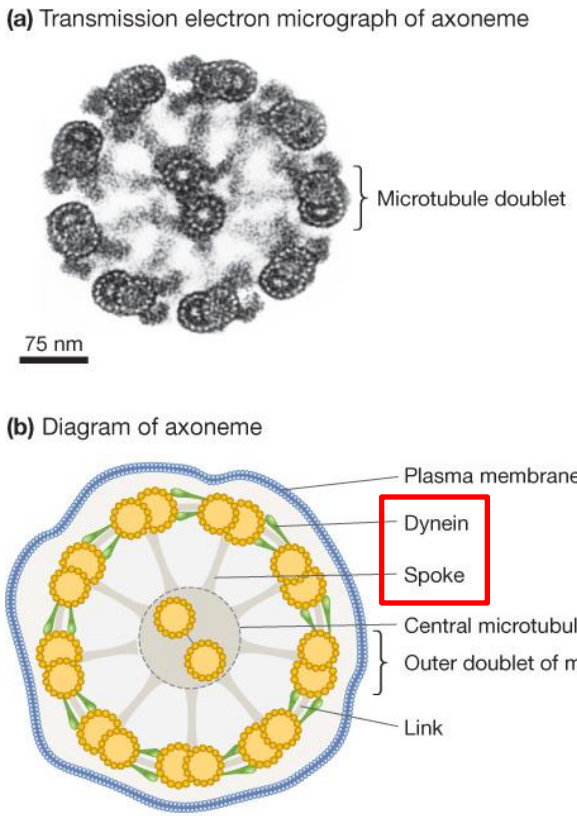
Centrosome = "microtubule-organizing center"

Current view of dynein complex (Science 2014 345:270)

Cilia and flagella utilise microtubules and a motor protein (dynein) to move the whole cell (Fig. 7.36-7.37)

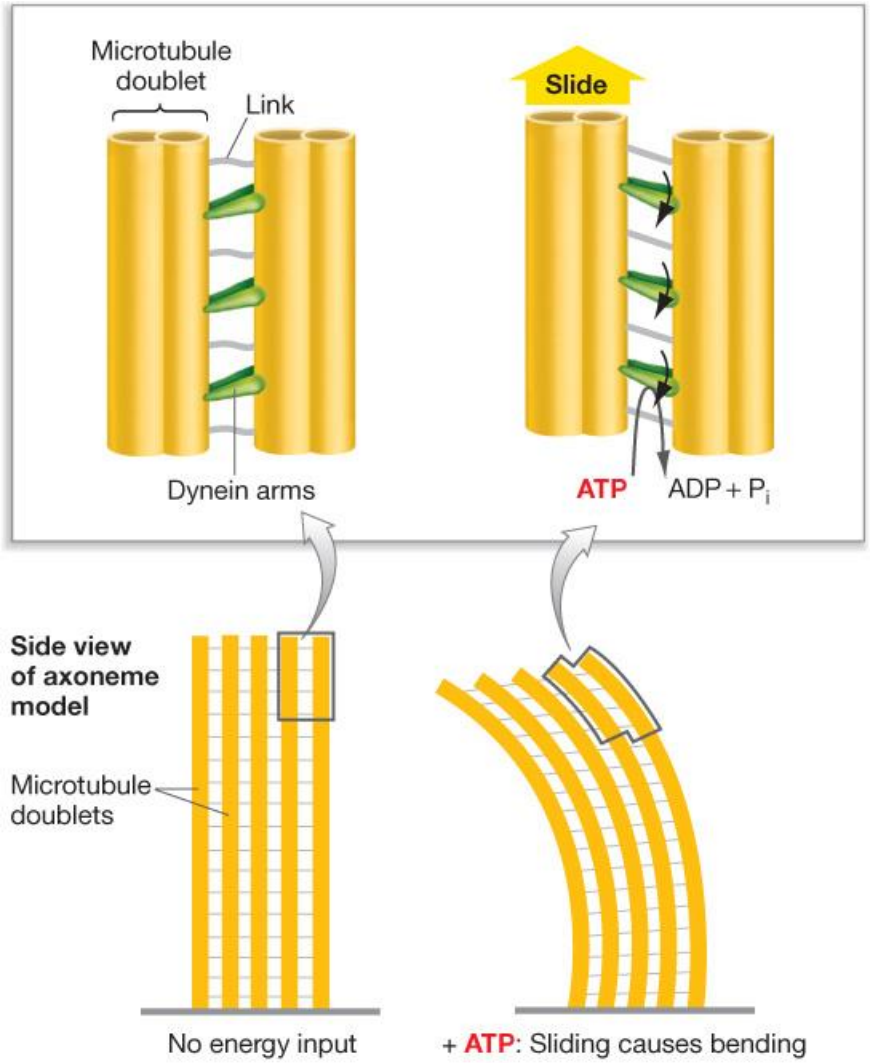






- Most cilia and flagella have a 9 + 2 arrangement of microtubules
- 9 double microtubules + 2 single microtubules, covered by an extension of the plasma membrane
- Whole structure = axoneme, attached to cell by basal body

What provides the force required for movement of cilia and flagella? (Fig. 7.38)



- Doublet microtubules are connected by dynein (motor protein)
- Beating (movement) requires ATP = energy-demanding process
- ATP changes the shape of dynein allowing it to "walk" up the microtubule (see slide 14)

- This causes the adjacent microtubules to slide past each other
- BUT the microtubules are anchored by the basal body and connected by spokes
- So sliding causes bending = beating

Multi-cellularity requires connections between cells (Chapter 8)

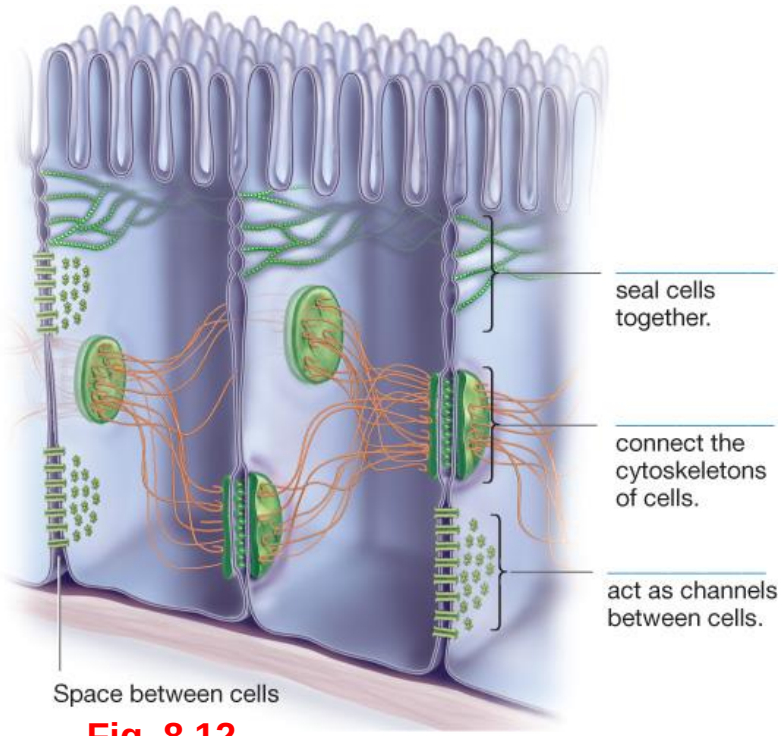


Fig. 8.12

Desmosomes function like rivets binding adjacent cytoskeletons (e.g. muscle cells)

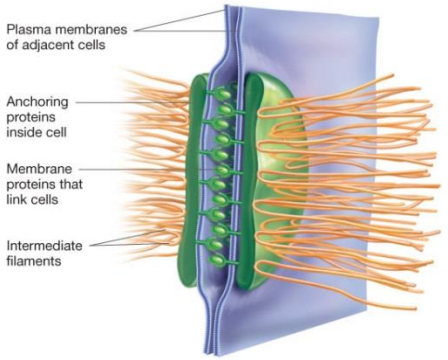


Fig. 8.8

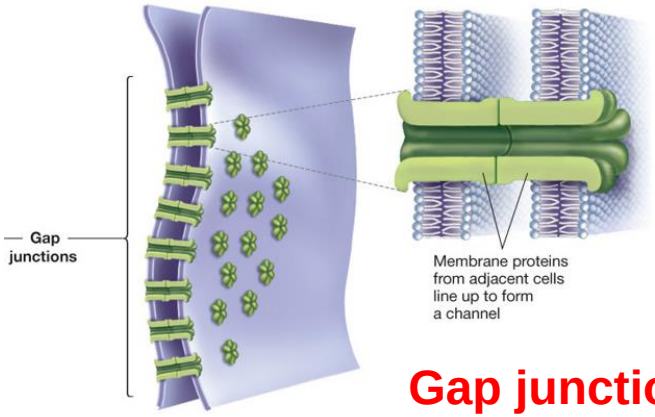
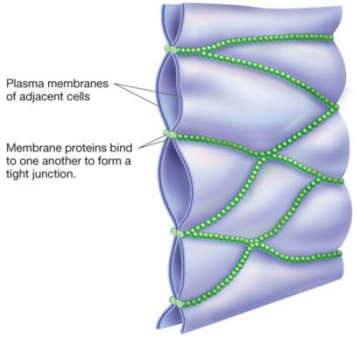


Fig. 8.11

Tight junctions form watertight seals, e.g. in cells that form barriers (epithelial cells)

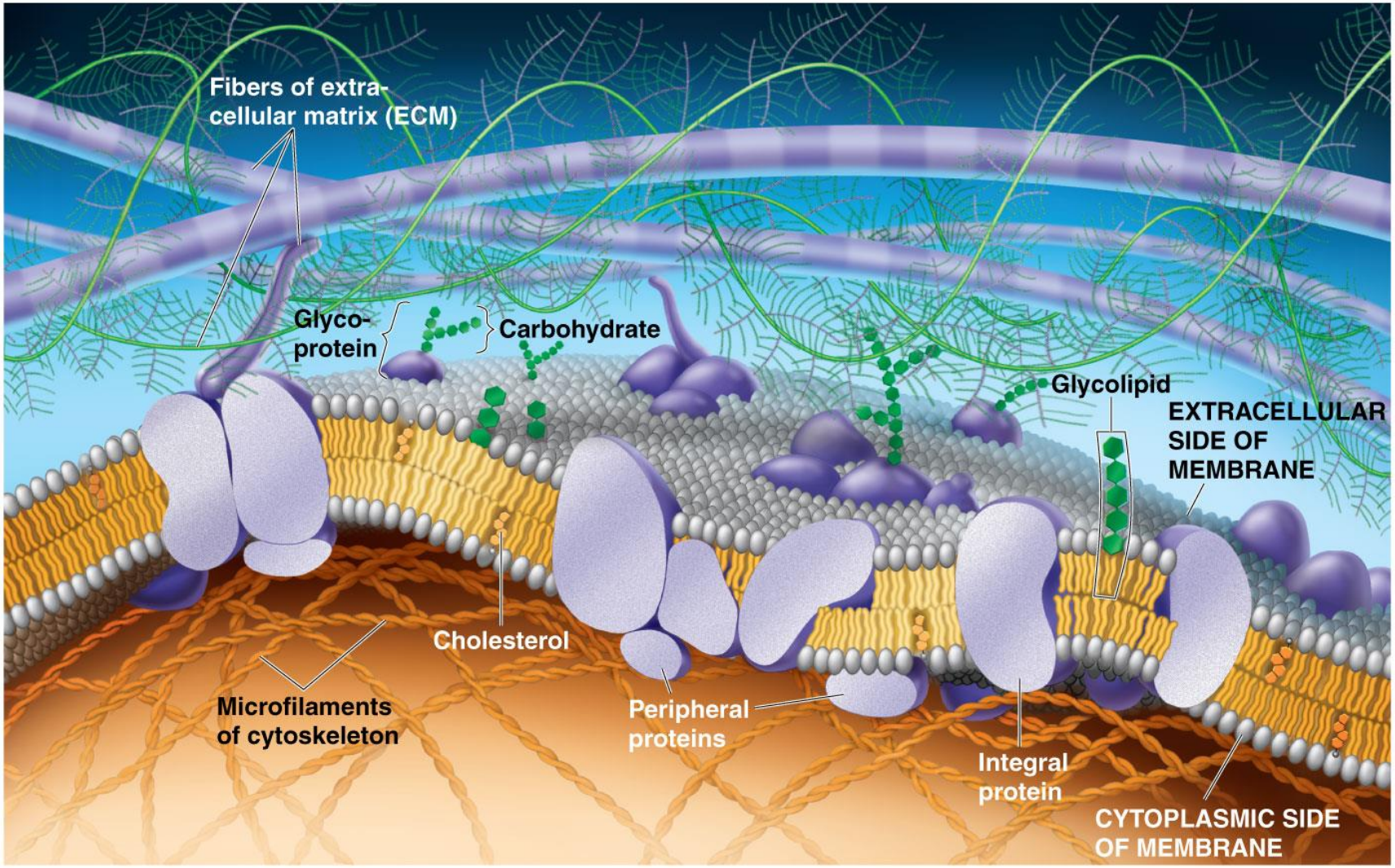
Fig. 8.7



Gap junctions provide cytoplasmic channels from one cell to another

Cell membranes: structure and function

(Chapters 6/7)



Key concepts – plasma membranes

- **Membranes are fluid mosaics of lipids and proteins; highly dynamic; this structure results in selective permeability**

i.e. the membrane allows some things to pass through more easily than others

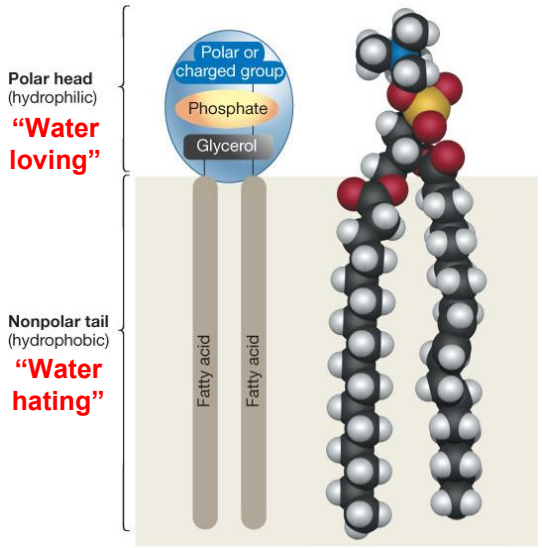
- **Passive transport (diffusion, osmosis) does not require energy**
- **Facilitated diffusion is where transmembrane protein channels aid (speed up) passive transport**
- **Active transport uses energy to move solutes against their (electro) chemical gradients (ion pumps, cotransporters)**

see Figure 6.30 for simple review

- **Bulk transport occurs via exocytosis and endocytosis**

Cell membranes are *highly dynamic* "fluid mosaics" of phospholipids and proteins

Fig. 6.3



Amphipathic phospholipids ….

form lipid bilayers

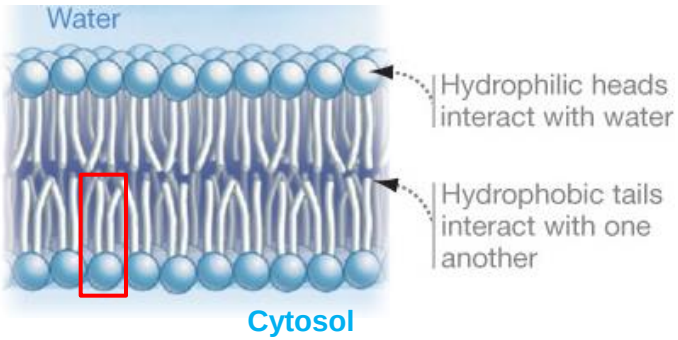
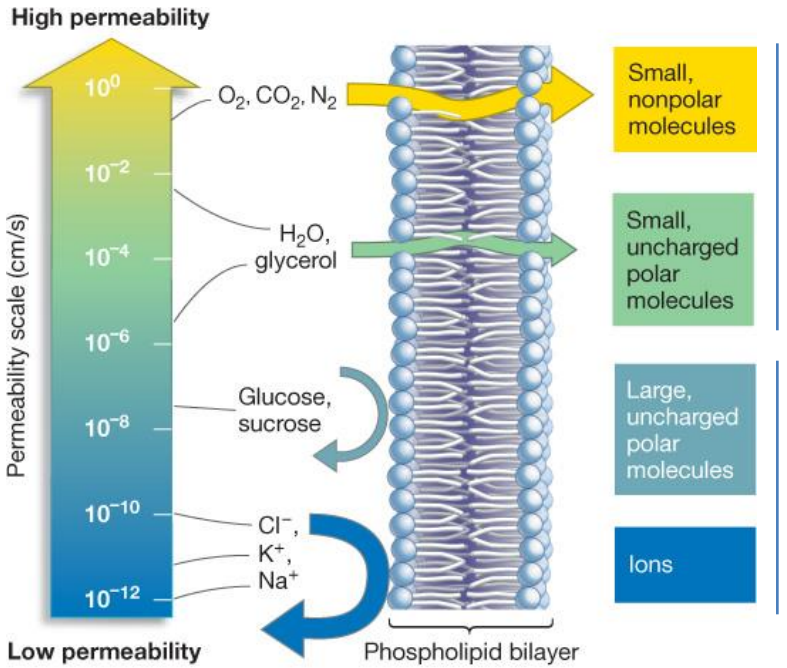


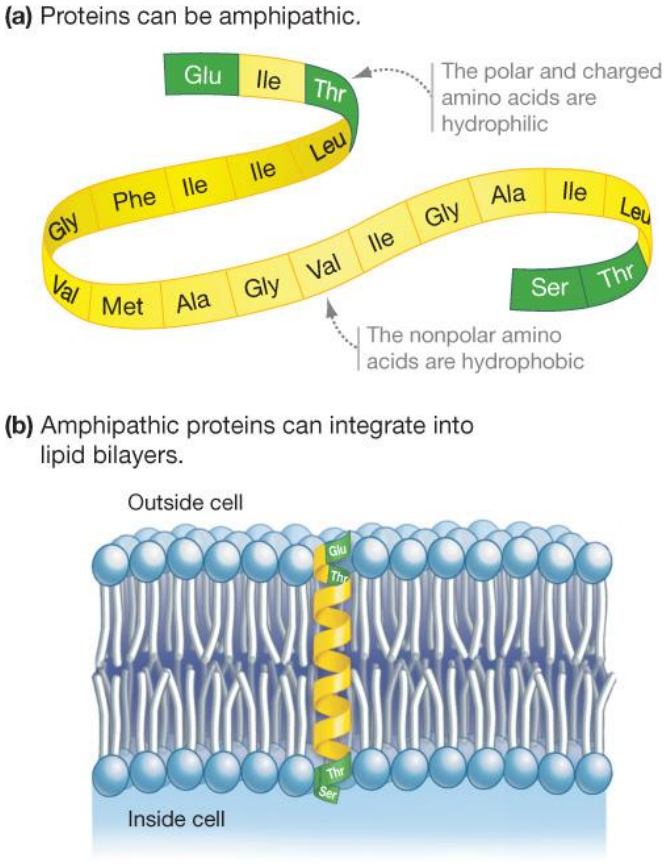
Fig. 6.7



- **Small polar, and non-polar molecules move across bilayers (membranes) quickly**

- **Large/charged molecules move slowly or not at all (unless they get "help" from membrane proteins)**

Membrane-associated proteins = "*mosaic*" part and have many different function



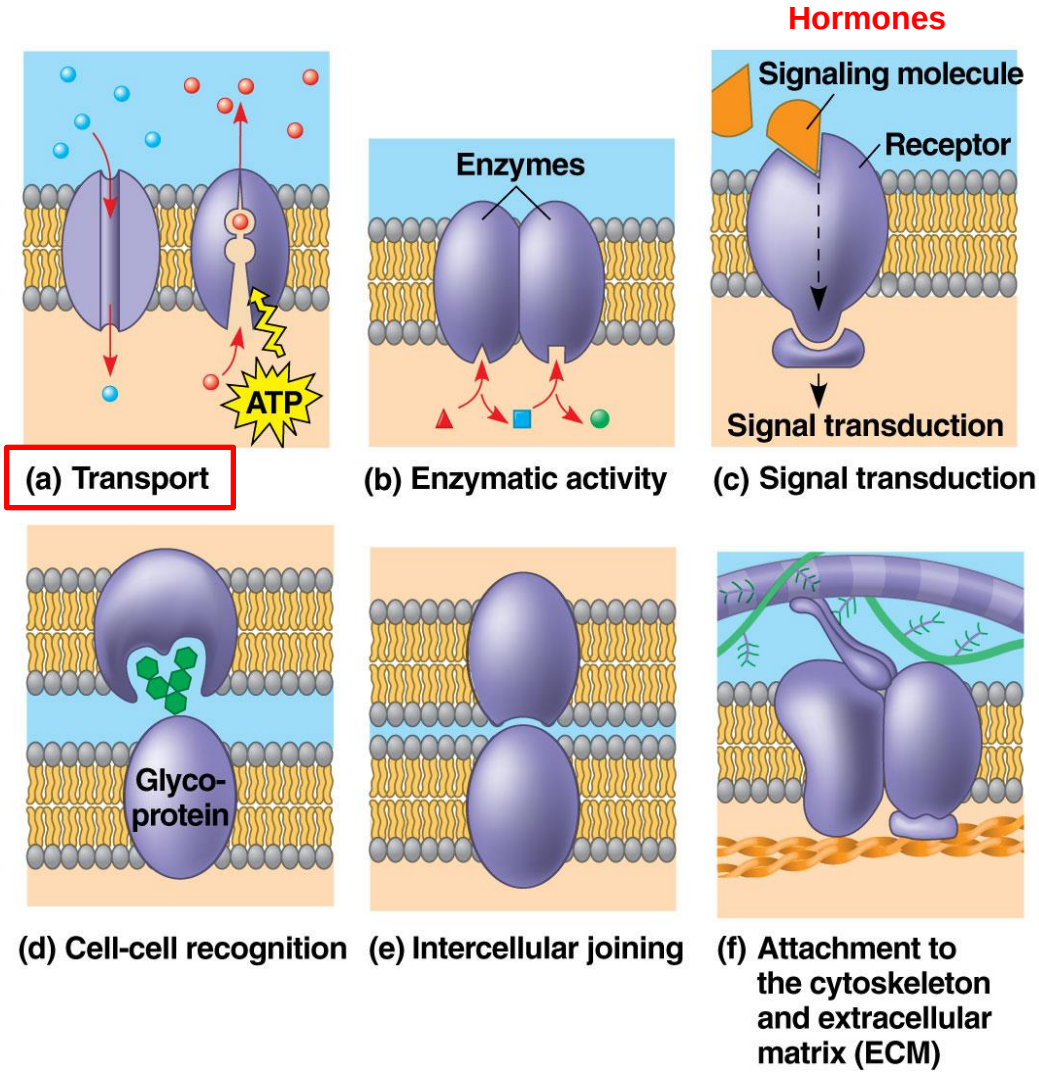


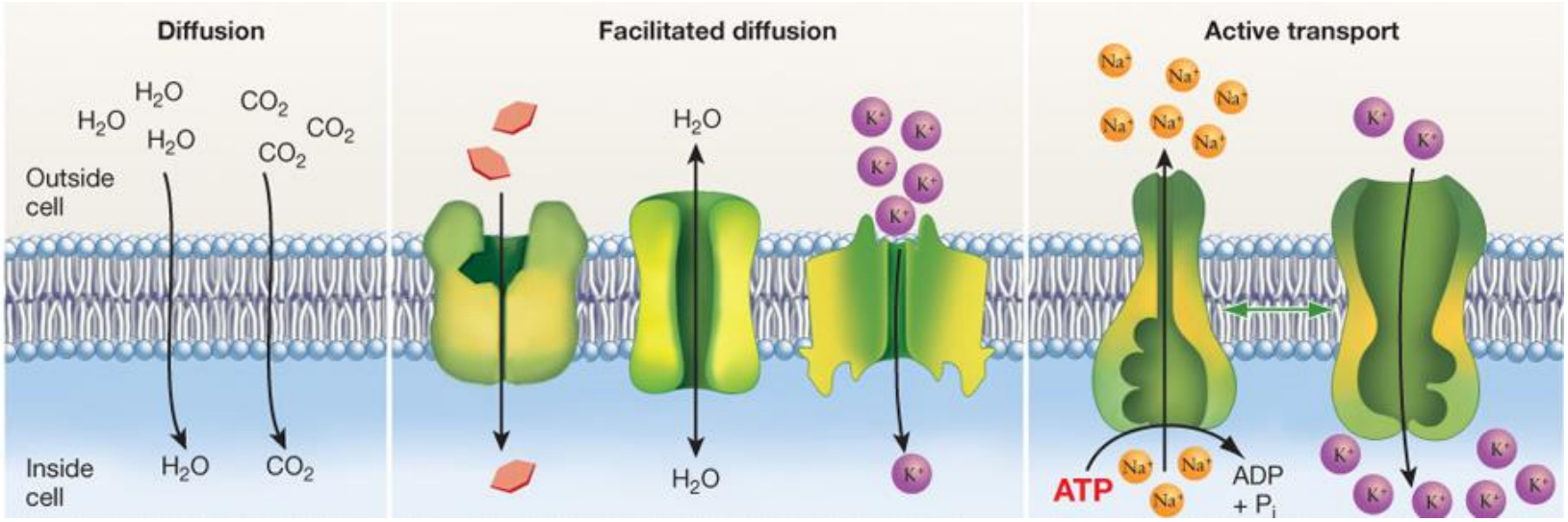
Fig. 6.19

Movement of substances across membranes depends on ….

1) Selective permeability of lipid bilayer (diffusion)

2) Transmembrane proteins that transport selected ions and molecules by facilitated diffusion and active transport

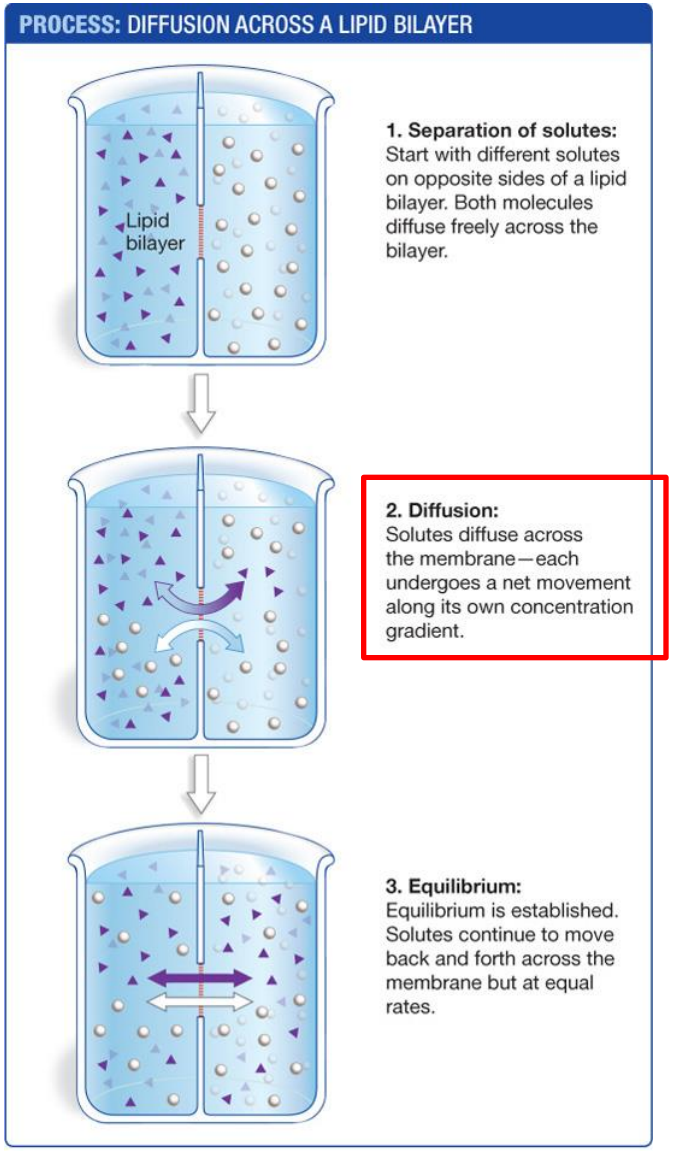
Fig. 6.30



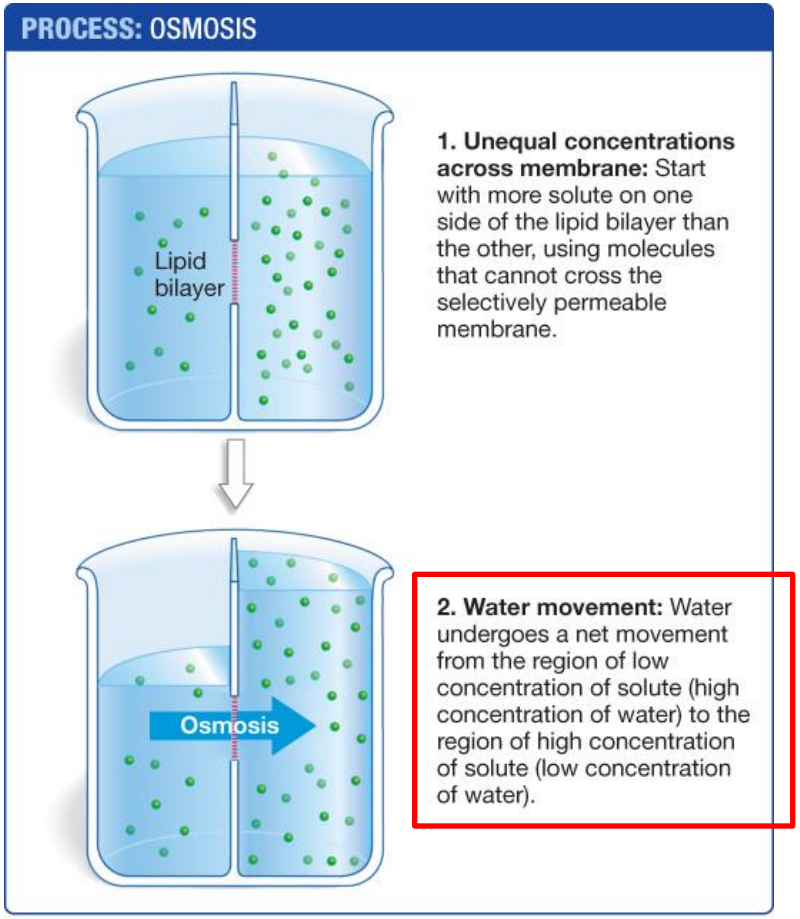
Movement down a concentration gradient = PASSIVE

Movement against concentration gradient

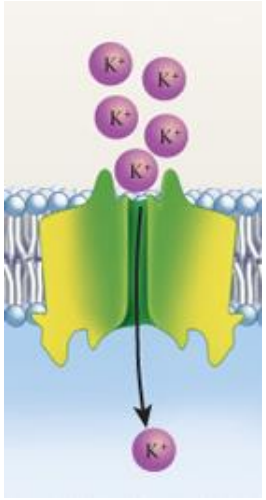
Why (some) molecules move across lipid bilayers: diffusion and osmosis (Fig. 6.15 and 6.16)



Small and uncharged molecules and hydrophobic compounds can cross membranes readily and spontaneously – without expenditure of energy



Facilitated diffusion: passive transport via channel proteins



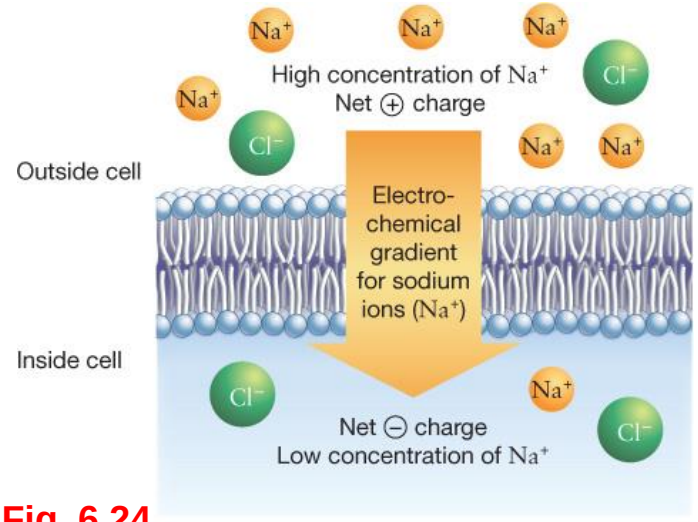


Fig. 6.24

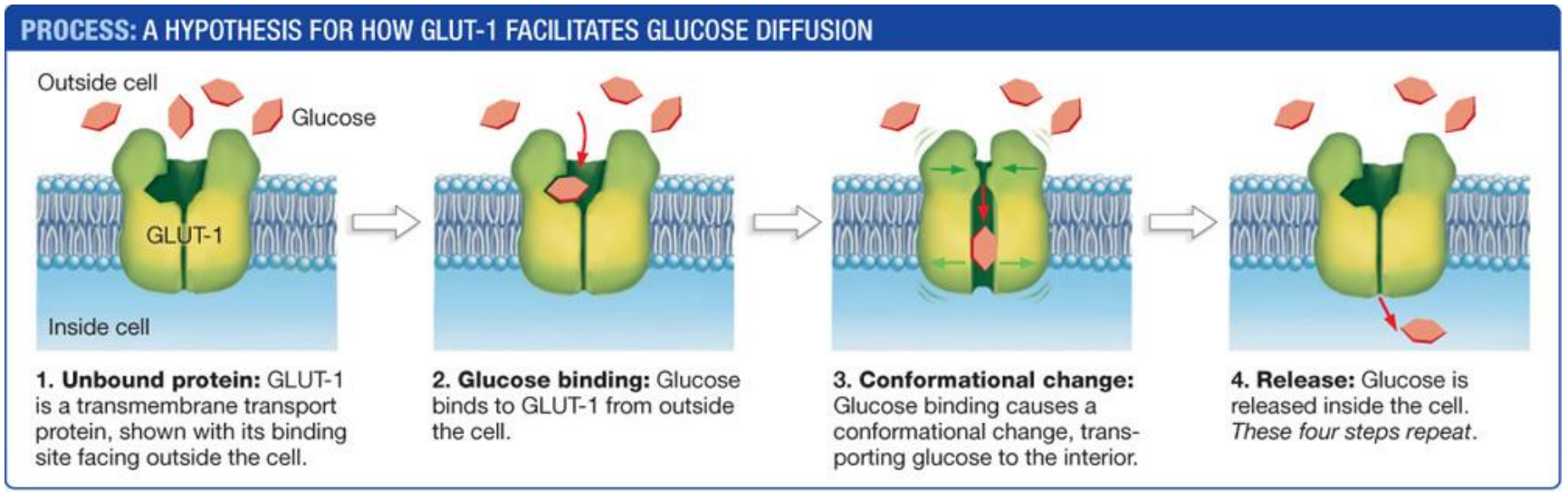
- Channel proteins or ion channels allow ions and large polar solutes to diffuse rapidly down their concentration gradient

- Ions are charged so they move in response to a combined electrical and chemical gradient (electrochemical gradient)

- Channels are highly selective (due to the structure of the protein)
  - water pores (aquaporins) only allow water to pass
  - potassium channels only allow potassium to pass

- Channels are highly dynamic and can be "gated" (open or closed) – see Fig. 6.26

Facilitated diffusion: passive transport via carrier proteins or transporters (Fig. 6.28)

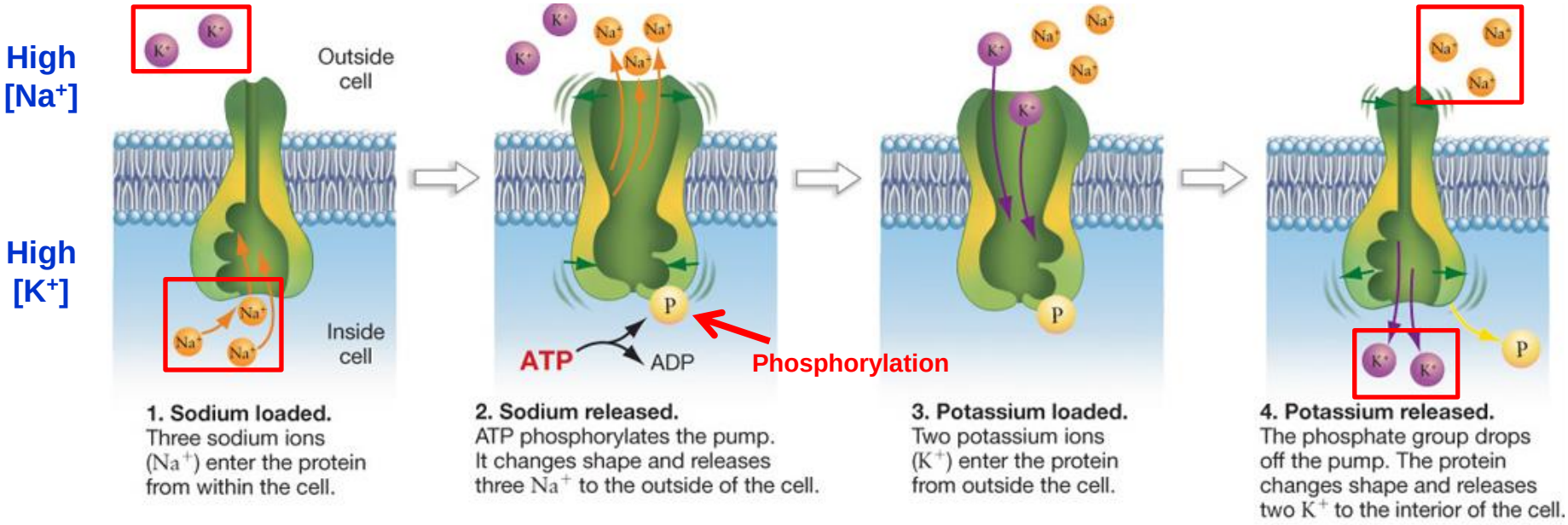


Carrier proteins, e.g. glucose transporter (GLUT-1), change shape to move molecules across the membrane

What powers the movement of molecules through transporters – diffusion!

(if the concentration of glucose is the same on each side of the membrane there will be no net movement even if GLUT-1 is present)

Active transport uses energy (ATP) to move molecules against their concentration gradients (Fig. 6.29 or 45.4)

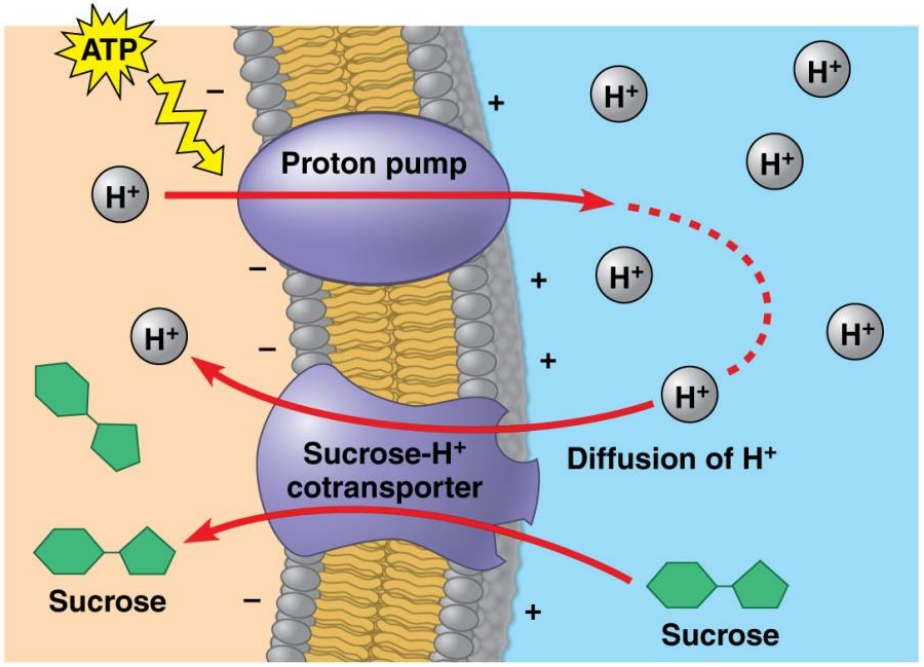


- **Sodium-potassium pump exchanges 3 Na^+ (OUT) for 2 K^+ (IN) across the cell membrane**
- **Requires energy in the form of ATP**
- **Involves a conformational change in the shape of the protein**
- **Net charge = 1 +ve (Na^+) loss each cycle = electrogenic**

Co-transport or secondary active transport

- Ion pumps using active transport (and the energy of ATP) can create concentration gradients across the membrane

- Concentration gradient sets up by the pump provide potential energy to power the movement of other molecules back across the membrane by against their concentration gradient



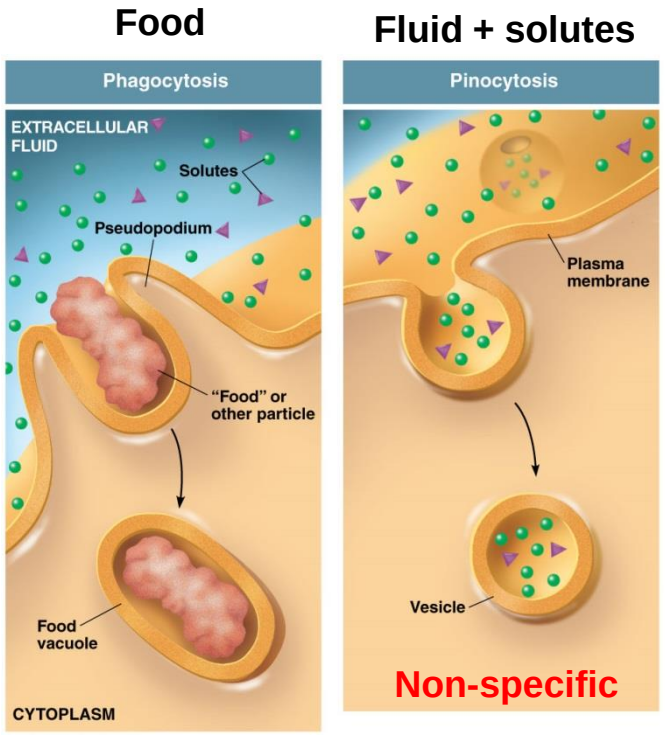
An example:

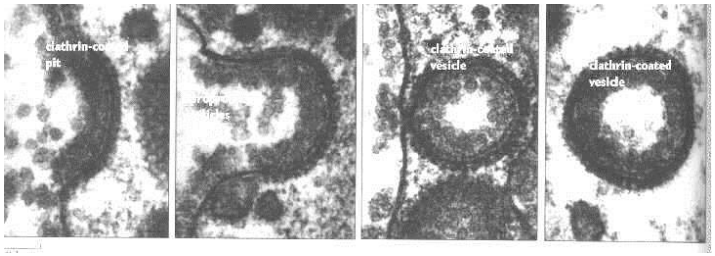
the sucrose-H^+ cotransporter

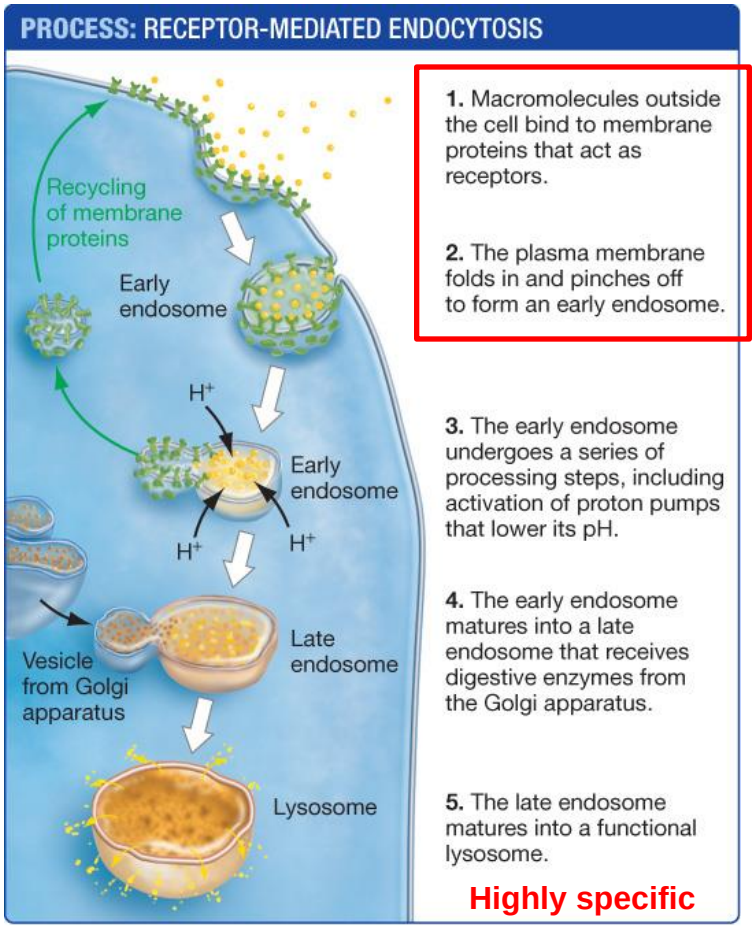
We will see lots of examples where H^+ (proton) gradients provide potential energy to do work!

Bulk transport across membranes occurs via endocytosis (and exocytosis)

Fig. 7.17

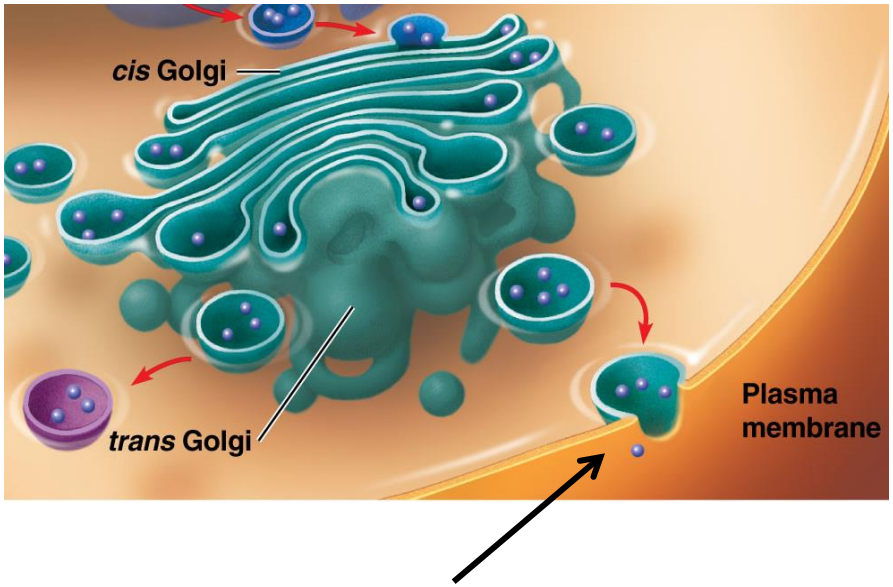




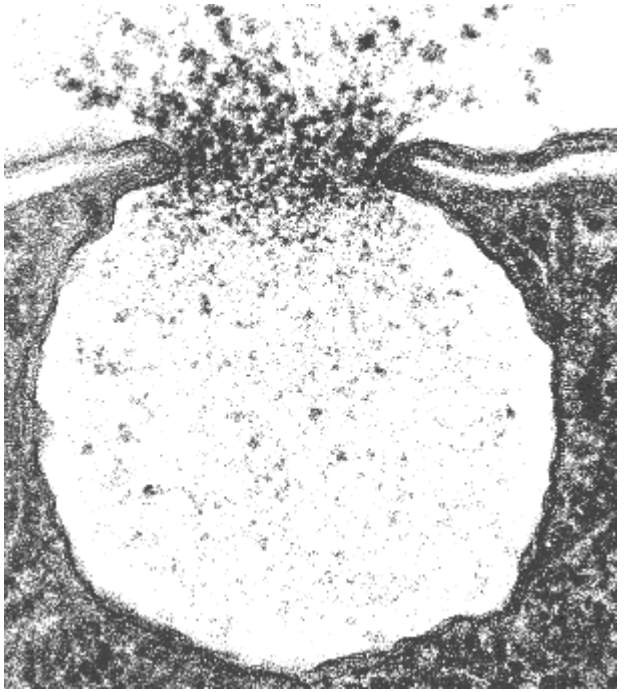


Endocytosis = food particles, fluid, specific molecules being taken up IN to the cell

Bulk transport across membranes occurs via (endocytosis and) exocytosis



Membrane-bound transport vesicle or secretory vesicle fuses with cell membrane to release contents



Exocytosis = reverse process where proteins, hormones etc are released FROM the cell into the extracellular space or into the circulation