BIOL 230: Cell & Molecular Biology
Fall 2019 17-205 MW, Sept. 16-17

http://accounts.smccd.edu/staplesn/biol230/

1. Pre-Lab writeups due each Mon. (for both M&W!!) at the start of lab. (*briefly*, **What**? **Why**? **How**? for each expt.). Question & **Hypothesis**?!
2. **LAB this week: Your own ENZYME Experiments!!! Midterm #1 review in Lab on Wed.!! Experiments 5 & 6!!**
3. ***Research topics!! ☺ ***Due Wed., Oct. 2 with a Professional, Primary Reference!!***
4. **QUIZ #2, first attempt, due Wed. night!!**
5. **Extra Credit: STEM SPEAKER SERIES, Weds. @ 5pm-6pm, Sept. 11-Nov. 6. (NOT Oct. 9) in 6-102. *Write 1 page summary by the following week, and upload to CANVAS*.**
6. **Midterm #1 on Monday!!!** Bring RED scantron & #2 pencil. **See "UPDATED" Study guide!!!**
   - ***PRACTICE, Review, & PRACTICE some more!!***

1

REVIEW

Leucine binding protein

1. State the **Cell Theory** and explain its implications for our understanding of life on earth. (Convert between **metric size units** of m, cm, mm, µm, & nm.)
2. List and describe, with diagrams, at least **8** important differences between **Prokaryotic and Eukaryotic Cells**. What are some similarities?

TODAY's Objectives: Students should be able to....

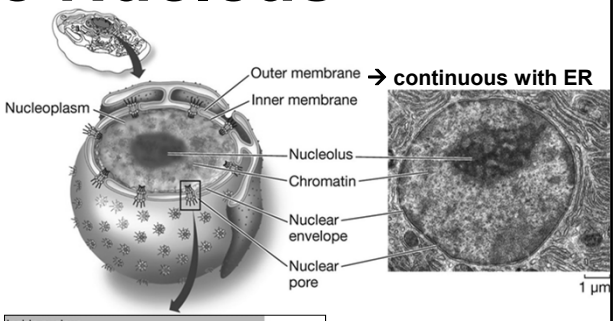
1. Diagram the structures and describe the functions of all of the major eukaryotic and prokaryotic **organelles & extracellular structures**.
2. Explain and describe the evidence for the **Theory that illustrates the origin of energetic organelles** in eukaryotic cells.
3. Diagram & describe the current **model for the structure of cellular membranes**. Explain the meaning of the name given to the theory.
4. Describe & diagram the **3 different cell connections** found in animal cells. What is the function of each, and in what tissues?
5. Diagram and explain the factors determining the **direction of movement of a solute** across a membrane. Discuss why sometimes a protein is needed or not, and why sometimes ATP is needed or not.
6. State the term use to describe the **diffusion of water** across a membrane. Predict the direction of movement of water for a cell placed into solutions of various different solute concentrations (***molarity*** or ***osmolality***).
7. Define **energetic coupling** and provide an example. What types of molecules can couple chemical reactions?
8. Explain how the **change in free energy** affects the equilibrium of a reaction.

❖ ***Objectives and Study Guide Questions are your HOMEWORK between classes!!! DUE every WED. at the end of Lecture!!***

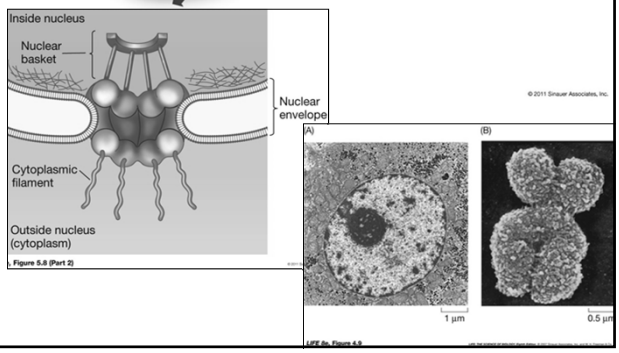
2

The Nucleus

- **Nuclear pores** –
  - complex structures governing what enters and leaves the nucleus.



❖ **Nuclear lamina** –
  - Protein matrix (***lamins***).
  - supports nuclear envelope.
  - Binds chromatin.

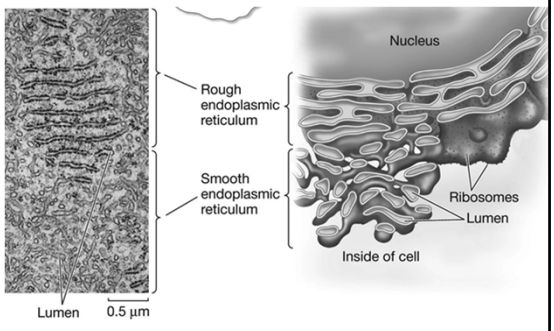


3

B.) The Endomembrane System

- The endomembrane system = a series of interrelated membranes and compartments.

1. **Rough ER:**
   - has ribosomes – synthesize proteins (for export)
2. **Smooth ER:**
   - lacks ribosomes.
   - site of lipid synthesis.



LIFE 8e, Figure 4.10

3. **Golgi apparatus:**
   - adds signal molecules to proteins -- directing them to destinations.
   - receives materials from the rough ER via vesicles that fuse with the *cis* region of the Golgi.

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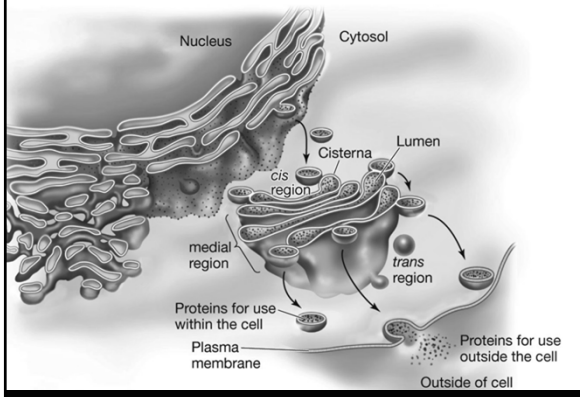
* Golgi Apparatus

- 3 Regions: ***cis, medial, trans.***
- ***Vesicles originating from the <u>trans</u> region of the Golgi contain proteins for different cellular locations*.**
  - Some fuse with the plasma membrane and release their contents outside the cell.



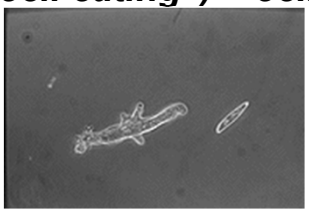
http://vcell.ndsu.nodak.edu/animations/proteintrafficking/movie-flash.htm

9e, Figure 5.10 (Part 2)

5

4. Lysosomes & Phagocytosis

- ***Phagocytosis ("cell eating") = cell engulfs large particles.***



- **Lysosomes** fuse with the **<u>phagosomes</u>** to form *secondary lysosomes (**<u>phago-lysosomes</u>**):*
  - Engulfed particles are <u>digested</u> in phagolysosome
    - Digested products released into cytoplasm for use
  - Undigested materials are <u>secreted</u> from the cell
    - phagolysosome fuses with the plasma membrane

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__lysosomes.html

http://www.stolaf.edu/people/giannini/flashanimat/cellstructures/phagocitosis.swf

http://www.sumanasinc.com/webcontent/animations/content/organelles.html

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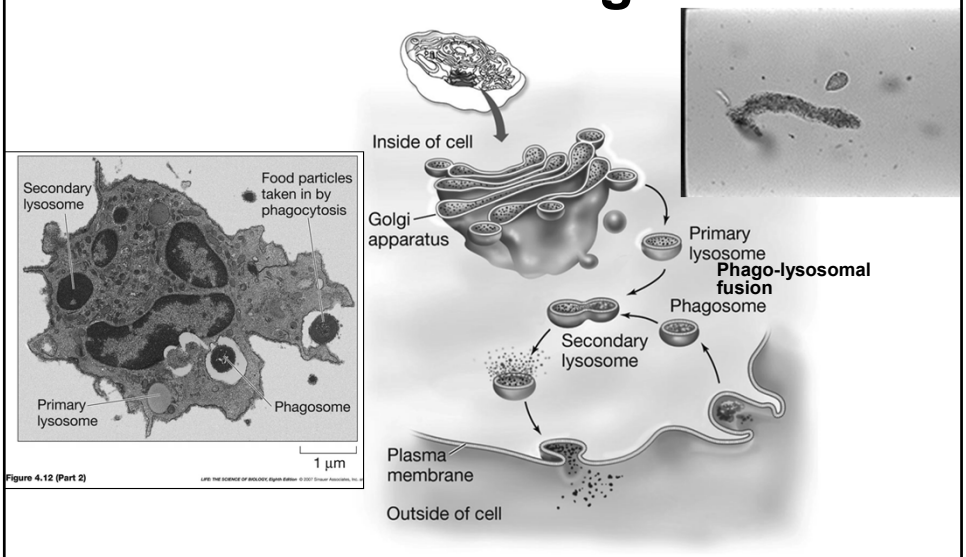
Phagocytosis and Intracellular Digestion



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C.) Organelles that Process Energy

1. Mitochondria are enclosed by
   - outer membrane &
   - inner membrane – folds inward to form ***cristae.***
     - ➢ contain proteins needed for cellular respiration and generation of ATP.

http://www.stolaf.edu/people/giannini/cell.html

http://www.stolaf.edu/people/giannini/biological%20anamations.html

http://www.stolaf.edu/people/giannini/movies.html

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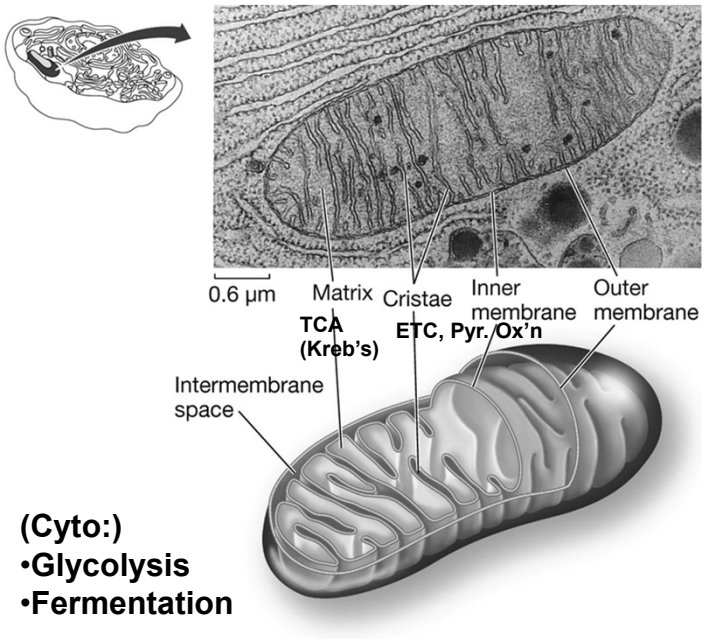
1. Mitochondrion



(Cyto:)
- **Glycolysis**
- **Fermentation**

9e, Figure 5.12

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2. The Chloroplast (a Plastid)

a) **<u>Plastids</u>** = chloroplasts, chromoplasts, leucoplasts ("amyloplasts").

b) Green plant & algae cells contain ***<u>chloroplasts</u>***:
   i. enclosed by double membranes.
   ii. contain an internal system of <u>thylakoids.</u>

c) Thylakoids – organized as <u>grana.</u>
   - contain the ***<u>chlorophyll</u>*** and proteins that harvest light energy for photosynthesis.

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Chloroplasts

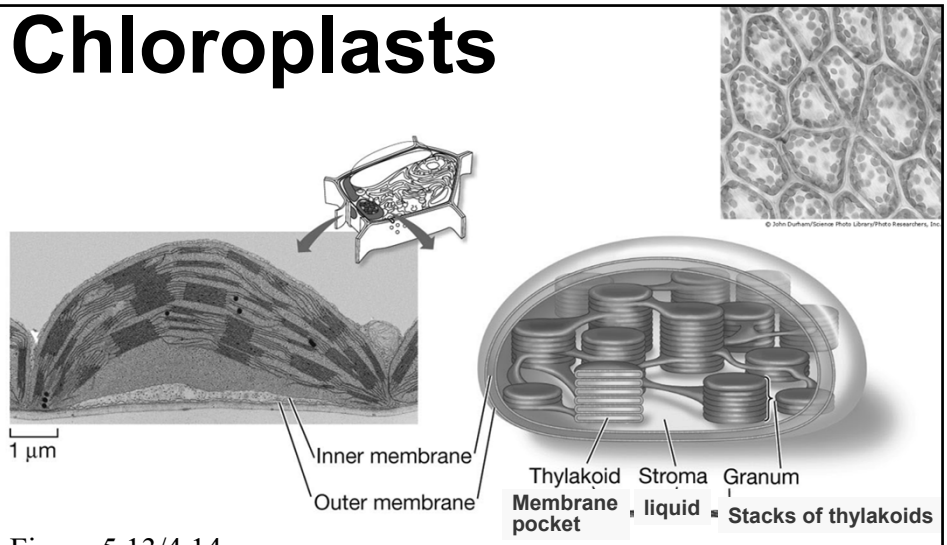

Figure 5.13/4.14

Two-Membrane Organelles:
- **Nuclei**
- **Mitochondria**
- **Chloroplasts**

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Mitochondria and Chloroplasts: …some early observations…

1. Have Double-membranes
2. Contain their own DNA and ribosomes!!
3. Can make some of their own proteins
4. Divide at their own rate ……

- *Possible scientific explanation??….*

http://www.sumanasinc.com/webcontent/animations/content/organelles.html

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Endo-sym-biosis Theory

1. The evolution of mitochondria and chloroplasts:
   - large prokaryotes engulfed (by "***endocytosis***"), but did not digest, smaller ones → DOUBLE MEMBRANE (from host & endosymbiont)

2. ***Mutual benefits permitted this symbiotic relationship to evolve into eukaryotic organelles of today***
   - Home & protection for small cell
   - New, powerful energy source for larger cell

http://www.sumanasinc.com/webcontent/animations/content/organelles.html

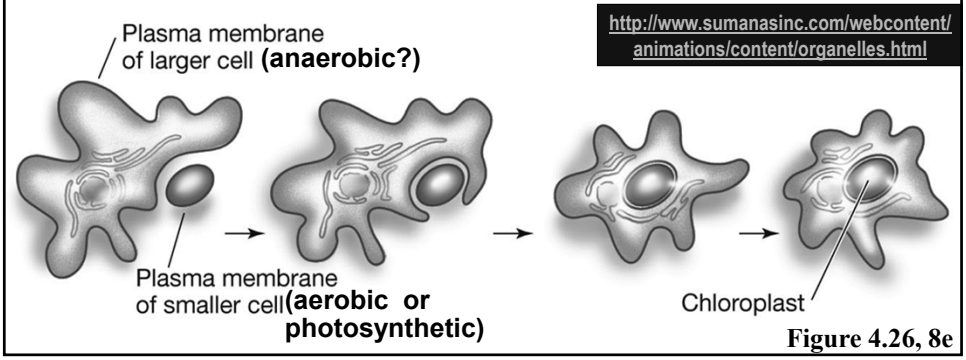

Figure 4.26, 8e

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Evidence for Endosymbiotic Origin of Mitochondria & Chloroplasts

1. Approximately the **same size and shape** of known prokaryotes ("bacteria").
2. Bacteria-like genetic information (chromosomal DNA):
   a) **Closed, circular DNA** (not linear, like Euk.)
   b) Encode own: metabolic proteins, prok.-type ribosomes
3. **Prok.-like division** mechanisms (***ftsZ*** gene)
   - **http://www.ncbi.nlm.nih.gov/** → **PubMed**, **Advanced** → "***ftsZ*** gene" → Article. Type: "**Review**"
   - **https://www.ncbi.nlm.nih.gov/pubmed/24266848** 2013
   - **https://www.ncbi.nlm.nih.gov/pubmed/24631929** 2013
4. Many organelle genes seem to have been lost to the Nuclear genome. (Eg: ribosomal genes)
   - ***Organelle genes in nucleus are more closely related to bacterial genes than to euk. genes in the same cell!***
5. ** Discovery of a single-celled eukaryote, *Hatena,* that ingests a green alga, *Nephroselmis.*
   - loses most of its structures and acts as a chloroplast.

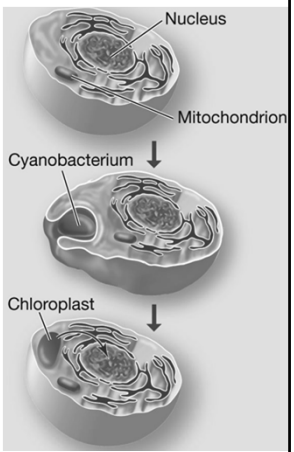

Figure 5.26, 9e
Origin of Organelles (B)

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D. Other Organelles Enclosed by Membranes

- ***Peroxisomes*** (very small) = store toxic peroxides – waste products of some rxns.
- ***Vacuoles*** = membrane-enclosed compartment of water and dissolved substances.
  - take in water and enlarge
    - Provide pressure to stretch the cell wall - growth
    - Provide structural support for a plant. ("***turgor pressure***")
  - Store **anthocyanins** (pink & blue pigments)
    - in flowers and fruits; colors attract pollinators
  - Vacuoles in seeds
    - have **digestive enzymes**
      - hydrolyze stored food for early growth

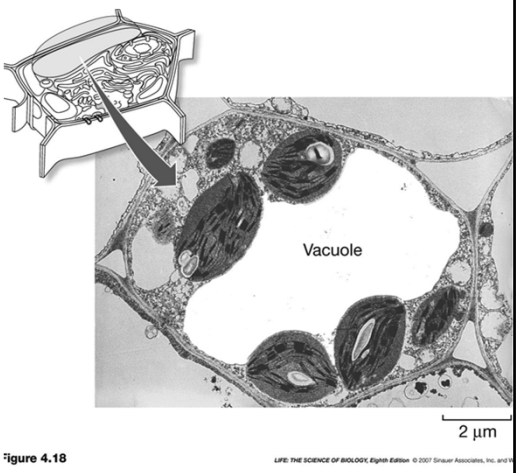

Figure 5.16 Vacuoles in Plant Cells Are Usually Large

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E. The Cytoskeleton

- Within the cytoplasm of eukaryotic cells
- Provides shape, strength, and movement
  - Holds organelles in position.
  - Moves organelles; Involved in cytoplasmic streaming.
  - Interacts with extracellular structures to hold cell in place.
- Consists of **three** interacting **types** of **protein fibers**:
  1) **Microfilaments** (***actin***) = 7 nm thick (diameter).
  2) **Intermediate Filaments** (***keratin, lamins***) = 8-12 nm thick.
  3) **Microtubules** (***tubulin***; hollow) = 25 nm thick.

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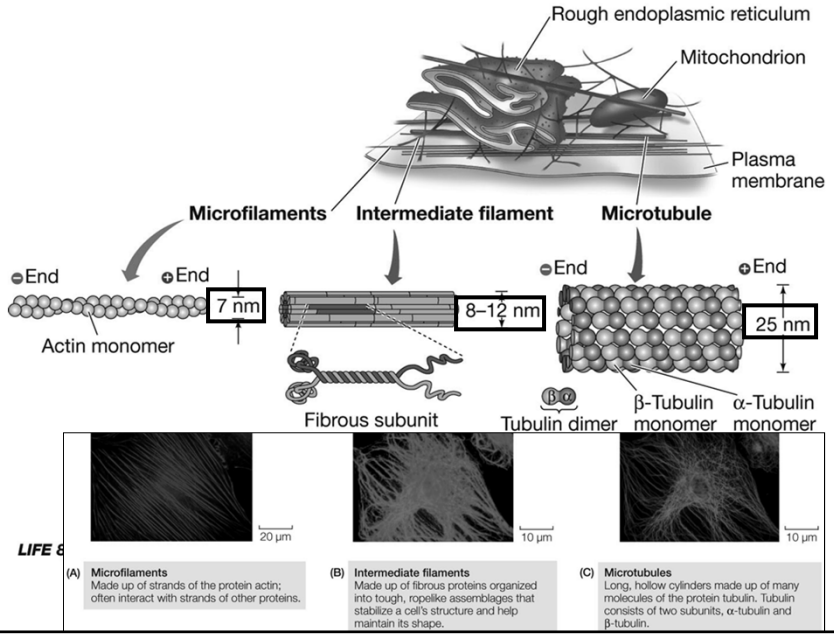
Cytoskeleton

Figure 5.17



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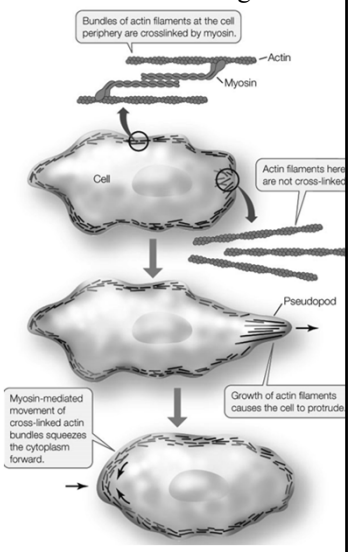
The Cytoskeleton

Figure 5.18

A. Microfilaments:

- = 2 chains of ***actin*** units forming a double helix.
- strengthen cellular structures
- provide movement in animals…
  1) **cell division,**
  2) **cytoplasmic streaming**
     - **(cyclosis),**
  3) **pseudopod extension**
     - **(amoeba, white blood cells)**
  4) **Actin/Myosin → muscle movement**

❖ occur as individual, bundled, or networked fibers



http://micro.magnet.fsu.edu/moviegallery/pondscum/protozoa/amoeba/t1/amoeba05.html

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Microfilaments – microvilli

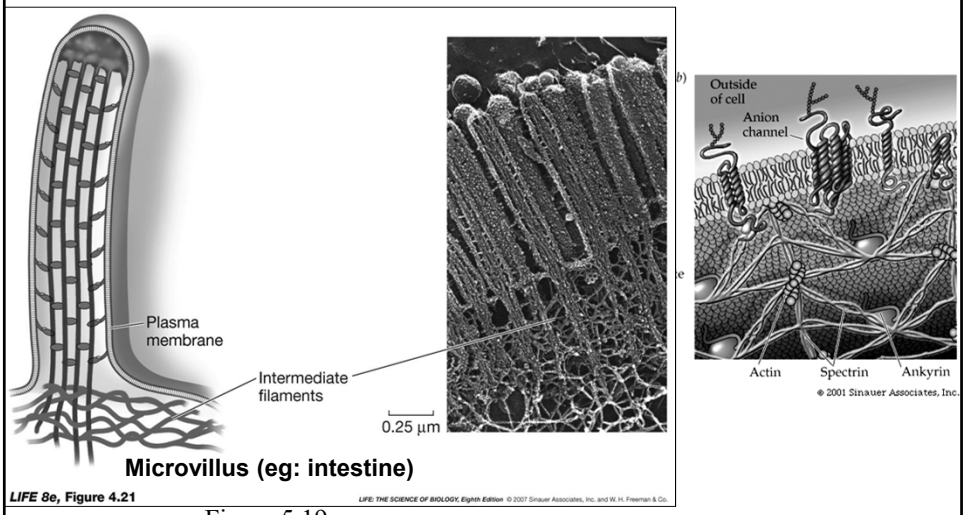

Figure 5.19

http://www.scripps.edu/cb/milligan/research/movies/myosin_mov.html

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The Cytoskeleton

B. <u>Intermediate filaments</u> are
1) formed of ***keratins*** (and ***lamin***)
2) add strength to cell attachments in multicellular organisms

C. <u>Microtubules</u> are
1) composed of dimers of the protein ***tubulin***
2) can lengthen and shorten

3) <u>Cilia</u> and <u>flagella</u> (Eukaryotic!)
- ***9 + 2 pattern*** **of microtubules.**

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Cilia & Flagella

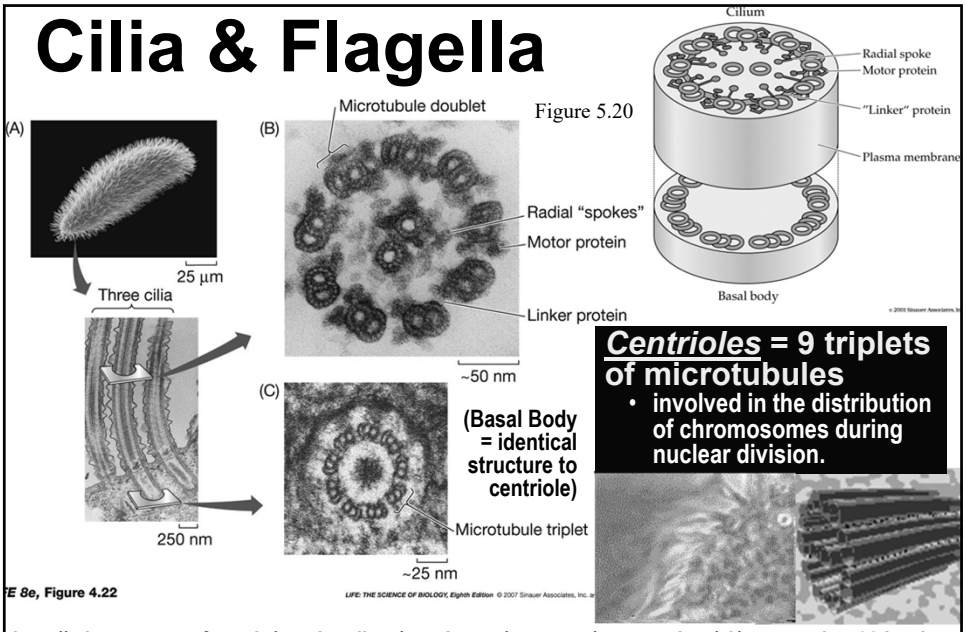

Figure 5.20

Centrioles **= 9 triplets of microtubules**

- **involved in the distribution of chromosomes during nuclear division.**

(Basal Body = identical structure to centriole)

http://micro.magnet.fsu.edu/moviegallery/pondscum/protozoa/paramecium/t1/paramecium08.html
http://www.northland.cc.mn.us/biology/Biology1111/animations/flagellum.html
http://www.bioscope.org/taste/cd1/a0255a.htm

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The Cytoskeleton


The Muscle Group, Leeds 2000

- Movements of cilia and flagella
  - due to binding of the motor protein dynein to microtubules.
- Microtubules also bind ***motor proteins*** that move organelles through the cell (***dynein*** and ***kinesin***).
  - **Dynein** = **minus end**-directed motor.
  - **Kinesin** = **plus end**-directed motor.
    - http://www.rpi.edu/dept/bcbp/molbiochem/MBWeb/mb2/part1/movies/kinesin.dcr
    - http://www.scripps.edu/cb/milligan/research/movies/kinesin_mov.html

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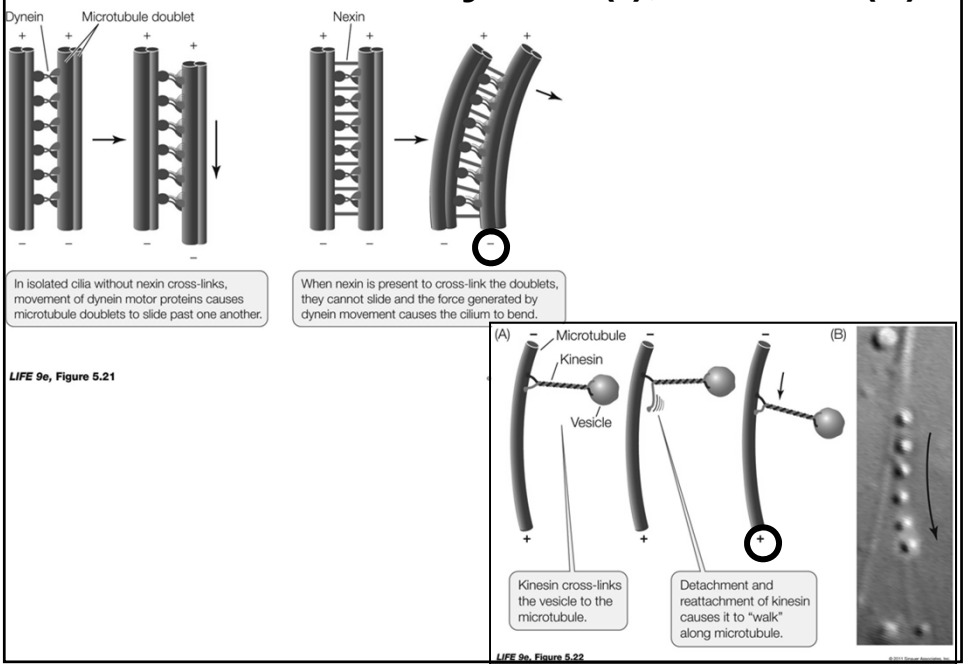
Motor Proteins: Dynein (-), Kinesin (+)



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F. Extracellular Structures

- **= *Materials external to the plasma membrane***
- provide **protection, support, and attachment** for cells in multicellular systems

1. Plants, Bacteria, Fungi = **cell wall**
   - (cellulose, peptidoglycan, chitin)
2. Animals = **extracellular matrix**

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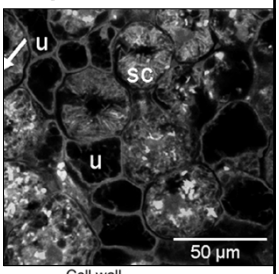
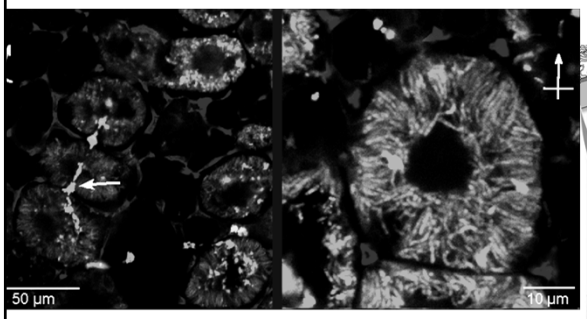
1. Plant Cell Wall

- Cell walls of plants consist principally of ***cellulose***
  - = pierced by plasmodesmata that join the cytoplasm of adjacent cells





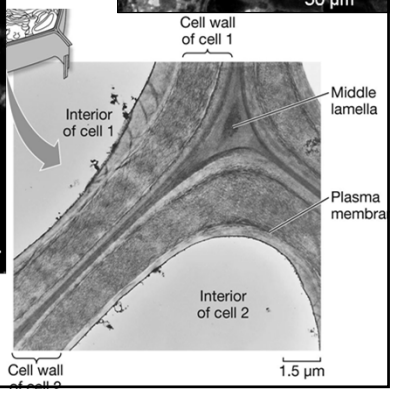


Fig. 4.24/5.24

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2. Animal Extracellular Matrix

- In multicellular animals, the ECM consists of different proteins, including ***proteoglycan***.
- In bone and cartilage, ***collagen*** predominates.

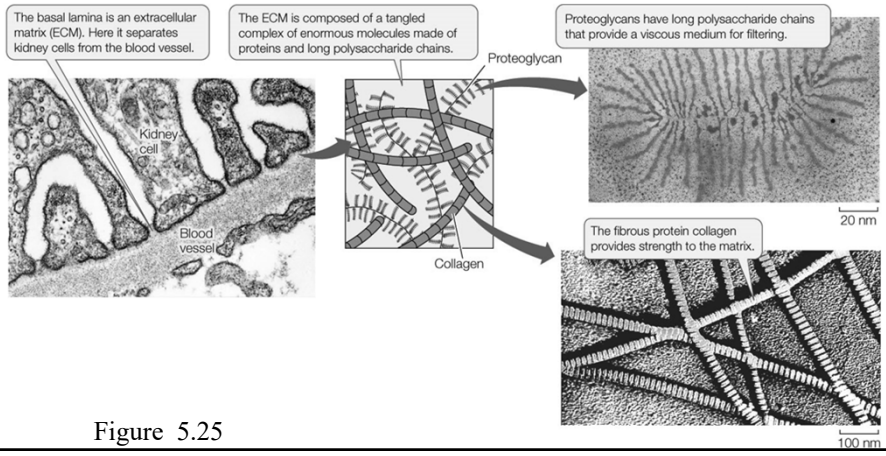

Figure 5.25

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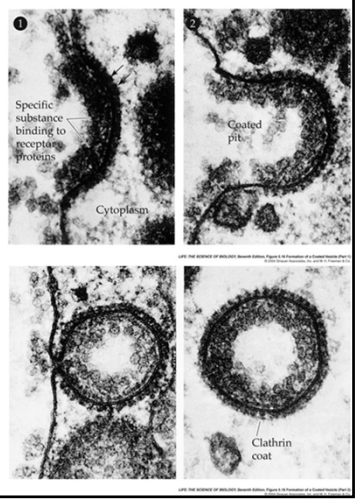
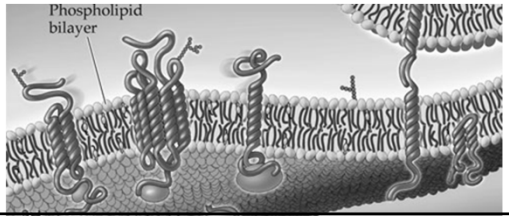
Ch. 6:
Cellular Membranes

1. Membrane Composition and Structure
2. Cell Adhesion
3. Passive Processes of Membrane Transport
4. Active Transport
5. Endocytosis and Exocytosis
6. Membranes Are Not Simply Barriers
7. Membranes Are Dynamic





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6.1) Membrane Composition & Structure

❖ Components of biological membranes:
- Lipids
- Proteins
- Carbohydrates

❖ The **fluid mosaic model**:
- a phospholipid bilayer in which membrane proteins move laterally within the membrane.

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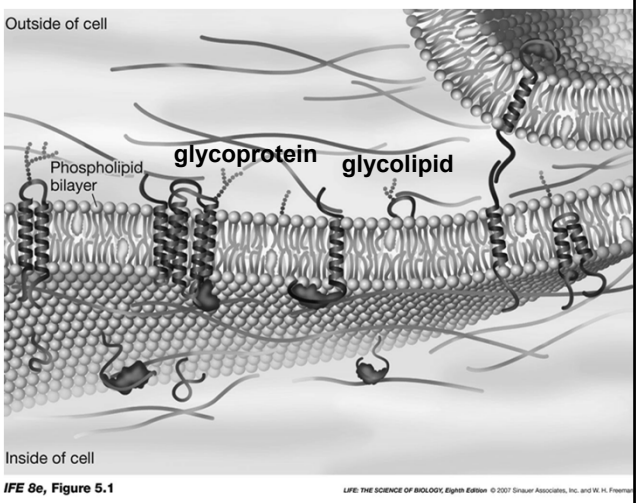
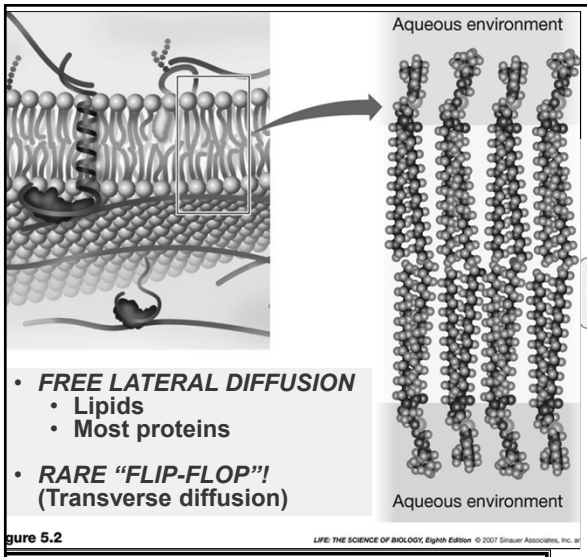
A. * Fluid Mosaic Model *

1. **Phospholipid Bilayer**
2. **Cholesterol**
3. **Integral membrane proteins**
   - embedded
4. **Peripheral membrane proteins**
   - surface of bilayer
5. **Cell-Cell Adhesion**



http://www.bio.davidson.edu/people/macampbell/111/memb-swf/membranes.swf

29

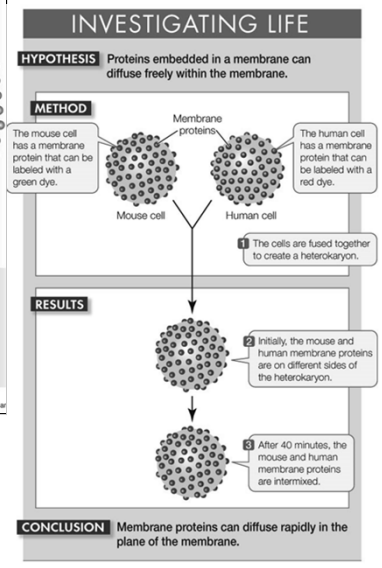


- *FREE LATERAL DIFFUSION*
  - **Lipids**
  - **Most proteins**
- *RARE "FLIP-FLOP"!* **(Transverse diffusion)**

Cell Fusion Experiment:

1. Labeled proteins in PMs of 2 different cells
2. Fuse together
3. Over time, the PM proteins from each original cell freely diffuse
   - → uniform distribution

Figure 6.5 Rapid Diffusion of Membrane Proteins



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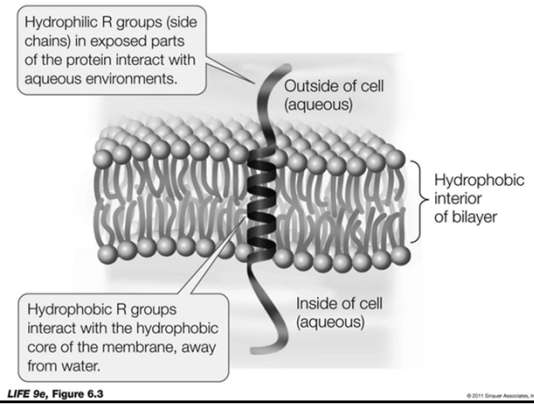
Membrane Composition & Structure

- **Integral membrane proteins** are partially inserted into the phospholipid bilayer.
- **Peripheral proteins** attach to its surface by ionic bonds.



LIFE 9e, Figure 6.3

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Membrane Composition and Structure

- The ***two surfaces of a membrane may have different properties*** due to different
  1. **phospholipid compositions,**
  2. **exposed domains of integral membrane proteins,**
  3. **peripheral membrane proteins.**
- Defined regions of a plasma membrane may have different membrane proteins.

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B. Cell-Cell Recognition

- Carbohydrates attached to proteins or phospholipids project out from PM
  - function as recognition signals between cells.

- In an organism or tissue,
  - cells recognize and bind to each other
  - by means of membrane proteins protruding from the cell surface.

http://aimediaserver4.com/studiodaily/videoplayer/?src=ai4/harvard/harvard.swf&width=640&height=520

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SPONGE CELLS

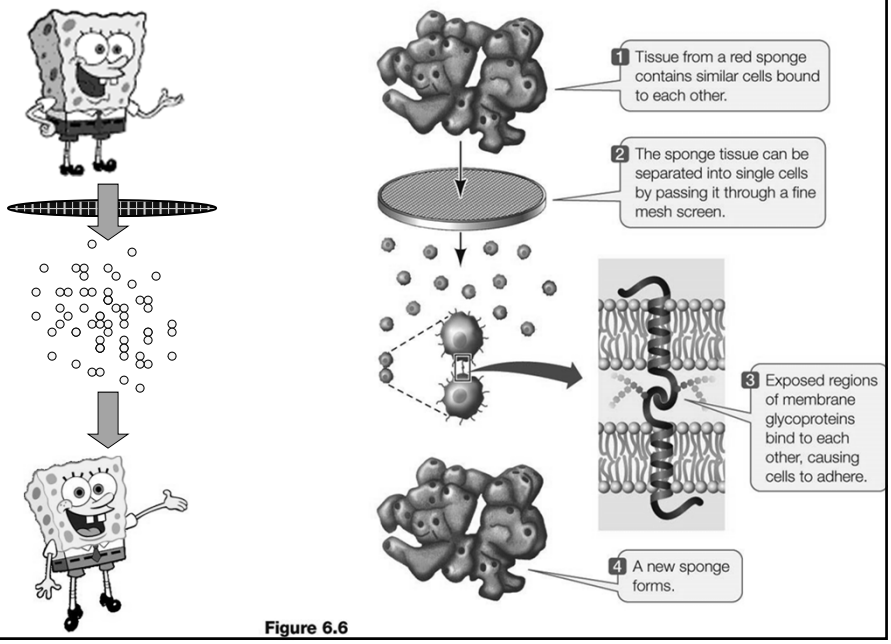

Figure 6.6

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6.2) Cell Adhesion

1. **Tight junctions**
   - prevent passage of molecules through space around cells
   - restrict migration of membrane proteins over the cell surface
     - define functional regions of the plasma membrane

2. **Desmosomes** allow cells to adhere strongly to one another.

3. **Gap junctions** = channels for chemical and electrical communication between cells.

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Tight Junctions & Desmosomes: EPITHELIAL TISSUES

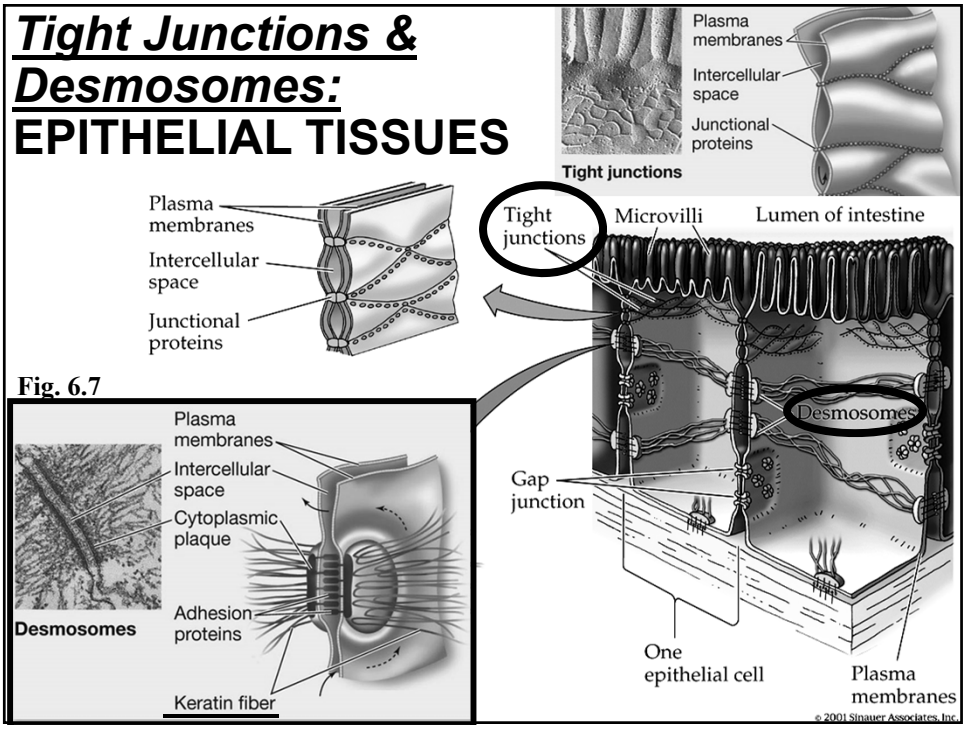

Fig. 6.7

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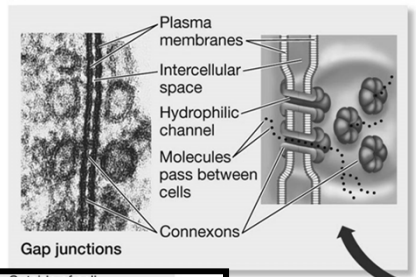
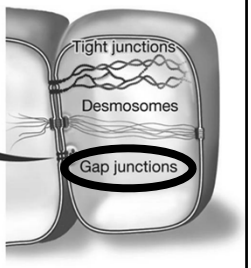
Gap Junctions: MUSCLES, NERVES

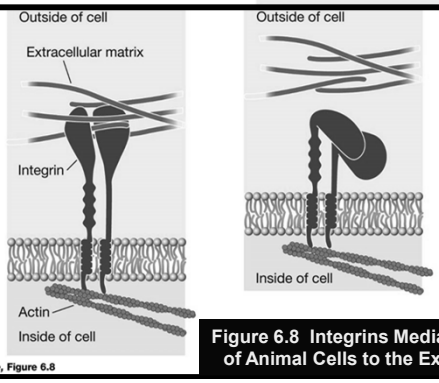




LIFE: THE SCIENCE OF BIOLOGY, Eighth Edition © 2007 Sinauer Associates, Inc. and W. H. Freeman & Co.

Fig. 6.7

Integrins:



LIFE 9e, Figure 6.8

Figure 6.8 Integrins Mediate the Attachment of Animal Cells to the Extracellular Matrix

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6.3) ***SELECTIVE PERMEABILITY***

*** Passive Membrane Transport ***

- Substances can ***diffuse passively*** across a membrane by:
  - ***Unaided (simple) diffusion*** through the PL bilayer,
  - ***facilitated diffusion*** through protein channels or
  - by means of a carrier protein

TABLE 5.1

Membrane Transport Mechanisms

TRANSPORT MECHANISM	EXTERNAL ENERGY REQUIRED?	DRIVING FORCE	MEMBRANE PROTEIN REQUIRED?	SPECIFICITY
Simple diffusion	No	With concentration gradient	No	Not specific
Facilitated diffusion	No	With concentration gradient	Yes	Specific
Active transport	Yes	ATP hydrolysis (against concentration gradient)	Yes	Specific

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Diffusion and Equilibrium

- Solutes diffuse across a membrane from regions of
  - **greater [solute] → lesser [solute] (NET!)**
- Equilibrium = is *often* when the concentrations are identical on both sides
  - **[solute] inside = [solute] outside**

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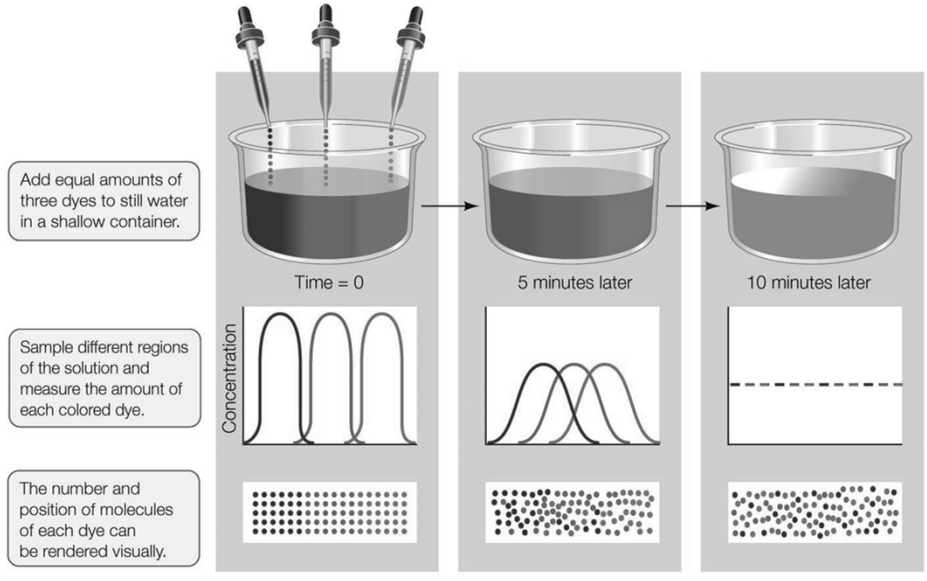
Figure 6.9 Diffusion Leads to Uniform Distribution of Solutes



LIFE 9e, Figure 6.9

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Diffusion Rate Across Membranes:

A. Simple Diffusion

- The **rate** of simple diffusion of a solute across a membrane
- is directly proportional to the **concentration gradient** across the membrane.
  - ***(= difference inside vs outside)***
  - **lipid-solubility** of the solute is also important!
  - **Size** of the molecule!

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Osmosis

- **= water diffuses from regions of higher water concentration to regions of lower concentration.**
  - ***From less solute → more solute***
- In ***hypo*tonic solutions**, cells tend to take up water
- In ***hyper*tonic solutions**, cells tend to lose water
  - Animal cells must remain ***iso*tonic** to the environment to prevent destructive loss or gain of water.

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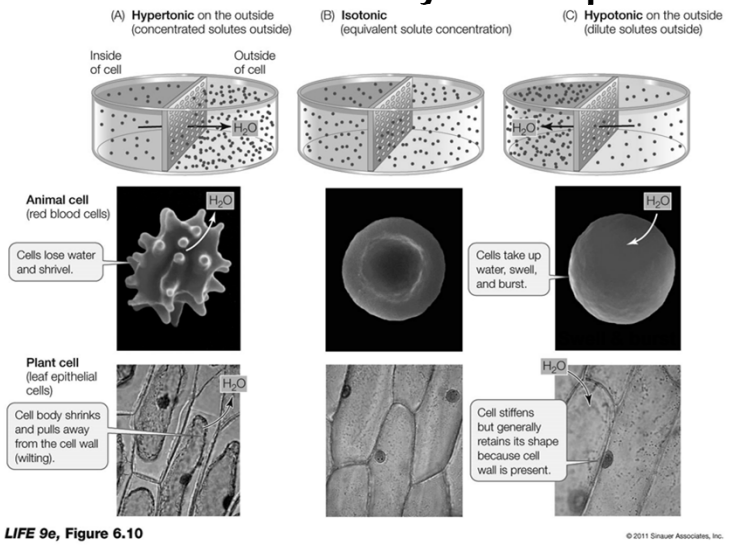
Fig. 6.10 Osmosis Can Modify the Shapes of Cells



- **Cell walls** prevent some cells from bursting under hypotonic conditions.
  - → **Turgor Pressure:** support plant, stretch cells during growth

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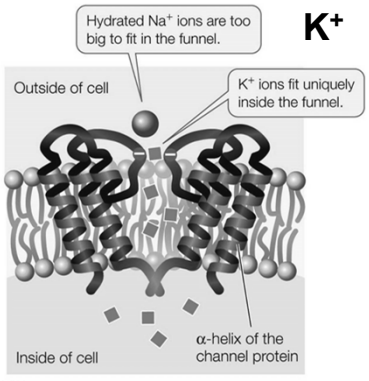
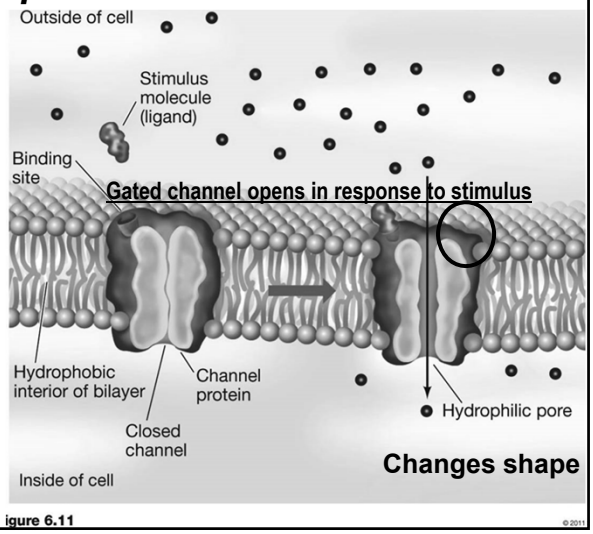
B. Facilitated Diffusion

- Requires **Channel** proteins & **carrier** proteins.
  - **Passive = no *external* energy required.**
    - ***Exergonic! / Spontaneous***

Channel Protein





6.12 igure 6.11 © 2011

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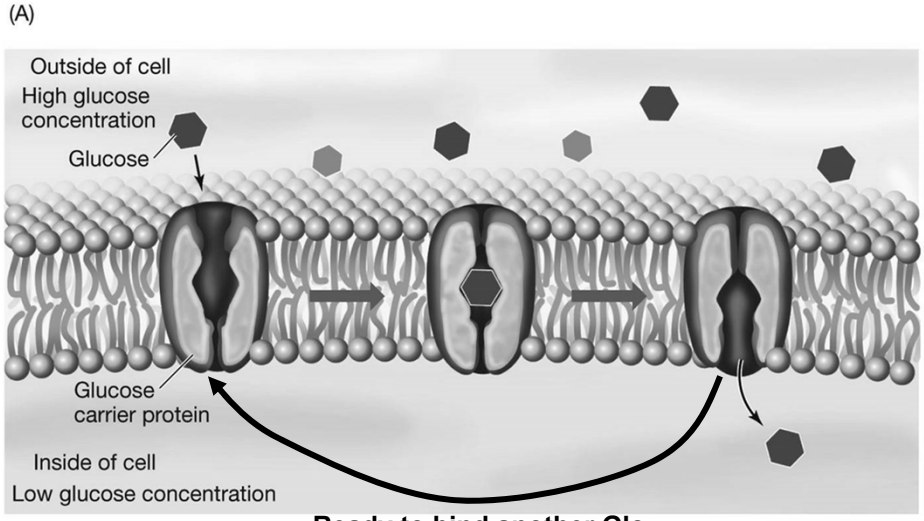
Carrier Protein



Ready to bind another Glc

LIFE 9e, Figure 6.14 (Part 1)

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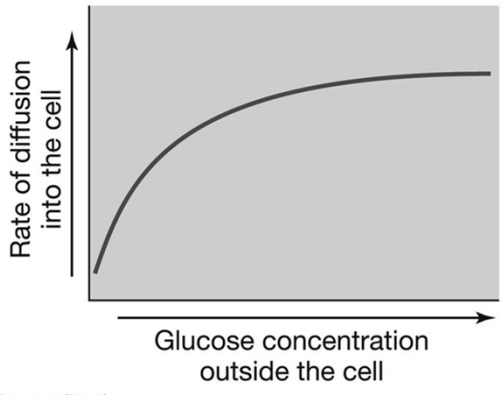
Passive Processes of Membrane Transport

❖ ***Maximum rate of carrier-mediated facilitated diffusion = when solute concentration saturates the carrier proteins***

- no rate increase is observed with further solute concentration increase!!
  - **All available carriers are busy/occupied!!**

Protein-Mediated Processes have:

1. ***Specificity!***
2. ***Saturation, &***
3. ***[Competition…]***



9e, Figure 6.14 (Part 2)

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C. Active Transport:

- **<u>requires energy</u> to move substances across a membrane <u>against a concentration gradient</u>**
  - ***Endergonic/ nonspontaneous!!***; eg: use ATP

TABLE 6.1

Membrane Transport Mechanisms

	SIMPLE DIFFUSION	DIFFUSION THROUGH CHANNEL	FACILITATED DIFFUSION	ACTIVE TRANSPORT
Cellular energy required?	No	No	No	Yes
Driving force	Concentration gradient	Concentration gradient	Concentration gradient	ATP hydrolysis (against concentration gradient)
Membrane protein required?	No	Yes	Yes	Yes
Specificity	No	Yes	Yes	Yes

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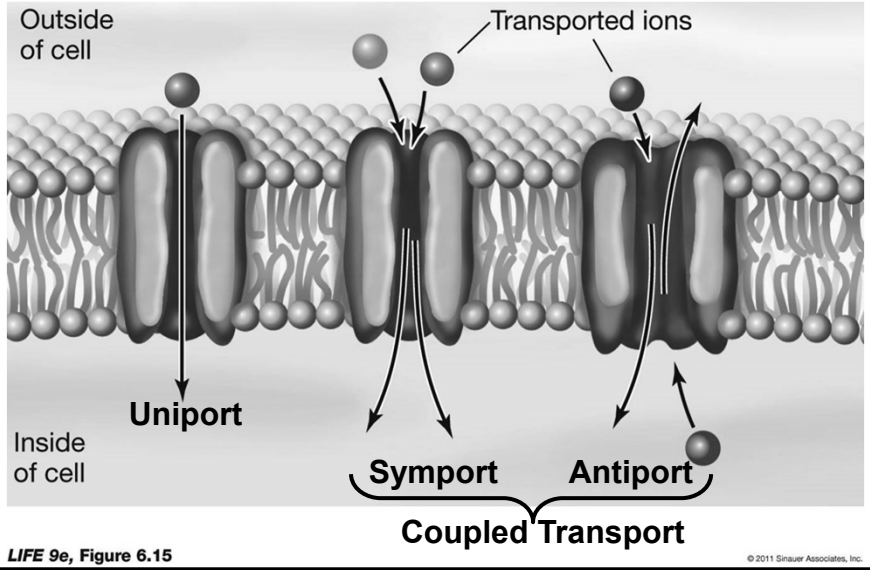
Active transport proteins = uniports, symports, or antiports



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Active Transport

1. **PRIMARY** – energy from the hydrolysis of ATP is used to move ions into or out of cells *against their concentration gradients*.
   - **= *"DIRECT Active Transport"***

2. **SECONDARY** – ***couples*** the
   a) **Passive** movement of one solute with its concentration gradient to
   b) **Active** movement of another solute against its concentration gradient
      - Energy from ATP is used indirectly (thru Prim. Act. Transp. of first solute) = ***"INDIRECT A.T."***

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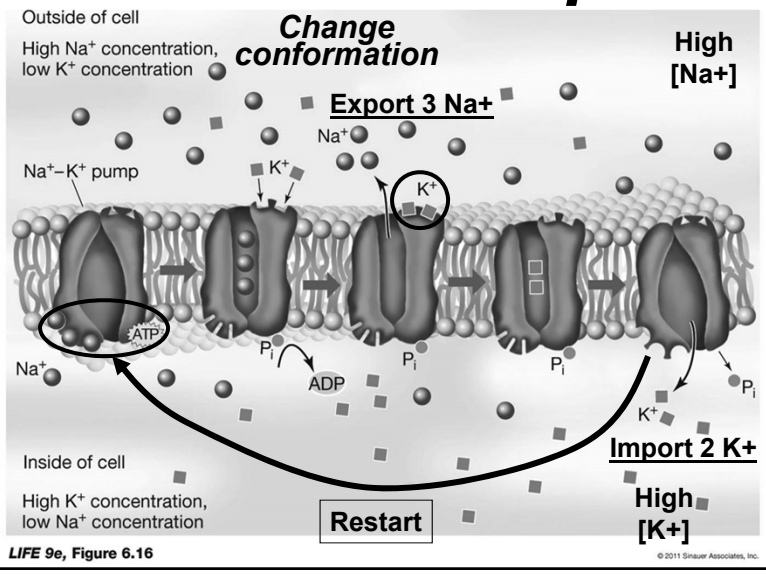
1. Na+/K+ Pump: *1° Active Transport*



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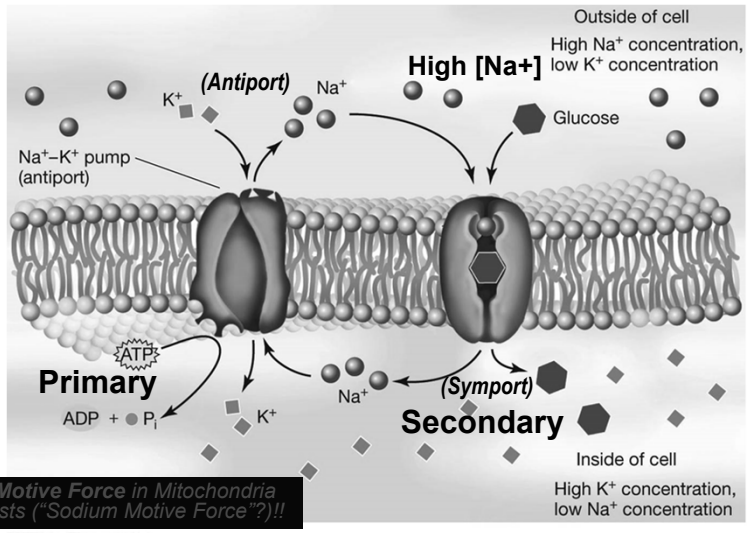
2. Glc/Na+ Symport: *2° Act. Transp*



*Like **Proton Motive Force** in Mitochondria and Chloroplasts ("Sodium Motive Force"?)!!*

LIFE 9e, Figure 6.17

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D. Endocytosis and Exocytosis

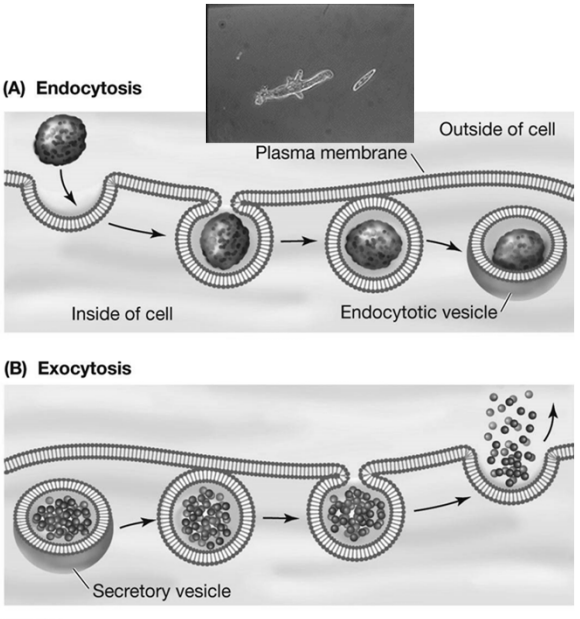

Figure 6.18

Move macromolecules into and out of cells

- **Phagocytosis = cell eating**
  - Large particles
- **Pinocytosis = cell drinking**
  - Small particles

http://www.stolaf.edu/people/giannini/flashanimat/cellstructures/phagocitosis.swf

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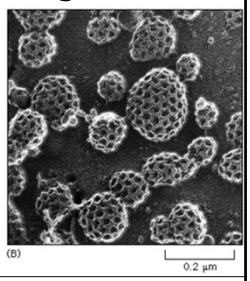
* Receptor-Mediated Endocytosis

- = a specific membrane receptor binds to a particular macromolecule.
  - ***Clathrin***-coated pits → ***Coated vesicles***

http://youtu.be/-ZFnO5RY1cU



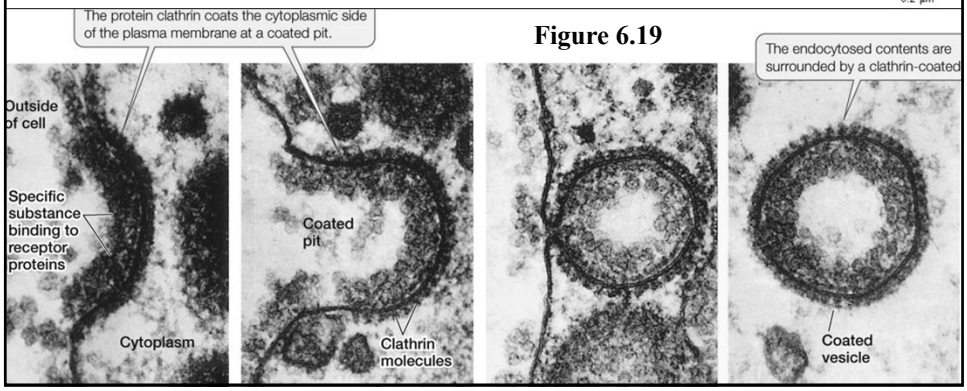


Figure 6.19

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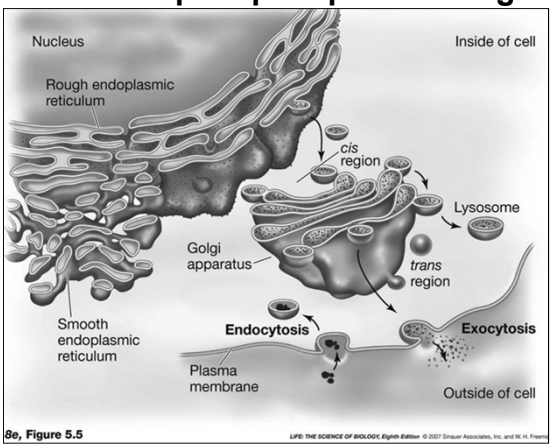
Membranes Are Dynamic!

- Membranes cycle between the ER and the PM by exocytosis and endocytosis.
  - **RER → New membrane proteins → Golgi → PM**
  - **SER → New membrane phospholipids → Golgi → PM**



Molecular Detail!:
http://stke.sciencemag.org/content/sigtrans/vol2001/issue88/images/data/re1/DC1/animation1.swf

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Membranes Are Not Simply Barriers

= SITES FOR:

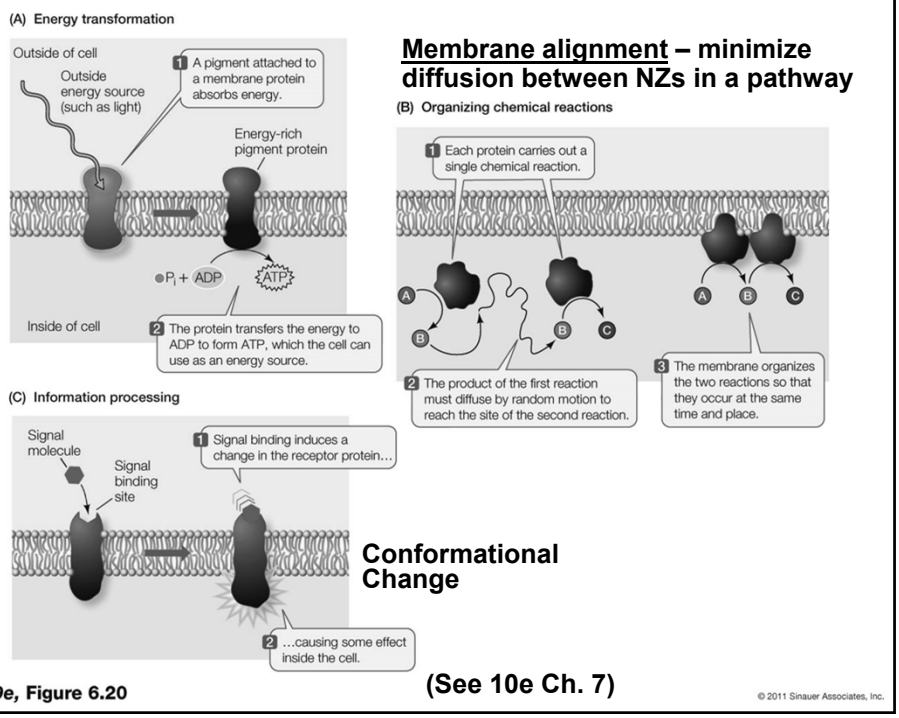
1. recognition and initial processing of extracellular signals
2. energy transformations
3. organizing chemical reactions

http://bcs.whfreeman.com/thelifewire/content/chp05/0502003.html

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__lysosomes.html

http://www.sumanasinc.com/webcontent/animations/content/organelles.html

55



Membrane alignment – minimize diffusion between NZs in a pathway

Conformational Change

***LIFE 9e*, Figure 6.20**

(See 10e Ch. 7)

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