A History of Advances in Cell Theory

A very primative compound microscope was invented by Zacharias and Hans Janssen

1665

Robert Hooke termed the structures he viewed "cells" in *Micrographia,* the first work devoted to micoscropy.

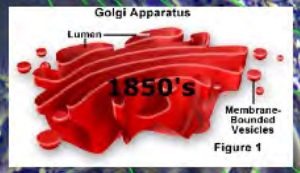
1760's

In Holland, while looking at pond water under the microscope, Anton Von Leeuwenhoek discovered protozoa. He called the microorganims "animalcules" in a letter to the Royal Society.

With microscope advancements, Leeuwenhoek identified bacteria for the first time.

Biologist and abbot, Lazzao Spallanzani of Italy, conducted several experiments concluding that organisms are derived from other organisms. This created a new gap between the living and nonliving.

Major microscope advancements and improvements in histological techniques made way for future microbiological advancements.



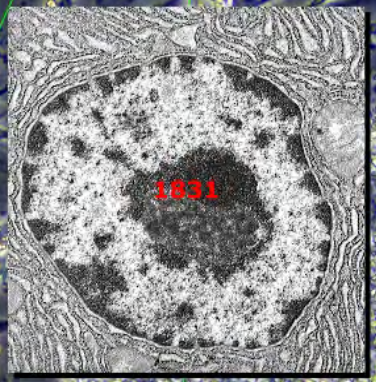
1957

Green florescent protein (GFP) was introduced as a marker to follow protein activity in cells.

Lazarides and Weber were the first to use fluorescent antibodies to stain the cytoskeleton.

1898

The phospholipid, bilayer of the cellmembrane was first described after being made visible by the electron microscope.



1902

The electron microscope was invented and allowed for the indentification of the intracellular structures that had not been seen up to that point.

Golgi discovered the apparatus, named after him, by staining cells with silver nitrate.

Boveri links chromosomes and heredity by observing chromosome behavior during sexual reproduction.

Robert Brown, a botanist,identified and termed the "nucleus" as an essential constituent to all living cells.

Schleiden and Schwann proposed the cell theory, stating that the nucleated cell is the foundation for all plant and animal tissue.

Robert Remak, Rudolf Virchow, and Albert Kolliker were able to demonstrate that all cells come from pre-existing cells, adding to the cell theory.

References:

Harris, H. *The birth of the cell.* Yale University Press, New Haven, CT, (1998).

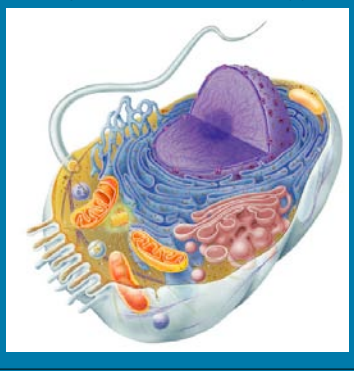
Mazzarello, Paolo, *A unifying concept: the history of cell theory*. Nature Cell Biology 1(1): E13-E15 (1999).

Mayr, E. *The growth of biological thought.* Belknap, Cambridge, MA, (1982).

Images:

www.en.academic.ru, www.wired.com, www.molecularstation.com, www.eng.ox.ac.uk, www.nsf.gov, www.zunal.com, www.tutornext.com, www.cartage.org.lb

Into the Cell



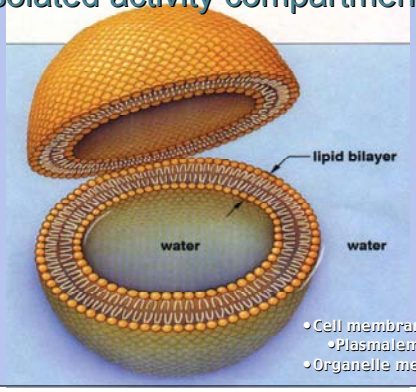
The Cell Theory
"Cell Doctrine"

1. All organisms are constructed of one or more cells.
2. The cell is the basic unit of life.
   - ✓ Minimum level of complexity that exhibits all characteristics of life.
3. All cells derive from previous cells.

What does a cell need?

- Selective isolation from environment (plasma membrane)
- Energy (ATP)
- Instructions (DNA)
- Machinery to carry out instructions and regulate processes (proteins)
- Compartmentalization of incompatible or specialized activities (organelles)

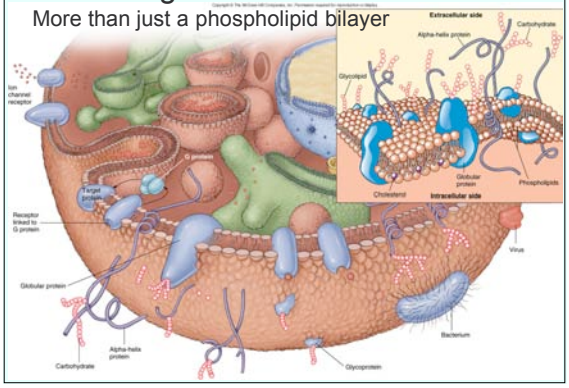
Isolated activity compartments



- Cell membrane
- Plasmalemma
- Organelle membranes

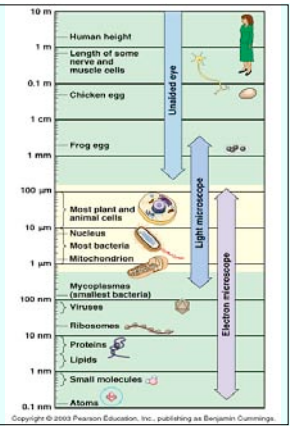
Cell & Organelle Membranes:

More than just a phospholipid bilayer

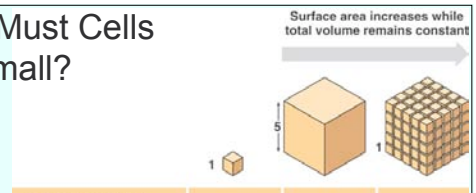


Cell Size Varies with Function

- Human nerve cell: > 1 meter
- Frog egg: 2 mm
- Average animal cell: 50 µm
- Human red blood cell: ~8 um
- Bacteria: 1–2 µm
- Organelle: 1 µm
- Virus: 50 nm



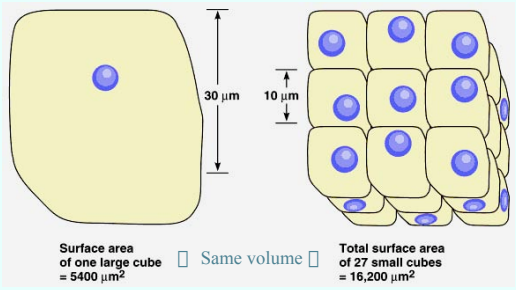
Why Must Cells Be Small?



Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-to-volume ratio (surface area ÷ volume)	6	1.2	6

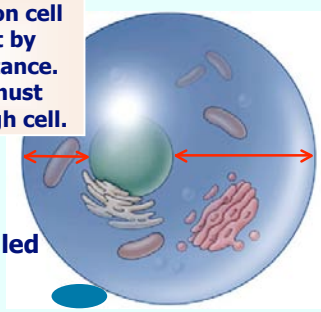
Smaller cells have more total surface area

- Increased surface area makes it easier for gasses, nutrients, etc. to enter a cell



Why Must Cells Be Small?

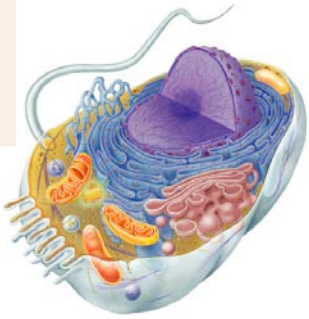
Upper limits on cell size are set by diffusion distance. Molecules must diffuse through cell.



- **Volume controlled by nucleus.**

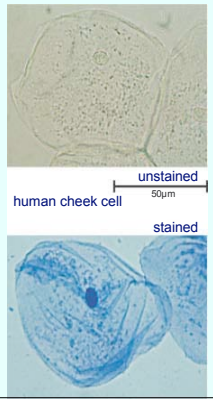
So, Why Can't Cells Be Even Smaller?

- **They must be big enough to hold all their parts!**
- **Macromolecules cannot be shrunk.**



Early views of cells

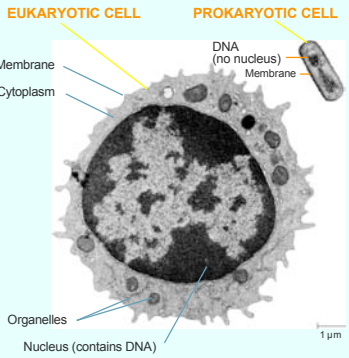
- Plasma membrane
- "Nucleus" ("center")
  - filled with "chromatin" ("colored stuff")
- "Cytoplasm" ("cell fluid")



Modern views of cells

- Better microscopes and stains
  - Electron microscope.
- "Cytoplasm" and "chromatin" much more complicated, structured, and dynamic than previously appreciated.

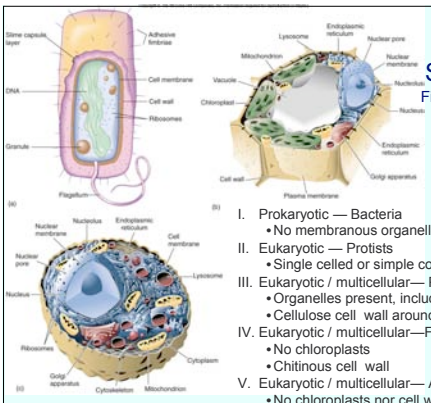
Two major types of cells



Contrasting eukaryotic and prokaryotic cells in size and complexity

Cell-Type Systematics

Five-Kingdom Model



I. Prokaryotic — Bacteria
- No membranous organelles

II. Eukaryotic — Protists
- Single celled or simple colonial

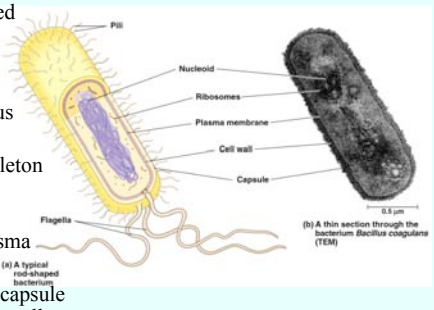
III. Eukaryotic / multicellular— Plant
- Organelles present, including chloroplasts
- Cellulose cell wall around plasma membrane

IV. Eukaryotic / multicellular—Fungi
- No chloroplasts
- Chitinous cell wall

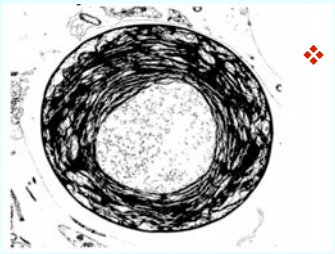
V. Eukaryotic / multicellular— Animal
- No chloroplasts nor cell wall
- Varied cell morphology

Prokaryotic Cell Structure

- Single-celled organisms
- No nucleus nor other membranous organelles
- No cytoskeleton
- Most with cell wall outside plasma membrane
- Some with capsule outside cell wall



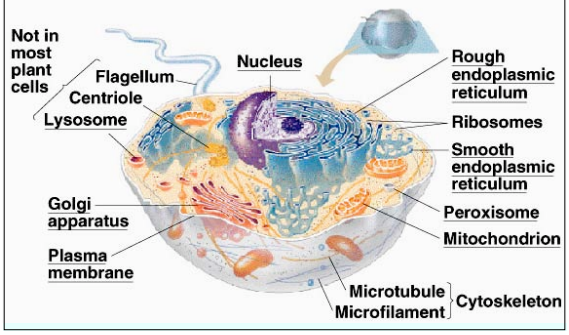
Prokaryotes lack a true endomembrane system



- **The plasma membrane is the only membrane.**

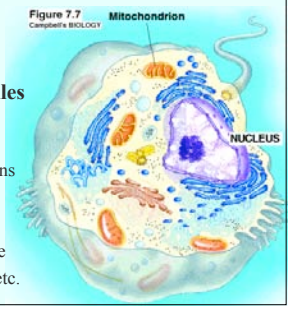
Photosynthetic prokaryote

Eukaryotic Cell Structure —organelles & cytoskeleton

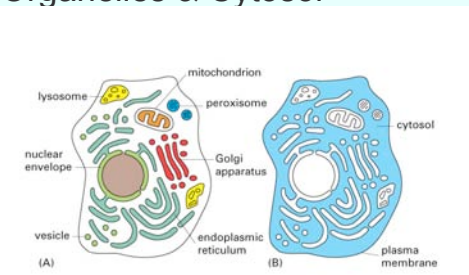


Cytoplasm

- Fills cell; contains
  - **cytosol**
    - fluids and more
    - gel & sol state
  - membrane-bound **organelles**
    - concentrate specific enzymatic activities
    - isolate incompatible reactions or toxic products
  - **cytoskeleton**
    - maintain and alter cell shape
    - hold and move organelles, etc.



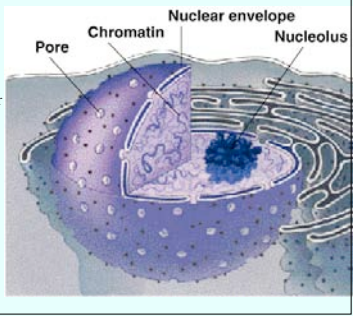
Organelles & Cytosol



- **Cytosol**: Dense, semisolid aqueous gel containing a tremendous variety of solutes and macromolecular machines

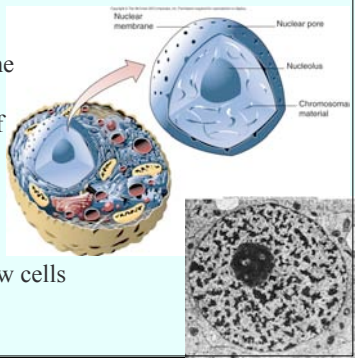
Cellular Organelles

- **Nucleus**
  - Nuclear envelope
  - Nucleolus
    - *Nucleus of nucleus*
    - Transcribes rRNA for ribosomes
  - Chromatin/ chromosomes
  - Nuclear lamina
    - Protein scaffolding underlying the envelope and supporting the chromatin

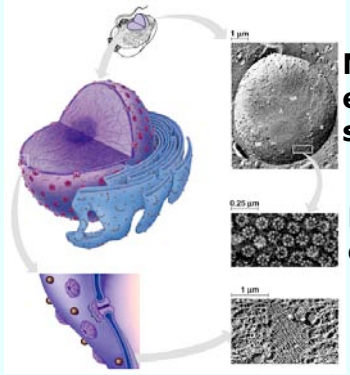


Nucleus

- Double-membrane with pores
- Contains DNA of chromosomes
- Controls cell
  - structure
  - function
- Blueprints for new cells



Nuclear envelope: 2 membranes

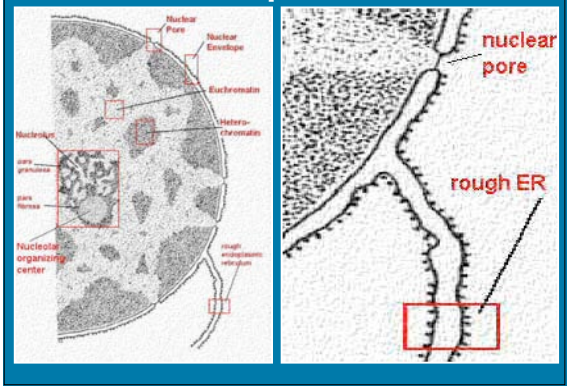


Nuclear envelope surface

Pore complexes

Nuclear lamina

Nuclear envelope: 2 membranes

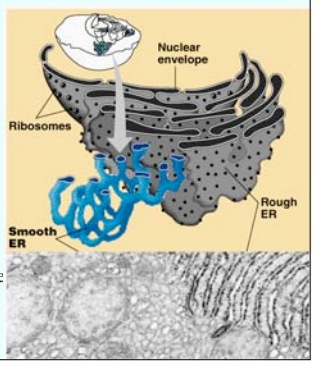


Cellular Organelles

- **Endoplasmic Reticulum**

Smooth E.R.

- New membrane synthesis
- Lipid synthesis & processing
- Steroid synthesis
- Lipophilic detoxification
- Intra-cellular Ca^{++} store
- Usually tubular appearance

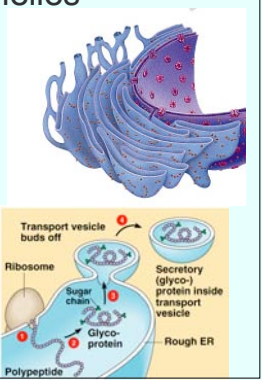


Cellular Organelles

- **Endoplasmic Reticulum**

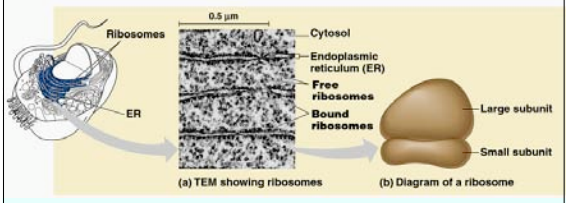
Rough E.R.

- **Ribosome** attachment sites
- Synthesis of membrane proteins
- Synthesis of proteins for secretion or intra-organelle storage
- Flattened beaded stacks; Membrane often continuous with nuclear envelope



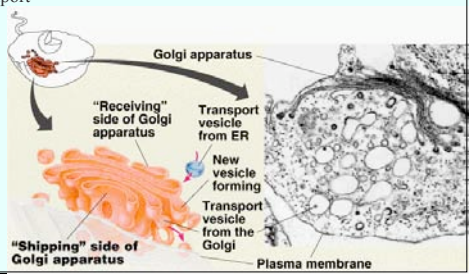
Cellular Organelles

- **Ribosomes**
  - Free and RER-bound



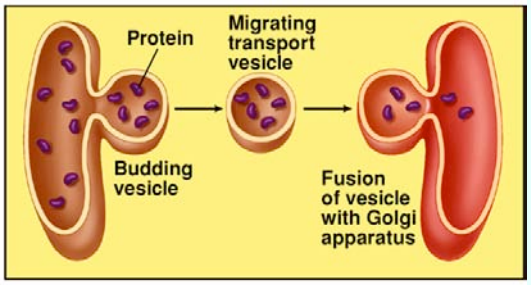
Cellular Organelles

- **Golgi Complex**
  - Further processing and trafficking of proteins from RER
  - Receives vesicles from ER; buds off vesicles to plasma membrane for export

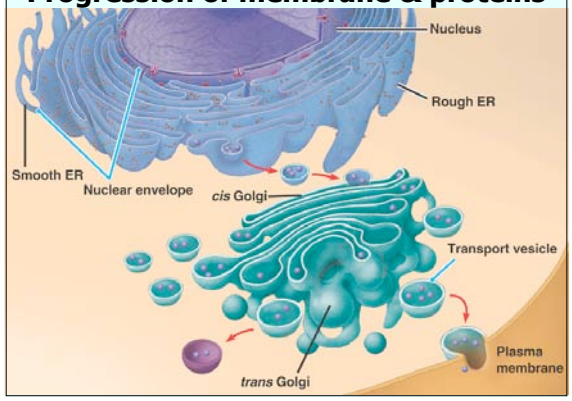


RER to Golgi

Transporting proteins in vesicles

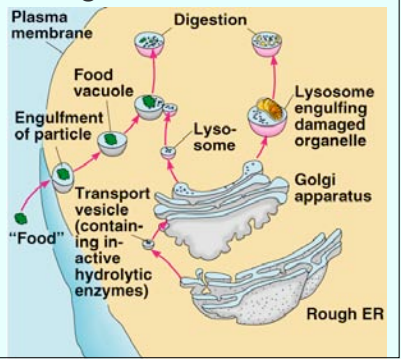


Progression of membrane & proteins



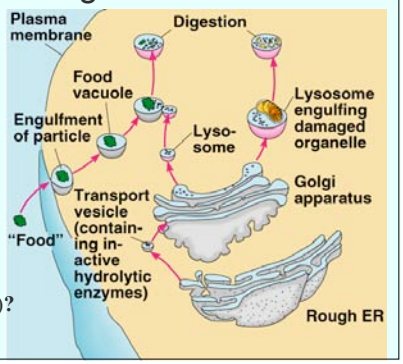
Cellular Organelles

- **Vesicles**
  - Shuttle between organelles and plasma membrane

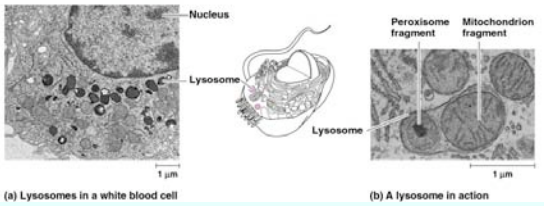


Cellular Organelles

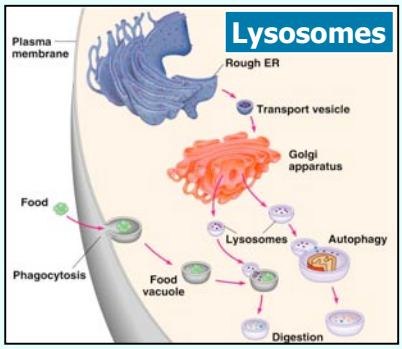
- **Lysosome**
  - **Contains hydrolytic enzymes**
  - Digest food, bacteria, old cell parts
  - Apoptosis (cellular self-destruct)?



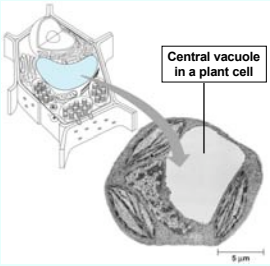
Lysosomes are digestive compartments



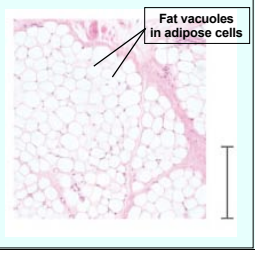
Lysosomes are digestive compartments



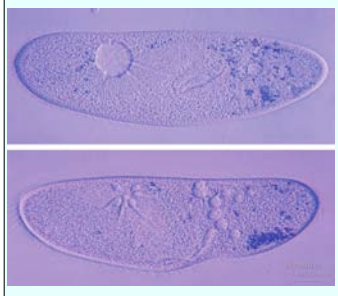
Vacuoles



Large storage vessels



Contractile vacuole

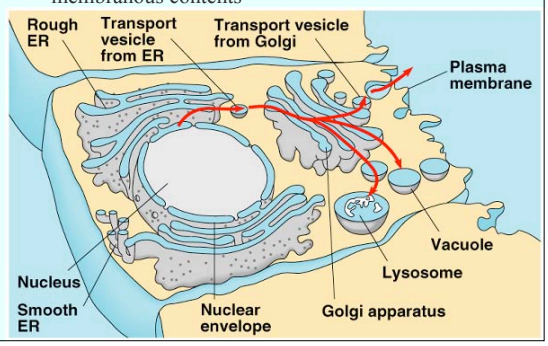


Paramecium lives in fresh water — takes on water by osmosis.

Pumps out water with the contractile vacuole.

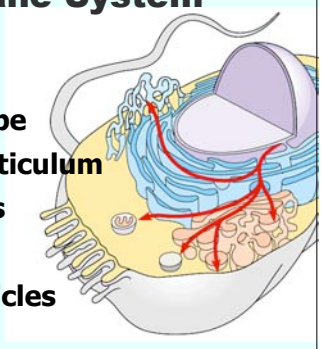
Endomembrane System

- Continuous exchange of membrane and membranous contents



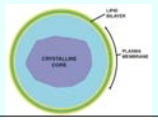
Endomembrane System

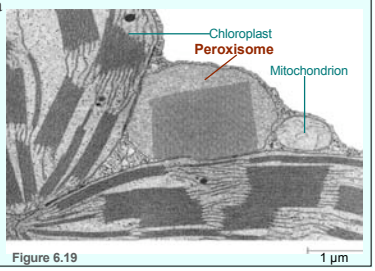
- **Nuclear envelope**
- **Endoplasmic reticulum**
- **Golgi apparatus**
- **Lysosomes**
- **Vacuoles & vesicles**



Peroxisomes

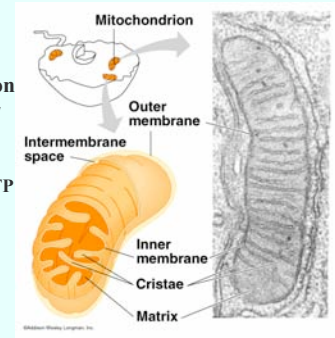
- May form from ER or autonomously
- Both produces and removes hydrogen peroxide
  - Detoxifies organic compounds, e.g. ethanol
  - Destroy bacteria
- ß-oxidation of fatty acids
- Phospholipid synthesis — esp. myelin





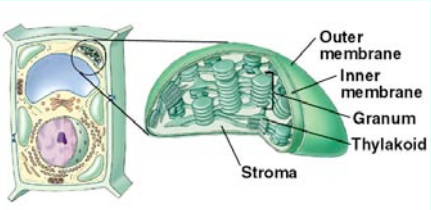
Cellular Organelles: bioenergetics

- **Mitochondria**
  - Double-membrane
  - **Aerobic respiration**
    - *Powerhouse of cell*
    - Converts chemical energy from catabolism into **ATP**
  - Have some of own DNA to maintain activity when nucleus is unavailable

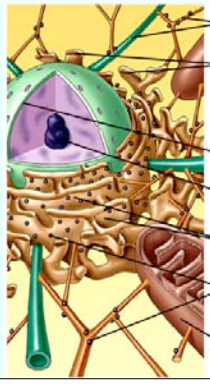


Cellular Organelles: bioenergetics

- **Chloroplast**
  - Triple-membrane
  - **Photosynthesis**
    - uses sunlight to construct organic molecules (CO_2 sugar)
  - Also have some of their own DNA
  - Plants & some protists



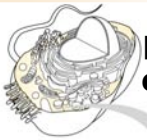
Cytoskeleton



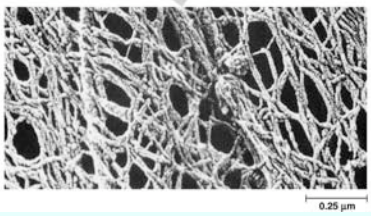
Cytoskeleton

Organizing the organelles

Cytoskeleton

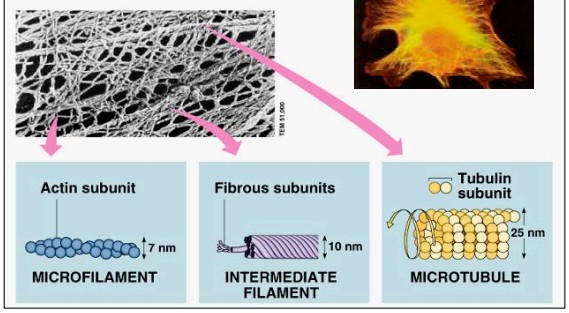


protein framework that extends throughout the cytoplasm

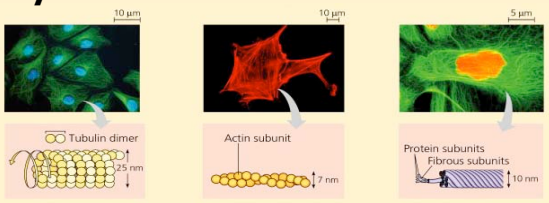


Cell Support Structures

- Cytoskeleton

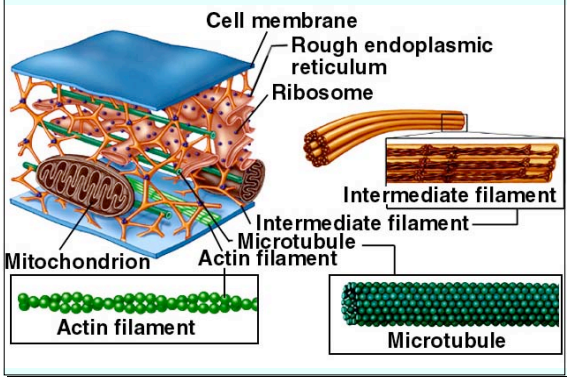


Cytoskeletal structures

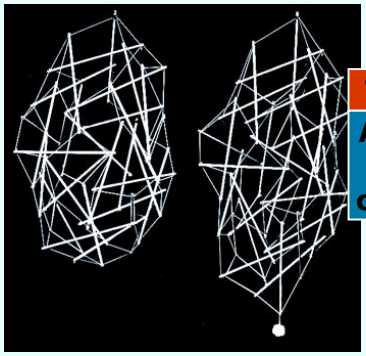


	micro-tubules	micro-filaments	intermediate filaments
structural protein	Tubulin (dimer)	Actin	Keratin (and others)
motor protein	Dynein (and others)	Myosin	∅

Cytoskeleton

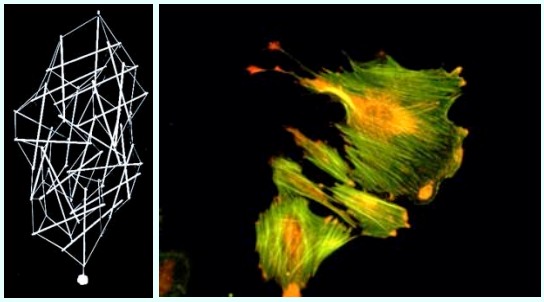


Cytoskeleton



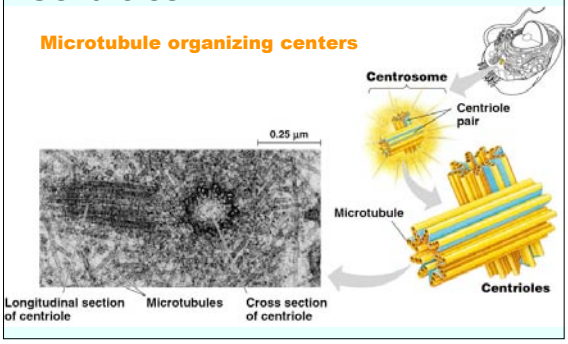
Tensegrity:
A balance of tension & compression

Cytoskeleton

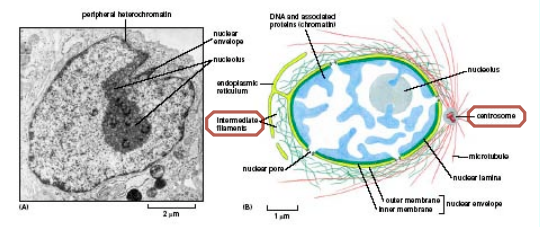


Cellular Structure: Centrioles

Microtubule organizing centers

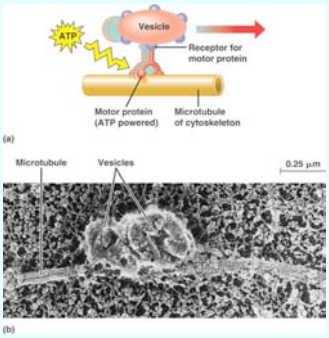


The nucleus & the cytoskeleton



- Intermediate filaments penetrate envelope to connect with nuclear lamina
- Microtubule organizing center adjacent to nucleus

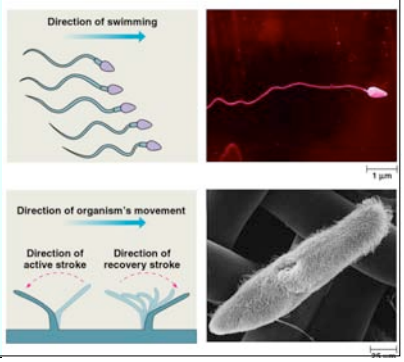
Vesicle transport along microtubule "rails"



ATP energy is used to pull vesicles along microtubules.

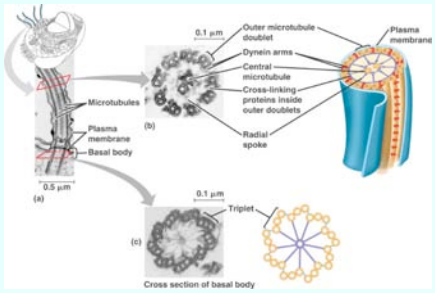
Cell Mobility Structures

- **Flagella**
- **Cilia**

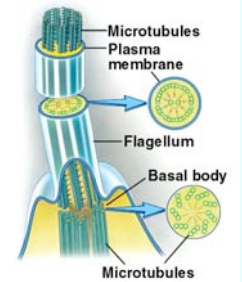


flagella & cilia

Eukaryotic versions

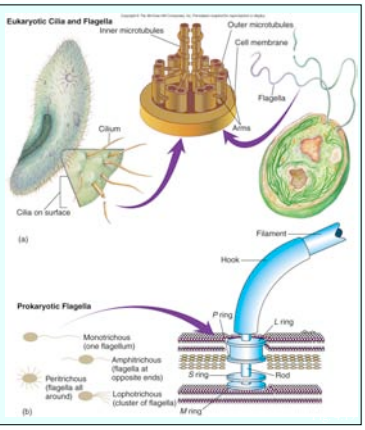


HOW DO CILIA AND FLAGELLA MOVE ?

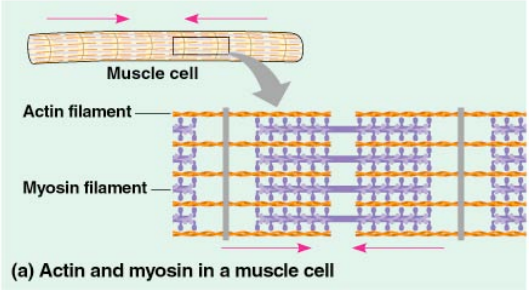


- Dynein arms cause microtubules to bend

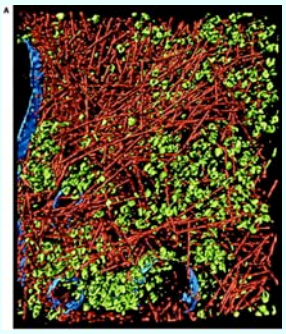
Molecular motors: structure of cilia & flagella



Myosin cross-bridges pull actin filaments along



Cytoskeletal support of cell membrane



Crowded network of cross-linked microfilaments (red) underlying the plasma membrane (blue) .

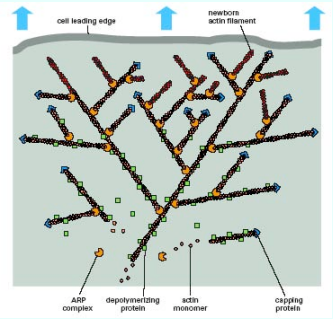
"cytoplasmic cortex"

Cytoplasmic Streaming

- Motor proteins pull cytoplasmic macromolecular complexes and organelles along the microfilament meshwork

Cytoskeleton and pseudopodia

- Selective growth of the microfilament meshwork produces a bulge (pseudopodium) in cell membrane for amoeboid movement or phagocytosis.



The Cell: A Living Unit greater than the sum of Its parts

- Cells rely on the integration of structures and organelles in order to function

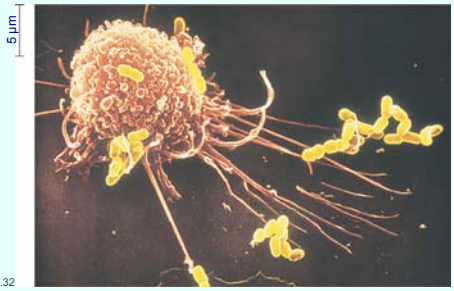


Figure 6.32

Many Variations in Theme