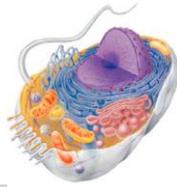


Chapter 7



The cell: Basic unit of Life

Biological diversity & Unity

- Underlying the diversity of life is a striking unity
 - DNA is universal genetic language
 - Cells are the basic unit of structure & function
 - Lowest level of structure capable of performing all activities of life

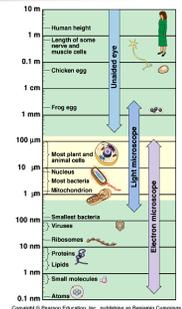
Activities of life

- Most everything you think of a whole organism needing to do, must be done at the cellular level...
 - Reproduction
 - Growth & development
 - Energy utilization
 - Response to the environment
 - homeostasis



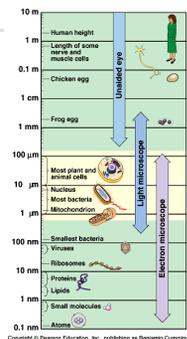
How do we study cells?

- Microscopes
 - Light microscope
 - Electron microscope
 - Transmission electron microscope (TEM)
 - Scanning electron microscope (SEM)



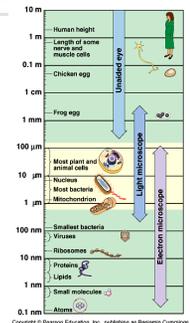
Light Microscope

- 0.2 μm resolution
- ~size of bacterium
- Visible light passed through specimen
- Can be used to study live cells



Electron Microscope

- 1950's
- 2.0 nm resolution
- 100 times > light microscope
- Reveals organelles
- But can only be used on dead cells

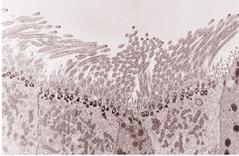


Transmission electron microscope

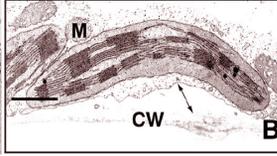
TEM

- Used mainly to study internal structure of cells
 - Aims an electron beam through thin section of specimen

rabbit trachea



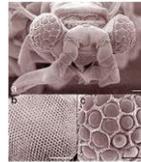
cucumber seed leaf



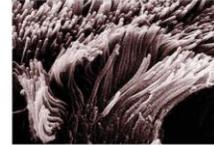
Scanning electron microscope

SEM

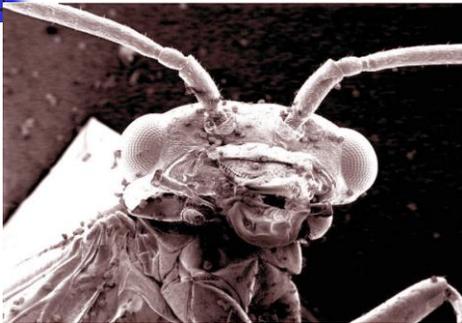
- Studying surface structures
 - Sample surface covered in thin film of gold
 - Beam excites electrons on surface
 - Great depth of field = an image that seems 3-D



rabbit trachea



SEM Images



SEM Images



Tour of the cell

Cell Characteristics

- All cells:
 - Surrounded by plasma membrane
 - Have cytosol
 - Semi-fluid substances within the membrane
 - Cytoplasm = cytosol + organelles
 - Contain chromosomes which have genes in the form of DNA
 - Have ribosomes
 - Tiny organelles that make proteins using instructions contained in genes

Types of cells

- Prokaryotic vs. eukaryotic cells

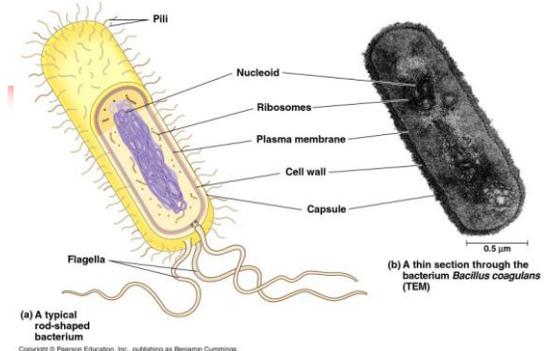
- Location of chromosomes

Prokaryotic cells

- DNA in nucleoid region, without a membrane separating it from the rest of the cell

Eukaryotic cells

- Chromosomes in nucleus, membrane-enclosed organelles



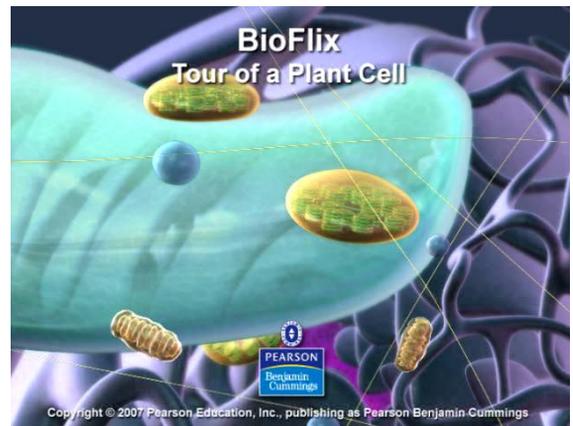
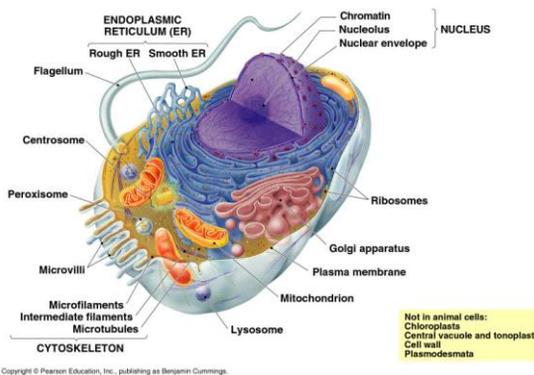
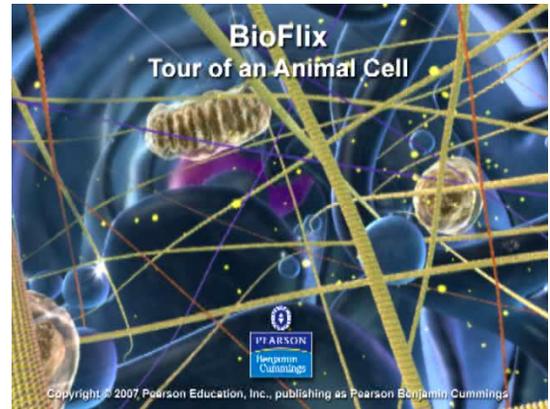
The prokaryote cell is much simpler in structure, lacking a nucleus and the other membrane-enclosed organelles of the eukaryotic cell.

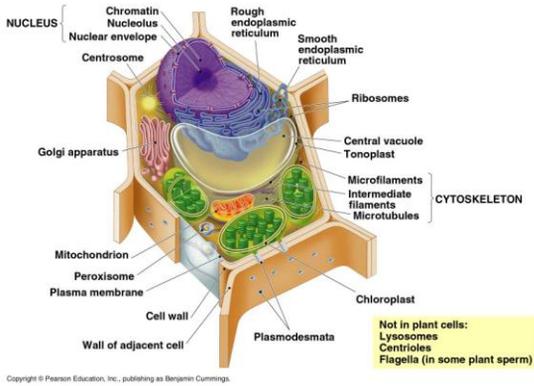
Eukaryotic cells

- Eukaryotic cells are more complex than prokaryotic cells

- Within cytoplasm is a variety of membrane-bounded organelles
 - Specialized structures in form & function

- Eukaryotic cells are generally bigger than prokaryotic cells





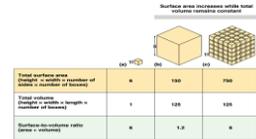
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What limits cell size?

- Surface to volume ratio
 - As cells gets bigger its volume increase faster than its surface area
 - Smaller objects have greater ratio of surface area to volume

What cell organelle governs this?

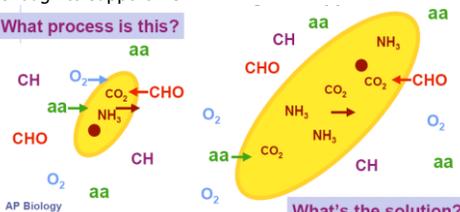
Why is a huge single-cell creature not possible?



Limits to cell size

- Metabolic requirements set upper limit
 - In large cell, cannot move material in & out of cell fast enough to support life

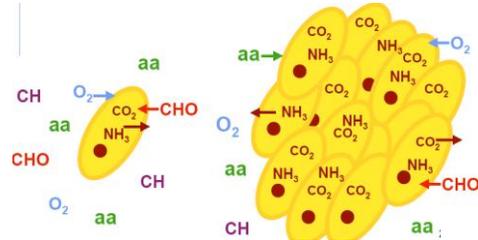
What process is this?



What's the solution?

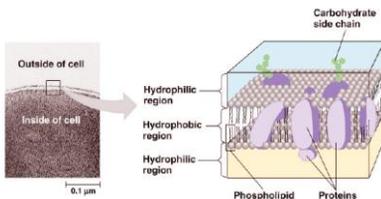
How to become bigger?

- Become multi-cellular (cell divide)
 - What challenges do you have now?



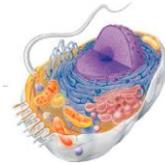
Cell membrane

- Exchange organelle
 - Plasma membrane function as selective barrier
 - Allows passage of O₂, nutrients & wastes



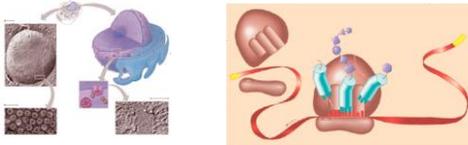
Organelles & internal membrane

- Eukaryotic cell
 - Internal membranes
 - Partition cell into compartments
 - Create different local environments
 - Compartmentalized functions
 - Membrane for different compartments are specialized for their function
 - Different structures for specific functions
 - Unique combinations of lipids & proteins



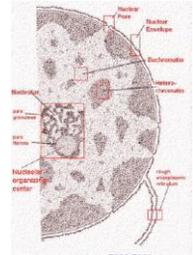
Chapter 7: The cell

Nucleus and Ribosomes



Nucleus

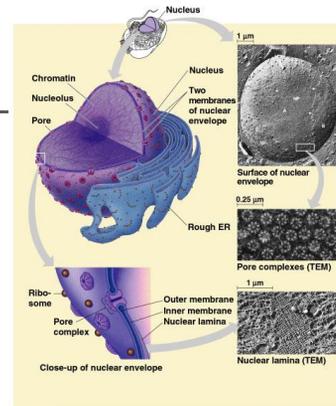
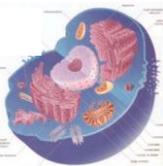
- Function
 - Contains eukaryotic cell's genetic library
 - Most genes in nucleus
 - Some genes located in mitochondria & chloroplasts
- Size
 - ~5 microns (μm) in diameter



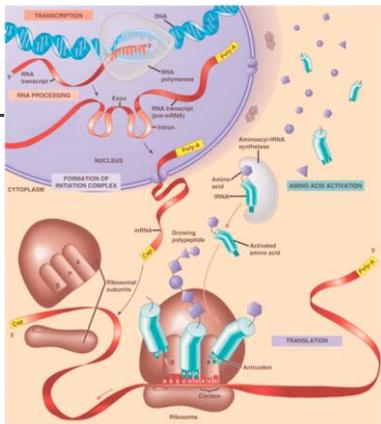
Nucleus structure

- Structure
 - Separated from cytoplasm by a double membrane, nuclear envelope
 - Double membrane is fused in spots forming pores
 - Allows large macromolecules & particles to pass through

What kind of molecules would need to pass through?

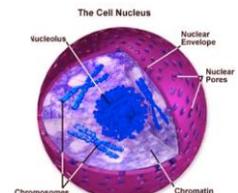


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Nucleus Structure

- Within nucleus, DNA organized into fibrous material, chromatin
 - In normal cell appears as diffuse mass
- When cell prepares to divide, chromatin fibers coil up separate structures, chromosomes



Nucleus structure

- Densely stained region = nucleolus
- Function
 - Production of ribosomal subunits from rRNA & protein
 - Pass through nuclear pores to cytoplasm & combine to form ribosomes

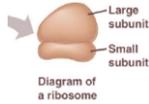
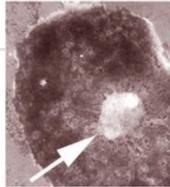


Figure 7.7 Overview of an animal cell

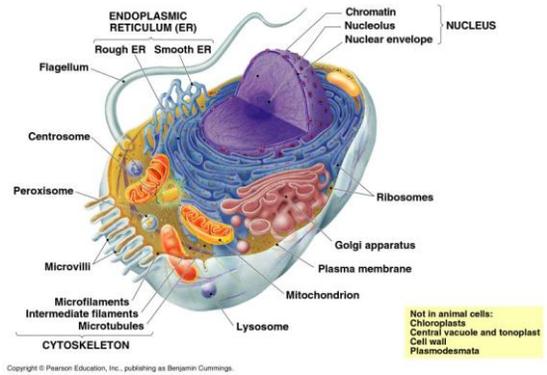
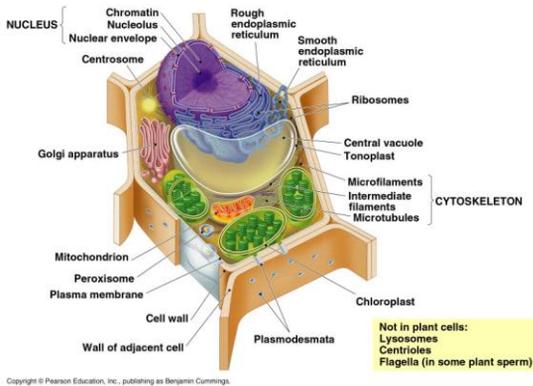
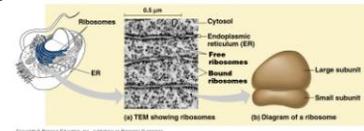


Figure 7.8 Overview of a plant cell



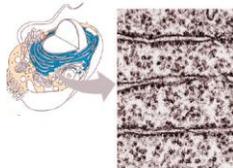
Ribosomes

- Function
 - Protein production
- Structure
 - Ribosomes contain rRNA & protein
 - Composed of 2 subunits that combine to carry out protein synthesis



Types of Ribosomes

- Free ribosomes
 - Suspended in cytosol
 - Synthesize proteins that function within cytosol
- Bound ribosomes
 - Attached to outside of endoplasmic reticulum
 - Synthesize proteins for export or for membranes

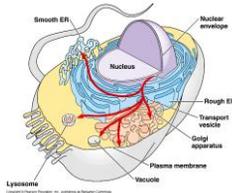


Chapter 7

- Endomembrane System
 - Endoplasmic reticulum
 - Golgi apparatus
 - Lysosomes
 - Peroxisomes
 - Vacuoles
 - Vesicles

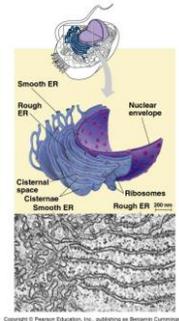
Overview

- Play key role in synthesis (& hydrolysis) of macromolecules in cell
- Various "players" modify macromolecules for various functions



Endoplasmic Reticulum

- Function
 - Manufactures membranes & performs many bio-synthesis functions
- Structures
 - Membrane connected to nuclear envelope & extends throughout cell
 - Accounts for 50% membranes in eukaryotic cell
 - Rough ER = bound ribosomes
 - Smooth ER = no ribosomes

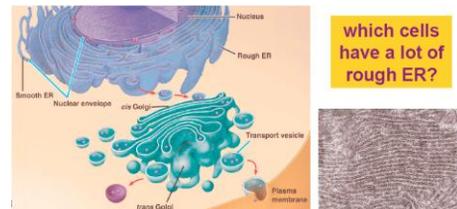


Smooth ER function

- Factory processing operation
 - Many metabolic processes
 - Synthesis & hydrolysis
 - Enzymes of smooth ER...
 - Synthesize lipids, oils, phospholipids, steroids, sex hormones
 - Hydrolysis (breakdown) of glycogen
 - Detoxify drugs & poisons (in liver)
 - Ex. Alcohol & barbiturates

Rough ER function

- Produce proteins for export out of cell
 - Protein secreting cells
 - Packaged into transport vesicles for export



Membrane Factory

- Synthesize membrane phospholipids
 - Build new membrane
 - As ER membrane expands, bud off & transfer to other parts if cell that need membrane
- Synthesis membrane proteins
 - Membrane bound proteins synthesized directly into membrane
 - Processing will make glycoproteins

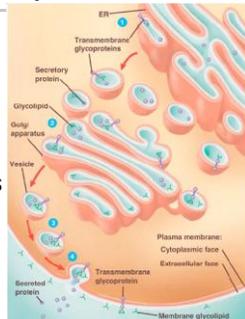


Figure 7.7 Overview of an animal cell

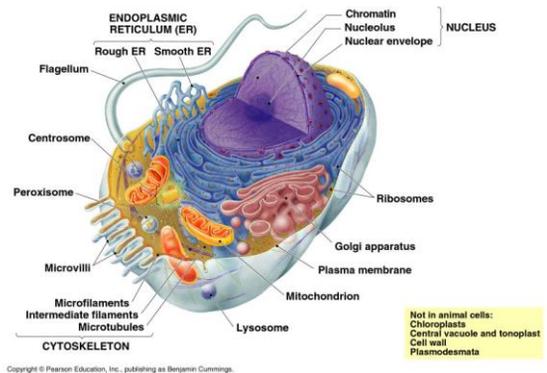
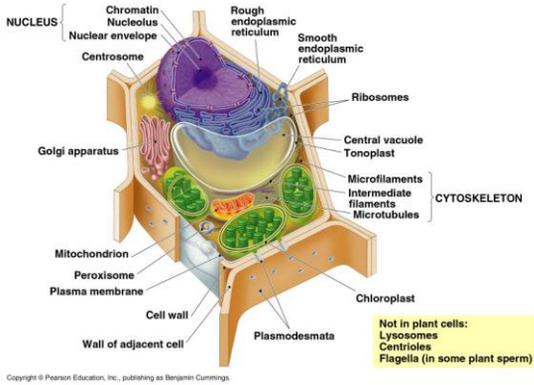
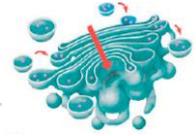


Figure 7.8 Overview of a plant cell



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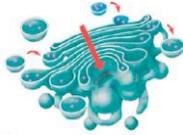
Golgi Apparatus



Function

- Finishes, sorts & ships cell products
 - "Shipping & receiving department"
- Center of manufacturing, warehousing, sorting, & shipping
- Extensive in cells specialized for excretion

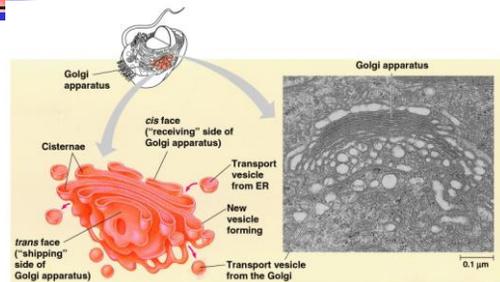
Golgi Apparatus



Structure

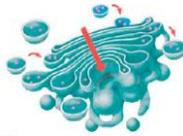
- Flattened membranous sacs = cisternae
 - Looks like stacks of pita bread
- 2 sides = 2 functions
 - Cis = receives material by fusing with vesicles = "receiving"
 - Trans buds off vesicles that travel to other sites = "shipping" (transport)

Golgi Apparatus



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Golgi Processing



- During path from cis to trans, products from ER are modified into final form
- Tags, sorts, & packages materials into transport vesicles
 - Golgi = "UPS headquarters"
 - Transport vesicles = "UPS truck"
 - Delivering packages that have been tagged with their own barcodes

Putting it together

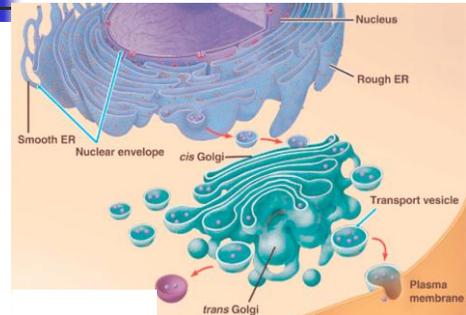


Figure 7.7 Overview of an animal cell

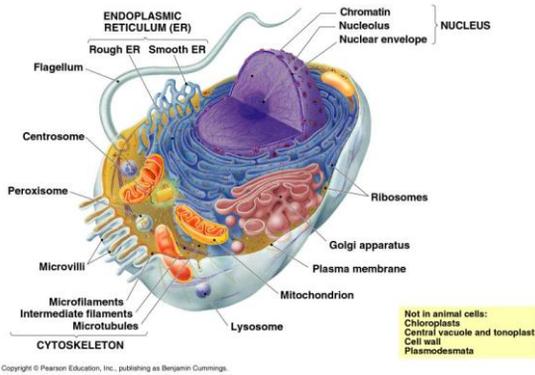
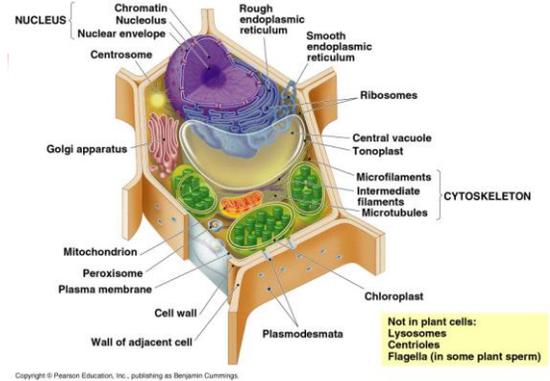


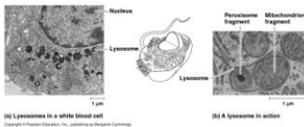
Figure 7.8 Overview of a plant cell



Lysosomes

Structure

- Membrane-bounded sac of hydrolytic enzymes that digests macromolecules
 - Enzymes & membrane of lysosomes are synthesized by rough ER & transferred to the Golgi



Only in animal Cells

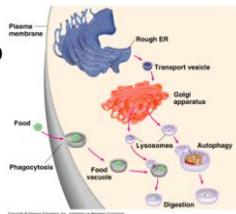
Lysosomes

Function

- A little "stomach" for the cell
 - Lyso- = breaking things apart
 - some = body
- Also the "clean up crew" of the cell

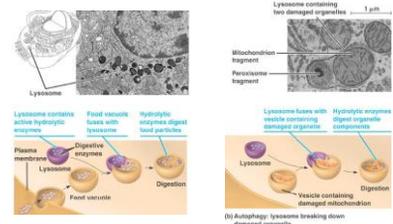
Cellular digestion

- Lysosomes fuses with food vacuoles
- Polymers are digested into monomers
 - Pass to cytosol to become nutrients of the cell



The recycler

- Fuse with organelles or macromolecules in cytosol to recycle materials

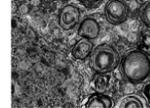


Lysosome enzymes

- Lysosomal enzymes work best at pH 5
 - organelle creates custom pH
 - How?
 - Proteins in lysosomal membrane pump H^+ ions from the cytosol into lysosomes
 - Why?
 - Enzymes are very sensitive to pH
 - Why?
 - Enzymes are proteins – pH effects structure
 - Why evolve digestive enzymes which function at pH different from cytosol?
 - Digestive enzymes won't function well if leak into cytosol = don't want to digest yourself!!

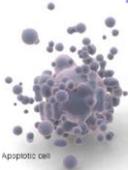
When things go wrong...

- What if a lysosome digestive enzyme doesn't function?
 - Don't digest biomolecule
 - Instead the biomolecule collects in lysosome
 - Lysosome will fill up with undigested material
 - Lysosomes will grow larger and larger
 - Eventually disrupt cell & organ function
 - "Lysosomal storage diseases" are usually fatal
 - Tay-Sachs disease
 - Lipids build up in brain cells
 - Child dies before 5



Sometimes its supposed to work that way...

- Apoptosis = cell death
 - Critical role in programmed destruction of cells in multicellular organisms
 - Auto-destruct mechanism
 - "cell-suicide"
 - Some cells have to die in an organized fashion, especially during development
 - Ex. Development of space between you fingers during embryonic development
 - Ex. If a cell grows improperly this self-destruct mechanism is triggered to remove damaged cell
 - Cancer over-rides this to enable tumor growth

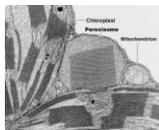


Fetal development



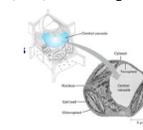
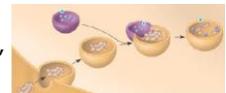
Peroxisomes

- Other digestive enzymes sacs
 - In both plants and animals
 - Breakdown of fatty acids to sugars
 - Easier to transport & use as energy source
 - Detoxify cell
 - Detoxify alcohol & other poisons
 - Produce peroxide (H_2O_2)
 - Must breakdown
 - $H_2O_2 \rightarrow H_2O$



Vacuole & vesicles

- Function
 - Little "transfer ships"
 - Food vacuole
 - Phagocytosis, fuse with lysosome
 - Contractile vacuole
 - In freshwater protists, pump excess H_2O out of cell
 - Central vacuole
 - In many plant cells



Vacuoles in plants

- **Function:**
 - **Storage**
 - Stockpiling proteins or inorganic ions
 - Depositing metabolic bi-products
 - Storing pigments
 - Storing defensive compounds against herbivores
 - **Selective membrane**
 - Control what comes in or goes out

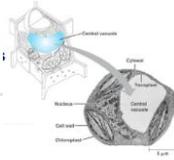


Figure 7.7 Overview of an animal cell

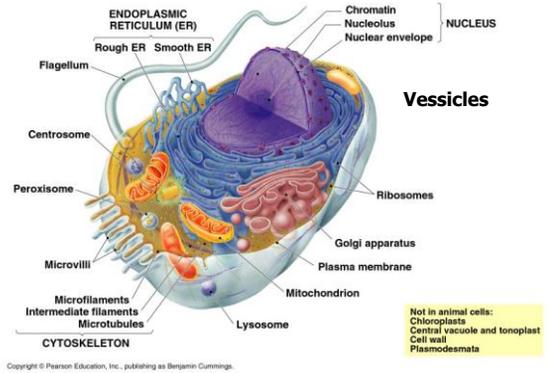
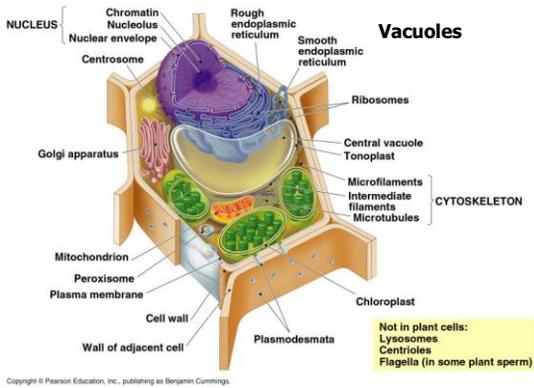
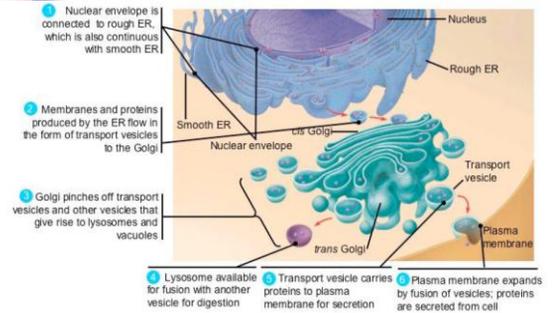


Figure 7.8 Overview of a plant cell

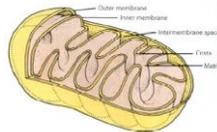
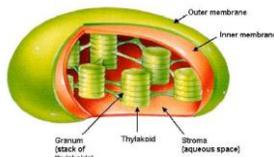


Putting it all together



The Cell:

Mitochondria & Chloroplasts



Overview

- Mitochondria & chloroplasts are the organelles that convert energy to forms that cells can use for work
- **Mitochondria:**
 - From glucose to ATP →
- **Chloroplasts:**
 - From sunlight to ATP to carbohydrates
 - ATP = active energy
 - Carbohydrates = stored energy



Mitochondria & Chloroplasts

- Important to see the similarities
 - Transform energy
 - Generate ATP
 - Double membrane = 2 membrane
 - Semi-autonomous organelles
 - Move, change shape, divide
 - Internal ribosomes, DNA, & enzymes



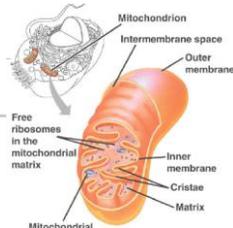
Mitochondria

Structure

- 2 membranes
 - Smooth outer membrane
 - Highly folded inner membrane
 - The cristae
- Fluid-filled space between 2 membranes
- Internal fluid-filled space
 - Mitochondrial matrix
 - DNA, ribosomes, enzymes

Why 2 membranes?

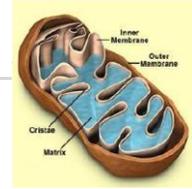
increase surface area for membrane-bound enzymes that synthesize ATP



Mitochondria

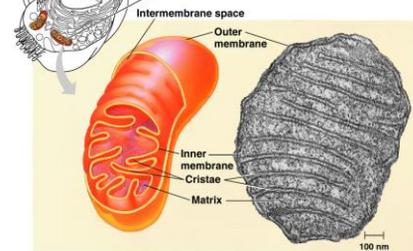
Function

- Cellular respiration
- Generates ATP
 - From breakdown of sugars, fats, & other fuels
 - In the presence of **Oxygen**
 - Break down larger molecules to smaller to generate energy = catabolism
 - Generate energy in presence of O₂ = aerobic respiration



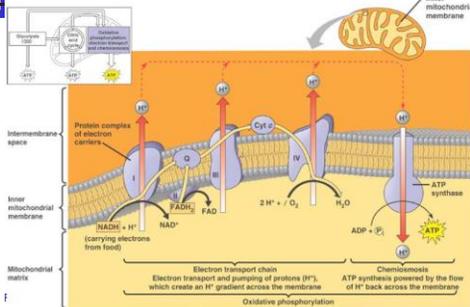
Mitochondria

Mitochondrion



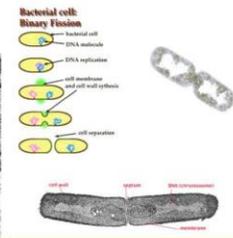
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Membrane-bound enzymes



Dividing mitochondria

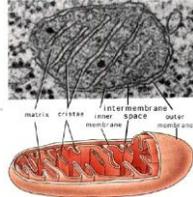
Who else divides like that?



What does this tell us about the evolution of eukaryotes?

Mitochondria

- Almost all eukaryotic cells have mitochondria
 - There may be 1 very large mitochondria or 100s to 1000s of individual mitochondria
 - Number of mitochondria is correlated with aerobic metabolic activity
 - More activity = more energy needed = more mitochondria



What cells would have a lot of mitochondria?

active cells:
 • muscle cells
 • nerve cells

Figure 7.7 Overview of an animal cell

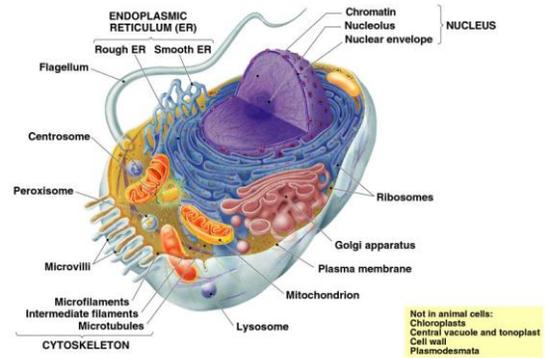
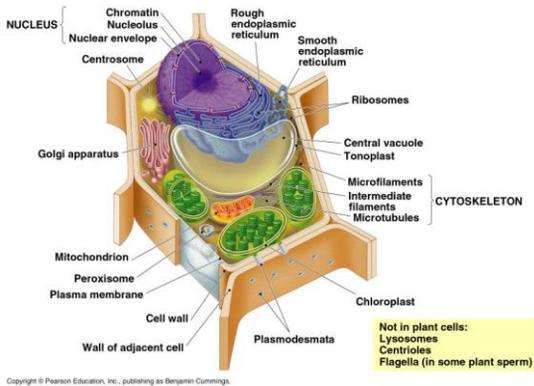
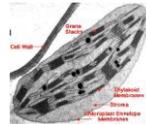


Figure 7.8 Overview of a plant cell



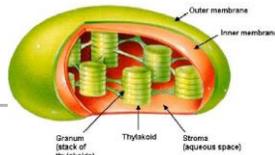
Chloroplasts

- Chloroplasts are plant organelles
 - Class of plant structure = **plastids**
 - Amyloplasts**
 - Store starch in roots & tubers
 - Chromoplasts**
 - Store pigments for fruits and flowers
 - Chloroplasts**
 - Store chlorophyll & function in photosynthesis
 - In leaves, other green structures of plants & in eukaryotic algae



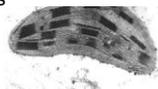
Chloroplasts

- Structure
 - 2 membranes
 - Outer membrane
 - Inner membrane
 - Internal fluid-filled space = **stroma**
 - DNA, ribosomes & enzymes
 - Thylakoids** = membranous sacs where ATP is made
 - Grana = stacks of thylakoids

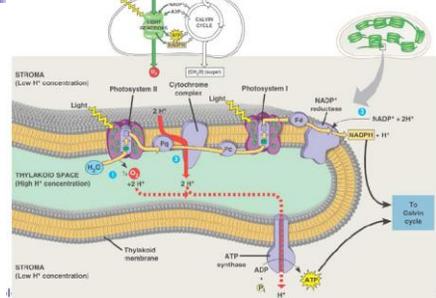


Why internal sac membranes?

Increase surface area for membrane-bound enzymes that synthesize ATP



Membrane-bound enzymes



Chloroplasts

Function

- Photosynthesis
- Generate ATP & synthesize sugars
 - Transforms solar energy into chemical energy
 - Produce sugars from CO₂ & H₂O
- Semi-autonomous
 - Moving, changing shape & dividing
 - Can reproduce by pinching in two

Who else divides like that?

bacteria!

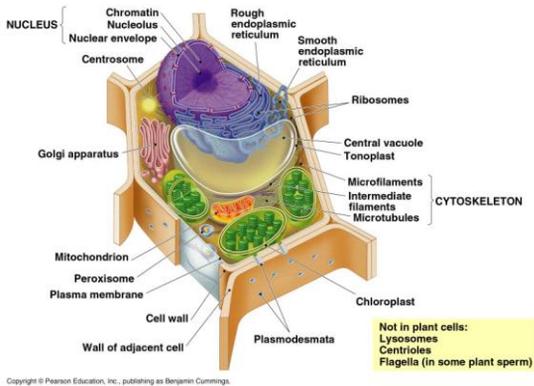


Chloroplasts

Why are chloroplasts green?



Figure 7.8 Overview of a plant cell

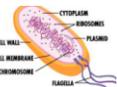


Mitochondria & chloroplasts are different

- Organelles not part of endomembrane system
- Grow & reproduce
 - Semi-autonomous organelles
- Proteins primarily from the free ribosomes in cytosol & a few from their own ribosomes
- Own cellular chromosome
 - Directs synthesis of proteins produced by own internal ribosomes

Who else has a circular chromosome not bound within a nucleus?

bacteria

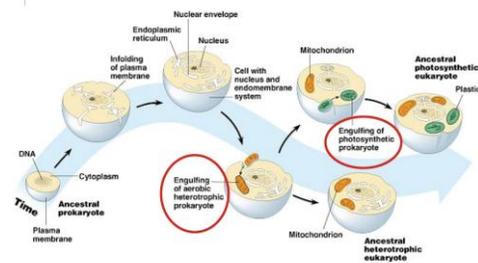


Endosymbiosis Theory

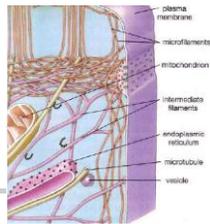
- Mitochondria & chloroplasts were once free living bacteria
 - Engulfed by ancestral eukaryote
- Endosymbiont
 - Cell that lives within another cell (host)
 - As a partnership
 - Evolutionary advantage for both
 - One supplies energy
 - The other supplies raw materials and protection

Endosymbiosis theory

Evolution of eukaryotes



The Cell



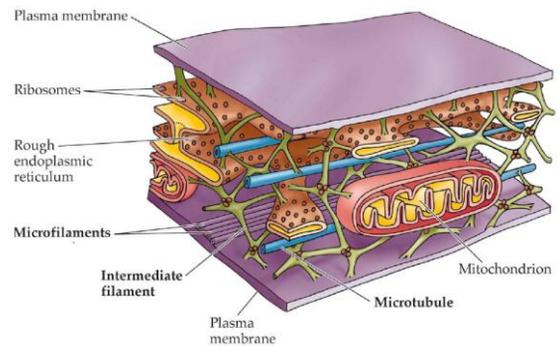
Cytoskeleton

Cytoskeleton

- Function
 - Structural support
 - Maintain shape of cell
 - Provides anchorage for organelles
 - Motility
 - Cell locomotion
 - Cilia, flagella, etc.
 - Regulation
 - Organizes structures & activities of cell

Cytoskeleton

- Structure:
 - Network of fibers extending throughout cytoplasm
 - 3 main protein fibers
 - Microtubules
 - Microfilaments
 - Intermediate filaments



Evolutionary perspective

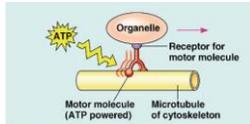
- Proteins that make up the fibers are very similar in all living things
 - From bacteria to humans
 - Tubulin (all cells)
 - Actin (eukaryotic cells)
- Means that they are both ancient and essential for life

Microtubules

- Structure
 - Thickest fibers
 - Hollow rods about 25nm in diameter
 - Constructed of protein, tubulin
 - Grow or shrink as more tubulin molecules are added or removed

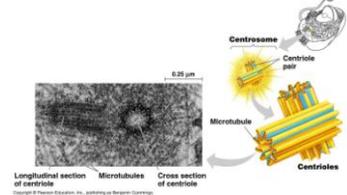
Microtubules

- Function
 - Structural support & cell movement
 - Move chromosomes during cell division
 - Centrioles
 - Tracks that guide motor proteins carrying organelles to their destination
 - Motor proteins: myosin & dynein
 - Motility
 - Cilia
 - flagella



Centrioles

- Cell division
 - In animal cells, pair of centrioles organize microtubules guiding chromosomes in cell division



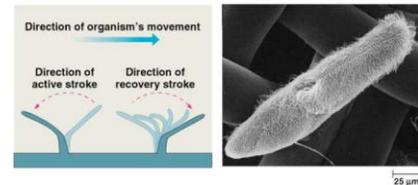
Cilia & flagella

- Extensions of eukaryotic cytoskeleton
- Cilia = numerous & short (hair-like)
- Flagella = 1-2 per cell & longer (whip-like)
 - Move unicellular & small multicellular organisms by propelling water past them
 - Cilia sweep mucus & debris from lungs
 - Flagellum of sperm cells



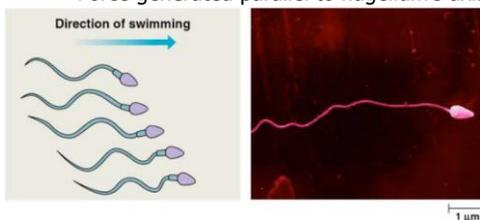
Cilia

- Oar-like movement
 - Alternating power & recovery strokes
 - Generates force perpendicular to cilia's axis



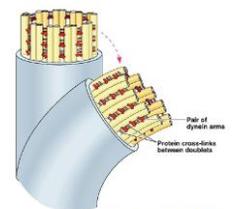
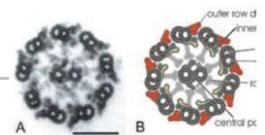
Flagella

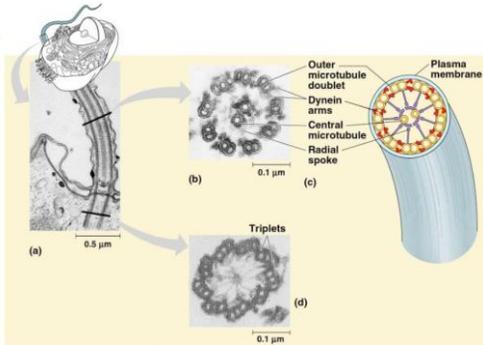
- Undulating movement
 - Force generated parallel to flagellum's axis



Cilia & flagella

- Structure
 - Remember 9+2!
 - 9 pairs of microtubules around 2 single microtubules in center
 - Bending of cilia & flagella is driven by motor protein
 - dynein



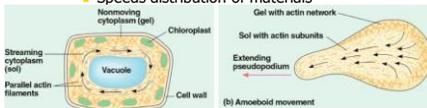


Microfilaments (actin filaments)

- Structure
 - Thinnest class of fibers
 - Solid rods of protein, actin
 - Twisted double chain of actin subunits
 - About 7nm in diameter
- Function
 - 3-D network inside cell membrane
 - In muscle cells, actin filaments interact with myosin filaments to create muscle contractions

Microfilaments (actin filaments)

- Dynamic process
 - Actin filaments constantly form & dissolve making cytoplasmic liquid or stiff during movement
 - Movement of Amoeba
 - Cytoplasmic streaming in plant cells
 - Speeds distribution of materials



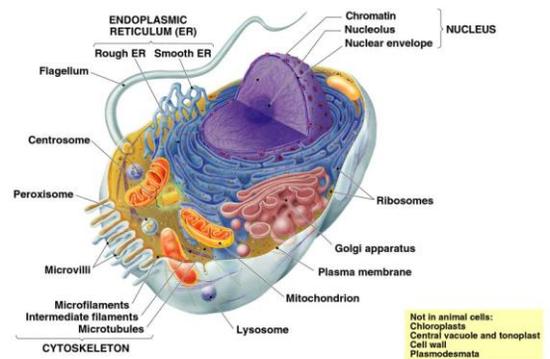
Intermediate Filaments

- Structure
 - Specialized for bearing tension
 - Build from keratin proteins
 - Same protein as hair
 - Intermediate in size 8-12 nm
- Function
 - Hold "things" in place inside cell
 - More permanent fixtures of cytoskeleton
 - Reinforce cell shape & fix organelle location
 - Nucleus held in place by network of intermediate filaments

Summary

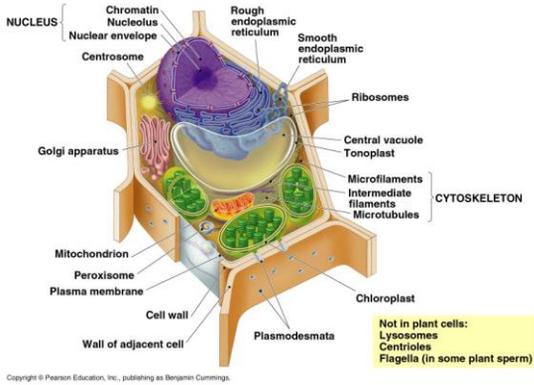
- Microtubules
 - Thickest
 - Cell structure & cell motility
 - Tubulin
- Microfilaments
 - Thinnest
 - Internal movements within the cell
 - Actin, myosin
- Intermediate filaments
 - Intermediate
 - More permanent fixtures
 - keratin

Figure 7.7 Overview of an animal cell



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Figure 7.8 Overview of a plant cell



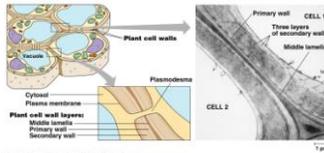
Cell Junctions

Where cells touch each other...

Plant cell wall

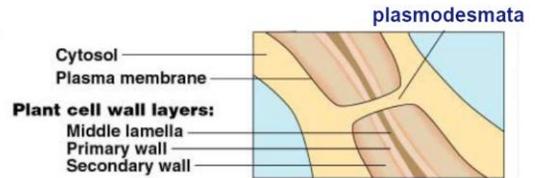
Structure

- Cellulose
- Primary cell wall
- Secondary cell wall
- Middle lamella = sticky polysaccharide



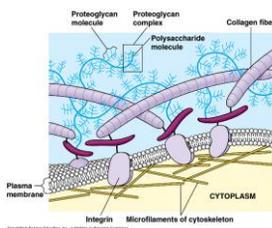
Intercellular junctions

- Plant cells
 - Plasmodesmata
 - Channels allowing cytosol to pass between cells

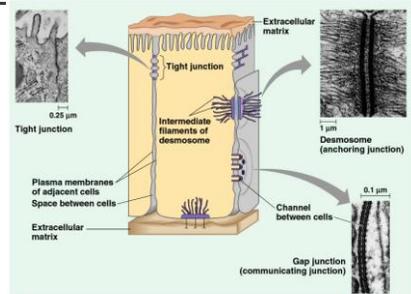


Animal Cell surface

- Extracellular matrix
 - Collagen fibers in network of glycoproteins
 - Support
 - Adhesion
 - Movement
 - Regulation



Intercellular junctions in animals



Intercellular junctions

- Animal cells
 - Tight junctions
 - Membranes of adjacent cells fused forming barrier between cells
 - Forces material through cell membrane
 - Gap junctions
 - Communicating junctions
 - Allow cytoplasmic movement between adjacent cells
 - Desmosomes
 - Anchoring junctions
 - Fasten cells together in strong sheets

A cell is a living unit greater than the sum of its parts

Cell Video

- [Inner life - Mitochondria](#)

- [Inner Life of Cell Narration](#)