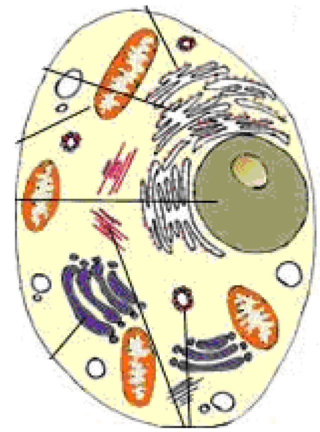
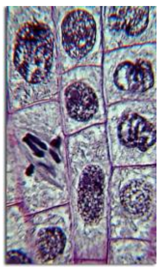
Chapter 6- Cell Structure and Function



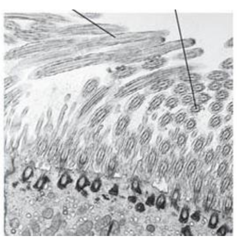
CELL THEORY:
All living things are made of cells
= Basic unit of structure and function
Cells are derived from existing cells

STUDY OF CELLS = CYTOLOGY

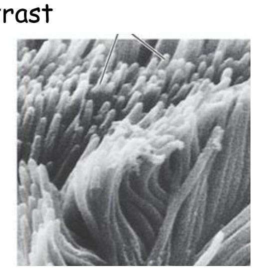


LIGHT MICROSCOPE(LM)
• Visible light passes through specimen; then through glass lenses
• Lenses focus light into eye
• Minimum resolution = size of small bacterium (~200 nm)
• Can see nucleus/chromosomes in dividing cells/central vacuole/NOT other organelles
• Can observe LIVING cells

ELECTRON MICROSCOPE (EM)
• Electromagnets focus beam of electrons
• Better resolution than light microscope
• Can only observe organelles in DEAD cells



Transmission electron microscope (TEM)
-Thin sections of specimen are stained with heavy metals for contrast
- can see organelles (ultrastructure) of cells



Scanning electron microscope (SEM)

- useful for studying surface structures.
- Sample surface is covered with a thin film of gold
- Image appears 3D

CELL FRACTIONATION

• Uses machine (ULTRACENTRIFUGE) to separate major organelles for study

• Spins up to 130,000 revolutions/min; Forces = 1 million times gravity (1,000,000 G)
• Separates by size/mass (Bigger/heavier organelles sink to pellet; lighter ones in supernatant)
• Svedberg unit (S) used to compare sedimentation rates (~size)
Ex: Prokaryotes have 70S ribosomes; eukaryotes have 80S ribosomes

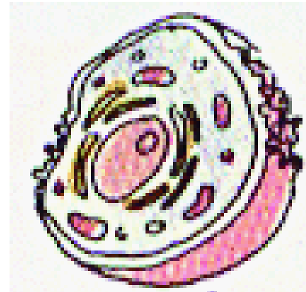
ALL CELLS
• Surrounded by plasma (cell) membrane.
• Semifluid substance within membrane =cytosol
• Organelle = small structure within cell with specific function
• Organelles suspended in semi-fluid substance = cytosol
• cytosol + organelles = cytoplasm
• contain chromosomes (contain DNA)
• have RIBOSOMES (make proteins)

PROKARYOTES (Bacteria)
• NO nuclear membrane
• NO membrane bound organelles
• DNA in NUCLEOID region

EUKARYOTES (Plants, animals, fungi, protists)
• DNA surrounded by NUCLEAR ENVELOPE
• Contains membrane bound organelles

SIZE LIMIT
Most bacteria- 1-10 μm (=microns)
Eukaryotic cells -10-100 μm
UPPER LIMIT set by metabolic requirements
As cells increase in size-volume increases faster than surface area (SA/volume ratio decreases)

Cell can't transport food/oxygen/waste fast enough for its needs
Large organisms have MORE cells; NOT BIGGER cells; MICROVILLI (surface extensions) can increase SA



INTERNAL MEMBRANES in EUKARYOTES (Mainly made of phospholipids + proteins)

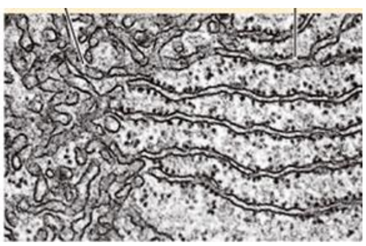
- Divide cell into compartments (allows different local environments)
- Participate in metabolism (many enzymes attached to membranes)
- Membrane surfaces Compartmentalize
- Proteins embedded in phospholipid bilayer
- Type of phospholipids and proteins vary depending on membrane function

PLASMA MEMBRANE (See Chapter 7)

- Phospholipid bilayer (polar/philic heads face out; nonpolar/phobic tails face in)
- SELECTIVELY PERMEABLE (due to phobic tails)
    - allow certain types of molecules to pass through; but not others

NUCLEAR ENVELOPE

- Contains genes in eukaryotes (Additional genes in mitochondria and chloroplasts)
- Surrounded by DOUBLE MEMBRANE separated by 20-40 nm space
- NUCLEAR PORES lined by proteins (NUCLEAR PORE COMPLEX)- regulates passage of molecules in and out
- Nuclear side of envelope lined by network of protein filaments (NUCLEAR LAMINA) – maintain shape
- CHROMATIN fibers = DNA + HISTONE proteins
- Chromatin wraps into CHROMOSOMES (more tightly packed form) during cell division
- Densely stained NUCLEOLUS = site of ribosome (rRNA) production

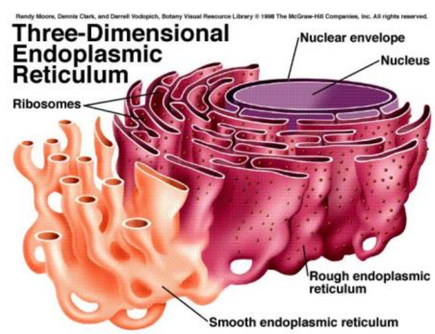


RIBOSOMES- synthesize proteins

- made of PROTEINS and RNA (rRNA)
- FREE ribosomes (suspended in cytosol)
    - make cytosol proteins
- BOUND ribosomes- attached to Rough ER OR nuclear envelope
    - make proteins for cell membranes or export

ENDOMEMBRANE SYSTEM

- directly continuous or connect via transfer of membrane sacs (VESICLES)
- includes nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, and plasma membrane



ENDOPLASMIC RETICULUM (ER)

- membranous tubules with internal fluid filled spaces (CISTERNAE)
- continuous with NUCLEAR ENVELOPE

ROUGH ER- ribosomes attached
- especially abundant in cells that secrete proteins
- proteins synthesized on attached ribosomes/inserted into cisternal space and folded into its 3D shape
- secretory proteins put into transport vesicles and sent to GOLGI
- membrane factory/make phopholipids
- As ER grows, vesicles move membranes to other places

SMOOTH ER- lacks ribosomes
- contains enzymes for many different metabolic processes
-synthesize oils, steroids, phospholipids
EX: sex hormones and adrenal steroids
IN LIVER- break down toxins
(nitrogen waste from cells, drugs, alcohol)
IN MUSCULE- store Ca^{++} ions/regulate muscle contraction

NOTE*
Frequent drug use leads to increased SER for increased break down
~ reason why tolerance increases and higher dose is needed for same effect
AND why frequent/extreme drug use leads to liver damage (CIRRHOSIS)

GOLGI APPARATUS

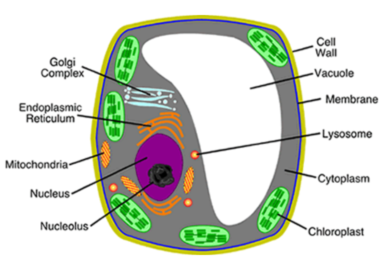
• look like "pancake stacks"
flattened membranous sacs = cisternae
• "UPS" of cell - center of manufacturing, warehousing, sorting, and shipping
• Has direction
  CIS face (faces ER) = "Receiving" side
  TRANS side = "Shipping" side –transport vesicles bud off
• extensive in secretory cells (EX: pancreas makes insulin)
• Products modified as pass from cis to trans side/sorted and packaged into vesicles
•can also manufacture its own macromolecules (amylopectin and other noncellulose polysaccharides)
• Molecular ID tags added to products to aid in sorting
  -identifiers such as phosphate groups act like ZIP codes to identify product's final destination

LYSOSOMES
• found in animal cell (plants – ?)
• membrane-bound sac of hydrolytic (digestive) enzymes
• enzymes made by ribosomes on rough ER/modified in Golgi
• can hydrolyze food, whole cells, damaged cell parts
• Example of COMPARTMENTALIZATION
  - enzymes work best at pH 5
  - H^+ ions pumped from cytosol into lysosome
  - if a lysosome ruptures, enzymes not very active in cytosol (neutral pH)
    (prevents accidental "self digestion")
  - Massive rupture of many lysosomes can destroy
    a cell by "self digestion" (AUTOPHAGY)

NOTE
Tay-Sachs = genetic disorder
-lack lysosomal enzymes needed to break down lipids;
-accumulation of lipids in brain causes blindness, seizures, retardation, death

USED FOR:
Digestion of food in unicellular organisms
Recycling of cell's organelles and macromolecules
Programmed cell death (APOPTOSIS)
  - embryonic development (form fingers/lose tail)
  - cells that are damaged get signal to self destruct
    (Cancer cells and HIV infected cells don't respond to signal)

VACUOLE
Vesicles and vacuoles (larger versions) = membrane-bound sacs with varied functions.
Food vacuoles- form by phagocytosis and fuse with lysosomes
Contractile vacuoles in freshwater protists- pump excess water out/maintain water-salt balance



Large CENTRAL VACUOLE in many mature plant cells
Surrounded by membrane = TONOPLAST
Stockpile proteins or inorganic ions
Dispose of metabolic byproducts
Hold pigments
Store defensive compounds to defend plant against herbivores
Large vacuole reduces area of cytosol, so surface area/volume ratio increases
Water storage makes plants TURGID

PEROXISOMES
• Surrounded by single membrane
• Don't come from endomembrane system; built from proteins and lipids in cytosol
• Divide when reach a certain size
• Role in metabolism:
  - break fatty acids down & transport to mitochondria=fuel for cellular respiration.
  - detoxify alcohol and other harmful compounds in liver
  - Specialized peroxisomes in seeds (GLYOXYSOMES) convert fatty acids → sugars
    used as energy source until able to start photosynthesizing
• Contain enzymes that transfer hydrogen from various substrates to oxygen
  - Make a poisonous intermediate product = hydrogen peroxide (H_2O_2)
  - Contain enzyme (CATALASE) that converts $H_2O_2 \rightarrow H_2O + O_2$

MITOCHONDRIA- Not part of Endomembrane system;
• Membrane proteins made by free ribosomes and ribosomes inside mitochondria
• Semiautonomous - grow and reproduce independently
• Mobile; move on cytoskeleton tracks

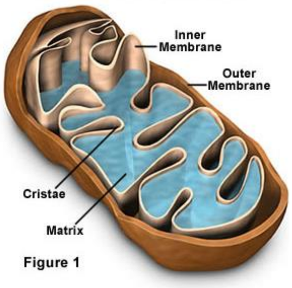


Figure 1

• DOUBLE membrane creates internal compartments
  - Smooth outer membrane/inner membrane separated by INTERMEMBRANE space
  - Folded inner membrane (CRISTAE) increases surface area for chemical reactions
  - Fluid filled space enclosed by inner membrane (MATRIX)
    CONTAINS DNA, ribosomes, enzymes for cellular respiration
• Site of cellular respiration
  - Break down sugars, fats, and other fuels in the presence of oxygen
  - Generate ATP
• Cells with high energy needs (EX: muscle cells) have large numbers of mitochondria

CHLOROPLASTS – Not part of Endomembrane system
• Plastid found in leaves and green organs of plants and algae
• Membrane proteins made by free ribosomes and ribosomes inside chloroplasts
• Semiautonomous - grow and reproduce independently
• Mobile; move on cytoskeleton tracks
• Site of photosynthesis
  - convert solar energy to chemical energy
  - synthesize new organic compounds such as sugars from CO_2 and H_2O
• DOUBLE membrane creates internal compartments
  - Smooth outer membrane/inner membrane separated by INTERMEMBRANE space
  - Fluid filled space inside inner membrane = STROMA
    CONTAINS DNA, ribosomes, enzymes for photosynthesis
  - GRANUM (pl. GRANA) stacks of THYLAKOID sacs surrounded by stroma
  - space inside thylakoid sac = THYLAKOID SPACE

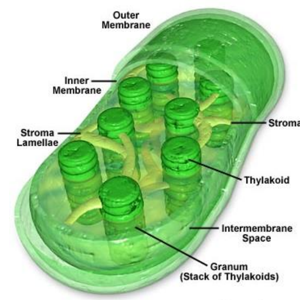
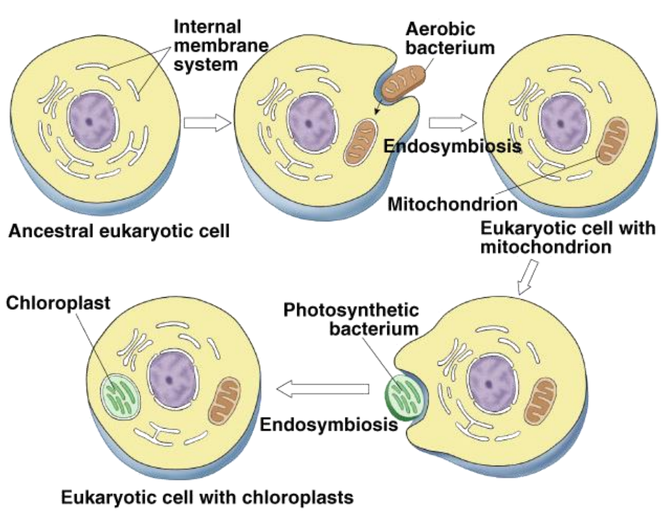


Figure 1

OTHER PLASTIDS:
AMYLOPLASTS- colorless plastids that store starch in roots and tubers
CHROMOPLASTS- store colored pigments for fruits and flowers

ENDOSYMBIOTIC THEORY
Engulfed prokaryotes shared symbiotic relationship with host cell
Origin of mitochondria and chloroplasts
Proposed in early 1900's
1963- reintroduced by Lynn Margulis
Advantages for both:
  ~ one- supplies energy
  ~ other- raw materials & protection



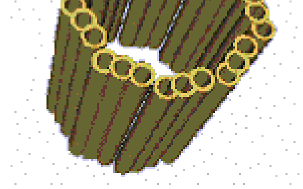
EVIDENCE:
• Only organelles besides nucleus with own DNA and double membranes

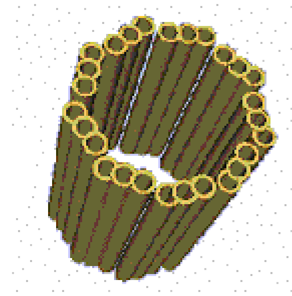
• All have single, circular, naked (no histones) DNA

• Inner membranes have enzymes and transport systems homologous to bacterial plasma membranes

• Replicate independently of nucleus using binary fission

• Ribosomes size, nucleotide sequence, sensitivity to certain antibiotics similar to bacterial ribosomes



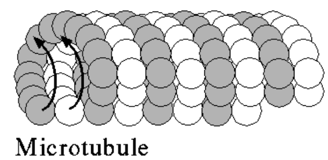


CENTRIOLES:
•Seen only in dividing animal cells
•Made of MICROTUBULES in pattern of 9 triplets
•Found inside CENTROSOME
•Replicate and move to poles during cell division

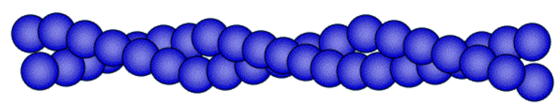
CYTOSKELETON
• network of fibers extending throughout the cytoplasm.
• provides mechanical support and maintains cell shape
• provides anchorage for many organelles and cytosolic enzymes
• dynamic; dismantled in one part and reassembled in another (changes shape of cell)
• major role in cell motility

THREE MAIN CYTOSKELETAL FIBERS:

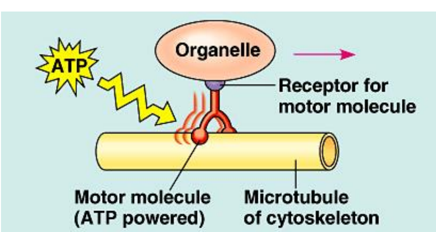
1) TUBULIN MICROTUBULES- thickest; hollow tube = dimer made up of protein subunits
   change length by adding/removing dimers
   make tracks for motor proteins to move organelles/vesicles
   separate chromosomes during cell division
   found in eukaryotic cilia + flagella/centrioles/basal bodies
   CENTROSOME = microtubule organizing region in many cells
   - In animal cells, centrosome contains CENTRIOLES



2) ACTIN MICROFILAMENTS- thinnest; made of protein ACTIN in double twisted chain
   support network inside cell membrane; supports cell shape
   interact with MYOSIN filaments
   - role in muscle contraction
   - cleavage furrow in cell division
   - amoeboid movement (PSEUDOPODIA)
   - cytoplasmic streaming (Plant cells)

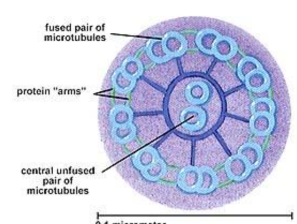


3) INTERMEDIATE FILAMENTS- middle size
   more permanent framework/anchor cell organelles in place
   made of keratin proteins



MOTOR PROTEINS – require ATP
"Walk" along cytoskeleton tracks to move
rganelles/vesicles/chromosomes
MYOSIN heads interact with ACTIN for muscle contraction
DYNEIN arms interact with TUBULIN to move cilia and flagella

EUKARYOTIC CILIA and FLAGELLA-
• Extend from cell surface
• Surrounded by plasma membrane sheath
• Anchored in the cell by a BASAL BODY (structure is identical to a centriole)
• Made of microtubules arranged in 9 + 2 pattern
  ◦ Nine doublets in a ring around pair in center
  ◦ Flexible protein "wheels" connect microtubule doublets and center
  ◦ Motor proteins (DYNEIN arms) connect outer doublets
    - "Walking" of dynein arms along microtubules causes bending and movement; requires ATP



DIFFERENCES:
CILIUM (pl. cilia) & FLAGELLUM (pl. flagella)- differ in length, size, beating pattern
  CILIA– short (2–20 microns) long, large numbers/ FLAGELLA long (10–200 microns), one or few
   EX: cilia lining the windpipe sweep mucus carrying trapped debris out of the lungs
PROKARYOTIC FLAGELLA-have single protein filament (not 9 + 2); no outer membrane sheath

EXTRACELLULAR COMPONENTS AND CONNECTIONS

PLANT CELL WALL * also found in prokaryotes, fungi, and some protists
• Protection/support/maintain shape
• thickness/chemical composition differs from species to species and among cell types
• microfibrils of cellulose embedded in a matrix of proteins and other polysaccharides
• mature cell wall=primary cell wall/middle lamella sticky polysaccharides hold cells together/secondary cell wall
PLASMODESMATA (channels between adjacent cells) connect cytosol
Water/small solutes/proteins can pass freely from cell to cell/ make plant one continuum

ANIMAL CELL EXTRACELLULAR MATRIX (ECM)
• Outside plasma membrane
• Composed of glycoproteins secreted by cell (mainly COLLAGEN fibers)
• Strengthen tissues
• Serves as conduit for transmitting external stimuli into cell
  - cell signaling
  - can turn on genes
  - modify biochemical activit
  - may coordinate the behavior of all the cells within a tissue

3 MAIN TYPES OF ANIMAL INTERCELLULAR LINKS:

1) TIGHT JUNCTIONS-
membranes are fused/form continuous seal/
prevents leakage of extracellular fluid

2) DESMOSOMES (ANCHORING JUNCTIONS)-
fasten cells together into strong sheets, like rivets
KERATIN proteins anchor to cytoplasm

3) GAP JUNCTIONS (COMMUNICATING JUNCTIONS)
- most SIMILAR to PLASMODESMATA in plants
- provide cytoplasmic channels between adjacent cells
- special proteins surround these pores
allow ions, sugars, amino acids, small molecules to pass.
- in embryos facilitate chemical communication during
development