Chapter 3: Cell Structure & Function
Microscopy:
I. Microscopes were 1st used during the 1600’s
II. There are 2 very important factors involved in microscopy
   A. magnification
   B. resolution - clarity
III. Light microscopes pass light through specimen
   A. LM 400x typed in next to Paramecium
      1. light microscope was used & the image of the specimen is 400 times real size
         a. LM have a maximum magnification of ~ 1,000x
   B. Robert Hooke discovered cells in 1665
   C. microorganisms, animal & plant cells & some cell structures were being viewed
   D. Cell theory was developed by mid-1800’s
      1. all living things are composed of one or more cells
   E. LM were the only type of scope available until the mid-1900’s
IV. Electron microscopes
   A. much higher level of magnification/resolution than LM
   B. developed during the 1950’s
   C. cannot view living specimens
   D. Scanning electron microscope (SEM)
      1. enables view of surface detail
   E. Transmission electron microscope (TEM)
      1. enables view of internal cell structure
Some Basics of Cells

I. An average human may consist of around 10 trillion cells
   A. cells need to be small enough to have an appropriate surface area: volume ratio
   B. cells need to be large enough to house everything needed by the cell
      1. SA is used to move molecules into & out of cells
         a. plasma membrane
            1) phospholipids
               a) hydrocarbon tails which are hydrophobic
               b) glycerol head containing a phosphate group – hydrophilic
            2) proteins
               a) hydrophobic AA will commonly be found in hydrophobic zone
               b) hydrophilic AA will commonly be found interfacing w/ cytosol & extra-cellular fluid
3) nonpolar molecules, $O_2$ & $CO_2$, can easily move across hydrophobic zone
4) some membrane proteins have channels to shield ions & polar molecules as they move across the hydrophobic zone
5) some proteins actively pump molecules across the membrane
II. All living things are made of 1 of the 2 distinct types of cells
   A. prokaryotic cells
      1. microorganisms that belong to Domain Bacteria & Domain Archaea
      2. smaller than eukaryotic cells
      3. lack membrane bound organelles
         a. e.g., they lack a membrane bound nucleus
            1) have a nucleoid region
      4. they have smaller & different ribosomes (vs. eukaryotes)
         a. this allows some antibiotics to target bacterial ribosomes
            1) stops protein production
5. chemically complex cell wall
   a. penicillin prevent cell wall production
6. may have a sticky coating, capsule
   a. helps them stick to one another or to surfaces
B. Eukaryotic cells

1. highly compartmentalized using membrane bound organelles
   a. “little organs”
   b. enables incompatible processes to occur simultaneously

2. make up animals, plants, fungi & protists
3. parts found in animal cells but not in most plant cells
   a. centrioles & lysosomes
4. parts found in plant cells but not in animal cells
   a. large central vacuole, chloroplasts, cell wall, plasmodesmata

III. Nucleus
   A. houses DNA which encodes the genetic instructions for cellular activity
      1. this is done by DNA directing protein synthesis
      2. DNA is associated w/ proteins to form chromosomes
      3. 46 chromosomes w/in each nucleated somatic cell is about 2 meters in length
4. referred to as chromatin when in a thin & diffuse non-dividing state
5. enclosed in a double phospholipid bilayer nuclear envelope
   a. protein pore complexes regulate what moves in/out of nucleus
      1) some are connected to rough endoplasmic reticulum
B. nucleolus is within the nucleus
   1. site of ribosomal subunit production
IV. Ribosomes

A. read copies of genes called mRNA (messenger RNA)
   1. & put together AA in the sequence dictated by the mRNA
      a. protein synthesis

B. made of rRNA & protein

C. consist of a large & small subunit

D. some are free in the cytosol

E. some are attached to the rough ER or nuclear envelope
   1. a free can become attached & an attached can become free
V. The Endomembrane System
*made up of organelles that are functionally (& physically in some cases) connected
A. Smooth endoplasmic reticulum (smooth ER)
   1. lacks attached ribosomes
   2. some of its enzymes produce lipids
      a. oils, steroids & phospholipids
         1) vertebrate testes & ovaries are rich in smooth ER
            a) for the production of steroid sex hormones
3. liver cells have a lot of smooth ER
   a. enzymes process drugs, alcohol etc...
      1) w/ continued exposure, there will be a proliferation of smooth ER w/ these specific enzymes that leads to the development of tolerance
         a) barbiturate abuse can decrease the effectiveness of some antibiotics
B. Rough ER

1. makes membranes for the cell
2. makes secretory proteins like insulin
   a. bound ribosome reads mRNA (copy of gene) & builds the primary structure of a polypeptide
   b. polypeptide is threaded into rough ER lumen
   c. H bonding & R group interactions cause protein to take on its shape
   d. short chains of sugars may be added
      1) this converts it into a glycoprotein
   e. protein is packaged in a transport vesicle which buds off from rough ER
   f. vesicle makes its way to the cis (receiving side) face of the Golgi apparatus
C. Golgi Apparatus

1. consists of flattened sacs that are not connected
2. *cis* face receives transport vesicles from rough ER
3. ER products are modified as they progress through the Golgi sacs
   a. may remove some sugars
   b. may substitute some sugars
   c. phosphate groups may be added
4. finished products are packaged & transported in vesicles from *trans* face (shipping side)
   a. may be exported from the cell
   b. may become part of plasma membrane
   c. may become part of another organelle
D. Lysosomes
1. are bags of digestive enzymes
2. may be involved in phagocytosis
   a. digest food w/in food vacuole
   b. macrophage digesting a bacterium
3. may be involved in autophagy
   a. dismantle defunct organelles
4. Tay-Sachs is a recessive genetic disorder involving impaired lysosomes
   a. lipids accumulate in brain cells because of a defective lipid-digesting enzyme
   b. life-expectancy is much reduced
E. Vacuoles
1. are large vesicles w/ many different functions
2. contractile vacuoles
   a. aids osmoregulation w/in freshwater protistans
      1) constantly taking on water
3. central vacuoles of plants
   a. may store food, water, waste, pigments etc...
VI. Organelles That Convert One Form Of Energy To Another Form
A. mitochondria
1. carry out cellular respiration
   a. using O$_2$ in the making of ATP
2. intermembrane space between outer & inner membrane
3. inner membrane is highly folded
   a. increases SA
      1) more electron transport chain complexes
         *produce greatest amount of ATP
   b. folds are called mitochondrial cristae
4. mitochondrial matrix is inside the inner membrane
   a. location of DNA & ribosomes
   b. location of Citric Acid Cycle enzymes
B. Chloroplasts Enable Humans To Exist
1. sites of photosynthesis
2. outer membrane
3. inner membrane
4. thylakoid membranes
   a. interconnected sacs
      1) stack = granum
   b. where photosynthetic pigments are embedded
   c. carry out the 1\textsuperscript{st} stage of photosynthesis
      1) light reactions
5. stroma is the fluid surrounding thylakoids
   a. location of enzymes for 2\textsuperscript{nd} stage of photosynthesis
      1) Calvin Cycle
VII. Cytoskeleton

A. types of protein fibers extending throughout the cell
B. 3 main kinds of fibers
   1. microtubules
      a. thickest, hollow & made of tubulin subunits
      b. grow out from centrosomes in animal cells
      c. make up centrioles
      d. allow motor proteins to walk vesicles to destinations
      e. guide the movement of chromosomes during cell division

- Microfilaments thicken the cortex around the inner edge of a cell; like rubber bands, they resist tension. Microtubules are found in the interior of the cell where they maintain cell shape by resisting compressive forces. Intermediate filaments are found throughout the cell and hold organelles in place.
2. Intermediate filaments
   a. Anchor some organelles
      1) Forms a cage around the nucleus
   b. Dead skin cells of outer layer of skin is pack w/ intermediate filaments
3. Microfilaments
   a. Are involved in cell movements
      1) Interact w/ thicker filaments, myosin, to cause contraction of muscle cells

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VIII. Extracellular Matrix (ECM)
A. holds cells together in tissues
B. consists of glycoproteins, collagen & fibronectins
   1. integrins (think integration) transmit signals between ECM & cytoskeleton
      a. can direct the path along which embryonic cells move
      b. can influence the activity of genes through the signals it relays
IX. 3 Types Of Cell Junctions Found In Animal Tissues

A. tight junctions
   1. neighboring cells held tightly together via proteins
   2. prevent leakage

B. desmosomes (anchoring junctions)
   1. function like rivets to hold cells together in strong sheets
   2. common in tissues subject to stretching or mechanical stress
      a. skin & muscle

C. gap junctions
   1. are communicating junctions
   2. protein lined pores
   3. allow small molecules to flow between adjacent cells
      a. ions of heart cells to coordinate contraction
      b. enable embryo cells to communicate

• A desmosome forms a very strong spot weld between cells. It is created by the linkage of cadherins and intermediate filaments.
  (credit: modification of work by Mariana Ruiz Villareal)
Membranes Are Fluid And Made of Many Kinds Of Lipids & Proteins W/ Many Functions

I. Membranes are selectively permeable
   A. Small nonpolar molecules may diffuse across the lipid bilayer (hydrophobic zone)
   B. Polar & ionic molecules need help

II. Phospholipids being able to slide laterally past one another
   A. kinking in phospholipid tails helps maintain appropriate fluidity
   B. cholesterol helps maintain appropriate fluidity
III. Protein diversity

A. enzymatic proteins may be grouped to carry out sequential reactions
B. membrane proteins may form intercellular junctions that attach adjacent cells
C. some proteins enable recognition of neighboring cells
D. glycoproteins may serve as ID tags
E. transport proteins allow specific ions or molecules to enter/exit cell
   1. channel & carrier (some of which will be involved in active transport – E)
F. receptor proteins respond to signal molecules & activate intracellular molecules
G. some integrins serve as attachments to fibronectins which enables communication between ECM & cytoskeleton
Passive Transport Involves Diffusion Across A Membrane W/out The Spending of E

I. Molecules are in constant motion because of their thermal E
   A. one result of this is diffusion
      1. molecules move down their concentration gradient
         a. molecules spread out (from an area of high concentration to low concentration)
         b. until dynamic equilibrium is reached
   2. this is how O$_2$ moves from the blood into our cells
   3. this is how CO$_2$ moves from our cells into our blood
   4. O$_2$ & CO$_2$ move through lipid bilayer (hydrophobic zone) via simple diffusion
   5. ionic & polar substances move through the lipid bilayer via facilitated diffusion
      a. transport proteins

- Diffusion through a permeable membrane moves a substance from an area of high concentration (extracellular fluid, in this case) down its concentration gradient (into the cytoplasm).
  (credit: modification of work by Mariana Ruiz Villareal)
II. Osmosis is the diffusion of water across a membrane
   A. the two beakers are divided in half by a selectively permeable membrane
      1. the left half of the left beaker has a lower concentration of solutes as compared to the right half
         a. hypotonic (lower concentration of solutes = higher concentration of free water molecules)
            1) free water molecules are water molecules that are not bound to solute molecules
         b. right half of beaker is hypertonic (higher concentration of solutes = lower concentration of free water molecules)
      2. water molecules move down the concentration gradient (thermal E) & establish a dynamic equilibrium
         a. shown in right beaker
            1) 2 halves are isotonic
   B. apply this to cells below
      1. hospital IV is not pure water (hypotonic to cells)
      2. cannot drink sea water (hypertonic to cells)

• In osmosis, water always moves from an area of higher water concentration to one of lower concentration. In the diagram shown, the solute cannot pass through the selectively permeable membrane, but the water can.
III. Facilitated diffusion depends on transport proteins
   A. is a passive process – E not needed
   B. O₂ & CO₂ move across the hydrophobic zone w/ little difficulty
      1. nonpolar
   C. Why are transport proteins needed?
      1. ions & polar molecules have difficulty getting past hydrophobic zone
      2. some transport proteins are channel proteins
         a. help a specific substance get across membrane
            1) aquaporins help water move across
      3. some transport proteins are carrier proteins
         a. glucose transporter in red blood cells

- Facilitated transport moves substances down their concentration gradients. They may cross the plasma membrane with the aid of channel proteins. (credit: modification of work by Mariana Ruiz Villareal)

- Some substances are able to move down their concentration gradient across the plasma membrane with the aid of carrier proteins. Carrier proteins change shape as they move molecules across the membrane. (credit: modification of work by Mariana Ruiz Villareal)
IV. Active transport requires the cell to expend $E$ to move a solute against its concentration gradient

A. solute is moved from where it is less concentrated to where it is more concentrated
B. ATP is the source of $E$ for most active transport work
C. enables the cell interior to be chemically different from cell exterior
   1. inside of animal cell has higher concentration of $K^+$
   2. inside of animal cell has lower concentration of $Na^+ & Ca^+$

• Primary active transport moves ions across a membrane, creating an electrochemical gradient (electrogenic transport). (credit: modification of work by Mariana Ruiz Villareal)
V. Endocytosis & exocytosis transport large molecules across membranes

A. endocytosis refers to uptake

1. phagocytosis “cellular eating”
   a. pseudopodia engulf the particle
   b. food vacuole merges w/ lysosome
   c. hydrolysis of particle
   d. macrophage eating bacteria

2. pinocytosis “cellular drinking”
   a. used primarily for uptake of ECF (extra-cellular fluid)

3. receptor-mediated endocytosis
   a. receptor binds to specific ligand
   b. coated pit forms
   c. how cells take up LDL’s
      1) familial hypercholesterolemia
         a) lack LDL receptors (have a high LDL level in the blood)

• In phagocytosis, the cell membrane surrounds the particle and engulfs it. (credit: Mariana Ruiz Villareal)

• In pinocytosis, the cell membrane invaginates, surrounds a small volume of fluid, and pinches off. (credit: Mariana Ruiz Villareal)

• In receptor-mediated endocytosis, uptake of substances by the cell is targeted to a single type of substance that binds to the receptor on the external surface of the cell membrane. (credit: modification of work by Mariana Ruiz Villareal)