Chapter 7: Membranes

1. What are the major roles of biological membranes?

2. What about phospholipids makes a bilayer when mixed with water? Use the term amphipathic, and contrast with what detergents do.

3. Describe the fluid mosaic model: what does it mean to have a 2-dimensional fluid and not a 3-dimensional one, and what does the “mosaic” term mean here?

4. Discuss membrane fluidity: why it is important and the ways it can be adjusted.

5. Contrast integral and peripheral membrane proteins.

6. Define and discuss these terms related to transport/transfer across cell membranes:
   - selectively permeable
   - diffusion
   - concentration gradient
   - osmosis
   - tonics
   - isotonic
   - hypertonic
   - hypotonic
   - turgor pressure


8. Describe how the sodium-potassium pump works.

9. Explain linked cotransport.

10. Define the processes of exocytosis and endocytosis (include different forms of endocytosis).

11. Summarize processes for transport of materials across membranes; include information about which ones are active (energy-requiring).

12. Discuss information transfer across a membrane (signal transduction); why is it needed, what are some concepts that you should associate with it?

13. Differentiate between the following in terms of structure and function:
   - anchoring junctions (such as desmosomes)
   - tight junctions
   - gap junctions
   - plasmodesmata
Chapter 7: Membranes

I. Roles of biological membranes
   A. membranes separate aqueous environments, so that differences can be maintained
      1. the plasma membrane surrounds the cell and separates the interior of the cell from the external environment
      2. membrane-bound organelles have their interior region separated from the rest of the cell
   B. passage of substances across membranes is generally regulated, helping to establish and maintain appropriate environments in the cell even as the outside environment changes
   C. membranes provide a surface on which many chemical events can occur
      1. enzymes embedded in membranes catalyze many chemical reactions, and the locations of reactants and products on one side or the other of the membrane is often used to help control reaction rates
      2. proteins and glycoproteins embedded in membranes are used for chemical recognition and signaling

II. Physical properties of cell membranes: the lipid bilayer and the fluid mosaic model
   A. biological membranes are lipid bilayers with associated proteins and glycoproteins
      1. most of the lipids involved are phospholipids, although others like cholesterol and various glycolipids are also present
   B. phospholipids molecules spontaneously form bilayers in aqueous environments due to their amphipathic nature and overall cylindrical structure
      1. amphipathic molecules have distinct hydrophobic and hydrophilic regions
      2. recall the hydrophilic “head” and hydrophobic “tails” of phospholipids
         - tails come from two chains of fatty acids linked to glycerol
         - head comes from a polar organic molecule linked via a phosphate group to the glycerol backbone
      3. the two tails combine with the head to give a roughly cylindrical shape to the phospholipids molecule, a shape that favors the formation of lipid bilayers over lipid spheres
      4. there are other amphipathic molecules, such as detergents (soaps, etc.), that come to a point at their single hydrophobic tail, thus tending to form spheres instead of bilayers
      5. detergents can “solubilize” lipids to varying degrees; high enough concentrations of detergents will disrupt cell membranes
   C. the fluid mosaic model describes the structure and properties of cell membranes
      1. while a structural model including a lipid bilayer was proposed in the 1930s, early models sandwiched the lipid bilayer with membrane-associated proteins
2. EM data after the 1950s showed that membrane bilayers are uniformly about 8 nm thick, too thin for the sandwich model; also, isolated membrane proteins were often found to have a globular nature that did not fit the sandwich model.

3. In 1972, the fluid mosaic model was proposed where some proteins are imbedded in lipid bilayers that act as two-dimensional fluids; this model explained the existing data and made two key predications that have been verified:
   - materials, including embedded proteins, can be moved along the membrane due to its fluid properties
   - digestion of certain “transmembrane” proteins applied to one side of a membrane will produce protein fragments that differ from those found if digestion is done only on the other side

4. Biological membranes act as **two-dimensional fluids**, or liquid crystals
   - free to move in two dimensions, but not in the third, the molecules of the membrane can rotate or move laterally
   - molecules rarely “flip” from one side of the membrane to the other (that would be movement in the third dimension)
   - the fluidity of a membrane is a function of both temperature and the molecules in the membrane
     - cells need membranes to be within a reasonable range of fluidity – too fluid and they are too weak, too viscous and they are more like solid gels
     - at a given temperature, phospholipids with saturated fats are less fluid than those with unsaturated fats
     - in an unsaturated fat, a carbon-carbon double bond produces a “bend” that causes the phospholipids to be spaced further away from its neighbors, thus retaining more freedom of motion
     - the upshot is: at colder temperatures, unsaturated fats are preferred in cell membranes; at higher temperatures, saturated fats are preferred
     - other lipids, such as **cholesterol**, can stabilize membrane fluidity
   - organisms control membrane fluidity by several means
     - by regulating their temperature
     - by changing the fatty acid profile of their membranes
     - by adding fluidity modifiers or stabilizers like cholesterol

5. Biological membranes resist having open ends
   - a lipid bilayer will spontaneously “self-seal”
   - usually, this results in nearly spherical vesicles with an internal, aqueous **lumen**
     - the spherical tendency can be modified with structural elements, such as structural proteins
     - winding membrane surfaces must be kept far enough apart and structurally supported to prevent them from self-sealing
BIOL 1020 – CHAPTER 7 LECTURE NOTES

- vesicle formation takes advantage of self-sealing as regions of membrane are pinched off by protein contractile rings
- fusion of membrane surfaces can occur when they are in close proximity
  - fusion is common between vesicles and various organelles
  - contents of two separate membrane-bound lumens are mixed when fusion occurs
  - fusion of vesicles with the plasma membrane delivers the material in the vesicle lumen to the outside of the cell

D. membrane-associated proteins

1. membrane proteins are classified as either integral or peripheral
   - **integral proteins** are amphipathic proteins that are firmly bound to the membrane, and can only be released from
     the membrane by detergents
   - some integral proteins are **transmembrane proteins**, extending completely across the membrane
     - hydrophobic alpha-helices are common in the membrane spanning domains of transmembrane proteins
     - some wind back-and-forth across the membrane, but most only span the membrane once
   - **peripheral proteins** are not embedded in the membrane; they are usually bound ionically or by hydrogen bonds to a
     hydrophilic portion of an integral protein
2. the protein profile of one membrane side typically differs from that of the other side
   - many more proteins are on the cytoplasmic side of the plasma membrane, as revealed by freeze-fracturing plasma
     membranes
   - the types of processing that a protein receives differs depending on the target side, or if it is integral
3. membrane proteins perform several functions, including acting as enzymes, regulating transport across the membrane,
   and in cell signaling

III. Transport and transfer across cell membranes

A. cell membranes are **selectively permeable**

1. some substances readily pass through, others do not
2. most permeable to small molecules and lipid-soluble substances
   - water(!) and other small molecules like CO₂ and O₂ can pass through easily
   - some examples of molecules that do not pass through easily: amino acids, sugars, ions
3. some passage across the membrane is assisted with special channels to allow or speed up the passage
4. the specific selectivity can vary depending on the membrane

B. **diffusion** across membranes is based on random motion of particles

1. particles move by random motion (kinetic energy); over time, the concentration across a membrane will tend to equalize
2. **diffusion** is the *net* movement of particles from an area with a high (initial) concentration to an area with a low (initial) concentration; a difference in concentrations establishes a **concentration gradient**, which provides the energy for diffusion.

3. given enough time, **equilibrium** will be reached (the concentrations on both sides of the membrane will be equal)

4. often equilibrium is never reached due to continual removal and/or continual production of a substance

5. rate of diffusion is a function temperature and of the size, shape, and charge nature of the substance

C. **osmosis** is diffusion of a solvent across a membrane

1. in biology, the solvent is typically water

2. solutes do not travel across membranes with water, but they affect movement by affecting the concentration of water; thus:

3. **osmotic pressure** is determined by the amount of dissolved substances in a solution; it is the tendency of water to move into the solution
   - when two solutions have the same osmotic pressure, they are **isotonic**
   - when a solution has a higher osmotic pressure than another, it is **hypertonic** to the other solution; water will tend to flow into the hypertonic solution
   - conversely, a **hypotonic** solution has a relatively lower osmotic pressure; water will tend to flow out of the hypotonic solution into the hypertonic solution

4. **turgor pressure** is hydrostatic pressure in cells with a cell wall
   - a cell wall enables cells to take in extra amounts of water without bursting
   - the cells take in water and push against the cell wall, which pushes back
   - many cells use turgor pressure as part of maintaining structure; thus, if they lose turgor pressure, plants wilt

D. special integral membrane proteins assist in transport across membranes (carrier-mediated transport)

1. **facilitated diffusion** – when net transport follows a concentration gradient, but proteins are needed to assist in transport
   - the **carrier protein** often provides a regulated **channel** or pore through the membrane
   - typically used to transport ions and large molecules like glucose, although water channels also exist
   - added energy is not required (concentration gradient provides the energy), and in some cases is harvested during transport

2. **carrier-mediated active transport** requires energy to work against a concentration gradient
   - energy is often supplied by ATP powering a protein “pump” that moves a substance against a gradient
     - example: **sodium-potassium pump** in nearly all animal cells (moves 3 Na\(^+\) out, 2 K\(^+\) in)
   - **linked cotransport** can also provide the energy for active transport
• Na⁺, K⁺, or H⁺ is transported down its gradient, providing energy
• another substance is transported at the same time against its gradient, using the energy
• the Na⁺, K⁺, or H⁺ gradient is often produced by active transport via a pump that uses ATP

E. large particles are transported across membranes via exocytosis and endocytosis

1. **exocytosis** - fusion of vesicles or vacuoles with the plasma membrane that results in secretion outside the cell or discarding waste outside the cell

2. **endocytosis** – vesicles or vacuoles bud into the cell from the plasma membrane, bringing materials into the cell
   - **phagocytosis** – large solid particles are ingested (including whole cells in some cases)
   - **pinocytosis** – smaller regions of dissolved materials are ingested
   - **receptor-mediated endocytosis** – receptor proteins in the plasma membrane bind to specific molecules, causing protein conformational (shape) changes that lead to the formation of a coated vesicle
   - typically, lysosomes bind with the vesicles or vacuoles formed via phagocytosis or receptor-mediated endocytosis

F. **signal transduction** is the transfer of information across the cell membrane

1. signal reception - special protein receptors in the cell membrane bind to signaling molecules outside the cell
2. signal transduction – the receptor, now activated, changes shape in some way and transfers information to the interior of the cells (often though a series of protein activations and eventual formation of cAMP on the cytosolic side of the cell membrane)

IV. Specialized contacts (junctions) between cells

A. cell junctions typically connect cells and can allow special transport between connected cells

B. anchoring junctions hold cells tightly together; one common type in animals is the desmosome
   1. **desmosomes** form strong bonds, including merging of cytoskeletons, making it hard to separate the cells from each other
   2. materials can still pass in the space between cells with anchoring junctions
   3. NOT involved in the transport of materials between cells

C. **tight junctions** between some animal cells are used to seal off body cavities
   1. cell plasma membranes are adjacent to each other and held together by a tight seal
   2. materials cannot pass between cells held together by tight junctions
   3. NOT involved in the transport of materials between cells

D. **gap junctions** between animal cells act as selective pores
   1. proteins connect the cells
   2. those proteins are grouped in cylinders of 6 subunits
   3. the cylinder can be opened to form a small pore (less than 2 nm), through which small molecules can pass
E. **plasmodesmata** act as selective pores between plant cells

1. Plant cell walls perform the functions of tight junctions and desmosomes

2. Plant cell walls form a barrier to cell-to-cell communication that must be breached by the functional equivalent of a gap junction

3. **Plasmodesmata** are relatively wide channels (20-45 nm) across the cell wall between adjacent cells; they actually connect the plasma membranes of the two cells, and allow exchange of some materials between the cells