Ch 7 MEMBRANE STRUCTURE AND FUNCTION

Review Questions

1. What is the primary function of the plasma membrane?

   "The plasma membrane is the edge of life, the boundary that separates the living cell from its nonliving surroundings. A remarkable film only about 8 nm thick—it would take over 8,000 to equal the thickness of this page—the plasma membrane controls traffic into and out of the cell it surrounds. Like all biological membranes, the plasma membrane exhibits selective permeability; that is, it allows some substances to cross it more easily than others. One of the earliest episodes in the evolution of life may have been the formation of a membrane that enclosed a solution different from the surrounding solution while still permitting the uptake of nutrients and elimination of waste products. This ability of the cell to discriminate in its chemical exchanges with its environment is fundamental to life, and it is the plasma membrane and its component molecules that make this selectivity possible." (Text quoted from page 125 of the textbook)

2. What does "selectively permeable" mean?

   "Like all biological membranes, the plasma membrane exhibits selective permeability; that is, it allows some substances to cross it more easily than others." (Text quoted from page 125 of the textbook)

3. What are the main structural components of a plasma membrane and how does each function?

   "Lipids and proteins are the staple ingredients of membranes, although carbohydrates are also important. The most abundant lipids in most membranes are phospholipids. The ability of phospholipids to form membranes is inherent in their molecular structure." (Text quoted from page 125 of the textbook)

4. How does the plasma membrane for a plant cell differ from that of an animal cell in its chemical composition?

   "The steroid cholesterol, which is wedged between phospholipid molecules in the plasma membranes of animal cells, has different effects on membrane fluidity at different temperatures (Figure 7.5c). At relatively warm temperatures—at 37° C, the body temperature of humans, for example—cholesterol makes the membrane less fluid by restraining the movement of phospholipids. However, because cholesterol also hinders the close packing of phospholipids, it lowers the temperature required for the membrane to solidify. Thus, cholesterol can be thought of as a "temperature buffer" for the membrane, resisting changes in membrane fluidity that can be caused by changes in temperature" (Text quoted from pages 125 and 126 of the textbook)

   "The lipid composition of cell membranes can change as an adjustment to changing temperature. For instance, in many plants that tolerate extreme cold, such as winter wheat, the percentage of unsaturated phospholipids increases in autumn, an adaptation that keeps the membranes from solidifying during winter." (Text quoted from page 126 of the textbook)

5. What forms the bilayer structure of a plasma membrane?

   "The ability of phospholipids to form membranes is inherent in their molecular structure. A phospholipid is an amphipathic molecule, meaning it has both a hydrophilic region and a hydrophobic region (see Figure 5.13)." (Text quoted from page 125 of the textbook)

“How are phospholipids and proteins arranged in the membranes of cells? You encountered the currently accepted model for the arrangement of these molecules in Chapter 6 (see Figure 6.7). In this fluid mosaic model, the membrane is a fluid structure with a “mosaic” of various proteins embedded in or attached to a double layer (bilayer) of phospholipids” (Text quoted from page 125 of the textbook)

6. Describe a glycoprotein. What is the function of a glycoprotein?

   “Cell-cell recognition, a cell’s ability to distinguish one type of neighboring cell from another, is crucial to the functioning of an organism. It is important, for example, in the sorting of cells into tissues and organs in an animal embryo. It is also the basis for the rejection of foreign cells (including those of transplanted organs) by the immune system, an important line of defense in vertebrate animals (see Chapter 43). Cells recognize other cells is by binding to surface molecules, often carbohydrates, on the plasma membrane (see Figure 7.9d).

   Membrane carbohydrates are usually short, branched chains of fewer than 15 sugar units. Some are covalently bonded to lipids, forming molecules called glycolipids. (Recall that glyco refers to the presence of carbohydrate.) However, most are covalently bonded to proteins, which are thereby glycoproteins (see Figure 7.7).” (Text quoted from page 130 of the textbook)

7. Contrast differences between integral proteins and peripheral proteins.

   ‘Notice in Figure 7.7 that there are two major populations of membrane proteins. Integral proteins penetrate the hydrophobic core of the lipid bilayer. Many are transmembrane proteins, which span the membrane; other integral proteins extend only partway into the hydrophobic core. The hydrophobic regions of an integral protein consist of one or more stretches of nonpolar amino acids (see Figure 5.17), usually coiled into α helices (Figure 7.8). The hydrophilic parts of the molecule are exposed to the aqueous solutions on either side of the membrane. Some proteins also have a hydrophilic channel through their center that allows passage of hydrophilic substances (see Figure 7.1). Peripheral proteins are not embedded in the lipid bilayer at all; they are appendages loosely bound to the surface of the membrane, often to the exposed parts of integral proteins (see Figure 7.7).” (Text quoted from page 129 of the textbook. See Figure 7.7 on page 128 and Figure 7.8 on page 129)

8. How do transport proteins contribute to a membrane’s selective permeability?

   “Cell membranes are permeable to specific ions and a variety of polar molecules. These hydrophilic substances can avoid contact with the lipid bilayer by passing through transport proteins that span the membrane. Some transport proteins, called channel proteins, function by having a hydrophilic channel that certain molecules or atomic ions use as a tunnel through the membrane (see Figure 7.9a, left). For example, the passage of water molecules through the membrane in certain cells is greatly facilitated by channel proteins known as aquaporins.“ (Text quoted from page 131 of textbook)

   “Other transport proteins, called carrier proteins, hold onto their passengers and change shape in a way that shuttles them across the membrane (see Figure 7.9a, right). A transport protein is specific for the substance it translocates (moves), allowing only a certain substance (or substances) to cross the membrane. For example, glucose carried in blood and needed by red blood cells for cellular activities enters the red blood cells rapidly via specific carrier proteins in the plasma membrane. The glucose passes through the membrane 50,000 times faster than if diffusing through on its own. This

"glucose transporter" is so selective as a carrier protein that it even rejects fructose, a structural isomer of glucose.
Thus, the selective permeability of a membrane depends on both the discriminating barrier of the lipid bilayer and the specific transport proteins built into the membrane." (Text quoted from page 131 of the textbook)

9. What kinds of substances can pass easily through the phospholipids bilayer of a plasma membrane?
   "Nonpolar molecules, such as hydrocarbons, carbon dioxide, and oxygen, are hydrophobic and can therefore dissolve in the lipid bilayer of the membrane and cross it easily, without the aid of membrane proteins." (Text quoted from page 131 of the textbook)

10. What kinds of substance cannot pass through the phospholipids bilayer of a plasma membrane?
    "However, the hydrophobic core of the membrane impedes the direct passage of ions and polar molecules, which are hydrophilic, through the membrane. Polar molecules such as glucose and other sugars pass only slowly through a lipid bilayer, and even water, an extremely small polar molecule, does not cross very rapidly. A charged atom or molecule and its surrounding shell of water (see Figure 3.7) find the hydrophobic layer of the membrane even more difficult to penetrate. Furthermore, the lipid bilayer is only one aspect of the gatekeeper system responsible for the selective permeability of a cell.. Proteins built into the membrane play key roles in regulating transport." (Text quoted from page 131 of the textbook)

11. Contrast the difference between passive and active transport.
    "The diffusion of a substance across a biological membrane is called passive transport because the cell does not have to expend energy to make it happen. The concentration gradient itself represents potential energy (see Chapter 2, p. 35) and drives diffusion. Remember, however, that membranes are selectively permeable and therefore have different effects on the rates of diffusion of various molecules. In the case of water, aquaporins allow water to diffuse very rapidly across the membranes of certain cells. (Text quoted from page 132 of the textbook)
    "To pump a molecule across a membrane against its gradient requires work; the cell must expend energy. Therefore, this type of membrane traffic is called active transport. The transport proteins that move solutes against a concentration gradient are all carrier proteins, rather than channel proteins. This makes sense, because when channel proteins are open, they merely allow molecules to flow down their concentration gradient, rather than picking them up and transporting them against their gradient." (Text quoted from page 135 of the textbook.)

12. Describe the reaction of an animal cell/plant cell when placed in an isotonic solution, a hypotonic solution, and a hypertonic solution.
    "When considering the behavior of a cell in a solution, both solute concentration and membrane permeability must be considered. Both factors are taken into account in the concept of tonicity, the ability of a solution to cause a cell to gain or lose water. The tonicity of a solution depends in part on its concentration of solutes that cannot cross the membrane (nonpenetrating solutes), relative to that inside the cell. If there are more nonpenetrating solutes in the surrounding solution, water will tend to leave the cell, and vice versa.

If a cell without a wall, such as an animal cell, is immersed in an environment that is isotonic to the cell (iso means “same”), there will be no net movement of water across the plasma membrane. Water flows across the membrane, but at the same rate in both directions. In an isotonic environment, the volume of an animal cell is stable (Figure 7.13a).

Now let′s transfer the cell to a solution that is hypertonic to the cell (hyper means “more,” in this case referring to nonpenetrating solutes). The cell will lose water to its environment, shrivel, and probably die. This is one reason why an increase in the salinity (saltiness) of a lake can kill the animals there—if the lake water becomes hypertonic to the animals′ cells, the cells might shrivel and die. However, taking up too much water can be just as hazardous to an animal cell as losing water. If we place the cell in a solution that is hypotonic to the cell (hypo means “less”), water will enter the cell faster than it leaves, and the cell will swell and lyse (burst) like an overfilled water balloon.

A cell without rigid walls can tolerate neither excessive uptake nor excessive loss of water. This problem of water balance is automatically solved if such a cell lives in isotonic surroundings. Seawater is isotonic to many marine invertebrates. The cells of most terrestrial (land-dwelling) animals are bathed in an extracellular fluid that is isotonic to the cells. Animals and other organisms without rigid cell walls living in hypertonic or hypotonic environments must have special adaptations for osmoregulation, the control of water balance. For example, the protist Paramecium lives in pond water, which is hypotonic to the cell. Paramecium has a plasma membrane that is much less permeable to water than the membranes of most other cells, but this only slows the uptake of water, which continually enters the cell. The Paramecium cell doesn′t burst because it is also equipped with a contractile vacuole, an organelle that functions as a bilge pump to force water out of the cell as fast as it enters by osmosis (Figure 7.14).” (Text quoted from pages 133 and 134 of the textbook)

“The cells of plants, prokaryotes, fungi, and some protists have walls(see Figure 6.28). When such a cell is immersed in a hypotonic solution—bathed in rainwater, for example—the wall helps maintain the cell′s water balance. Consider a plant cell. Like an animal cell, the plant cell swells as water enters by osmosis (Figure 7.13a) However, the relatively inelastic wall will expand only so much before it exerts a back pressure on the cell that opposes further water uptake. At this point, the cell is turgid (very firm), which is the healthy state for most plant cells. Plants that are not woody, such as most houseplants, depend for mechanical support on cells kept turgid by a surrounding hypotonic solution. If a plant′s cells and their surroundings are isotonic, there is no net tendency for water to enter, and the cells become flaccid (limp).

However, a wall is of no advantage if the cell is immersed in a hypertonic environment. In this case, a plant cell, like an animal cell, will lose water to its surroundings and shrink. As the plant cell shrivels, its plasma membrane pulls away from the wall. This phenomenon, called plasmolysis, causes the plant to wilt and can lead to plant death. The walled cells of bacteria and fungi also plasmolyze in hypertonic environments.” (Text quoted from page 134 of the textbook. See Figure 7.13 on page 133 of the textbook)

13. What is hemolysis? How can hemolysis occur?

When red blood cells are in an environment that is hypotonic to the cell, the cell takes in water more rapidly. The plasma membrane ruptures or lyses. This is called hemolysis because the protein hemoglobin which is normally contained in the red blood cell is released from the lysed cell. (See figure 7.13 on page 133 of the textbook)

14. What is plasmolysis? How can plasmolysis occur?

    "However, a wall is of no advantage if the cell is immersed in a hypertonic environment. In this case, a plant cell, like an animal cell, will lose water to its surroundings and shrink. As the plant cell shrivels, its plasma membrane pulls away from the wall. This phenomenon, called plasmolysis, causes the plant to wilt and can lead to plant death. The walled cells of bacteria and fungi also plasmolyze in hypertonic environments." (Text quoted from page 134 of the textbook)

15. What are some examples of passive transport?

    "As mentioned earlier, many polar molecules and ions impeded by the lipid bilayer of the membrane diffuse passively with the help of transport proteins that span the membrane. This phenomenon is called facilitated diffusion. Cell biologists are still trying to learn exactly how various transport proteins facilitate diffusion. Most transport proteins are very specific: They transport only particular substances but not others.

    As described earlier, the two types of transport proteins are channel proteins and carrier proteins. Channel proteins simply provide corridors that allow a specific molecule or ion to cross the membrane (Figure 7.15a). The hydrophilic passageways provided by these proteins allow water molecules or small ions to flow very quickly from one side of the membrane to the other. Although water molecules are small enough to cross through the phospholipid bilayer, the rate of water movement by this route is relatively slow because of their polarity. Aquaporins, the water channel proteins, facilitate the massive amounts of diffusion that occur in plant cells and in animal cells such as red blood cells (see Figure 7.13). Kidney cells also have a high number of aquaporins, allowing them to reclaim wate from the urine before it is excreted." (Text quoted from page 134 of the textbook)

    "Another group of channels are ion channels, many of which function as gated channels; which open or close in response to a stimulus. The stimulus may be electrical or chemical; if chemical, the stimulus is a substance other than the one to be transported. For example, stimulation of a nerve cell by certain neurotransmitter molecules opens gated channels that allow sodium ions into the cell. " (Text quoted from pages 133 and 134 of the textbook)

16. What is an example of active transport?

    "To pump a molecule across a membrane against its gradient requires work; the cell must expend energy. Therefore, this type of membrane traffic is called active transport. The transport proteins that move solutes against a concentration gradient are all carrier proteins, rather than channel proteins." (Text quoted from page 135 of the textbook)

    "Active transport enables a cell to maintain internal concentrations of small molecules that differ from concentrations in its environment. For example, compared to its surroundings, an animal cell has a much higher concentration of potassium ions and a much lower concentration of sodium ions. The plasma membrane helps maintain these steep gradients by pumping sodium out of the cell and potassium into the cell.

    As in other types of cellular work, ATP supplies the energy for most active transport. One way ATP can power active transport is by transferring its terminal phosphate group directly to the transport protein. This can induce the protein to change its shape in a manner that translocates a solute bound to the protein across the membrane. One transport system that works this way is the sodium-potassium pump, which exchanges sodium (Na+) for potassium (K+) across the plasma membrane of animal cells (Figure 7.16). Figure 7.17 reviews the distinction between passive transport and active transport." (Text quoted from pages 135 and 136 of the textbook. See Figure 7.16 and Figure 7.17 on page 136 of the textbook)

17. How is facilitated transport similar to active transport? How is facilitated transport different from active transport?

    Both facilitated transport and active transport use transmembrane proteins to move molecules across the membrane. However facilitated transport does not use energy to move the molecules across the membrane while energy is required to move molecules with active transport.

18. Describe the process of phagocytosis.

    "In phagocytosis, a cell engulfs a particle by wrapping pseudopodia (singular psuedopodium) around it and packaging it within a membrane-enclosed sac that can be large enough to be classified as a vacuole. The particle is digested after the vacuole fuses with a lysosome containing hydrolytic enzymes." (Text quoted from Figure 7.20 on page 139 of textbook)

19. What is endocytosis? What are some examples of endocytosis? How is endocytosis like active transport?

    In endocytosis, the cell takes in biological molecules and particulate matter by forming new vesicles from the plasma membrane. Although the proteins involved in the processes are different, the events of endocytosis look like the reverse of exocytosis. A small area of the plasma membrane sinks inward to form a pocket. As the pocket deepens, it pinches in, forming a vesicle containing material that had been outside the cell. There are three types of endocytosis: phagocytosis ("cellular eating"), pinocytosis ("cellular drinking"), and receptor-mediated endocytosis.(study Figure 7.20)" (Text quoted from page 138 of the textbook)

    Both endocytosis and active transport are powered by ATP.

20. What is exocytosis? What is the function of exocytosis?

    "As we described in Chapter 6, the cell secretes certain biological molecules by the fusion of vesicles with the plasma membrane; this is called exocytosis. A transport vesicle that has budded from the Golgi apparatus moves along microtubules of the cytoskeleton to the plasma membrane. When the vesicle membrane and plasma membrane come into contact, the lipid molecules of the two bilayers rearrange themselves so that the two membranes fuse. The contents of the vesicle then spill to the outside of the cell, and the vesicle membrane becomes part of the plasma membrane (see Figure 7.10).

    Many secretory cells use exocytosis to export their products. For example, certain cells in the pancreas make insulin and secrete it into the blood by exocytosis. Another example is the neuron(nerve cell), which uses exocytosis to release neurotransmitters that signal other neurons or muscle cells. When plant cells are making walls, exocytosis delivers proteins and carbohydrates from Golgi vesicles to the outside of the cell." (Text quoted from page138 of the textbook See Figure 7.10 on page 130 of the textbook.)

Concept check 7.1 Page 130 questions 1 and 2
Concept check 7.2 Page 131 questions 1, 2 and 3
Concept check 7.3 Page 135 questions 2 and 3
Concept check 7.5 Page 138 questions 1 and 2

Pages 141 of textbook

- Questions 1, 2, 4, 5, and 6

KEY TERMS

Active transport
Concentration gradient
Cotransport
Endocytosis
Exocytosis
Facilitated diffusion
Flaccid
Gated channels
Glycolipid
Glycoprotein
Hypertonic
Hypotonic
Integral protein
Ion channels
Isotonic
Membrane potential
Osmosis
Osmoregulation
Passive transport
Peripheral protein
Phagocytosis
Pinocytosis
Plasmolysis
Selective permeability
Transport proteins
Turgid

ACTIVITIES ON CD

- Concept 7.1: Cellular membranes are fluid mosaics of lipids and proteins
  - Activity: Membrane Structure (interactive)
- Concept 7.2: Membrane structure results in selective permeability
  - Activity: Selective Permeability of Membranes
- Concept 7.3: Passive transport is diffusion of a substance across a membrane with no energy investment
  - Activity: Diffusion
  - Activity: Osmosis and Water Balance in Cells (interactive)
  - Activity: Facilitated Diffusion
- Concept 7.4: Active transport uses energy to move solutes against their gradients
  - Activity: Active Transport (interactive)
- Concept 7.5: Bulk transport across the plasma membrane occurs by exocytosis and endocytosis
  - Activity: Exocytosis and Endocytosis (interactive read captions above choices)