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Chapter 7: Membrane Structure and Function

1. What four main classes do the large molecules of all living things fall into?

Unlike lipids, carbohydrates, proteins, and nucleic acids are macromolecular chain-like molecules called polymers.

2. Explain the term "amphipathic".

Amphipathic molecules have both a hydrophilic and a hydrophobic region.

3. Describe the Davson-Danielli model of membrane structure.

In Davson and Danielli's sandwich model, proposed in 1935, the membrane is coated on both sides with hydrophilic proteins, forming a phospholipid bilayer between two layers of proteins. By the late 1960s, however, many cell biologists recognized two problems with the model. First, inspection of a variety of membranes revealed that membranes with different functions differ in structure and chemical composition. Secondly, unlike proteins dissolved in the cytosol, membrane proteins are not very soluble in water because they are amphipathic. If such proteins were layered on the surface of the membrane, their hydrophobic parts would be in aqueous surroundings.

4. Describe the fluid mosaic model of membrane structure.

In 1972, Singer and Nicolson proposed that membrane proteins reside in the phospholipid bilayer with their hydrophilic regions protruding. This molecular arrangement maximizes contact between the hydrophilic regions of proteins and phospholipids with water in the cytosol and extracellular fluid, while providing their hydrophobic parts with a non-aqueous environment. In this fluid mosaic model, the membrane is a mosaic of protein molecules bobbing in a fluid bilayer of phospholipids.

5. What is meant by membrane fluidity?

Membranes are not static sheets of molecules locked rigidly in place. Most of the lipids and some of the proteins can shift about laterally. It is quite rare for a molecule to flip-flop transversely across the membrane, switching from one phospholipid layer to the other.

6. Describe how the following factors can affect membrane fluidity.

A membrane remains fluid as temperature decreases until finally the phospholipids settle into a closely packed arrangement and the membrane solidifies. The membrane remains fluid to a lower temperature if it is rich in phospholipids with unsaturated hydrocarbon chains. Because of kinks in the tails where double bonds are located, unsaturated hydrocarbon tails cannot pack together as closely as saturated hydrocarbon tails, making the membrane more fluid. The steroid cholesterol, which is wedged between phospholipid molecules in the plasma membranes of animal cells, makes the membrane less fluid at high temperatures by restraining phospholipid movement and lowers the temperature required for the membrane to solidify by hindering the close packing of phospholipids. Thus, cholesterol can be thought of as a "fluidity buffer" for the membrane.

7. Membrane proteins are the mosaic part of the model.

Integral proteins penetrate the hydrophobic interior of the lipid bilayer. Peripheral proteins are not embedded in the lipid bilayer at all; they are appendages loosely bound to the surface of the membrane, often to exposed parts of integral proteins.

8. Describe major functions of membrane proteins.

Function	*Description*

transport	protein that spans membrane may provide hydrophilic channel across membrane; others shuttle substances from one side to another by changing shape; some hydrolyze ATP as an energy source to actively pump substances across membrane
enzymatic activity	protein built into membrane may be an enzyme with active site exposed to substances in adjacent solution; several enzymes may be organized as a team carrying out sequential steps of a metabolic pathway
signal transduction	membrane protein (receptor) may have binding site with specific shape that fits shape of chemical messenger, such as hormone; external messenger (signaling molecule) may cause protein to change shape, allowing it to relay message to inside of cell
cell-cell recognition	some glycoproteins serve as ID tags specifically recognized by membrane proteins of other cells
intercellular joining	membrane proteins of adjacent cells may hook together in various kinds of junctions; longer-lasting than cell-cell recognition
attachment to cytoskeleton and ECM	microfilaments, other elements of cytoskeleton may noncovalently bind to membrane proteins; helps maintain cell shape, stabilizes location of certain membrane proteins; proteins bound to ECM molecules can coordinate extracellular, intercellular changes

9. Membrane carbohydrates are important in cell-cell recognition. What are two examples of this?

Cell-cell recognition is important in the sorting of cells into tissues and organs in an animal embryo and the basis for the rejection of foreign cells by the immune system, an important line of defense in vertebrates.

10. Compare and contrast glycolipids and glycoproteins.

Glycolipids are membrane carbohydrates (short, branched chains of fewer than 15 sugar units) covalently bonded to lipids. However, most are covalently bonded to proteins, forming glycoproteins.

12. Compare and contrast channel proteins and carrier proteins.

Channel proteins such as aquaporins function by having a hydrophilic channel that certain molecules or atomic ions use as a tunnel through the membrane. Carrier proteins hold onto their passengers and change shape in a way that shuttles them across the membrane.

13. Are transport proteins specific?

Transport proteins are specific for the substances they translocate. For example, a specific carrier protein in the plasma membrane of red blood cells transports glucose across the membrane 50,000 times faster than glucose can pass through on its own. This “glucose transporter” is so selective that it even rejects fructose.

14. Peter Agre received the Nobel Prize in 2003 for the discovery of aquaporins. What are they?

Passage of water molecules through the membranes of certain cells is greatly facilitated by channel proteins known as aquaporins. Each aquaporin allows entry of up to 3 billion water molecules per second, passing single file through its central channel, which fits ten at a time.

15. Consider the following materials that must cross the membrane.

Material	*Method*
CO_2	simple diffusion
glucose	transport proteins
H^+	transport proteins
O_2	simple diffusion
H_2O	simple diffusion and protein channels (aquaporins)

16. Define the following terms.

Diffusion is the movement of molecules of any substance so that they spread out evenly into the available space. In the absence of other forces, a substance will diffuse down its concentration gradient, i.e. from where it is more concentrated to where it is less concentrated. Passive transport does not need to be induced by the cell through expenditure of energy. The diffusion of free water across a selectively permeable membrane, whether artificial or cellular, is called osmosis. If a cell without a wall is immersed in an environment that is isotonic to the cell, there will be no net movement of water across the plasma membrane. In a hypertonic solution, the cell will lose water, shrivel, and probably die. In a hypotonic solution, water will enter the cell faster than it leaves, and the cell will swell and lyse (burst). Plant cells are turgid (firm) in hypotonic environments, flaccid (limp) in isotonic environments, and plasmolyzed (shriveled) in hypertonic environments.

17. Use words from #16 to describe why a carrot left on the counter overnight would become limp.

The cells of the carrot contain more water molecules than the air surrounding it, meaning the cells are hypotonic to the air, and the air is hypertonic to the cells, so water will leave the carrot cells down its concentration gradient via osmosis causing the carrot cells to change from turgid to flaccid before finally undergoing plasmolysis. The diffusion of water is a form of passive transport.

18. What is facilitated diffusion?

In facilitated diffusion, polar molecules and ions impeded by the lipid bilayer of the membrane diffuse passively with the help of transport proteins that span the membrane. Aquaporins facilitate the massive amounts of diffusion that occur in plant and animal cells. The "glucose transporter" in the plasma membrane of red blood cells specifically facilitates the transport of glucose.

20. Why doesn't the plant cell burst?

The plant cell is protected from lysis by the cell wall.

21. Describe active transport.

In active transport, the cell must expend energy to pump a solute across a membrane against its gradient. Energy for this work is usually supplied by ATP. The transport proteins that move solutes against their concentration gradients are all carrier, rather than channel, proteins.

22. Label a diagram of the sodium-potassium pump.

(1) Cytoplasmic Na^+ binds to the sodium-potassium pump. The affinity for Na^+ is high when the protein has this shape. (2) Na^+ binding stimulates phosphorylation by ATP. (3) Phosphorylation leads to a change in protein shape, reducing its affinity for Na^+, which is released outside. (4) The new shape has a high affinity for K^+, which binds on the extracellular side and triggers release of the phosphate group. (5) Loss of the phosphate group restores the protein's original shape, which has a lower affinity for K^+. (6) K^+ is released; affinity for Na^+ is high again, and the cycle repeats.

23. Label the diagram with each type of transport.

An example of facilitated diffusion with a carrier protein is the movement of glucose through glucose transporters. An example of facilitated diffusion with a channel protein is aquaporins transporting water. An example of active transport with a carrier protein is the sodium-potassium pump. An example of simple diffusion is the movement of oxygen.

24. What is membrane potential?

Membrane potential is the voltage across a membrane, ranging from ~–50 to ~–200 mV. The interior of the cell is negative relative to the exterior.

25. What are the two forces that drive the diffusion of ions across the membrane?

The electrochemical gradient is the combination of a chemical force (the ion's concentration gradient) and an electrical force (the effect of the membrane potential on the ion's movement) acting on the ion.

26. What is cotransport? Explain how understanding it is used in our treatment of diarrhea.

In cotransport, a single ATP-powered pump that transports a specific solute drives the active transport of several other solutes. Normally, sodium in waste is reabsorbed in the colon, maintaining constant levels in the body, but diarrhea expels waste so rapidly that reabsorption is not possible, and sodium levels fall precipitously. To treat this life-threatening condition, patients are given a solution to drink containing high concentrations of salt and glucose. The solutes are taken up by sodium-glucose cotransporters on the surface of intestinal cells and passed through the cells into the blood. This simple treatment has lowered infant mortality worldwide.

27. Define each of the following and give a specific cellular example.

In exocytosis, the cell secretes certain biological molecules by the fusion of vesicles with the plasma membrane. The cells in the pancreas that make insulin secrete it into the extracellular fluid by exocytosis. In endocytosis, the cell takes in biological molecules and particulate matter by forming new vesicles from the plasma membrane. Human cells use receptor-mediated endocytosis to take in cholesterol for membrane synthesis and the synthesis of other steroids. In receptor-mediated endocytosis, receptor proteins cluster in regions of the membrane called coated pits, which are lined on their cytoplasmic side by a fuzzy layer of coat proteins. Each coated pit forms a vesicle containing the ligand molecules. This enables cells to acquire bulk quantities of specific substances, even though those substances may not be very concentrated in the extracellular fluid. In phagocytosis, a cell engulfs a particle by wrapping pseudopodia around it and packaging it within a membranous sac (food vacuole). In pinocytosis, the cell "gulps" droplets of extracellular fluid into tiny vesicles. It is not the fluid itself that is needed by the cell, but the molecules dissolved in the droplets. Pinocytosis is nonspecific to the substances it transports.

28. What is a ligand?

A ligand is any molecule that binds specifically to a receptor site on another molecule. Ligands bind to proteins with specific receptor sites exposed to the extracellular fluid in the process of receptor-mediated endocytosis.

29. Are the processes in #23 active or passive transport?

Diffusion and facilitated diffusion are both forms of passive transport as they do not move substances against the concentration gradient.