ANSWERS

1 A) There will be no net movement of K^+ (although the ions will move in both directions).

B) K^+ will move out the vesicle, down its concentration gradient, creating a membrane potential, negative inside. The movement will continue until the electrical gradient counterbalances the concentration gradient.

C) K^+ will move in the vesicle, down its concentration gradient, creating a membrane potential, negative outside. The movement will continue until the electrical gradient counterbalances the concentration gradient. Note: the K^+ leak channel works the same way, independent of its orientation in the membrane: it always enables K^+ ions to move down their electrochemical gradient.

2 A) We respond that this is not true. Indeed, the presence of a ligand will increase the frequency of opening of a channel. However, the channel will still open and close. This can be visualized in the figure.

B) Each of the rectangular peaks corresponds to the opening of a single channel that allows a small current to pass. Each channel remains open for a small amount of time (about 5-10 msec).

C) Acetylcholine must bind to the extracellular side of the channel. Hence, the presence of acetylcholine on the other side (corresponding to the cytoplasmic side) would not open the channel.

D) The current doubles, which means that 2 channels were opened at the same time (hence the patch contains at least two channels).

3 The reasons for Na^+ and H^+ not passing through the channel are different.

- For Na^+: the size of the pore is too small for hydrated Na^+ to pass through, hence the only possibility would be for it to become dehydrated. This process is very unfavorable energetically. The pore, which has a hydrophobic wall, cannot interact with dehydrated Na^+ to compensate for the loss of water. Hence, the energy cost is too high, preventing Na^+ to pass.
- For H^+: H^+ cannot diffuse from one water molecule to the next in the pore, because of the presence of two Asn residues at the center of the pore. These Asn bind and occupy the two free valencies of the oxygen of H_2O. Hence, the oxygen cannot act as a proton acceptor at that step, and H^+ passage is blocked.

4

A. In absence of ATP, no ions will be pumped.

B. The pumps will use ATP hydrolysis to transport Na^+ into vesicles and K^+ out, generating concentration gradients. The pump will work until ATP is consumed or when there is no K^+ inside the vesicles anymore.

C. The pump will proceed through steps 1-3, and then stop. Because the conformational changes are strictly sequential, the pump will be stuck.

D. The result will be the same as in B, except that the pumps oriented with the ATP hydrolysis site inside the vesicle would be inactive because they would not have access to it.

5 There is little net movement of K^+ because this cation is nearly at its equilibrium: the membrane potential opposes its exit of the cell down its concentration gradient. Ca^{++} would enter, but its concentration outside the cell is only ~1 mM, compared to ~150 mM for Na^+. Hence, when an acetylcholine-gated cation channel opens, it is mostly Na^+ ions that enter.

6 PVPA

7:

1. B Channel
2. E Passive transport
3. D Membrane transport protein
4. A Active transport
5. C Electrochemical gradient

8 : The order is CO_2 (small and nonpolar) > ethanol (small and slightly polar) > H_2O (small and polar) > glucose (large and polar) > Ca^{2+} (small and charged) > RNA (very large and highly charged). his list nicely illus- trates the two basic properties that govern the capacity of molecules to difuse through a lipid bilayer: size (small > large) and polarity (nonpolar > polar > charged).

9: TRUE/FALSE + Explanations

A: False. Lipid bilayers are impermeable to ions, but the plasma membrane contains specific ion channels and transporters that make it very perme- able to particular ions and charged solutes under certain circumstances.

B: True. Transporters bind specific molecules and undergo a series of con- formational changes to move the bound molecule across a membrane. hey can transport passively down the electrochemical gradient, or the transporters can link the conformational changes to a source of meta- bolic energy such as ATP hydrolysis to drive active transport. By contrast, channels form aqueous pores that can be open or shut, but always trans- port downhill; that is, passively. Channels interact much more weakly with the solute to be transported, and they do not undergo conforma- tional changes to accomplish transport. As a consequence, transport through channels cannot be linked to an energy source and is always passive.

C: False. A symporter binds two diferent solutes on the *same side* of the membrane. Turning it around would not change it into an antiporter, which must bind two diferent solutes on *opposite sides* of the membrane.

D: False. Primary active transport is mediated by carriers that are driven by ATP hydrolysis. In co-transport of Na^+ and a solute into a cell, the energy in the Na^+ gradient is used to drive uptake of the solute. he Na^+ that enters the cell is then pumped back out by an ATP-dependent Na^+ pump. Because the Na^+ gradient must be restored by ATP hydrolysis in a subse- quent event, co-transport of Na^+ and a solute is termed secondary active transport.

E: False. Transporters *and* channels saturate. It is thought that permeating ions have to shed most of their associated water molecules in order to pass, in single file, through the narrowest part—the selectivity ilter—of the channel. his requirement limits their rate of passage. hus, as ion concentrations increase, the lux of ions through a channel increases proportionally, but then levels of (saturates) at a maximum rate.

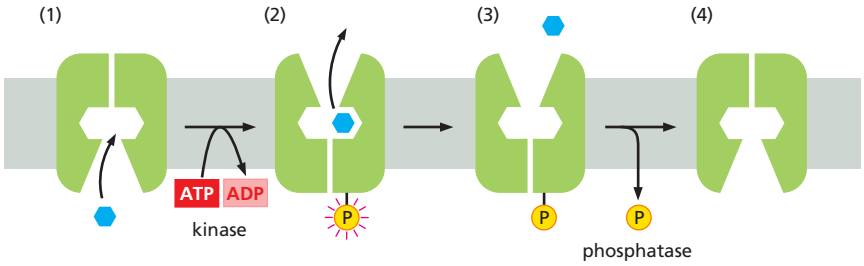
F: True. It takes a diference of only a minute number of ions to set up the membrane potential.

G: False. Channels open in an all-or-nothing fashion. hus, the aggregate current does not indicate the degree to which individual channels are open, but rather the total number of channels in the membrane that are open at any one time.

H: True. In the absence of a specific ligand, such ion channels will remain closed, preventing them from generating an action potential.

10: The equilibrium distribution of a molecule across a membrane depends on the chemical gradient (concentration) and on the electrical gradient (membrane potential). An uncharged molecule does not experience the electrical gradient and, thus, will be at equilibrium when it is at the same concentration on both sides of the membrane. A charged molecule responds to both components of the electrochemical gradient and will distribute accordingly. K^+ ions, for example, are nearly at their equilibrium distribution across the plasma membrane even though they are about 30-fold more concentrated inside the cell. The diference in concentration is balanced by the membrane potential (negative inside), which opposes the movement of cations to the outside of the cell.

11: One model for incorporating ATP into the cycle of conformational changes necessary to drive glucose transport against its concentration gradient is shown in **Figure 11–16**. ATP donates a phosphate group to the transporter when—and only when it has glucose bound on the inside face of the membrane. The binding of glucose signals to the kinase that the transporter is ready to be phosphorylated (step 1 → 2). The attach- ment of the phosphate would trigger an immediate conformational change, thereby capturing the glucose and exposing it to the outside



12: Ion channels are ion-selective and they are gated, whereas simple aqueous pores allow movement of many diferent ions and they are open all the time.

13: The narrow pore in aquaporins is lined with hydrophobic amino acids on one side and a string of carbonyl oxygens on the other, which forms a path that water molecules follow. The narrowness of the pore does not allow passage of hydrated ions of K+, Na+, Ca+, and Cl–, nor does the channel provide enough polar groups to balance the charge on the ions.

H+ ions, which are present in cells as H3O+, ofer a special challenge because they normally “move” through solution by relay along a chain of hydrogen-bonded water molecules. If such a chain of water molecules existed in the aquaporin pore, then H+ ions would whiz through membranes unobstructed. Aquaporins prevent this eventuality by positioning two asparagines in the middle of the pore, thereby tying up both free valences of the central water molecule in the string (Figure 11–18). Without a free valence for hydrogen-binding, the central water molecule can- not participate in the relay of the H+ ion.

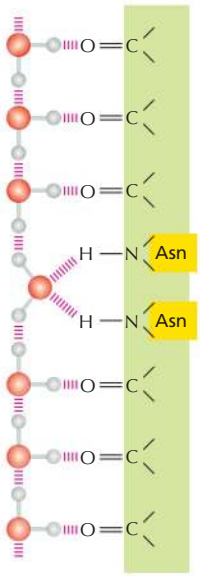


Figure 11–18 Interruption of H^+ relay by central asparagines in the aquaporin channel (Problem 11–59).

14: There is little net movement of K^+ because it is nearly at its equilibrium distribution; the membrane potential opposes movement out of the cell down its concentration gradient. By contrast, Na^+ is not at its equilibrium distribution; both the concentration difference and the membrane potential tend to push it into the cell. The same is true for Ca^{2+}; however, its external concentration is only about 1 mM versus about 145 mM for Na^+. Thus, when an acetylcholine-gated channel opens, Na^+ ions constitute the great majority of the cations that enter.