Book test bank

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Transport across plasma membrane + action potential

1. Which of the following characteristics is shared by simple and facilitated diffusion of glucose?

(A) Occurs down an electrochemical gradient
(B) Is saturable
(C) Requires metabolic energy
(D) Is inhibited by the presence of galactose
(E) Requires a Na^+ gradient

1. The answer is A [II A 1, C]. Both types of transport occur down an electrochemical gradient ("downhill") and do not require metabolic energy. Saturability and inhibition by other sugars are characteristic only of carrier-mediated glucose transport; thus, facilitated diffusion is saturable and inhibited by galactose, whereas simple diffusion is not.

2. During the upstroke of the nerve action potential

(A) there is net outward current and the cell interior becomes more negative
(B) there is net outward current and the cell interior becomes less negative
(C) there is net inward current and the cell interior becomes more negative
(D) there is net inward current and the cell interior becomes less negative

diffusion is saturable and inhibited by galactose, whereas simple diffusion is not.

2. The answer is D [IV E 1 a, b, 2 b]. During the upstroke of the action potential, the cell depolarizes or becomes less negative. The depolarization is caused by inward current, which is, by definition, the movement of positive charge into the cell. In nerve and in most types of muscle, this inward current is carried by Na^+.

3. Solutions A and B are separated by a semipermeable membrane that is permeable to K^+ but not to Cl^-. Solution A is 100 mM KCl, and solution B is 1 mM KCl. Which of the following statements about solution A and solution B is true?

(A) K^+ ions will diffuse from solution A to solution B until the $[K^+]$ of both solutions is 50.5 mM
(B) K^+ ions will diffuse from solution B to solution A until the $[K^+]$ of both solutions is 50.5 mM
(C) KCl will diffuse from solution A to solution B until the [KCl] of both solutions is 50.5 mM
(D) K^+ will diffuse from solution A to solution B until a membrane potential develops with solution A negative with respect to solution B
(E) K^+ will diffuse from solution A to solution B until a membrane potential develops with solution A positive with respect to solution B

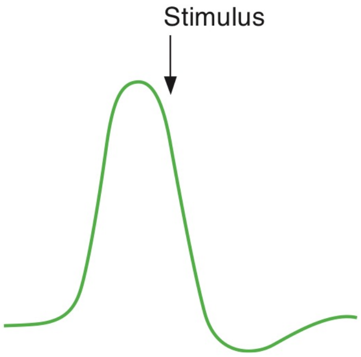
3. The answer is D [IV B]. Because the membrane is permeable only to K^+ ions, K^+ will diffuse down its concentration gradient from solution A to solution B, leaving some Cl^- ions behind in solution A. A diffusion potential will be created, with solution A negative with respect to solution B. Generation of a diffusion potential involves movement of only a few ions and, therefore, does not cause a change in the concentration of the bulk solutions.

7. Solutions A and B are separated by a membrane that is permeable to Ca^{2+} and impermeable to Cl^-. Solution A contains 10 mM $CaCl_2$, and solution B contains 1 mM $CaCl_2$. Assuming that 2.3 RT/F = 60 mV, Ca^{2+} will be at electrochemical equilibrium when

(A) solution A is +60 mV
(B) solution A is +30 mV
(C) solution A is –60 mV
(D) solution A is –30 mV
(E) solution A is +120 mV
(F) solution A is –120 mV
(G) the Ca^{2+} concentrations of the two solutions are equal
(H) the concentrations of the two solutions are equal

7. The answer is D [IV B]. The membrane is permeable to Ca^{2+} but impermeable to Cl^-. Although there is a concentration gradient across the membrane for both ions, only Ca^{2+} can diffuse down this gradient. Ca^{2+} will diffuse from solution A to solution B, leaving negative charge behind in solution A. The magnitude of this voltage can be calculated for electrochemical equilibrium with the Nernst equation as follows: $E_{Ca^{2+}} = 2.3\ RT/zF \log C_A/C_B = 60\ mV/{+2} \log 10\ mM/1\ mM = 30\ mV \log 10 = 30\ mV$. The sign is determined with an intuitive approach—Ca^{2+} diffuses from solution A to solution B, so solution A develops a negative voltage (–30 mV). Net diffusion of Ca^{2+} will cease when this voltage is achieved, that is, when the chemical driving force is exactly balanced by the electrical driving force (not when the Ca^{2+} concentrations of the solutions become equal).

10. During a nerve action potential, a stimulus is delivered as indicated by the arrow shown in the following figure. In response to the stimulus, a second action potential



(A) of smaller magnitude will occur
(B) of normal magnitude will occur
(C) of normal magnitude will occur but will be delayed
(D) will occur but will not have an overshoot
(E) will not occur

10. The answer is E [IV E 3 a]. Because the stimulus was delivered during the absolute refractory period, no action potential occurs. The inactivation gates of the Na^+ channel were closed by depolarization and remain closed until the membrane is repolarized. As long as the inactivation gates are closed, the Na^+ channels cannot be opened to allow for another action potential.

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11. Solutions A and B are separated by a membrane that is permeable to urea. Solution A is 10 mM urea, and solution B is 5 mM urea. If the concentration of urea in solution A is doubled, the flux of urea across the membrane will

(A) double
(B) triple
(C) be unchanged
(D) decrease to one-half
(E) decrease to one-third

11. The answer is B [II A]. Flux is proportional to the concentration difference across the membrane, $J = -PA (C_A - C_B)$. Originally, $C_A - C_B = 10$ mM $- 5$ mM $= 5$ mM. When the urea concentration was doubled in solution A, the concentration difference became 20 mM $-$ 5 mM $=$ 15 mM or three times the original difference. Therefore, the flux would also triple. Note that the negative sign preceding the equation is ignored if the lower concentration is subtracted from the higher concentration.

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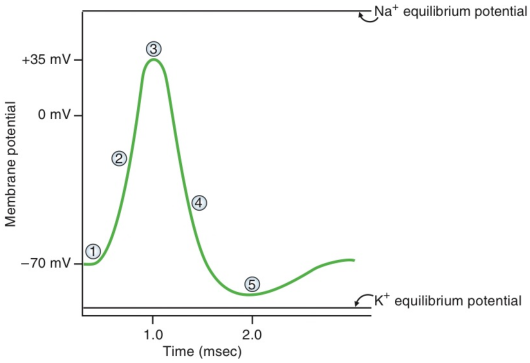
12. A muscle cell has an intracellular $[Na^+]$ of 14 mM and an extracellular $[Na^+]$ of 140 mM. Assuming that 2.3 RT/F = 60 mV, what would the membrane potential be if the muscle cell membrane were permeable only to Na^+?

(A) 80 mV
(B) –60 mV
(C) 0 mV
(D) +60 mV
(E) +80 mV

12. The answer is D [IV B 3 a, b]. The Nernst equation is used to calculate the equilibrium potential for a single ion. In applying the Nernst equation, we assume that the membrane is freely permeable to that ion alone. $E_{Na^+} = 2.3\ RT/zF \log C_e/C_i = 60\ mV \log 140/14 = 60\ mV \log 10 = 60\ mV$. Notice that the signs were ignored and that the higher concentration was simply placed in the numerator to simplify the log calculation. To determine whether E_{Na^+} is +60 mV or –60 mV, use the intuitive approach—Na^+ will diffuse from extracellular to intracellular fluid down its concentration gradient, making the cell interior positive.

QUESTIONS 13–15

The following diagram of a nerve action potential applies to Questions 13–15.



13. At which labeled point on the action potential is K^+ closest to electrochemical equilibrium?

(A) 1
(B) 2
(C) 3
(D) 4
(E) 5

14. What process is responsible for the change in membrane potential that occurs between point 1 and point 3?

(A) Movement of Na^+ into the cell
(B) Movement of Na^+ out of the cell
(C) Movement of K^+ into the cell

15. What process is responsible for the change in membrane potential that occurs between point 3 and point 4?

(A) Movement of Na^+ into the cell
(B) Movement of Na^+ out of the cell
(C) Movement of K^+ into the cell
(D) Movement of K^+ out of the cell
(E) Activation of the Na^+–K^+ pump
(F) Inhibition of the Na^+–K^+ pump

13. The answer is E [IV E 2 d]. The hyperpolarizing afterpotential represents the period during which K^+ permeability is highest, and the membrane potential is closest to the K^+ equilibrium potential. At that point, K^+ is closest to electrochemical equilibrium. The force driving K^+ movement out of the cell down its chemical gradient is balanced by the force driving K^+ into the cell down its electrical gradient.

14. The answer is A [IV E 2 b (1)–(3)]. The upstroke of the nerve action potential is caused by opening of the Na^+ channels (once the membrane is depolarized to threshold). When the Na^+ channels open, Na^+ moves into the cell down its electrochemical gradient, driving the membrane potential toward the Na^+ equilibrium potential.

15. The answer is D [IV E 2 c]. The process responsible for repolarization is the opening of K^+ channels. The K^+ permeability becomes very high and drives the membrane potential toward the K^+ equilibrium potential by flow of K^+ out of the cell.

16. The velocity of conduction of action potentials along a nerve will be increased by

(A) stimulating the Na^+–K^+ pump
(B) inhibiting the Na^+–K^+ pump
(C) decreasing the diameter of the nerve
(D) myelinating the nerve
(E) lengthening the nerve fiber

16. The answer is D [IV E 4 b]. Myelin insulates the nerve, thereby increasing conduction velocity; action potentials can be generated only at the nodes of Ranvier, where there are breaks in the insulation. Activity of the Na^+–K^+ pump does not directly affect the formation or conduction of action potentials. Decreasing nerve diameter would increase internal resistance and, therefore, slow the conduction velocity.

19. Which of the following will double the permeability of a solute in a lipid bilayer?

(A) Doubling the molecular radius of the solute
(B) Doubling the oil/water partition coefficient of the solute
(C) Doubling the thickness of the bilayer
(D) Doubling the concentration difference of the solute across the bilayer

19. The answer is B [II A 4 a–c]. Increasing oil/water partition coefficient increases solubility in a lipid bilayer and therefore increases permeability. Increasing molecular radius and increased membrane thickness decrease permeability. The concentration difference of the solute has no effect on permeability.

20. A newly developed local anesthetic blocks Na^+ channels in nerves. Which of the following effects on the action potential would it be expected to produce?

(A) Decrease the rate of rise of the upstroke of the action potential
(B) Shorten the absolute refractory period
(C) Abolish the hyperpolarizing afterpotential
(D) Increase the Na^+ equilibrium potential
(E) Decrease the Na^+ equilibrium potential

20. The answer is A [IV E 1–3]. Blockade of the Na^+ channels would prevent action potentials. The upstroke of the action potential depends on the entry of Na^+ into the cell through these channels and therefore would also be reduced or abolished. The absolute refractory period would be lengthened because it is based on the availability of the Na^+ channels. The hyperpolarizing afterpotential is related to increased K^+ permeability. The Na^+ equilibrium potential is calculated from the Nernst equation and is the theoretical potential at electrochemical equilibrium (and does not depend on whether the Na^+ channels are open or closed).

22. An inhibitory postsynaptic potential

(A) depolarizes the postsynaptic membrane by opening Na^+ channels
(B) depolarizes the postsynaptic membrane by opening K^+ channels
(C) hyperpolarizes the postsynaptic membrane by opening Ca^{2+} channels
(D) hyperpolarizes the postsynaptic membrane by opening Cl^- channels

22. The answer is D [V C 2 b]. An inhibitory postsynaptic potential hyperpolarizes the postsynaptic membrane, taking it farther from threshold. Opening Cl^- channels would hyperpolarize the postsynaptic membrane by driving the membrane potential toward the Cl^- equilibrium potential (about –90 mV). Opening Ca^{2+} channels would depolarize the postsynaptic membrane by driving it toward the Ca^{2+} equilibrium potential.

23. Which of the following would occur as a result of the inhibition of Na^+, K^+-ATPase?

(A) Decreased intracellular Na^+ concentration
(B) Increased intracellular K^+ concentration
(C) Increased intracellular Ca^{2+} concentration
(D) Increased Na^+–glucose cotransport
(E) Increased Na^+–Ca^{2+} exchange

23. The answer is C [II D 2 a]. Inhibition of Na^+, K^+-adenosine triphosphatase (ATPase) leads to an increase in intracellular Na^+ concentration. Increased intracellular Na^+ concentration decreases the Na^+ gradient across the cell membrane, thereby inhibiting Na^+–Ca^{2+} exchange and causing an increase in intracellular Ca^{2+} concentration. Increased intracellular Na^+ concentration also inhibits Na^+–glucose cotransport.

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25. Which of the following transport processes is involved if transport of glucose from the intestinal lumen into a small intestinal cell is inhibited by abolishing the usual Na^+ gradient across the cell membrane?

(A) Simple diffusion
(B) Facilitated diffusion
(C) Primary active transport
(D) Cotransport
(E) Countertransport

25. The answer is D [II D 2 a, E 1]. In the "usual" Na^+ gradient, the $[Na^+]$ is higher in extracellular than in intracellular fluid (maintained by the Na^+–K^+ pump). Two forms of transport are energized by this Na^+ gradient—cotransport and countertransport. Because glucose is moving in the same direction as Na^+, one can conclude that it is cotransport.

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28. Adenosine triphosphate (ATP) is used indirectly for which of the following processes?

(A) Accumulation of Ca^{2+} by the sarcoplasmic reticulum (SR)
(B) Transport of Na^+ from intracellular to extracellular fluid
(C) Transport of K^+ from extracellular to intracellular fluid
(D) Transport of H^+ from parietal cells into the lumen of the stomach
(E) Absorption of glucose by intestinal epithelial cells

28. The answer is E [II D 2]. All of the processes listed are examples of primary active transport (and therefore use adenosine triphosphate [ATP] directly), except for absorption of glucose by intestinal epithelial cells, which occurs by secondary active transport (i.e., cotransport). Secondary active transport uses the Na^+ gradient as an energy source and, therefore, uses ATP indirectly (to maintain the Na^+ gradient).

31. Assuming complete dissociation of all solutes, which of the following solutions would be hyperosmotic to 1 mM NaCl?

(A) 1 mM glucose
(B) 1.5 mM glucose
(C) 1 mM $CaCl_2$
(D) 1 mM sucrose
(E) 1 mM KCl

31. The answer is C [III A]. Osmolarity is the concentration of particles (osmolarity = g × C). When two solutions are compared, that with the higher osmolarity is hyperosmotic. The 1 mM $CaCl_2$ solution (osmolarity = 3 mOsm/L) is hyperosmotic to 1 mM NaCl (osmolarity = 2 mOsm/L). The 1 mM glucose, 1.5 mM glucose, and 1 mM sucrose solutions are hyposmotic to 1 mM NaCl, whereas 1 mM KCl is isosmotic.

32. A new drug is developed that blocks the transporter for H^+ secretion in gastric parietal cells. Which of the following transport processes is being inhibited?

(A) Simple diffusion
(B) Facilitated diffusion
(C) Primary active transport
(D) Cotransport
(E) Countertransport

hyposmotic to 1 mM NaCl, whereas 1 mM KCl is isosmotic.

32. The answer is C [II D c]. H^+ secretion by gastric parietal cells occurs by H^+–K^+ adenosine triphosphatase (ATPase), a primary active transporter.

Challenge Yourself

Answer each question with a word, phrase, sentence, or numerical solution. When a list of possible answers is supplied with the question, one, more than one, or none of the choices may be correct. Correct answers are provided at the end of the book.

1 *Solution A contains 100 mM NaCl, Solution B contains 10 mM NaCl, and the membrane separating them is permeable to Cl^- but not Na^+. What is the orientation of the potential difference that will be established across the membrane?*

2 *The osmolarity of a solution of 50 mmol/L $CaCl_2$ is closest to the osmolarity of which of the following: 50 mmol/L NaCl, 100 mmol/L urea, 150 mmol/L NaCl, or 150 mmol/L urea?*

3 *How does the intracellular Na^+ concentration change following inhibition of Na^+-K^+ ATPase?*

4 *Which phase of the nerve action potential is responsible for propagation of the action potential to neighboring sites?*

[illegible]

10 *Solution A contains 10 mmol/L glucose, and Solution B contains 1 mmol/L glucose. If the glucose concentration in both solutions is doubled, by how much will the flux (flow) of glucose between the two solutions change (e.g., halve, remain unchanged, double, triple, quadruple)?*

[illegible]

bound to myosin: rigor, conformational change in myosin that reduces its affinity for actin, power stroke?

[illegible]

CHAPTER 1

1 Solution B, negative; or Solution A, positive

2 150 mmol/L urea

3 Increases

4 Upstroke of the action potential

[illegible]

10 Double (Hint: $\Delta C = 10 - 1 = 9$. If both sides doubled, $\Delta C = 20 - 2 = 18$.)

[illegible]

1. The uptake of a novel drug by hepatocytes occurs down an electrochemical gradient. Uptake is independent of other solutes, and the rate of uptake is saturated at high extracellular drug concentrations. Which membrane transport process is most likely to account for all these characteristics of drug uptake?

A. Antiport with Cl^-
B. Cotransport with Na^+
C. Facilitated diffusion
D. Primary active transport
E. Simple diffusion through ion channels
F. Simple diffusion through plasma membrane

1—C. Facilitated diffusion only occurs passively down the solute electrochemical gradient; it occurs via uniporters, with no dependence on other solutes and is saturable.

1. The resting membrane potential of a cell is measured to be −70 mV in a solution with ion concentrations resembling extracellular fluid. Which of the following manipulations would result in a hyperpolarization of the cell?

A. Reduction in the membrane permeability to sodium ion
B. Reduction in the membrane permeability to potassium ion
C. Influx of calcium ion through the cell membrane
D. Increase in the extracellular sodium ion concentration
E. Increase in the extracellular potassium ion concentration

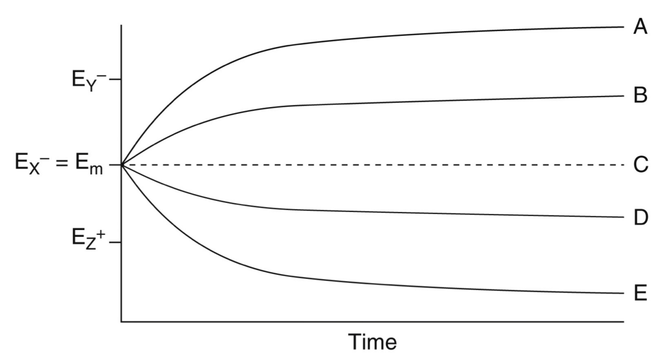
1. **A.** Reduced permeability of sodium ion will result in hyperpolarization of the cell. Ordinarily, sodium leakage into the cell contributes to the actual resting membrane potential, making it less negative than would be predicted on the basis of potassium concentration and permeability. Reduction in potassium ion permeability, on the other hand, would cause depolarization of the cell, as would influx of calcium ion or increased extracellular concentration of sodium or potassium ion.

4. When depolarization of an axon reaches the synaptic bouton, release of neurotransmitter stored in presynaptic vesicles is most closely associated with:

A. influx of Ca^{2+}.
B. influx of Na^+.
C. efflux of Na^+.
D. influx of K^+.
E. efflux of K^+.

4. **A.** When axonal depolarization reaches the synaptic bouton, voltage-gated Ca^{2+} channels are opened, resulting in influx of Ca^{2+} and vesicular release of neurotransmitter into the synaptic cleft.

7. In the diagram shown, E_m represents the measured initial membrane potential for a hypothetical cell in vivo. In relation to this membrane potential, the equilibrium potentials of three ions (X^-, Y^-, Z^+) are represented. Pick the path most likely taken by the membrane potential when membrane conductance to ion Y is increased.



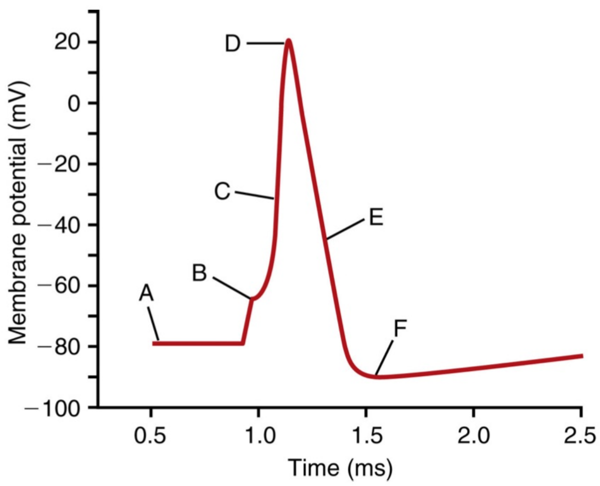
7. **B)** The resting membrane potential of a typical cell in the body is closest to the equilibrium potential of the ion with the highest conductance (i.e., permeability). In most cells of the body, the conductance to potassium is relatively high, causing the membrane potential to approach the potassium equilibrium potential. In the diagram shown, the initial membrane potential (E_m) is represented by the level of line C. When the membrane conductance to ion Y is increased, the membrane potential approaches the equilibrium potential of ion Y; this eliminates answers C, D, and E. Answer A can also be eliminated because the membrane potential cannot become greater than the equilibrium potential of the ion.

17. Which of the following substances have a higher extracellular concentration compared with the intracellular concentration?
A) Calcium and chloride
B) Potassium and sodium
C) Calcium and potassium
D) Potassium and proteins
E) Chloride and proteins

17. **A)** The extracellular fluid contains a large amount of sodium, calcium, and chloride but only a small amount of potassium. The opposite is true of the intracellular fluid. However, the concentrations of phosphates and proteins in the intracellular fluid are considerably greater than those in the extracellular fluid. These differences are extremely important to the life of the cell, as discussed in Chapter 4.

Questions 43–45

Match each of the descriptions in the next three questions to one of the points of the nerve action potential shown in the figure.



43. Point at which the membrane potential (V_m) is closest to the Na^+ equilibrium potential
44. Point at which the driving force for Na^+ is the greatest
45. Point at which the ratio of K^+ permeability to Na^+ permeability (P_K/P_{Na}) is the greatest

43. **D)** During an action potential in a nerve cell, V_m approaches E_{Na} during the rapid depolarization phase when the permeability of the membrane to Na^+ (P_{Na}) increases relative to its permeability to K^+ (P_K). In a "typical" cell, E_{Na} is close to 60 millivolts. V_m is closest to E_{Na} at point D in this figure. At this point, the ratio of P_{Na} to P_K is the greatest.

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44. **F)** The driving force for Na^+ is greatest at the point at which V_m is the farthest from E_{Na}. If E_{Na} is very positive (≈ 60 millivolts), V_m is farthest from E_{Na} at point F, or when the cell is the most hyperpolarized.

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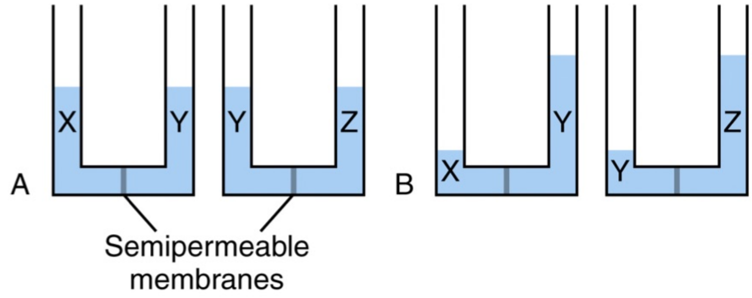
45. **F)** Generally, V_m is closest to the equilibrium potential of the most permeant ion. In nerve cells, $P_K >> P_{Na}$ at rest. As a result, V_m is relatively close to E_K. During the after-potential or the hyperpolarization phase of the action potential, the ratio of P_K to P_{Na} is even greater than it is at rest because of the residual opening of voltage-gated K^+ channels and the inactivation of the voltage-gated Na^+ channels. P_K:P_{Na} is greatest at point F, at which point V_m comes closest to E_K.



47. In the experiment illustrated in part **A** of the figure, equal volumes of solutions X, Y, and Z are placed into the compartments of the two U-shaped vessels shown. The two compartments of each vessel are separated by semipermeable membranes (i.e., membranes that are impermeable to ions and large polar molecules). Part **B** illustrates the fluid distribution across the membranes at equilibration. Assuming complete dissociation, identify each of the solutions shown.

	Solution X	Solution Y	Solution Z
A)	1 M $CaCl_2$	1 M NaCl	1 M glucose
B)	1 M glucose	1 M NaCl	1 M $CaCl_2$
C)	1 M NaCl	2 M glucose	3 M $CaCl_2$
D)	2 M NaCl	1 M NaCl	Pure water
E)	Pure water	1 M $CaCl_2$	2 M glucose

Questions 48 and 49

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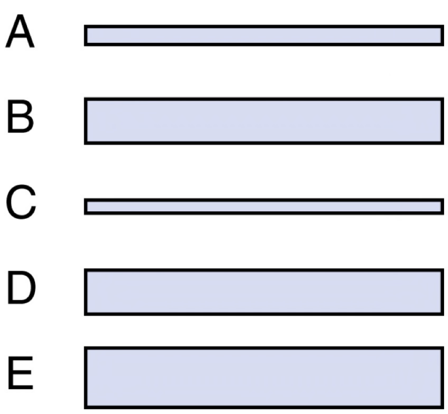
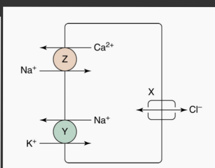
47. **B)** The redistribution of fluid volume shown in part **B** reflects the net diffusion of water, or osmosis, because of differences in the osmolarity of the solutions on either side of the semipermeable membrane. Osmosis occurs from solutions of high water concentration to low water concentration or from low osmolarity to high osmolarity. In part **B**, osmosis has occurred from X to Y and from Y to Z. Therefore, the osmolarity of solution Z is higher than that of solution Y, and the osmolarity of solution Y is higher than that of solution X.



27. **B)** Prolonged or repeated maximal contraction results in a concomitant increase in the synthesis of contractile proteins and an increase in muscle mass. This increase in mass, or hypertrophy, is observed at the level of individual muscle fibers.

28. Five hypothetical nerve axons are shown in the above figure. Axons A and B are myelinated, whereas axons C, D, and E are nonmyelinated. Which axon is most likely to have the fastest conduction velocity for an action potential?
A) A
B) B
C) C
D) D
E) E

6. A model cell with three different transporters (X, Y, and Z) and a resting membrane potential of −90 millivolts is shown. Consider the intracellular and extracellular concentrations of all three ions to be typical of a normal cell. Inhibition of transporter Y with ouabain is most likely to cause which of the following changes in the intracellular concentrations of sodium and calcium ions?



A) Decreased sodium; decreased calcium
B) Decreased sodium; increased calcium
C) Increased sodium; decreased calcium
D) Increased sodium; increased calcium

6. **D)** Under basal conditions, the intracellular concentrations of sodium, calcium, and chloride are less than the extracellular concentrations, whereas potassium has a higher intracellular concentration compared with its extracellular concentration. Transporter Y in the figure moves both potassium and sodium ions against their concentration gradients, which is primary active transport and is powered by ATP at the pump. Therefore, when transporter Y is inhibited by ouabain, the intracellular concentration of sodium increases (and the intracellular concentration of potassium decreases). This increase in intracellular sodium concentration decreases the sodium concentration gradient across the cell membrane. Now because the energy required to move calcium ions out of the cell is powered by the sodium concentration gradient (via secondary active transport), a decrease in the transmembrane sodium gradient leads to an increase in the intracellular calcium concentration. So, inhibition of transporter Y leads to increases in the intracellular concentrations of both sodium and calcium ions. Cardiac glycosides increase intracellular calcium concentration in cardiac muscle cells by this mechanism.

ANS

1. Which autonomic receptor is blocked by hexamethonium at the ganglia, but not at the neuromuscular junction? → in handout (Action potential)

(A) Adrenergic α receptors
(B) Adrenergic β_1 receptors
(C) Adrenergic β_2 receptors
(D) Cholinergic muscarinic receptors
(E) Cholinergic nicotinic receptors

1. The answer is E [I C 2 a]. Hexamethonium is a nicotinic blocker, but it acts only at ganglionic (not neuromuscular junction) nicotinic receptors. This pharmacologic distinction emphasizes that nicotinic receptors at these two locations, although similar, are not identical.

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7. Which of the following is a feature of the sympathetic, but not the parasympathetic nervous system?

(A) Ganglia located in the effector organs
(B) Long preganglionic neurons
(C) Preganglionic neurons release norepinephrine
(D) Preganglionic neurons release acetylcholine (ACh)
(E) Preganglionic neurons originate in the thoracolumbar spinal cord
(F) Postganglionic neurons synapse on effector organs
(G) Postganglionic neurons release epinephrine
(H) Postganglionic neurons release ACh

7. The answer is E [I A, B; Table 2.1; Figure 2.1]. Sympathetic preganglionic neurons originate in spinal cord segments T1–L3. Thus, the designation is thoracolumbar. The sympathetic nervous system is further characterized by short preganglionic neurons that synapse in ganglia located in the paravertebral chain (not in the effector organs) and postganglionic neurons that release norepinephrine (not epinephrine). Common features of the sympathetic and parasympathetic nervous systems are preganglionic neurons that release acetylcholine (ACh) and postganglionic neurons that synapse in effector organs.

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8. Which autonomic receptor mediates an increase in heart rate?

(A) Adrenergic α receptors
(B) Adrenergic β_1 receptors
(C) Adrenergic β_2 receptors
(D) Cholinergic muscarinic receptors
(E) Cholinergic nicotinic receptors

8. The answer is B [I C 1 c]. Heart rate is increased by the stimulatory effect of norepinephrine on β_1 receptors in the sinoatrial (SA) node. There are also sympathetic β_1 receptors in the heart that regulate contractility.

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13. Which adrenergic receptor produces its stimulatory effects by the formation of inositol 1,4,5-triphosphate (IP_3) and an increase in intracellular [Ca^{2+}]?

(A) α_1 Receptors
(B) α_2 Receptors
(C) β_1 Receptors
(D) β_2 Receptors
(E) Muscarinic receptors
(F) Nicotinic receptors

13. The answer is A [I C 1 a]. Adrenergic α_1 receptors produce physiologic actions by stimulating the formation of inositol 1,4,5-triphosphate (IP_3) and causing a subsequent increase in intracellular [Ca^{2+}]. Both β_1 and β_2 receptors act by stimulating adenylate cyclase and increasing the production of cyclic adenosine monophosphate (cAMP). α_2 Receptors inhibit adenylate cyclase and decrease cAMP levels. Muscarinic and nicotinic receptors are cholinergic.

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16. Which autonomic receptor mediates secretion of epinephrine by the adrenal medulla?

(A) Adrenergic α receptors
(B) Adrenergic β_1 receptors
(C) Adrenergic β_2 receptors
(D) Cholinergic muscarinic receptors
(E) Cholinergic nicotinic receptors

16. The answer is E [I C 2 a; Figure 2.1]. Preganglionic sympathetic fibers synapse on the chromaffin cells of the adrenal medulla at a nicotinic receptor. Epinephrine and, to a lesser extent, norepinephrine are released into the circulation.

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27. Which autonomic receptor is activated by low concentrations of epinephrine released from the adrenal medulla and causes vasodilation?

(A) Adrenergic α receptors
(B) Adrenergic β_1 receptors
(C) Adrenergic β_2 receptors
(D) Cholinergic muscarinic receptors
(E) Cholinergic nicotinic receptors

27. The answer is C [I C 1 d]. β_2 Receptors on vascular smooth muscle produce vasodilation. α Receptors on vascular smooth muscle produce vasoconstriction. Because β_2 receptors are more sensitive to epinephrine than are α receptors, low doses of epinephrine produce vasodilation, and high doses produce vasoconstriction.

NERVOUS SYSTEM

18. Preganglionic nerve cell bodies in the sympathetic nervous system are located in the:

A. cervical spinal cord.
B. thoracolumbar spinal cord.
C. sacral spinal cord.
D. sympathetic chain ganglia.
E. brainstem.

18. **B.** Preganglionic nerves of the sympathetic nervous system originate in the intermediolateral and intermediomedial cell columns of the thoracolumbar spinal cord (T1 to L3). Their axons extend to the chain ganglia, where they synapse with postganglionic nerves. Preganglionic nerves of the parasympathetic nervous system have cell bodies in the brainstem.

19. Release of acetylcholine and subsequent binding to muscarinic receptors is the major mode of neurotransmission at:

A. parasympathetic ganglia.
B. neuroeffector junctions of the SNS.
C. sympathetic ganglia.
D. neuroeffector junctions of the PNS.
E. All of the above.

19. **D.** Postganglionic neurons of the parasympathetic nervous system (PNS) release acetylcholine, which acts at muscarinic receptors at the neuroeffector junction. Postganglionic neurons of the sympathetic nervous system (SNS) primarily release norepinephrine and epinephrine, which act at a variety of adrenergic receptors on effector organs and tissues. Both sympathetic and parasympathetic preganglionic nerves achieve ganglionic neurotransmission by release of acetylcholine, which acts at nicotinic receptors.

20. β_2-adrenergic receptors mediate which of the following effects of the sympathetic nervous system?

A. Constriction of vascular smooth muscle
B. Increased cardiac contractility
C. Dilation of bronchial smooth muscle
D. Dilation of the pupil (mydriasis)
E. Sweat gland secretion

20. **C.** β_2-adrenergic receptors mediate sympathetic bronchial dilation. Constriction of vascular smooth muscle and mydriasis are produced by norepinephrine and epinephrine release by postganglionic sympathetic nerves and subsequent binding to α_1 receptors; increased contractility is mediated by β_2 receptors. Sweat gland secretion is stimulated by atypical sympathetic postganglionic nerve fibers that secrete acetylcholine.