Study Questions

Choose the ONE best answer.

IV.1. A 65-year-old man with a history of hypertension is prescribed a Ca^{2+}-channel blocker to help reduce his blood pressure. What is the likely effect of this drug on the ventricular myocardium?

A. It would have no effect.
B. It would increase contractility.
C. It would increase heart rate.
D. Phase 2 would be reduced.
E. Phase 1 would be prolonged.

Best answer = D. Ca^{2+}-channel blockers reduce Ca^{2+} influx via L-type Ca^{2+} channels during phase 2 of the ventricular action potential, thereby reducing phase 2 and decreasing contractility (see 16·V·A). Phase 1 is mediated by Na^{+} and K^{+} channels (see 16·V·B) and would not be affected by a Ca^{2+}-channel blocker. Heart rate is determined by the rate of phase 4 depolarization in sinoatrial nodal cells, which is governed in part by L-type Ca^{2+} channels (see 16·V·C·4). Ca^{2+}-channel blockers would be expected to decrease heart rate.

IV.2. A mean electrical axis value of −60° would most likely be associated with which of the following conditions?

A. Pulmonary hypertension
B. Premature ventricular contractions
C. Aortic stenosis
D. Pulmonary edema
E. Left ventricular infarction

Best answer = C. Aortic stenosis forces the left ventricle (LV) to work harder and generate higher peak systolic pressures to sustain cardiac output (see 40·V·A). Over time, this causes LV hypertrophy, which manifests on an electrocardiogram as left-axis deviation (normal range = +105° to −30°; see 16·VI·E). Pulmonary hypertension and edema promote right ventricular hypertrophy. A left ventricular myocardial infarction would likely shift the axis to the right, not left, because viable LV muscle mass is reduced. Premature ventricular contractions do not directly alter the mean electrical axis.

IV.3. A 50-year-old woman reports "thumping" sensations in her chest. An electrocardiogram records occasional wide, premature QRS complexes. Which of the following most likely explains the origin of these complexes?

A. Atrial fibrillation
B. Ventricular fibrillation
C. An irritable ectopic focus
D. First-degree heart block
E. Myocardial ischemia

Best answer = C. Premature ventricular contractions (PVCs) are characterized by wide and abnormally shaped QRS complexes. They reflect waves of excitation that travel through the myocardium via the slow myocyte-to-myocyte route rather than the fast conduction His–Purkinje system (see 16·VI·D·3). PVCs are typically triggered by irritable foci located in the ventricular myocardium (i.e., ectopic) rather than the sinoatrial node. Atrial fibrillation manifests as loss of a P wave, whereas first-degree heart block prolongs the PR interval. A fibrillating ventricle shows no organized electrocardiogram waveforms. Ischemia may affect the ST segment, but QRS complexes still occur in normal position.

IV.4. Which of the following electrocardiogram events coincides with the "reduced ventricular ejection" phase of the cardiac cycle?

A. P wave
B. PR interval
C. QRS complex
D. ST segment
E. T wave

Best answer = E. The T wave corresponds to ventricular repolarization (see 16·VI·C), which occurs during reduced ejection (see 17·II). The P wave coincides with atrial systole, which continues during the PR interval. The QRS complex is caused by ventricular excitation, which is followed by isovolumic contraction and rapid ejection. The ST segment encompasses isovolumic contraction and persists through rapid ejection.

IV.5. A 7-year-old boy of normal height and build for his age is undergoing a routine physical. The family physician notes a third heart sound (S_3) during auscultation. Which of the following statements best describes the cause of the S3 in this boy?

A. It coincides with rapid ventricular ejection.
B. It indicates atrial hypertrophy.
C. An electrocardiogram would show right-axis deviation.
D. It is caused by aortic valve regurgitation.
E. It is the sound of ventricular filling.

Best answer = E. The third heart sound (S_3) occurs during ventricular filling and is caused by sudden tensing and reverberation of the ventricular walls (see 17·II·E). Although usually a sign of underlying pathology in adults, it is a normal finding in children. Ventricular filling and S_3 occur during diastole, not rapid ejection. Atrial hypertrophy would yield an S_4, whereas a right-axis deviation does not necessarily correlate with a heart sound. Regurgitant valves produce murmurs, not heart sounds (see Clinical Application 17.1).

IV.6. A 44-year-old woman is diagnosed with dilated cardiomyopathy, a condition caused by impaired ventricular contractility and compensatory fluid retention. What is the advantage to fluid retention and preloading?

A. It increases ventricular wall tension.
B. It increases ventricular stroke volume.
C. It decreases ventricular afterload.
D. It reduces cardiac workload.
E. It reduces the need for resting cardiac output.

Best answer = B. Increased preloading stretches the myocardium, thereby increasing the amount of force developed upon contraction through length-dependent activation of the sarcomere (see 17·IV·D). Preloading increases stroke volume and ejection fraction, which helps compensate for reduced ventricular contractility. The disadvantage to enhanced preloading is that it increases ventricular radius and wall tension, thereby increasing afterload and overall workload (law of Laplace; see 17·VI·B). Resting cardiac output is determined by the metabolic needs of the tissues, not by preload.

IV.7. A patient is given an α_1-adrenergic agonist during surgery. The patient has catheters connected in series with pressure transducers in the radial artery and vena cava. Echocardiography is conducted during bolus administration of the drug. Which of the following would most likely be increased during the first heart beat following drug administration?

A. Left ventricular preload
B. Ejection fraction
C. End-diastolic pressure-volume relationship
D. Left-ventricular end-systolic volume
E. Ventricular shortening velocity

Best answer = D. An α_1-adrenergic agonist would increase systemic vascular resistance (SVR) and left ventricular (LV) afterload, increasing the pressure needed to open the aortic valve during systole (see 17·IV·E). Stroke volume (SV) and ejection fraction both decrease, thereby raising LV end-systolic volume. An SVR increase lowers central venous pressure at any given cardiac output (see 19·V·D). The end-diastolic pressure-volume relationship is not altered by acute SVR changes. Cardiac inotropy and LV shortening velocity will likely rise soon after the SVR change to maintain SV, but this will take a number of beats to establish (see 19·V·E).

IV.8. Cardiac muscle contraction is dependent on a rise in sarcoplasmic Ca^{2+} concentration. The bulk of the Ca^{2+} required for full force generation flows through which of the following Ca^{2+} channel types?

A. Dihydropyridine receptors
B. Ryanodine receptors
C. IP_3-gated channels
D. Transient receptor-potential channels
E. Stretch-activated channels

Best answer = B. Full force development by a cardiac myocyte relies on Ca^{2+} release from stores in the sarcoplasmic reticulum (SR; 17·III·A). Release is mediated by Ca^{2+}-induced Ca^{2+} release (CICR) channels, also known as ryanodine receptors. Dihydropyridine receptors are L-type Ca^{2+} channels that mediate voltage-gated Ca^{2+} fluxes across the T-tubule membrane. Ca^{2+} influx via this pathway acts as a trigger for CICR. IP_3 mediates Ca^{2+} release from the SR in smooth muscle. Transient receptor-potential channels are found in many tissues, often mediating cellular sensory stimulus transduction (2·VI·D). Stretch-activated channels are also widespread, but ryanodine receptors are the principal pathway for Ca^{2+} fluxes during contraction.

IV.9. Phospholamban is a regulatory protein associated with the cardiac sarcoplasmic reticulum Ca^{2+} ATPase. Phospholamban phosphorylation would most likely increase the rate of which of the following events?

A. Relaxation
B. Ca^{2+} influx
C. Crossbridge cycling
D. Electrical conduction
E. Nodal cell depolarization

Best answer = A. Phospholamban normally acts as a rate limiter on sarcoplasmic reticulum (SR) Ca^{2+} ATPase (SERCA) function (17·IV·F). Phospholamban phosphorylation reduces its inhibitory effects, allowing the pump to speed up. SERCA normally helps remove Ca^{2+} from the sarcoplasm following excitation. Increasing pump speed causes sarcoplasmic free Ca^{2+} levels to fall faster than normal, promoting decreased relaxation times. Ca^{2+} influx occurs during excitation and probably would not be appreciably affected by changes in SERCA. Crossbridge cycling rate is dependent on actin–myosin interactions. Electrical conduction between myocytes is dependent on gap junction function. Although faster relaxation times do facilitate heart rate increases, the rate of nodal cell depolarization is controlled through ion channel modulation.

IV.10. An 11-year-old boy's dentist gives him nitrous oxide gas (N_2O) via a face mask to anesthetize him. Which among the following choices is the main route by which the N_2O reached the brain?

A. Endocytosis across the capillary wall
B. Specialized endothelial transporters
C. Bulk flow through fenestrations
D. Diffusion through intercellular junctions
E. Diffusion through the endothelial cells

Best answer = E. N_2O is a small, highly soluble molecule that, like O_2 and CO_2, easily diffuses through endothelial cell membranes (see 18·VI). Endocytosis is used primarily as a means of moving large proteins between the bloodstream and tissues, whereas transporters are typically used to transport charged molecules against a concentration gradient. Fenestrations and intercellular junctions provide routes for passage of water and any dissolved ions.

IV.11. Kwashiorkor is a severe form of childhood malnutrition seen mostly in developing countries. Symptoms include hepatomegaly and pitting edema of the lower extremities. The pitting edema is most likely due to which of the following?

A. A plasma protein deficit
B. Inadequate cardiac output
C. Excessive fluid retention
D. Reduced interstitial pressure
E. Decreased hematocrit

Best answer = A. Plasma proteins create an osmotic potential (plasma colloid osmotic pressure) that holds fluid in the vasculature (see 18·VII·D). Kwashiorkor results from inadequate protein intake, which impairs the liver's ability to synthesize proteins. Fluid filters into the interstitium and causes edema as a consequence. Reduced cardiac output and pressure would reduce fluid filtration. Excessive fluid retention would exacerbate edema caused by the plasma protein deficit. Interstitial pressure is increased by and counters fluid filtration, whereas changes in hematocrit have no effect.

IV.12. Skeletal muscle metabolism increases dramatically during physical activity, sustained by equally dramatic perfusion increases. Which of the following mechanisms facilitates activity-induced increases in muscle blood flow?

A. Flow-induced nitric oxide release
B. Norepinephrine-induced vasodilation
C. Rising metabolite levels
D. Antidiuretic hormone release
E. Histamine release

Best answer = C. Increased blood flow to active tissues ("active hyperemia") is mediated by local accumulation of metabolic byproducts, including CO_2, H^+, and adenosine, which cause reflexive dilation of resistance vessels (see 19·II·A). Norepinephrine (from sympathetic nerve terminals) and antidiuretic hormone (from the posterior pituitary) both constrict resistance vessels. Flow-induced nitric oxide release may contribute to increased flow at high levels of cardiac output (see 19·II·E), but this effect is secondary to the influence of metabolic byproducts. Histamine can cause vasodilation but usually only as a part of an allergic reaction.

IV.13. An 11-year-old girl wrestling with her younger brother causes him to faint when inadvertently applying pressure on his left carotid sinus. Syncope most likely occurred as a result of which of the following?

A. Occlusion of his carotid artery
B. Occlusion of his jugular vein
C. Cerebral vasculature vasoconstriction
D. Carotid baroreceptor stimulation
E. Carotid chemoreceptor stimulation

Best answer = D. Applying pressure in the area of the carotid sinus stimulates the baroreceptors within the vessel walls, thereby mimicking the effects of increased blood pressure (see 19·III·A). This promotes a reflex decrease in cardiac output and systemic vascular resistance (SVR). Arterial pressure falls as a result, causing cerebral hypotension and syncope. Occlusion of only one of the cerebral arteries or veins is unlikely to decrease cerebral perfusion or change cerebral CO_2 levels sufficiently to cause syncope. Carotid body chemoreceptors do not directly sense blood pressure, but, when stimulated, they increase SVR and blood pressure.

IV.14. A 45-year-old woman faints when standing up following a 90-minute Medical Physiology lecture. Which of the following variables increases in a healthy compensating person after rising to an upright position?

A. Systemic vascular resistance
B. Left ventricular preload
C. Right ventricular preload
D. Cerebral venous pressure
E. Aortic baroreceptor firing rate

Best answer = A. When a person stands upright, blood pools in the lower extremities (see 19·III·D). Decreased venous return causes right and left ventricular preload to fall, which reduces ventricular stroke volume and cardiac output. Arterial pressure begins to fall as a result, which is sensed via a decrease in arterial (carotid sinus and aortic) baroreceptor firing rate. If the pressure drop is severe, cerebral blood flow can be compromised. Normally compensating individuals tolerate the upright position by initiating a baroreceptor reflex, which includes an increase in systemic vascular resistance.

IV.15. A 60-year old woman is semi-recumbent in a hospital bed. One of her functional goals is to retain muscle mass during her hospital stay. Physical therapy prescribes and oversees quad sets (isometric contractions of her quadriceps) and ankle pumps (rhythmic contractions of her soleus and gastrocnemius muscles) as part of her rehabilitation plan. Her central venous pressure increases during these exercises. Which of the following is the most likely mechanism?

A. Venous pump
B. Increased heart rate
C. Frank-Starling effect
D. Decrease in cardiac stroke volume
E. Cardiac autoregulation

Best answer = A. Muscle contractions engage the venous pump, which pushes blood from the lower extremities back toward the right heart (see 19·V·C). Retrograde flow between contractions is prevented by venous valves. Blood volume moving into the vena cava increases central venous pressure (CVP). Increasing CVP increases cardiac stroke volume via the Frank-Starling relationship (see 17·IV·D). Heart rate increases during exercise, for example, and tends to decrease CVP. Cardiac autoregulation helps to match coronary blood flow to myocardial needs, not venous blood flow (see 20·III·B).

IV.16. A 55-year-old man with severe angina is scheduled for quadruple bypass surgery. The coronary arterioles downstream of the stenotic regions during the anginal episodes are most likely dilated fully. What is the primary cause of this vasodilation?

A. Parasympathetic activity
B. Norepinephrine
C. Adenosine
D. Lactic acid
E. High-velocity flow

Best answer = C. Coronary resistance vessels are controlled by the needs of the myocardium via changes in local metabolite concentrations, especially adenosine (see Section III·B). Lactic acid also causes vasodilation but to a lesser degree than adenosine. The shear stress caused by high-velocity flow can cause vasodilation via nitric oxide release but is unlikely in the setting of decreased perfusion and angina. The parasympathetic nervous system does not have any significant role in coronary vessel regulation, whereas norepinephrine constricts blood vessels.