Review Test

1. A 53-year-old woman is found, by arteriography, to have 50% narrowing of her left renal artery. What is the expected change in blood flow through the stenotic artery?

(A) Decrease to ½
(B) Decrease to ¼
(C) Decrease to ⅛
(D) Decrease to 1/16
(E) No change

2. When a person moves from a supine position to a standing position, which of the following compensatory changes occurs?

(A) Decreased heart rate
(B) Increased contractility
(C) Decreased total peripheral resistance (TPR)
(D) Decreased cardiac output
(E) Increased PR intervals

3. At which site is systolic blood pressure the highest?

(A) Aorta
(B) Central vein
(C) Pulmonary artery
(D) Right atrium
(E) Renal artery
(F) Renal vein

4. A person's electrocardiogram (ECG) has no P wave, but has a normal QRS complex and a normal T wave. Therefore, his pacemaker is located in the

(A) sinoatrial (SA) node
(B) atrioventricular (AV) node
(C) bundle of His
(D) Purkinje system
(E) ventricular muscle

5. If the ejection fraction increases, there will be a decrease in

(A) cardiac output
(B) end-systolic volume
(C) heart rate
(D) pulse pressure
(E) stroke volume
(F) systolic pressure

QUESTIONS 6 AND 7

An electrocardiogram (ECG) on a person shows ventricular extrasystoles.

6. The extrasystolic beat would produce

(A) increased pulse pressure because contractility is increased
(B) increased pulse pressure because heart rate is increased
(C) decreased pulse pressure because ventricular filling time is increased
(D) decreased pulse pressure because stroke volume is decreased
(E) decreased pulse pressure because the PR interval is increased

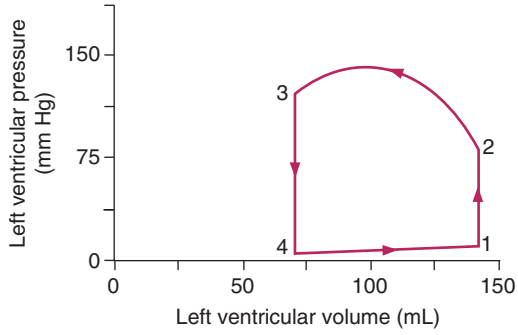
7. After an extrasystole, the next "normal" ventricular contraction produces

(A) increased pulse pressure because the contractility of the ventricle is increased
(B) increased pulse pressure because total peripheral resistance (TPR) is decreased
(C) increased pulse pressure because compliance of the veins is decreased
(D) decreased pulse pressure because the contractility of the ventricle is increased
(E) decreased pulse pressure because TPR is decreased

8. An increase in contractility is demonstrated on a Frank-Starling diagram by

(A) increased cardiac output for a given end-diastolic volume
(B) increased cardiac output for a given end-systolic volume
(C) decreased cardiac output for a given end-diastolic volume
(D) decreased cardiac output for a given end-systolic volume

QUESTIONS 9–12



9. On the graph showing left ventricular volume and pressure, isovolumetric contraction occurs between points

(A) 4 → 1
(B) 1 → 2
(C) 2 → 3
(D) 3 → 4

10. The aortic valve closes at point

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

11. The first heart sound corresponds to point

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

12. If the heart rate is 70 beats/min, then the cardiac output of this ventricle is closest to

(A) 3.45 L/min
(B) 4.55 L/min
(C) 5.25 L/min
(D) 8.00 L/min
(E) 9.85 L/min

QUESTIONS 13 AND 14

In a capillary, P_c is 30 mm Hg, P_i is –2 mm Hg, π_c is 25 mm Hg, and π_i is 2 mm Hg.

13. What is the direction of fluid movement and the net driving force?

(A) Absorption; 6 mm Hg
(B) Absorption; 9 mm Hg
(C) Filtration; 6 mm Hg
(D) Filtration; 9 mm Hg
(E) There is no net fluid movement

14. If K_f is 0.5 mL/min/mm Hg, what is the rate of water flow across the capillary wall?

(A) 0.06 mL/min
(B) 0.45 mL/min
(C) 4.50 mL/min
(D) 9.00 mL/min
(E) 18.00 mL/min

15. The tendency for blood flow to be turbulent is increased by

(A) increased viscosity
(B) increased hematocrit
(C) partial occlusion of a blood vessel
(D) decreased velocity of blood flow

16. A 66-year-old man, who has had a sympathectomy, experiences a greater-than-normal fall in arterial pressure upon standing up. The explanation for this occurrence is

(A) an exaggerated response of the renin–angiotensin–aldosterone system
(B) a suppressed response of the renin–angiotensin–aldosterone system
(C) an exaggerated response of the baroreceptor mechanism
(D) a suppressed response of the baroreceptor mechanism

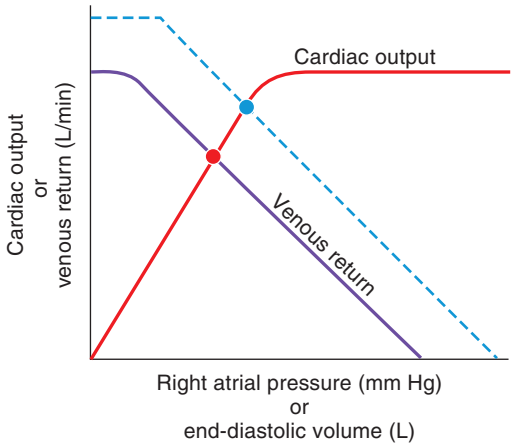
17. The ventricles are completely depolarized during which isoelectric portion of the electrocardiogram (ECG)?

(A) PR interval
(B) QRS complex
(C) QT interval
(D) ST segment
(E) T wave

18. In which of the following situations is pulmonary blood flow greater than aortic blood flow?

(A) Normal adult
(B) Fetus
(C) Left-to-right ventricular shunt
(D) Right-to-left ventricular shunt
(E) Right ventricular failure
(F) Administration of a positive inotropic agent

19. The change indicated by the dashed lines on the cardiac output/venous return curves shows



(A) decreased cardiac output in the "new" steady state
(B) decreased venous return in the "new" steady state
(C) increased mean systemic pressure
(D) decreased blood volume
(E) increased myocardial contractility

20. A 30-year-old female patient's electrocardiogram (ECG) shows two P waves preceding each QRS complex. The interpretation of this pattern is

(A) decreased firing rate of the pacemaker in the sinoatrial (SA) node
(B) decreased firing rate of the pacemaker in the atrioventricular (AV) node
(C) increased firing rate of the pacemaker in the SA node
(D) decreased conduction through the AV node
(E) increased conduction through the His-Purkinje system

21. An acute decrease in arterial blood pressure elicits which of the following compensatory changes?

(A) Decreased firing rate of the carotid sinus nerve
(B) Increased parasympathetic outflow to the heart
(C) Decreased heart rate
(D) Decreased contractility
(E) Decreased mean systemic pressure

22. The tendency for edema to occur will be increased by

(A) arteriolar constriction
(B) increased venous pressure
(C) increased plasma protein concentration
(D) muscular activity

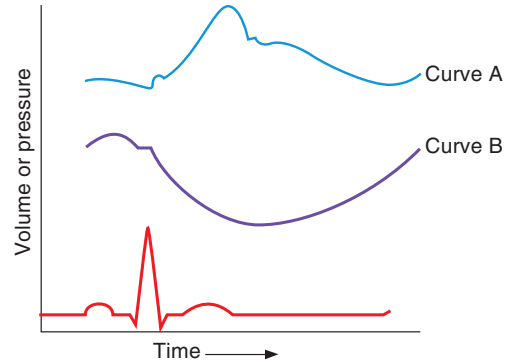
23. Inspiration "splits" the second heart sound because

(A) the aortic valve closes before the pulmonic valve
(B) the pulmonic valve closes before the aortic valve
(C) the mitral valve closes before the tricuspid valve
(D) the tricuspid valve closes before the mitral valve
(E) filling of the ventricles has fast and slow components

24. During exercise, total peripheral resistance (TPR) decreases because of the effect of

(A) the sympathetic nervous system on splanchnic arterioles
(B) the parasympathetic nervous system on skeletal muscle arterioles
(C) local metabolites on skeletal muscle arterioles
(D) local metabolites on cerebral arterioles
(E) histamine on skeletal muscle arterioles

QUESTIONS 25 AND 26



25. Curve A in the figure represents

(A) aortic pressure
(B) ventricular pressure
(C) atrial pressure
(D) ventricular volume

26. Curve B in the figure represents

(A) left atrial pressure
(B) ventricular pressure
(C) atrial pressure
(D) ventricular volume

27. An increase in arteriolar resistance, without a change in any other component of the cardiovascular system, will produce

(A) a decrease in total peripheral resistance (TPR)
(B) an increase in capillary filtration
(C) an increase in arterial pressure
(D) a decrease in afterload

28. The following measurements were obtained in a male patient:

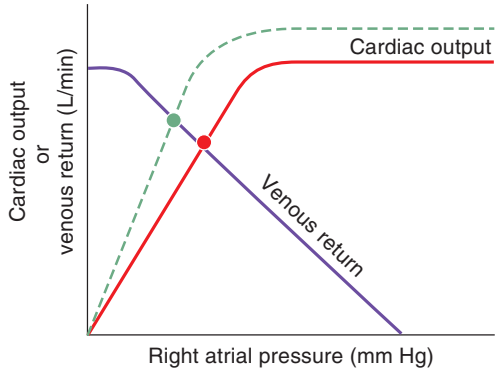
Central venous pressure: 10 mm Hg
Heart rate: 70 beats/min
Systemic arterial $[O_2] = 0.24$ mL O_2/mL
Mixed venous $[O_2] = 0.16$ mL O_2/mL
Whole body O_2 consumption: 500 mL/min
What is this patient's cardiac output?

(A) 1.65 L/min
(B) 4.55 L/min
(C) 5.00 L/min
(D) 6.25 L/min
(E) 8.00 L/min

29. Which of the following is the result of an inward Na^+ current?

(A) Upstroke of the action potential in the sinoatrial (SA) node
(B) Upstroke of the action potential in Purkinje fibers
(C) Plateau of the action potential in ventricular muscle
(D) Repolarization of the action potential in ventricular muscle
(E) Repolarization of the action potential in the SA node

QUESTIONS 30 AND 31



30. The dashed line in the figure illustrates the effect of

(A) increased total peripheral resistance (TPR)
(B) increased blood volume
(C) increased contractility
(D) a negative inotropic agent
(E) increased mean systemic pressure

31. The x-axis in the figure could have been labeled

(A) end-systolic volume
(B) end-diastolic volume
(C) pulse pressure
(D) mean systemic pressure
(E) heart rate

32. The greatest pressure decrease in the circulation occurs across the arterioles because

(A) they have the greatest surface area
(B) they have the greatest cross-sectional area
(C) the velocity of blood flow through them is the highest
(D) the velocity of blood flow through them is the lowest
(E) they have the greatest resistance

33. Pulse pressure is

(A) the highest pressure measured in the arteries
(B) the lowest pressure measured in the arteries
(C) measured only during diastole
(D) determined by stroke volume
(E) decreased when the capacitance of the arteries decreases
(F) the difference between mean arterial pressure and central venous pressure

34. In the sinoatrial (SA) node, phase 4 depolarization (pacemaker potential) is attributable to

(A) an increase in K^+ conductance
(B) an increase in Na^+ conductance
(C) a decrease in Cl^- conductance
(D) a decrease in Ca^{2+} conductance
(E) simultaneous increases in K^+ and Cl^- conductances

35. A healthy 35-year-old man is running a marathon. During the run, there is a increase in his splanchnic vascular resistance. Which receptor is responsible for the increased resistance?

(A) α_1 Receptors
(B) β_1 Receptors
(C) β_2 Receptors
(D) Muscarinic receptors

36. During which phase of the cardiac cycle is aortic pressure highest?

(A) Atrial systole
(B) Isovolumetric ventricular contraction
(C) Rapid ventricular ejection
(D) Reduced ventricular ejection
(E) Isovolumetric ventricular relaxation
(F) Rapid ventricular filling
(G) Reduced ventricular filling (diastasis)

37. Myocardial contractility is best correlated with the intracellular concentration of

(A) Na^+
(B) K^+
(C) Ca^{2+}
(D) Cl^-
(E) Mg^{2+}

38. Which of the following is an effect of histamine?

(A) Decreased capillary filtration
(B) Vasodilation of the arterioles
(C) Vasodilation of the veins
(D) Decreased P_c
(E) Interaction with the muscarinic receptors on the blood vessels

39. Carbon dioxide (CO_2) regulates blood flow to which one of the following organs?

(A) Heart
(B) Skin
(C) Brain
(D) Skeletal muscle at rest
(E) Skeletal muscle during exercise

40. Cardiac output of the right side of the heart is what percentage of the cardiac output of the left side of the heart?

(A) 25%
(B) 50%
(C) 75%
(D) 100%
(E) 125%

41. The physiologic function of the relatively slow conduction through the atrioventricular (AV) node is to allow sufficient time for

(A) runoff of blood from the aorta to the arteries
(B) venous return to the atria
(C) filling of the ventricles
(D) contraction of the ventricles
(E) repolarization of the ventricles

42. Blood flow to which organ is controlled primarily by the sympathetic nervous system rather than by local metabolites?

(A) Skin
(B) Heart
(C) Brain
(D) Skeletal muscle during exercise

43. Which of the following parameters is decreased during moderate exercise?

(A) Arteriovenous O_2 difference
(B) Heart rate
(C) Cardiac output
(D) Pulse pressure
(E) Total peripheral resistance (TPR)

44. A 72-year-old woman, who is being treated with propranolol, finds that she cannot maintain her previous exercise routine. Her physician explains that the drug has reduced her cardiac output. Blockade of which receptor is responsible for the decrease in cardiac output?

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

45. During which phase of the cardiac cycle is ventricular volume lowest?

(A) Atrial systole
(B) Isovolumetric ventricular contraction
(C) Rapid ventricular ejection
(D) Reduced ventricular ejection
(E) Isovolumetric ventricular relaxation
(F) Rapid ventricular filling
(G) Reduced ventricular filling (diastasis)

46. Which of the following changes will cause an increase in myocardial O_2 consumption?

(A) Decreased aortic pressure
(B) Decreased heart rate
(C) Decreased contractility
(D) Increased size of the heart
(E) Increased influx of Na^+ during the upstroke of the action potential

47. Which of the following substances crosses capillary walls primarily through water-filled clefts between the endothelial cells?

(A) O_2
(B) CO_2
(C) CO
(D) Glucose

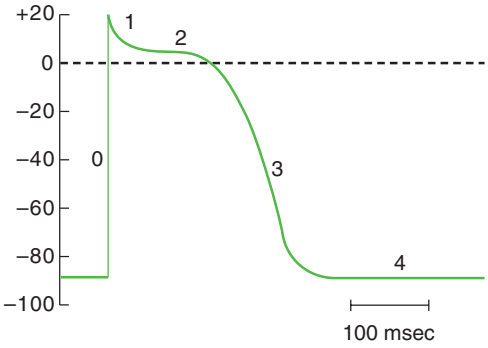
48. A 24-year-old woman presents to the emergency department with severe diarrhea. When she is supine (lying down), her blood pressure is 90/60 mm Hg (decreased) and her heart rate is 100 beats/min (increased). When she is moved to a standing position, her heart rate further increases to 120 beats/min. Which of the following accounts for the further increase in heart rate upon standing?

(A) Decreased total peripheral resistance
(B) Increased venoconstriction
(C) Increased contractility
(D) Increased afterload
(E) Decreased venous return

49. A 60-year-old businessman is evaluated by his physician, who determines that his blood pressure is significantly elevated at 185/130 mm Hg. Laboratory tests reveal an increase in plasma renin activity, plasma aldosterone level, and left renal vein renin level. His right renal vein renin level is decreased. What is the most likely cause of the patient's hypertension?

(A) Aldosterone-secreting tumor
(B) Adrenal adenoma secreting aldosterone and cortisol
(C) Pheochromocytoma
(D) Left renal artery stenosis
(E) Right renal artery stenosis

QUESTIONS 50–52



50. During which phase of the ventricular action potential is the membrane potential closest to the K^+ equilibrium potential?

(A) Phase 0
(B) Phase 1
(C) Phase 2
(D) Phase 3
(E) Phase 4

51. During which phase of the ventricular action potential is the conductance to Ca^{2+} highest?

(A) Phase 0
(B) Phase 1
(C) Phase 2
(D) Phase 3
(E) Phase 4

52. Which phase of the ventricular action potential coincides with diastole?

(A) Phase 0
(B) Phase 1
(C) Phase 2
(D) Phase 3
(E) Phase 4

53. Propranolol has which of the following effects?

(A) Decreases heart rate
(B) Increases left ventricular ejection fraction
(C) Increases stroke volume
(D) Decreases splanchnic vascular resistance
(E) Decreases cutaneous vascular resistance

54. Which receptor mediates slowing of the heart?

(A) α_1 Receptors
(B) β_1 Receptors
(C) β_2 Receptors
(D) Muscarinic receptors

55. Which of the following agents or changes has a negative inotropic effect on the heart?

(A) Increased heart rate
(B) Sympathetic stimulation
(C) Norepinephrine
(D) Acetylcholine (ACh)
(E) Cardiac glycosides

56. The low-resistance pathways between myocardial cells that allow for the spread of action potentials are the

(A) gap junctions
(B) T tubules
(C) sarcoplasmic reticulum (SR)
(D) intercalated disks
(E) mitochondria

57. Which agent is released or secreted after a hemorrhage and causes an increase in renal Na^+ reabsorption?

(A) Aldosterone
(B) Angiotensin I
(C) Angiotensinogen
(D) Antidiuretic hormone (ADH)
(E) Atrial natriuretic peptide

58. During which phase of the cardiac cycle does the mitral valve open?

(A) Atrial systole
(B) Isovolumetric ventricular contraction
(C) Rapid ventricular ejection
(D) Reduced ventricular ejection
(E) Isovolumetric ventricular relaxation
(F) Rapid ventricular filling
(G) Reduced ventricular filling (diastasis)

59. A hospitalized patient has an ejection fraction of 0.4, a heart rate of 95 beats/min, and a cardiac output of 3.5 L/min. What is the patient's end-diastolic volume?

(A) 14 mL
(B) 37 mL
(C) 55 mL
(D) 92 mL
(E) 140 mL

Answers and Explanations

1. **The answer is D** [II C, D]. If the radius of the artery decreased by 50% (1/2), then resistance would increase by 2^4, or 16 ($R = 8\eta l/\pi r^4$). Because blood flow is inversely proportional to resistance ($Q = \Delta P/R$), flow will decrease to 1/16 of the original value.

2. **The answer is B** [IX A; Table 3.4]. When a person moves to a standing position, blood pools in the leg veins, causing decreased venous return to the heart, decreased cardiac output, and decreased arterial pressure. The baroreceptors detect the decrease in arterial pressure, and the vasomotor center is activated to increase sympathetic outflow and decrease parasympathetic outflow. There is an increase in heart rate (resulting in a decreased PR interval), contractility, and total peripheral resistance (TPR). Because both heart rate and contractility are increased, cardiac output will increase toward normal.

3. **The answer is E** [II G, H, I]. Pressures on the venous side of the circulation (e.g., central vein, right atrium, renal vein) are lower than pressures on the arterial side. Pressure in the pulmonary artery (and all pressures on the right side of the heart) are much lower than their counterparts on the left side of the heart. In the systemic circulation, systolic pressure is actually slightly higher in the downstream arteries (e.g., renal artery) than in the aorta because of the reflection of pressure waves at branch points.

4. **The answer is B** [III A]. The absent P wave indicates that the atrium is not depolarizing and, therefore, the pacemaker cannot be in the sinoatrial (SA) node. Because the QRS and T waves are normal, depolarization and repolarization of the ventricle must be proceeding in the normal sequence. This situation can occur if the pacemaker is located in the atrioventricular (AV) node. If the pacemaker were located in the bundle of His or in the Purkinje system, the ventricles would activate in an abnormal sequence (depending on the exact location of the pacemaker) and the QRS wave would have an abnormal configuration. Ventricular muscle does not have pacemaker properties.

5. **The answer is B** [IV G 3]. An increase in ejection fraction means that a higher fraction of the end-diastolic volume is ejected in the stroke volume (e.g., because of the administration of a positive inotropic agent). When this situation occurs, the volume remaining in the ventricle after systole, the end-systolic volume, will be reduced. Cardiac output, pulse pressure, stroke volume, and systolic pressure will be increased.

6. **The answer is D** [V G]. On the extrasystolic beat, pulse pressure decreases because there is inadequate ventricular filling time—the ventricle beats "too soon." As a result, stroke volume decreases.

7. **The answer is A** [IV C I a (2)]. The postextrasystolic contraction produces increased pulse pressure because contractility is increased. Extra Ca^{2+} enters the cell during the extrasystolic beat. Contractility is directly related to the amount of intracellular Ca^{2+} available for binding to troponin C.

8. **The answer is A** [IV D 5 a]. An increase in contractility produces an increase in cardiac output for a given end-diastolic volume, or pressure. The Frank-Starling relationship demonstrates the matching of cardiac output (what leaves the heart) with venous return (what returns to the heart). An increase in contractility (positive inotropic effect) will shift the curve upward.

9. **The answer is B** [IV E 1 a]. Isovolumetric contraction occurs during ventricular systole, before the aortic valve opens. Ventricular pressure increases, but volume remains constant because blood cannot be ejected into the aorta against a closed valve.

10. The answer is C [IV 1 c]. Closure of the aortic valve occurs once ejection of blood from the ventricle has occurred and the left ventricular pressure has decreased to less than the aortic pressure.

11. The answer is A [V B]. The first heart sound corresponds to closure of the atrial–ventricular valves. Before this closure occurs, the ventricle fills (phase 4 → 1). After the valves close, isovolumetric contraction begins and ventricular pressure increases (phase 1 → 2).

12. The answer is C [IV E 1, G 1, 2]. Stroke volume is the volume ejected from the ventricle and is represented on the pressure–volume loop as phase 2 → 3; end-diastolic volume is about 140 mL and end-systolic volume is about 65 mL; the difference, or stroke volume, is 75 mL. Cardiac output is calculated as stroke volume × heart rate or 75 mL × 70 beats /min = 5250 mL/min or 5.25 L/min.

13. The answer is D [VII C 1]. The net driving force can be calculated with the Starling equation

$$\begin{aligned}\text{Net pressure} &= (P_c - P_i) - (\pi_c - \pi_i)\\ &= \left[(30-(-2)) - (25-2)\right] \text{ mm Hg}\\ &= 32 \text{ mm Hg} - 23 \text{ mm Hg}\\ &= +9 \text{ mm Hg}\end{aligned}$$

Because the net pressure is positive, filtration out of the capillary will occur.

14. The answer is C [VII C 1]. K_f is the filtration coefficient for the capillary and describes the intrinsic water permeability.

$$\begin{aligned}\text{Water flow} &= K_f \times \text{Net pressure}\\ &= 0.5 \text{ mL/min/mm Hg} \times 9 \text{ mm Hg}\\ &= 4.5 \text{ mL/min}\end{aligned}$$

15. The answer is C [II D 2 a, b]. Turbulent flow is predicted when the Reynolds number is increased. Factors that increase the Reynolds number and produce turbulent flow are decreased viscosity (hematocrit) and increased velocity. Partial occlusion of a blood vessel increases the Reynolds number (and turbulence) because the decrease in cross-sectional area results in increased blood velocity ($v = Q/A$).

16. The answer is D [IX A]. Orthostatic hypotension is a decrease in arterial pressure that occurs when a person moves from a supine to a standing position. A person with a normal baroreceptor mechanism responds to a decrease in arterial pressure through the vasomotor center by increasing sympathetic outflow and decreasing parasympathetic outflow. The sympathetic component helps to restore blood pressure by increasing heart rate, contractility, total peripheral resistance (TPR), and mean systemic pressure. In a patient who has undergone a sympathectomy, the sympathetic component of the baroreceptor mechanism is absent.

17. The answer is D [III A]. The PR segment (part of the PR interval) and the ST segment are the only portions of the electrocardiogram (ECG) that are isoelectric. The PR interval includes the P wave (atrial depolarization) and the PR segment, which represents conduction through the atrioventricular (AV) node; during this phase, the ventricles are not yet depolarized. The ST segment is the only isoelectric period when the entire ventricle is depolarized.

18. The answer is C [I A]. In a left-to-right ventricular shunt, a defect in the ventricular septum allows blood to flow from the left ventricle to the right ventricle instead of being ejected into the aorta. The "shunted" fraction of the left ventricular output is therefore added to the output of the right ventricle, making pulmonary blood flow (the cardiac output of the right ventricle) higher than systemic blood flow (the cardiac output of the left ventricle). In normal adults, the outputs of both ventricles are equal in the steady state. In the fetus, pulmonary blood flow is near zero. Right ventricular failure results in decreased pulmonary blood flow. Administration of a positive inotropic agent should have the same effect on contractility and cardiac output in both ventricles.

19. The answer is C [IV F 2 a]. The shift in the venous return curve to the right is consistent with an increase in blood volume and, as a consequence, mean systemic pressure. Both cardiac output and venous return are increased in the new steady state (and are equal to each other). Contractility is unaffected.

20. The answer is D [III E 1 b]. A pattern of two P waves preceding each QRS complex indicates that only every other P wave is conducted through the atrioventricular (AV) node to the ventricle. Thus, conduction velocity through the AV node must be decreased.

21. The answer is A [VI A 1 a-d]. A decrease in blood pressure causes decreased stretch of the carotid sinus baroreceptors and decreased firing of the carotid sinus nerve. In an attempt to restore blood pressure, the parasympathetic outflow to the heart is decreased and sympathetic outflow is increased. As a result, heart rate and contractility will be increased. Mean systemic pressure will increase because of increased sympathetic tone of the veins (and a shift of blood to the arteries).

22. The answer is B [VII C 4 c; Table 3.2]. Edema occurs when more fluid is filtered out of the capillaries than can be returned to the circulation by the lymphatics. Filtration is increased by changes that increase P_c or decrease π_c. Arteriolar constriction would decrease P_c and decrease filtration. Dehydration would increase plasma protein concentration (by hemoconcentration) and thereby increase π_c and decrease filtration. Increased venous pressure would increase P_c and filtration.

23. The answer is A [V E]. The second heart sound is associated with closure of the aortic and pulmonic valves. Because the aortic valve closes before the pulmonic valve, the sound can be split by inspiration.

24. The answer is C [IX B 2]. During exercise, local metabolites accumulate in the exercising muscle and cause local vasodilation and decreased arteriolar resistance of the skeletal muscle. Because muscle mass is large, it contributes a large fraction of the total peripheral resistance (TPR). Therefore, the skeletal muscle vasodilation results in an overall decrease in TPR, even though there is sympathetic vasoconstriction in other vascular beds.

25. The answer is A [V A-G]. The electrocardiogram (ECG) tracing serves as a reference. The QRS complex marks ventricular depolarization, followed immediately by ventricular contraction. Aortic pressure increases steeply after QRS, as blood is ejected from the ventricles. After reaching peak pressure, aortic pressure decreases as blood runs off into the arteries. The characteristic dicrotic notch ("blip" in the aortic pressure curve) appears when the aortic valve closes. Aortic pressure continues to decrease as blood flows out of the aorta.

26. The answer is D [V A-G]. Ventricular volume increases slightly with atrial systole (P wave), is constant during isovolumetric contraction (QRS), and then decreases dramatically after the QRS, when blood is ejected from the ventricle.

27. The answer is C [II C]. An increase in arteriolar resistance will increase total peripheral resistance (TPR). Arterial pressure = cardiac output × TPR, so arterial pressure will also increase. Capillary filtration decreases when there is arteriolar constriction because P_c decreases. Afterload of the heart would be increased by an increase in TPR.

28. The answer is D [IV J]. Cardiac output is calculated by the Fick principle if whole body oxygen (O_2) consumption and [O_2] in the pulmonary artery and pulmonary vein are measured. Mixed venous blood could substitute for a pulmonary artery sample, and peripheral arterial blood could substitute for a pulmonary vein sample. Central venous pressure and heart rate are not needed for this calculation.

$$\text{Cardiac output} = \frac{500 \text{ mL/min}}{0.24 \text{ mL } O_2/\text{mL} - 0.16 \text{ mL } O_2/\text{mL}}$$
$$= 6250 \text{ mL/min, or } 6.25 \text{ L/min}$$

29. The answer is B [III B 1 a, c, d, 2 a]. The upstroke of the action potential in the atria, ventricles, and Purkinje fibers is the result of a fast inward Na^+ current. The upstroke of the action potential in the sinoatrial (SA) node is the result of an inward Ca^{2+} current. The plateau of the ventricular action potential is the result of a slow inward Ca^{2+} current. Repolarization in all cardiac tissues is the result of an outward K^+ current.

30. The answer is C [IV F 3 a (1)]. An upward shift of the cardiac output curve is consistent with an increase in myocardial contractility; for any right atrial pressure (sarcomere length), the force of contraction is increased. Such a change causes an increase in stroke volume and cardiac output. Increased blood volume and increased mean systemic pressure are related and would cause a rightward shift in the venous return curve. A negative inotropic agent would cause a decrease in contractility and a downward shift of the cardiac output curve.

31. The answer is B [IV F 3]. End-diastolic volume and right atrial pressure are related and can be used interchangeably.

32. The answer is E [II A 2, 3, F]. The decrease in pressure at any level of the cardiovascular system is caused by the resistance of the blood vessels ($\Delta P = Q \times R$). The greater the resistance is, the greater the decrease in pressure is. The arterioles are the site of highest resistance in the vasculature. The arterioles do not have the greatest surface area or cross-sectional area (the capillaries do). Velocity of blood flow is lowest in the capillaries, riot in the arterioles.

33. The answer is D [II G 3]. Pulse pressure is the difference between the highest (systolic) and lowest (diastolic) arterial pressures. It reflects the volume ejected by the left ventricle (stroke volume). Pulse pressure increases when the capacitance of the arteries decreases, such as with aging.

34. The answer is B [III B 2 c]. Phase 4 depolarization is responsible for the pacemaker property of sinoatrial (SA) nodal cells. It is caused by an increase in Na^+ conductance and an inward Na^+ current (I_f), which depolarizes the cell membrane.

35. The answer is A [VIII E 1; Table 3.1]. During exercise, the sympathetic nervous system is activated. The observed increase in splanchnic vascular resistance is due to sympathetic activation of α_1 receptors on splanchnic arterioles.

36. The answer is D [V A–G]. Aortic pressure reaches its highest level immediately after the rapid ejection of blood during left ventricular systole. This highest level actually coincides with the beginning of the reduced ventricular ejection phase.

37. The answer is C [IV B 6]. Contractility of myocardial cells depends on the intracellular $[Ca^{2+}]$, which is regulated by Ca^{2+} entry across the cell membrane during the plateau of the action potential and by Ca^{2+} uptake into and release from the sarcoplasmic reticulum (SR). Ca^{2+} binds to troponin C and removes the inhibition of actin–myosin interaction, allowing contraction (shortening) to occur.

38. The answer is B [VIII B 2 a]. Histamine causes vasodilation of the arterioles, which increases P_c and capillary filtration. It also causes constriction of the veins, which contributes to the increase in P_c. Acetylcholine (ACh) interacts with muscarinic receptors (although these are not present on vascular smooth muscle).

39. The answer is C [VIII C, D, E 2, F]. Blood flow to the brain is autoregulated by the Pco_2. If metabolism increases (or arterial pressure decreases), the Pco_2 will increase and cause cerebral vasodilation. Blood flow to the heart and to skeletal muscle during exercise is also regulated metabolically, but adenosine and hypoxia are the most important vasodilators for the heart. Adenosine, lactate, and K^+ are the most important vasodilators for exercising skeletal muscle. Blood flow to the skin is regulated by the sympathetic nervous system rather than by local metabolites.

40. The answer is D [I A]. Cardiac output of the left and right sides of the heart is equal. Blood ejected from the left side of the heart to the systemic circulation must be oxygenated by passage through the pulmonary circulation.

41. The answer is C [III C]. The atrioventricular (AV) delay (which corresponds to the PR interval) allows time for filling of the ventricles from the atria. If the ventricles contracted before they were filled, stroke volume would decrease.

42. The answer is A [VIII C–F]. Circulation of the skin is controlled primarily by the sympathetic nerves. The coronary and cerebral circulations are primarily regulated by local metabolic factors. Skeletal muscle circulation is regulated by metabolic factors (local metabolites) during exercise, although at rest it is controlled by the sympathetic nerves.

43. The answer is E [IX B]. In anticipation of exercise, the central command increases sympathetic outflow to the heart and blood vessels, causing an increase in heart rate and contractility. Venous return is increased by muscular activity and contributes to an increase in cardiac output by the Frank-Starling mechanism. Pulse pressure is increased because stroke volume is increased. Although increased sympathetic outflow to the blood vessels might be expected to increase total peripheral resistance (TPR), it does not because there is an overriding vasodilation of the skeletal muscle arterioles as a result of the buildup of vasodilator metabolites (lactate, K^+ adenosine). Because this vasodilation improves the delivery of O_2, more O_2 can be extracted and used by the contracting muscle.

44. The answer is B [III 3; Table 3.1]. Propranolol is an adrenergic antagonist that blocks both β_1 and β_2 receptors. When propranolol is administered to reduce cardiac output, it inhibits β_1 receptors in the sinoatrial (SA) node (heart rate) and in ventricular muscle (contractility).

45. The answer is E [V E]. Ventricular volume is at its lowest value while the ventricle is relaxed (diastole), just before ventricular filling begins.

46. The answer is D [IV I]. Myocardial O_2 consumption is determined by the amount of tension developed by the heart. It increases when there are increases in aortic pressure (increased afterload), when there is increased heart rate or stroke volume (which increases cardiac output), or when the size (radius) of the heart is increased ($T = P \times r$). Influx of Na^+ ions during an action potential is a purely passive process, driven by the electrochemical driving forces on Na^+ ions. Of course, maintenance of the inwardly directed Na^+ gradient over the long term requires the Na^+–K^+ pump, which is energized by adenosine triphosphate (ATP).

47. The answer is D [VII B 1, 2]. Because O_2, CO_2, and CO are lipophilic, they cross capillary walls primarily by diffusion through the endothelial cell membranes. Glucose is water soluble; it cannot cross through the lipid component of the cell membrane and is restricted to the water-filled clefts, or pores, between the cells.

48. The answer is E [VI A]. Diarrhea causes a loss of extracellular fluid volume, which produces a decrease in arterial pressure. The decrease in arterial pressure activates the baroreceptor mechanism, which produces an increase in heart rate when the patient is supine. When she stands up, blood pools in her leg veins and produces a decrease in venous return, a decrease in cardiac output (by the Frank-Starling mechanism), and a further decrease in arterial pressure. The *further* decrease in arterial pressure causes *further* activation of the baroreceptor mechanism and a *further* increase in heart rate.

49. The answer is D [VI B]. In this patient, hypertension is most likely caused by left renal artery stenosis, which led to increased renin secretion by the left kidney. The increased plasma renin activity causes an increased secretion of aldosterone, which increases Na^+ reabsorption by the renal distal tubule. The increased Na^+ reabsorption leads to increased blood volume and blood pressure. The right kidney responds to the increase in blood pressure by decreasing its renin secretion. Right renal artery stenosis causes a similar pattern of results, except that renin secretion from the right kidney, not the left kidney, is increased. Aldosterone-secreting tumors cause increased levels of aldosterone but decreased plasma renin activity (as a result of decreased renin secretion by both kidneys). Pheochromocytoma is associated with increased circulating levels of catecholamines, which increase blood pressure by their effects on the heart (increased heart rate and contractility) and blood vessels (vasoconstriction); the increase in blood pressure is sensed by the kidneys and results in decreased plasma renin activity and aldosterone levels.

50. The answer is E [III B 1 e]. Phase 4 is the resting membrane potential. Because the conductance K^+ is highest, the membrane potential approaches the equilibrium potential for K^+.

51. The answer is C [III B 1 c]. Phase 2 is the plateau of the ventricular action potential. During this phase, the conductance to Ca^{2+} increases transiently. Ca^{2+} that enters the cell during the plateau is the trigger that releases more Ca^{2+} from the sarcoplasmic reticulum (SR) for the contraction.

52. The answer is E [III B 1 e]. Phase 4 is electrical diastole.

53. The answer is A [III E 2, 3; Table 3.1]. Propranolol, a β-adrenergic antagonist, blocks all sympathetic effects that are mediated by a β_1 or β_2 receptor. The sympathetic effect on the sinoatrial (SA) node is to increase heart rate via a β_1 receptor; therefore, propranolol decreases heart rate. Ejection fraction reflects ventricular contractility, which is another effect of β_1 receptors; thus, propranolol decreases contractility, ejection fraction, and stroke volume. Splanchnic and cutaneous resistance are mediated by α_1 receptors.

54. The answer is D [III E 2 a; Table 3.1]. Acetylcholine (ACh) causes slowing of the heart via muscarinic receptors in the sinoatrial (SA) node.

55. The answer is D [IV C]. A negative inotropic effect is one that decreases myocardial contractility. Contractility is the ability to develop tension at a fixed muscle length. Factors that decrease contractility are those that decrease the intracellular $[Ca^{2+}]$. Increasing heart rate increases intracellular $[Ca^{2+}]$ because more Ca^{2+} ions enter the cell during the plateau of each action potential. Sympathetic stimulation and norepinephrine increase intracellular $[Ca^{2+}]$ by increasing entry during the plateau and increasing the storage of Ca^{2+} by the sarcoplasmic reticulum (SR) [for later release]. Cardiac glycosides increase intracellular $[Ca^{2+}]$ by inhibiting the Na^+–K^+ pump, thereby inhibiting Na^+–Ca^{2+} exchange (a mechanism that pumps Ca^{2+} out of the cell). Acetylcholine (ACh) has a negative inotropic effect on the atria.

56. The answer is A [IVA 3]. The gap junctions occur at the intercalated disks between cells and are low-resistance sites of current spread.

57. The answer is A [VI C 4; IX C]. Angiotensin I and aldosterone are increased in response to a decrease in renal perfusion pressure. Angiotensinogen is the precursor for angiotensin I. Antidiuretic hormone (ADH) is released when atrial receptors detect a decrease in blood volume. Of these, only aldosterone increases Na^+ reabsorption. Atrial natriuretic peptide is released in response to an increase in atrial pressure, and an increase in its secretion would not be anticipated after blood loss.

58. The answer is E [V E]. The mitral [atrioventricular (AV)] valve opens when left atrial pressure becomes higher than left ventricular pressure. This situation occurs when the left ventricular pressure is at its lowest level—when the ventricle is relaxed, blood has been ejected from the previous cycle, and before refilling has occurred.

59. The answer is D [IV G]. First, calculate stroke volume from the cardiac output and heart rate: Cardiac output = stroke volume × heart rate; thus, stroke volume = cardiac output/heart rate = 3500 mL/95 beats/min = 36.8 mL. Then, calculate end-diastolic volume from stroke volume and ejection fraction: Ejection fraction = stroke volume/end-diastolic volume; thus end-diastolic volume = stroke volume/ejection fraction = 36.8 mL/0.4 = 92 mL.