The Blood Vessels and Blood Pressure

Chapter Overview

The circulatory system aids in the performance of many vital functions. The circulatory contribution to all these functions is flow. Flow depends on pressure and resistance. The circulatory system includes arteries, arterioles, capillaries, venules, and veins. It is the flow of blood through these vessels that is so important to homeostasis. For this system to function, pressure and resistance are essential. The heart and the blood vessels provide the pressure. The pressure is monitored by baroreceptors which provide the CNS with the information necessary to control the blood flow. Arteries and veins play a major role in the gross transport of blood. The cardiac output is distributed throughout the body in a highly variable pattern. In this capacity it is the arterioles and capillaries that play the major role. Through changes in resistance the arterioles provide the mechanism for the distributional changes. The distribution of cardiac output is adjusted to maintain homeostasis. Consider all the substances released into or removed from the blood. Many of these molecules have typical cells as their destinations, but most are being transported to specific tissues. The capillaries are the sites of exchange. Arterioles, which respond to intrinsic and extrinsic controls, provide the proper pressure for the exchanges to occur. The circulatory system, like the other body systems, functions to maintain homeostasis. Again, all levels of organization are performing to maintain homeostasis for the survival of cells.

Chapter Outline

INTRODUCTION

Materials are transported within the body by the blood as it is pumped through the blood vessels.

- The majority of the body cells are not in direct contact with the external environment, yet these cells must make exchanges with the environment, such as picking up oxygen and nutrients and eliminating wastes.
- All blood pumped by the right side of the heart passes through the lungs for oxygen pickup and carbon dioxide removal.
- The blood pumped by the left side of the heart is parcelled out in various proportions to the systemic organs through a parallel arrangement of vessels that branch from the aorta.
- Blood is constantly “reconditioned” so that its composition remains relatively constant despite an ongoing drain of supplies to support metabolic activities and the continual addition of wastes from the tissues.
- The organs that recondition the blood (digestive tract, kidneys, and skin) normally receive substantially more blood than is necessary to meet their basic metabolic needs so that they can perform homeostatic adjustments on the blood.
- Reconditioning organs can withstand temporary reductions in blood flow.
- In contrast, the brain can least tolerate a disruption in its blood supply.

Blood flow through vessels depends on the pressure gradient and vascular resistance.

- Arteries carry blood from the heart.
- When a small artery reaches the organ it is supplying, it branches into numerous arterioles.
• Arterioles branch further within the organs into capillaries.
• Capillaries rejoin to form small venules, which further merge to form small veins.
• The small veins unite to form larger veins.
• The arterioles, capillaries and venules are collectively referred to as the microcirculation.
• The flow rate of blood through a vessel is directly proportional to the pressure gradient and inversely proportional to vascular resistance.
• The pressure gradient—the difference in pressure between the beginning and end of a vessel—is the main driving force for flow through the vessel.
• The greater the pressure gradient forcing blood through a vessel, the greater the rate of flow through that vessel.
• Resistance is a measure of the hindrance to blood flow through a vessel caused by friction between the moving fluid and the stationary vascular walls.
• Resistance to blood flow depends on three factors: (1) viscosity of the blood; (2) vessel length, and (3) vessel radius.

**Arteries**

Arteries serve as rapid-transit passageways to the tissues and as a pressure reservoir.

• Arteries are specialized to serve as rapid-transit passageways for blood from the heart to the tissues and to act as a pressure reservoir to provide the driving force for blood when the heart is relaxing.
• Capillary flow does not fluctuate between cardiac systole and diastole; blood flow is continuous through the capillaries supplying the tissues.
• The driving force for the continued flow of blood to the tissues during cardiac relaxation is provided by the elastic properties of the arterial wall.
• The arteries' elasticity enables them to expand to temporarily hold an excess volume of ejected blood, storing some of the pressure energy imparted by the cardiac contraction.
• When the heart relaxes and ceases pumping blood into the arteries, the stretched arterial walls passively recoil and push the excess blood contained in the arteries into the vessels downstream.

**Arterial pressure fluctuates in relation to ventricular systole and diastole.**

• The maximum pressure exerted in the arteries when the blood is ejected into them during systole, the systolic pressure, averages 120 mm Hg.
• The minimum pressure within the arteries when blood is draining off into the remainder of the vessels during diastole, the diastolic pressure, averages 80 mm Hg.

**Blood pressure can be indirectly measured by using a sphygmomanometer.**

• It is convenient and reasonably accurate to measure the pressure indirectly through the use of a sphygmomanometer, an externally applied inflatable cuff attached to a pressure gauge.
• During the determination of blood pressure, a stethoscope is placed over the brachial artery.
• At the onset of a blood pressure determination, the cuff is inflated to a pressure greater than systolic blood pressure so that the brachial artery collapses.
• The pressure in the cuff is gradually reduced.
• The highest cuff pressure at which the first sound can be heard is indicative of the systolic blood pressure.
• The highest cuff pressure at which the last sound can be detected is indicative of the diastolic pressure.
• The pressure difference between systolic and diastolic pressures is known as the pulse pressure.

**Mean arterial pressure is the main driving force for blood flow.**

• The mean arterial pressure is the average pressure responsible for driving blood forward into the tissues throughout the cardiac cycle.
• The mean arterial pressure equals the diastolic pressure plus one-third the pulse pressure.
• The mean arterial pressure averages 93 mm Hg.
• Arterial pressure is essentially the same throughout the arterial tree.
Arterioles
Arterioles are the major resistance vessels.

- The arterioles are the major resistance vessels in the vascular tree, even though the capillaries have smaller radii than the arterioles.
- The radii of arterioles supplying individual organs can be adjusted independently to determine the distribution of cardiac output and to regulate arterial blood pressure.
- Arteriolar walls have a thick layer of smooth muscle that is richly innervated by sympathetic nerve fibers.
- The smooth muscle layer runs circularly around the arteriole so when it contracts, the vessel's circumference becomes smaller, thus increasing resistance and decreasing the flow through that vessel.
- Local (intrinsic) controls and extrinsic controls influence the level of contractile activity in arteriolar smooth muscle.

Local control of arteriolar radius is important in determining distribution of cardiac output so that blood flow is matched with the tissues' metabolic needs.

- Blood is delivered to all tissues at the same mean arterial pressure.
- The distribution of cardiac output can be varied by differentially adjusting arteriolar resistance in the various vascular beds.
- Local controls are changes within a tissue that alter the radii of the vessels and hence adjust blood flow through the tissue by directly affecting the smooth muscle of the tissue's arterioles.
- Local influences may be either chemical or physical in nature.
- Local arteriolar vasodilation increasing blood flow to a particular area is called active hyperemia.
- Local chemical changes produce dilation without involving nerves or hormones.
- The following local chemical factors produce relaxation of arteriolar smooth muscles: decreased oxygen, increased carbon dioxide, increased acid, increased potassium, increased osmolarity, adenosine release, and prostaglandin release.

- The single layer of specialized epithelial cells that line the lumen of all blood vessels-the endothelial cells-release nitric oxide.
- Nitric oxide causes relaxation of arteriolar smooth muscle.
- By dilating the arterioles of the penis, nitric oxide is the direct mediator of penile erection.
- Macrophages produce nitric oxide, which they use as "chemical warfare" against bacteria and cancer cells.
- Nitric oxide interferes with platelet function and blood clotting at sites of vessel damage.
- Nitric oxide serves as a neurotransmitter in the brain and elsewhere.
- Nitric oxide helps regulate peristalsis.
- Nitric oxide may play a role in relaxation of skeletal muscle.
- Nitric oxide plays a role in the changes underlying memory.
- The endothelial cells release other important chemicals, such as endothelin, which bring about vasoconstriction by causing arteriolar smooth muscle contraction.
- Histamine is another local chemical mediator that influences arteriolar smooth muscle, but it is not released in response to local metabolic changes and is not derived from the endothelial cells.
- Histamine is synthesized and stored within special connective tissue cells in many tissues and in certain types of circulating white blood cells.
- When tissues are injured or during allergic reactions, histamine is released in the damaged region.
- Histamine is the major cause of vasodilation in an injured area.
- Local physical influences on arterioles include heat or cold and myogenic responses to stretch.
- Myogenic responses appear to be important in reactive hyperemia and pressure autoregulation.
- When the blood supply to a region is completely occluded, arterioles in the region dilate due to (1) myogenic relaxation, which occurs in response to the diminished stretch accompanying no blood flow, and (2) changes in local chemical composition.
• After the occlusion is removed, blood flow to the previously deprived tissue is transiently much higher than normal because the arterioles are widely dilated.
• This is called reactive hyperemia.
• When mean arterial pressure falls, the driving force is reduced, so blood flow to tissues decreases.
• Widespread arteriolar dilation reduces the mean arterial pressure, which aggravates the problem.
• In the presence of sustained elevations in mean arterial pressure, local chemical and myogenic influences triggered by the initial increased flow of blood bring about an increase in arteriolar tone and resistance.
• This greater degree of vasoconstriction reduces tissue blood flow toward normal despite the elevated blood pressure.
• Pressure autoregulation is the term applied to these local arteriolar mechanisms that are aimed at keeping tissue blood flow fairly constant.

Extrinsic control of arteriolar radius is primarily important in the regulation of arterial blood pressure.
• Extrinsic control of arteriolar radius includes both neural and hormonal influences, with the effects of the sympathetic nervous system being the most important.
• Sympathetic nerve fibers supply arteriolar smooth muscle everywhere except in the brain.
• A certain level of ongoing sympathetic activity contributes to vascular tone.
• Increased sympathetic activity produces generalized arteriolar vasoconstriction, whereas decreased sympathetic activity leads to generalized arteriolar vasodilation.
• The extent to which each organ actually receives blood flow is determined by local arteriolar adjustments that override the sympathetic constrictor effect.
• The main region of the brain responsible for adjusting sympathetic output to the arterioles is the cardiovascular control center in the medulla of the brain stem.
• Several hormones also extrinsically influence arteriolar radius including epinephrine, norepinephrine, vasopressin and angiotensin II.

CAPILLARIES
*Capillaries are ideally suited to serve as sites of exchange.*
• Capillaries, the sites of exchange of materials between the blood and tissues, branch extensively to bring blood within the reach of every cell.
• Exchange of materials across capillary walls is accomplished primarily by the process of diffusion.
• Diffusing molecules have only a short distance to travel between the blood and surrounding cells because of the thin capillary wall and small capillary diameter, coupled with the close proximity of each and every cell to a capillary.
• Because capillaries are distributed in such incredible numbers, a tremendous total surface area is available for exchange.
• Diffusion is enhanced because blood flows more slowly in the capillaries than elsewhere in the circulatory system.

*Water-filled pores in the capillary walls permit passage of small, water-soluble substances that cannot cross the endothelial cells themselves.*
• Diffusion across capillary walls also depends on the walls' permeability to the materials being exchanged.
• In most capillaries, narrow, water-filled clefts, or pores, are present at the junctions between the cells.
• The size of the capillary pore varies from organ to organ.
• In response to appropriate signals, the endothelial cells can readjust themselves to vary the size of the pores.
• Vesicular transport also plays a limited role in the passage of materials across the capillary wall.

*Many capillaries are not open under resting conditions.*
• Precapillary sphincters act as stopcocks to control blood flow through a particular capillary.
• Capillaries themselves have no smooth muscle, so they cannot actively participate in the regulation of their own blood flow.

**Diffusion across the capillary wall is important in solute exchange.**

• Exchanges are not made directly between blood and the tissue cells.
• Cells exchange materials directly with the interstitial fluid, the type and extent of exchange being governed by the properties of the cellular plasma membranes.
• Passive diffusion down concentration gradients is the primary mechanism for exchange of individual solutes.

**Bulk flow across the capillary wall is important in extracellular fluid distribution.**

• Bulk flow is the process whereby a volume of protein-free plasma filters out of the capillary, mixes with the surrounding interstitial fluid, and is subsequently reabsorbed.
• Bulk flow occurs because of differences in the hydrostatic and colloid osmotic pressures between the plasma and interstitial fluid.
• Bulk flow does not play an important role in the exchange of individual solutes between blood and tissues, because the quantity of solutes moved across the capillary wall by bulk flow is extremely small compared to the much larger transfer of solutes by diffusion.
• Bulk flow plays an extremely important role in regulating the distribution of ECF between plasma and interstitial fluid.

**The lymphatic system is an accessory route by which interstitial fluid can be returned to the blood.**

• Even under normal circumstances, slightly more fluid is filtered out of the capillaries into the interstitial fluid than is reabsorbed from the interstitial fluid back into the plasma.
• The extra fluid filtered out as a result of this filtration-reabsorption imbalance is picked up by the lymphatic system.
• Small, blind-ended terminal lymph vessels permeate almost every tissue of the body.
• Once interstitial fluid enters a lymphatic vessel, it is called lymph.

• Lymphatics converge to form larger and larger lymph vessels, which eventually empty into the venous system.
• The most important functions of the lymphatic system are as follows: (1) the return of excess filtered fluid to the blood, (2) the defense against disease provided by phagocytic cells in the lymph nodes, (3) the transport of absorbed fat, and (4) the return of filtered protein to the blood.

**Edema occurs when too much interstitial fluid accumulates.**

• Swelling of the tissues because of excess interstitial fluid is known as edema.
• The cause of edema can be grouped into four general categories: (1) a reduced concentration of plasma proteins; (2) an increased permeability of the capillary walls; (3) an increased venous pressure; and (4) the blockage of lymph vessels.
• Whatever the cause of edema, an important consequence is a reduction in exchange of materials between the blood and cells.

**VEINS**

*Veins serve as a blood reservoir as well as passageways back to the heart.*

• Because the total cross-sectional area of the venous system gradually decreases as smaller veins converge into progressively fewer but larger vessels, the velocity of blood flow increases as the blood approaches the heart.
• Systemic veins serve as a blood reservoir.
• When the stored blood is needed, such as during exercise, extrinsic factors drive the extra blood from the veins to the heart.
• A delicate balance exists between the capacity of the veins, the extent of venous return, and the cardiac output.

**Venous return is enhanced by a number of extrinsic factors.**

• Changes in venous capacity directly influence the magnitude of venous return, which in turn is an important determinant of effective circulating blood volume.
• Sympathetic stimulation produces venous vasoconstriction, which modestly elevates venous pressure; this in turn, increases the
pressure gradient to drive more blood from the veins into the right atrium.

- Venous vasoconstriction enhances venous return by decreasing venous capacity.
- Many of the large veins in the extremities lie between skeletal muscles so when the muscles contract, the veins are compressed.
- External venous compression decreases venous capacity and increases venous pressure, in effect squeezing fluid contained in the veins forward toward the heart.
- This pumping action, known as the skeletal muscle pump, is one way by which extra blood stored in the veins is returned to the heart during exercise.
- Increased muscular activity pushes more blood out of the veins and into the heart.
- Blood can only be driven forward because the large veins are equipped with one-way valves.
- These valves permit blood to move forward toward the heart but prevent it from moving back toward the tissues.
- Varicose veins occur when the venous valves become incompetent and can no longer support the column of blood above them.
- The most serious consequence of varicose veins is the possibility of abnormal clot formation in the sluggish, pooled blood.
- As a result of respiratory activity, the pressure within the chest cavity averages 5 mm Hg less than atmospheric pressure.
- The pressure difference between the lower veins and the chest veins squeeizes blood from the lower veins to the chest veins, promoting venous return.
- This mechanism of facilitating venous return is known as the respiratory pump.
- During ventricular contraction, the AV valves are drawn downward, enlarging the atrial cavities, which drops the atrial pressure to below 0 mm Hg, thus enhancing venous return.
- Thus, the heart functions as a “suction pump” to facilitate cardiac filling.

BLOOD PRESSURE

Regulation of mean arterial blood pressure is accomplished by controlling cardiac output, total peripheral resistance, and blood volume.
autonomic nervous system influences on the heart, veins, and arterioles.

- Long-term control involves adjusting total blood volume by restoring normal salt and water balance through mechanisms that regulate urine output and thirst.

The baroreceptor reflex is the most important mechanism for short-term regulation of blood pressure.

- Any change in mean blood pressure triggers an autonomically mediated baroreceptor reflex that influences the heart and blood vessels to adjust cardiac output and total peripheral resistance in an attempt to restore blood pressure to normal.
- The carotid sinus and aortic arch baroreceptors are sensitive to changes in both mean arterial pressure and pulse pressure.
- The integrating center that receives the afferent impulses about the status of arterial pressure is the cardiovascular control center.
- The cardiovascular control center alters the ratio between sympathetic and parasympathetic activity to the effector organs.
- If arterial pressure becomes elevated above normal, the carotid sinus and aortic arch baroreceptors increase the rate of firing in their respective afferent neurons.
- The cardiovascular control center responds by decreasing sympathetic and increasing parasympathetic activity.
- These efferent signals decrease heart rate, decrease stroke volume, and produce arteriolar and vasodilation.
- When blood pressure falls below normal, baroreceptor activity decreases, inducing the cardiovascular center to increase sympathetic cardiac and vasoconstrictor nerve activity while decreasing its parasympathetic output.
- This efferent activity leads to an increase in heart rate and stroke volume coupled with arteriolar and venous vasoconstriction.

Other reflexes and responses influence blood pressure.

- The sole function of the baroreceptor reflex is blood pressure regulation Other reflexes and responses that influence the cardiovascular system include the following:

  (1) left atrial volume receptors and hypothalamic osmoreceptors; (2) chemoreceptors located in the carotid and aortic arteries; (3) cardiovascular responses associated with behaviors and emotions; (4) cardiovascular responses associated with exercise; (5) hypothalamic control over cutaneous arterioles; (6) vasoactive substances released by endothelial cells; and (7) numerous neurotransmitters from various regions of the brain.

Hypertension is a serious national public health problem, but its causes are largely unknown.

- The causes of secondary hypertension fall into four categories: (1) cardiovascular hypertension; (2) renal hypertension; (3) endocrine hypertension; and (4) neurogenic hypertension.
- The underlying cause is known in primary hypertension.
- There is a strong genetic tendency to develop primary hypertension, which can be hastened or worsened by contributing factors such as obesity, stress, smoking, and excessive ingestion of salt.
- Whatever the underlying defect, once initiated, hypertension appears to be self-perpetuating.
- Constant exposure to elevated blood pressure predisposes vessel walls to the development of atherosclerosis, which further elevates blood pressure.
- The baroreceptors do not respond to bring the blood pressure back to normal during hypertension because they adapt or are "reset" to operate at a higher level.
- Complications of hypertension include congestive heart failure, strokes, or heart attacks.

Inadequate sympathetic activity is responsible for dizziness or fainting accompanying transient hypotension.

- Hypotension occurs either when there is a disproportion between vascular capacity and blood volume or when the heart is too weak to impart sufficient driving pressure to the blood.
• Two common situations in which hypotension occurs transiently are orthostatic hypotension and emotional fainting.
• Both are due to inadequate sympathetic activity.

Circulatory shock can become irreversible.
• When blood pressure falls so low that adequate blood flow to the tissues can no longer be maintained, the condition known as circulatory shock occurs.
• Circulatory shock is categorized into four main types: (1) hypovolemic shock; (2) cardiogenic shock; (3) vasogenic shock; and (4) neurogenic shock.
• Following severe loss of blood, the resultant reduction in circulating blood volume leads to a decrease in venous return and a subsequent fall in cardiac output and arterial pressure.
• The baroreceptor reflex to the fall in blood pressure brings about increased sympathetic and decreased parasympathetic activity to the heart.
• As a result of increased sympathetic activity to the veins, generalized venous vasoconstriction occurs.
• Sympathetic stimulation of the heart increases the heart’s contractility, as does increasing the stroke volume.
• Sympathetically induced generalized arteriolar vasoconstriction leads to an increase in total peripheral resistance.
• The increase in cardiac output and total peripheral resistance bring about a compensatory increase in arterial pressure.
• The original fall in arterial pressure results in fluid shifts from the interstitial fluid into the capillaries to expand the plasma volume.
• The ECF fluid shift is enhanced by plasma-protein synthesis by the liver following the hemorrhage.
• Urinary output is reduced, thereby conserving water.
• The reduced plasma volume also triggers increased secretion of the hormone vasopressin and activation of the salt-and-water-conserving renin-angiotensin-aldosterone hormonal pathway.
• Increased thirst is also stimulated by a fall in plasma volume.
• Lost red blood cells are replaced through increased red blood cell production triggered by a reduction in oxygen delivery to the kidneys.
• Compensatory mechanisms are often insufficient in the face of substantial fluid loss.
• Fluid volume must be replaced from the outside through drinking, transfusion, or a combination of both.
• A point may be reached at which blood pressure continues to drop rapidly because of tissue damage, despite vigorous therapy.
• This condition is termed irreversible shock, in contrast to reversible shock, which can be corrected by compensatory mechanisms and effective therapy.

Key Terms

Active hyperemia
Arteries
Arterioles
Baroreceptors
Baroreceptor reflex
Blood pressure
Bulk flow
Capacitance vessels
Capillary blood pressure
Carotid sinus
Circulatory shock
Compliance

Diastolic pressure
Distensibility
Endothelin
Endothelial-derived relaxing factor (EDRF)
Effective circulating volume
Essential or idiopathic hypertension
Flow rate
Hypertension
Hypotension
Interstitial fluid-colloid osmotic pressure
Interstitial fluid hydrostatic pressure
Lymph nodes
Lymphatic system
Mean arterial pressure
Metarteriole
Microcirculation
Myoardial toxic factor
Nitric oxide
Orthostatic (postural) hypotension
Plasma-colloid osmotic pressure
Poiseuille's law
Precapillary sphincters
Pressure gradient
Pulse pressure
Reabsorption
Resistance
Respiratory pump
Secondary hypertension
Sphygmomanometer
Systolic pressure
Vasodilation
Veins
Venous return
Venules
Viscosity
**True/False**

1. Blood flows more slowly in capillaries than elsewhere in the circulatory system.

2. Diffusion across capillary walls also depends on the wall's permeability to the materials being exchanged.

3. The size of the capillary pores are consistent throughout the body.

4. Capillaries have no smooth muscle, so they cannot actively participate in the regulation of their own blood flow.

5. Solute exchanges are made directly between blood and the tissue cells.

6. Bulk flow occurs because of differences in the hydrostatic and colloid osmotic pressures between the plasma and interstitial fluid.

7. The inability to return filtered protein is a cause of edema.

8. All blood pumped by the left side of the heart passes through the lungs for oxygen pickup and carbon dioxide removal.

9. Reconditioning organs can withstand temporary reductions in blood flow.

10. The greater the pressure gradient forcing blood through a vessel, the lesser the rate of flow through that vessel.

11. Capillary flow fluctuates between cardiac systole and diastole.

12. Systolic pressure averages 120 mm Hg and diastolic pressure averages 80 mm Hg.

13. To determine blood pressure, a stethoscope is placed over the brachial artery.

14. Arterial pressure is essentially the same throughout the arterial tree.
15. Orthostatic hypotension caused by emotional stress can also cause dizziness or fainting.

16. Anaphylactic shock, which may accompany massive infections, is due to vasodilator substances released from the infective agents.

17. Mean arterial blood pressure is the main driving force for propelling blood to the tissues.

18. Long-term adjustments are accomplished by alterations in cardiac output and total peripheral resistance, mediated by means of autonomic nervous system influences on the heart, veins, and arterioles.

19. The cardiovascular control center alters the ratio between sympathetic and parasympathetic activity to the effector organs.

20. The blood flow to the brain is increased during exercise.

21. Baroreceptors respond and help bring the blood pressure back to normal during hypertension.

22. Arterioles are the major resistance vessels in the vascular tree.

23. Local (intrinsic) controls are changes within a tissue that alter the radii of the vessels and hence adjust blood flow through the tissue by directly affecting the smooth muscle of the tissue's arterioles.

24. Local influences can only be chemical not physical in nature.


26. Histamine is a local chemical mediator that influences arteriolar smooth muscle.

27. Sympathetic nerve fibers supply arteriolar smooth muscle everywhere including the brain.

28. Extrinsic control of arteriolar radius includes both neural and hormonal influences.

29. Systemic veins also serve as a blood reservoir.

30. Venous vasoconstriction enhances venous return by increasing venous capacity.

31. Increased muscular activity pushes more blood out of the veins and into the heart.

32. Blood can be driven forward or backward through the veins.

33. Abnormal clot formation in the sluggish, pooled blood is a serious risk to a person with varicose veins.

34. The pressure within the chest cavity averages 11 mm Hg less than atmospheric pressure.
Fill in the Blank

35. ______________ is when the blood pressure is above 140/90 mm Hg.

36. ______________ in its extreme form is circulatory shock.

37. The causes of secondary hypertension are (1) ______________, (2) __________, (3) ______________, and (4) ______________ hypertension.

38. ______________ is a transient hypotensive condition resulting from insufficient compensatory responses to the gravitational shifts in blood that occur when a person moves from a horizontal to a vertical position.

39. __________ shock is due to a weakened heart's failure to pump blood adequately.

40. __________ shock is induced by a fall in blood volume, through hemorrhage or loss of fluids like diarrhea and sweating.

41. __________ shock is when a point is reached where the blood pressure continues to drop rapidly because of tissue damage, despite vigorous therapy.

42. Veins are often referred to as ________________.

43. ______________ refers to the volume of blood that the veins can accommodate.

44. ______________ refers to the volume of blood entering each atrium per minute from the veins.

45. ______________ occur when the venous valves become incompetent and can no longer support the column of blood above them.

46. Mean arterial pressure is constantly monitored by ______________ within the circulatory system.

47. ______________ and ______________ are mechanoreceptors sensitive to changes in both mean arterial pressure and pulse pressure.

48. __________ carry blood from the heart.

49. Arterioles, capillaries, and venules are collectively referred to as the ________________
50. ______________ of blood through a vessel is directly proportional to the pressure gradient and inversely proportional to vascular resistance.

51. The maximum pressure exerted in the arteries when blood is ejected into them during systole averages ______________.

52. The pressure difference between systolic and diastolic is known as the ______________.

53. ______________ is the average pressure responsible for driving blood forward into the tissues throughout the cardiac cycle.

54. When a small artery reaches the organ it is supplying, it branches into numerous ______________.

55. Exchange of materials across capillary walls is accomplished primarily by the process of ______________.

56. Capillaries typically branch either directly from an arteriole or from a thoroughfare channel known as a(n) ______________.

57. ______________ is a volume of protein-free plasma that actually filters out of the capillary, mixes with the surrounding interstitial fluid, and is subsequently reabsorbed.

58. ______________ is the fluid or hydrostatic pressure exerted on the inside of the capillary walls by the blood.

59. The extra fluid filtered out as a result of this ultrafiltration reabsorption imbalance is picked up by the ______________.

60. Swelling of the tissues because of excess interstitial fluid is known as ______________.

61. ______________ is the term applied to such narrowing of a vessel.

62. Arteriolar smooth muscle normally displays a state of partial constriction known as ______________.

63. ______________ causes local arteriolar vasodilation by inducing relaxation of arteriolar smooth muscle in the vicinity.

64. ______________ is a single layer of specialized epithelial cells that line the lumen of all blood vessels.
The main region of the brain responsible for adjusting sympathetic output to the arterioles is the

Matching
Match the cardiovascular variable to the change as a result of exercise.

a. increases
b. decreases
c. unchanged

66. Blood flow to skin
67. Cardiac output
68. Venous return
69. Blood flow to digestive track
70. Blood flow to brain
71. Stroke volume
72. Blood flow to bone
73. Blood flow to heart
74. Blood flow to kidney
75. Heart rate
76. Median arterial blood pressure
77. Blood flow to active skeletal muscles
78. Total peripheral resistance
79. Stored blood

Multiple Choice

80. Which of the following is caused by atherosclerosis?
   a. neurogenic hypertension
   b. endocrine hypertension
   c. cardiovascular hypertension
   d. pheochromocytoma
   e. hypotension

81. Which disorder is associated with an increased production of aldosterone by the adrenal cortex?
   a. neurogenic hypertension
   b. pheochromocytoma
   c. cardiovascular hypertension
   d. Conn's syndrome
   e. primary hypertension

82. Which disorder may be characterized by a defect in the baroreceptors?
   a. neurogenic hypertension
   b. cardiovascular hypertension
   c. Conn's syndrome
   d. hypotension
   e. none of the above
83. Which of the following does not hasten the development of primary hypertension?
   a. obesity
   b. smoking
   c. stress
   d. excessive ingestion of salt
   e. none of the above

84. Which of the following is characterized by excessive secretions of epinephrine and norepinephrine?
   a. varicose veins
   b. renal hypertension
   c. pheochromocytoma
   d. Conn's syndrome
   e. cardiovascular syndrome

85. Which disorder is brought about by massive hemorrhage?
   a. varicose veins
   b. hypovolemic shock
   c. vasogenic shock
   d. Conn's syndrome
   e. endocrine hypertension

86. Which of the following is due to a weakened heart's failure to pump blood adequately?
   a. hypovolemic shock
   b. pheochromocytoma
   c. cardiogenic shock
   d. Conn's syndrome
   e. vasogenic shock

87. Which condition is characterized by an inability to eliminate the normal salt load?
   a. Conn's syndrome
   b. hypovolemic shock
   c. cardiovascular hypertension
   d. neurogenic hypertension
   e. renal hypertension

88. Which disorder is caused by a loss of sympathetic vascular tone?
   a. cardiogenic shock
   b. neurogenic shock
   c. hypovolemic shock
   d. vasogenic shock
   e. none of the above

89. Which of the following disorders has an unknown cause?
   a. renal hypertension
   b. neurogenic shock
   c. Conn's syndrome
   d. pheochromocytoma
   e. primary hypertension
Modified Multiple Choice

Indicate which of the vessels performs the function listed by writing the appropriate letter in the blank using the answer code below.

A = arteries
B = arterioles
C = capillaries
D = veins
E = lymphatics

90. _____ Site of exchange of nutrients and waste products between the blood and tissues.
91. _____ Serve as low resistance passageways from the heart to the tissues.
92. _____ Serve as blood reservoir to accommodate variations in blood volume.
93. _____ Major resistance vessels.
94. _____ Portion of the circulatory system through which the velocity of blood flow is the slowest.
95. _____ Serve as low-resistance passageways from the tissues to the heart.
96. _____ Act as a pressure reservoir to drive blood forward through the vasculature during diastole.
97. _____ Changes in the radius of this vessel type regulate the distribution of the cardiac output to various areas of the body.
98. _____ Vessels that pick up fluid that is filtered but not reabsorbed.

If the blood pressure is recorded as 118/76, indicate the correct value of the pressure in question by writing the appropriate letter in the blank using the answer code below.

A = 118 mm Hg
B = 42 mm Hg
C = 97 mm Hg
D = 76 mm Hg
E = 90 mm Hg

99. _____ What is the systolic pressure?
100. _____ What is the diastolic pressure?
101. _____ What is the pulse pressure?
102. _____ What is the mean pressure?

The calculations below are based on the following pressures:

Blood capillary pressure at arteriolar end of tissue capillaries = 35 mm Hg.
Blood capillary pressure at venule end of tissue capillaries = 15 mm Hg.
Blood-colloid osmotic pressure = 20 mm Hg.
Interstitial-fluid hydrostatic pressure = 1 mm Hg.
Interstitial-fluid colloid osmotic pressure = 0 mm Hg.

102. What would the ultrafiltration pressure be?
   a. 14 mm Hg
   b. 16 mm Hg
   c. 9 mm Hg
   d. 10 mm Hg
   e. 35 mm Hg
103. What would the reabsorption pressure be?
   a. 21 mm Hg
   b. 15 mm Hg
   c. 6 mm Hg
   d. 14 mm Hg
   e. 20 mm Hg

104. Would edema occur in this situation?
   a. yes
   b. no

Indicate the relative comparison of each of the paired items by writing the appropriate letter in the blank using the answer code below.

A = A is greater than B
B = B is greater than A
C = A and B are equal

105. _____ A. Blood flow through an arteriole upon increased sympathetic activity.
     B. Blood flow through an arteriole upon decreased sympathetic activity.

106. _____ A. Blood flow through a vein upon increased sympathetic activity.
     B. Blood flow through a vein upon decreased sympathetic activity.

107. _____ A. Velocity of blood flow through the veins.
     B. Velocity of blood flow through the capillaries.

108. _____ A. Local arteriole radius in the presence of local decreased oxygen concentration and increased carbon dioxide concentration.
     B. Local arteriole radius with normal local concentration of both oxygen and carbon dioxide.

109. _____ A. Circulation through the skin during exercise.
     B. Circulation through the skin at rest.

110. _____ A. Circulation to the brain at rest.
     B. Circulation to the brain during an examination.

111. _____ A. Net ultrafiltration pressure at the arteriolar end of the capillary.
     B. Net reabsorption pressure at the venous end of the capillary.

**Points to Ponder**

1. Having learned about active hyperemia can you think of an example of passive hyperemia?

2. How do the palace guards in London avoid fainting?
3. Why is the cardiovascular center in the medulla as opposed to some cortical, hypothalamic or thalamic area?

4. Since there is blood in the blood vessels, why do they need an addition external blood supply?

5. With respect to blood vessels, what causes dark circles under your eyes?

6. Based on your knowledge of capillaries, why do your cheeks turn red on a very cold day?

7. What changes occur in the circulatory system during exercise?

8. How does lifting weights cause a fall in cardiac output and blood pressure?

9. One of the consequences of the Frank-Starling law is that the outputs of the right and left ventricles are matched. Why is this important and how is this matching accomplished?

10. Why is hypotension a result of hypovolemia?

**Clinical Perspectives**

1. How does hypertension affect the risk of coronary heart disease?

2. How would explain to your friend the fact that blood pressure is higher at one time of the day than during other times?

3. Since you are taking a physiology course, how would you explain to your friend the cause of elephantiasis and how it is related to edema?

4. During prolonged exercise on a very hot day, a substantial amount of water will be lost from the body through sweating. This causes hyperthermia. Why can’t the body be immediately rehydrated by drinking pure water?

5. How would you explain to your friend how the class of drugs known as ACE inhibitors work?

6. Cocaine inhibits the re-uptake of norepinephrine in the adrenergic axons. Based on this fact, why is myocardial ischemia a common side affect of cocaine abuse?

7. How does nitric oxide contribute to hypertension?

8. How would you explain to your friend why he becomes dizzy when he stands up too fast?

9. Preeclampsia is a toxemia of late pregnancy characterized by high blood pressure, proteinuria, and edema. Based on your knowledge of blood vessels and blood pressure, why does preeclampsia occur?

10. People with congestive heart failure are often treated with the drug digitalis. Digitalis works by inhibiting the sodium-potassium pump and causing the intracellular concentration of calcium to increase. What affect is this drug going to have on the heart and blood pressure?
Experiments of the Day

1. On a classmate's arm try to locate the venous valves?

2. The next time you go to the grocery store or your local pharmacy, if there is a blood pressure machine there, take your blood pressure.
Chapter 10: The Blood Vessels and Blood Pressure

**True/False**

1. True  
2. True  
3. False—Vary from organ to organ.  
4. True  
5. False—Exchanges are not made directly.  
6. True  
7. False—Is a function of the lymphatic system.  
8. False—Right.  
9. True  
10. False—The greater the rate of flow.  
12. True  
13. True  
14. True  
15. False—Transient hypotension.  
17. True  
18. False—Short term.  
19. True  
20. False—Unchanged.  
21. False—Does not respond and adapts or "reset" to operate at a higher level.  
22. True  
23. True  
24. False—Can either be chemical or physical.  
25. True  
26. True  
27. False—Except the brain.  
28. True  
29. True  
30. False—Decreasing.  
31. True  
32. False—Can only be driven forward.  
33. True  
34. False—5 mm Hg.

**Matching**

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<th>66. a</th>
<th>67. a</th>
<th>68. a</th>
<th>69. d</th>
<th>70. c</th>
<th>71. a</th>
<th>72. b</th>
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**Multiple Choice**

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**Modified Multiple Choice**

| 80. c | 81. d | 82. a | 83. e | 84. c | 85. b | 86. c | 87. e | 88. b | 89. e | 90. c | 91. a | 92. d | 93. b | 94. c | 95. d | 96. a | 97. b | 98. e | 99. a | 100. d | 101. b | 102. e | 103. a | 104. c | 105. b | 106. a | 107. a | 108. a | 109. a | 110. c | 111. a |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
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**Fill in the Blank**

35. Hypertension  
36. Hypotension  
37. Cardiovascular, renal, endocrine, neurogenic  
38. Orthostatic hypertension  
39. Cardiogenic  
40. Hypovolemic  
41. Irreversible shock  
42. Capacitance vessels  
43. Venous capacity  
44. Venous return  
45. Varicose veins  
46. Baroreceptors  
47. Carotid-sinus, aortic-arch baroreceptors  
48. Arteries  
49. Microcirculation