The Cardiovascular System: Blood Vessels Outline

PART 1: BLOOD VESSEL STRUCTURE AND FUNCTION

A. The three major types of blood vessels are arteries, capillaries, and veins. (p. 699; Fig. 19.1)
   1. Arteries carry blood away from the heart; veins carry blood toward the heart.
   2. In the systemic circulation, arteries carry oxygenated blood, while veins carry oxygen-poor blood; this is opposite in the pulmonary circulation.
   3. Only capillaries directly exchange with tissues to meet cellular demands.

19.1 Most blood vessel walls have three layers (p. 701; Fig. 19.2; Table 19.1)

A. The walls of all blood vessels except the smallest consist of three layers: the tunica intima (endothelium), tunica media (smooth muscle and elastin), and tunica externa (loosely woven collagen fibers). (p. 701; Fig. 19.2; Table 19.1)
   1. The tunica intima reduces friction between the vessel walls and blood; the tunica media controls vasoconstriction and vasodilation of the vessel; and the tunica externa protects, reinforces, and anchors the vessel to surrounding structures.

19.2 Arteries are pressure reservoirs, distributing vessels, or resistance vessels (p. 702)

A. Elastic, or conducting, arteries contain large amounts of elastin, which enables these vessels to withstand and smooth out pressure fluctuations due to heart action. (p. 702; Fig. 19.1; Table 19.1)

B. Muscular, or distributing, arteries deliver blood to specific body organs and have the greatest proportion of tunica media of all vessels, making them more active in vasoconstriction. (p. 702; Table 19.1)

C. Arterioles are the smallest arteries and regulate blood flow into capillary beds through vasoconstriction and vasodilation. (p. 702)

19.3 Capillaries are exchange vessels (pp. 702–704; Figs. 19.3–19.4)

A. Capillaries are the smallest vessels and allow for exchange of substances between the blood and interstitial fluid. (pp. 702–703; Fig. 19.3; Table 19.1)
   1. Continuous capillaries are most common and allow passage of fluids and small solutes.
   2. Fenestrated capillaries are more permeable to fluids and solutes than continuous capillaries.
   3. Sinusoid capillaries are leaky capillaries that allow large molecules to pass between the blood and surrounding tissues.

B. Capillary beds are microcirculatory networks consisting of a vascular shunt and true capillaries, which function as the exchange vessels. (pp. 703–704; Fig. 19.4)

C. A cuff of smooth muscle, called a precapillary sphincter, surrounds each capillary at the metarteriole and acts as a valve to regulate blood flow into the capillary. (p. 704; Fig. 19.4)

19.4 Veins are blood reservoirs that return blood toward the heart (p. 704; Fig. 19.5)

A. Venules are formed where capillaries converge and allow fluid and white blood cells to move easily between the blood and tissues. (p. 704; Table 19.1)

B. Venules join to form veins, which are relatively thin-walled vessels with large lumens that act as blood reservoirs, containing about 65% of the total blood volume. (pp. 704–705; Fig. 19.5; Table 19.1)

19.5 Anastomoses are special interconnections between blood vessels (pp. 705–706)

A. Vascular anastomoses form where vascular channels unite, allowing blood to be supplied to and drained from an area even if one channel is blocked. (p. 705)

PART 2: PHYSIOLOGY OF CIRCULATION

19.6 Blood flows from high to low pressure against resistance (pp. 707–708)

A. Blood flow is the volume of blood flowing through a vessel, organ, or the entire circulation in a given period and may be expressed as ml/min. (p. 707)

B. Blood pressure is the force per unit area exerted by the blood against a vessel wall and is expressed in millimeters of mercury (mm Hg). (p. 708)

C. Resistance is a measure of the friction between blood and the vessel wall and arises from three sources: blood viscosity, blood vessel length, and blood vessel diameter. (p. 708)

D. Relationship Between Flow, Pressure, and Resistance (p. 708)

1. If blood pressure increases, blood flow increases; if peripheral resistance increases, blood flow decreases.
2. Peripheral resistance is the most important factor influencing local blood flow: Vasoconstriction or vasodilation can dramatically alter local blood flow, while systemic blood pressure remains unchanged.

19.7 Blood pressure decreases as blood flows from arteries through capillaries and into veins (pp. 708–711; Figs. 19.6–19.8)

A. The pumping action of the heart generates blood flow, and blood pressure results when blood flow is opposed by resistance. (p. 709)

1. Systemic blood pressure is highest in the aorta and declines throughout the pathway until it reaches 0 mm Hg in the right atrium.

B. Arterial blood pressure reflects how much the arteries close to the heart can be stretched (compliance, or distensibility) and the volume forced into them at a given time. (pp. 709–710; Figs. 19.6–19.7)

1. When the left ventricle contracts, blood is forced into the aorta, producing a peak in pressure, called systolic pressure, which averages 120 mm Hg in a healthy adult.
2. Diastolic pressure occurs when the ventricles enter diastole, the aortic valve closes, and the walls of the aorta recoil, which maintains pressure at 70–80 mmHg, so that blood continues to flow forward into the smaller vessels.
3. The difference between diastolic and systolic pressure is called the pulse pressure.
4. The mean arterial pressure (MAP) represents the pressure that propels blood to the tissues, and is calculated as diastolic pressure + 1/3 pulse pressure.

C. Capillary blood pressure is low, ranging from 15–40 mm Hg, which protects the capillaries from rupture but is still adequate to ensure exchange between blood and tissues. (p. 710; Fig. 19.6)

D. Venous blood pressure is low, not pulsatile, and changes very little during the cardiac cycle, reflecting cumulative effects of peripheral resistance. (pp. 710–711; Fig. 19.8)

   1. Three functional adaptations are critical to venous return: compression of veins by muscle contraction, changes in abdominal and thoracic pressure during ventilation, and sympathetic venoconstriction.

19.8 Blood pressure is regulated by short- and long-term controls (pp. 711–718; Figs. 19.9–19.12; Table 19.2)

A. Maintaining blood pressure involves three key variables: cardiac output, peripheral resistance, and blood volume. (pp. 711–712)

B. Short-term neural controls of peripheral resistance alter blood distribution to meet specific tissue demands and maintain adequate MAP by altering blood vessel diameter. (pp. 712–713; Fig. 19.10)

   1. Clusters of neurons in the medulla oblongata, the cardioacceleratory, cardioinhibitory, and vasomotor centers, form the cardiovascular center that regulates blood pressure by altering cardiac output and blood vessel diameter.
   2. Baroreceptors located in the carotid sinus and aortic arch detect stretch and send impulses to the vasomotor center, inhibiting its activity and promoting vasodilation of arterioles and veins.
   3. Chemoreceptors detect a rise in carbon dioxide levels of the blood and stimulate the cardioacceleratory and vasomotor centers, which increases cardiac output and vasoconstriction.
   4. The cortex and hypothalamus can modify arterial pressure by signaling the medullary centers.

C. Hormonal controls influence blood pressure by acting on vascular smooth muscle or the vasomotor center. (p. 714; Table 19.2)

   1. Norepinephrine and epinephrine promote an increase in cardiac output and generalized vasoconstriction.
   2. Angiotensin II acts as a vasoconstrictor, as well as promoting the release of aldoste-rone and antidiuretic hormone.
   3. Atrial natriuretic peptide acts as a vasodilator and an antagonist to aldosterone, resulting in a drop in blood volume.
   4. Antidiuretic hormone promotes vasoconstriction and water conservation by the kidneys, resulting in an increase in blood volume.

D. Long-Term Regulation: Renal Mechanisms (pp. 714–716; Figs. 19.11–19.12)

   1. The direct renal mechanism counteracts changes in blood pressure by altering blood volume, through adjustments in the rate of kidney filtration, resulting in an increased or decreased loss of fluids and solutes in the urine.
   2. The indirect renal mechanism is the renin-angiotensin-aldosterone mechanism, which counteracts a decline in arterial blood pressure by causing release of aldosterone and ADH, triggering thirst, and promoting systemic vasoconstriction.

E. Summary of Blood Pressure Regulation (p. 716; Fig. 19.12)

1. The goal of pressure regulation is to keep blood pressure high enough to provide adequate tissue perfusion, but not so high that vessels are damaged.

F. Alterations in blood pressure may result in hypotension (low blood pressure) or transient or persistent hypertension (high blood pressure). (pp. 716–717)
   1. Hypertension is characterized by a sustained increase in either systolic or diastolic pressure: Primary hypertension accounts for 90% of cases, and has no identifiable cause, while secondary hypertension, 10% of cases, has a root cause such as artery obstruction, kidney disease, or other causes.
   2. Hypotension is often due to individual variation, but is only a concern if blood flow to tissues becomes inadequate.

G. Circulatory shock is any condition in which blood volume is inadequate and cannot circulate normally, resulting in blood flow that cannot meet the needs of a tissue. (p. 717; Fig. 19.18)
   1. Hypovolemic shock results from a large-scale loss of blood, and may be characterized by an elevated heart rate and intense vasoconstriction.
   2. Vascular shock is characterized by a normal blood volume accompanied by extreme vasodilation, resulting in poor circulation and a rapid drop in blood pressure.
   3. Transient vascular shock is due to prolonged exposure to heat, such as while sunbathing, resulting in vasodilation of cutaneous blood vessels.
   4. Cardiogenic shock occurs when the heart is too inefficient to sustain normal blood flow and is usually related to myocardial damage, such as repeated myocardial infarcts.

19.9 Intrinsic and extrinsic controls determine blood flow through tissues (pp. 718–722; Figs. 19.13–19.15)

A. Tissue perfusion is involved in delivery of oxygen and nutrients to, and removal of wastes from, tissue cells; gas exchange in the lungs; absorption of nutrients from the digestive tract; and urine formation in the kidneys. (p. 718; Fig. 19.13)

B. Autoregulation: Local Regulation of Blood Flow (p. 718–720; Figs. 19.14–19.15)
   1. Autoregulation is the automatic adjustment of blood flow to each tissue in proportion to its needs and is controlled intrinsically by modifying the diameter of local arterioles.
   2. Metabolic controls of autoregulation are most strongly stimulated by a shortage of oxygen at the tissues.
   3. Myogenic control involves the localized response of vascular smooth muscle to passive stretch.
   4. Long-term autoregulation develops over weeks or months and involves an increase in the size of existing blood vessels and an increase in the number of vessels in a specific area, a process called angiogenesis.

C. Blood Flow in Special Areas (pp. 720–722)
   1. Blood flow to skeletal muscles varies with level of activity and fiber type.
   2. Muscular autoregulation occurs almost entirely in response to decreased oxygen concentrations.

3. Cerebral blood flow is tightly regulated to meet neuronal needs, because neurons cannot tolerate periods of ischemia, and increased blood carbon dioxide causes marked vasodilation.
4. In the skin, local autoregulatory events control oxygen and nutrient delivery to the cells, while neural mechanisms control the body temperature regulation function.
5. Autoregulatory controls of blood flow to the lungs are the opposite of what happens in most tissues: low pulmonary oxygen causes vasoconstriction, while higher oxygen causes vasodilation.
6. Movement of blood through the coronary circulation of the heart is influenced by aortic pressure and the pumping of the ventricles.

19.10 Slow blood flow through capillaries promotes diffusion of nutrients and gases, and bulk flow of fluids (pp. 722–726; Figs. 19.16–19.18; Focus Figure 9.1)

A. Velocity or speed of blood flow changes as it passes through the systemic circulation; it is fastest in the aorta and declines in velocity as vessel diameter decreases. (p. 722; Fig. 19.16)
B. Vasomotion, the slow, intermittent flow of blood through the capillaries, reflects the action of the precapillary sphincters in response to local autoregulatory controls. (p. 722)
C. Capillary exchange of nutrients, gases, and metabolic wastes occurs between the blood and interstitial space through diffusion. (pp. 722–723; Fig. 19.17)
D. Fluid Movements: Bulk Flow (pp. 723–726; Fig. 19.18; Focus Figure 19.1)
   1. Hydrostatic pressure (HP) is the force of a fluid against a membrane.
   2. Colloid osmotic pressure (OP), the force opposing hydrostatic pressure, is created by the presence of large, nondiffusible molecules that are prevented from moving through the capillary membrane.
   3. Fluids will leave the capillaries if net HP exceeds net OP, but fluids will enter the capillaries if net OP exceeds net HP.

PART 3: CIRCULATORY PATHWAYS: BLOOD VESSELS OF THE BODY

A. Two distinct pathways travel to and from the heart: pulmonary circulation runs from the heart to the lungs and back to the heart; systemic circulation runs to all parts of the body before returning to the heart. (p. 726)
B. There are three important differences between arteries and veins. (p. 727)
   1. Arteries run deep and are well protected, but veins are both deep, which run parallel to the arteries, and superficial, which run just beneath the skin.
   2. Arterial pathways tend to be clear, but there are often many interconnections in
      venous pathways, making them difficult to follow.
   3. There are at least two areas where venous drainage does not parallel the arterial supply: the dural sinuses draining the brain, and the hepatic portal system draining from the digestive organs to the liver before entering the main systemic circulation.

19.11 The vessels of the systemic circulation transport blood to all body tissues (pp. 727–751; Figs. 19.19–19.30; Tables 19.3–19.13)

In the following sections (XII. A.–K.), vessels have been arranged in tables in order to facilitate presentation by the instructor. More commonly taught vessels are presented, as well as the branching pattern of these vessels, indicated as "levels." Also, general areas served by the listed vessels are presented.

A. Pulmonary and Systemic Circulations: The pulmonary circulation functions only to bring blood into close contact with the alveoli of the lungs for gas exchange and then circulates it back to the heart to be pumped out to the rest of the body. (pp. 728–729; Figs. 19.19–19.20; Table 19.3)

Pulmonary Circulation

Start	Level 1	Level 2	Level 3	Level 4	Level 5	End
R. ventricle of heart	Main vessel out of R. ventricle →	Vessels arising from Level 1 →	Vessels arising from Level 2 →	Vessels arising from Level 3 →	Vessels arising from Level 4 →	L. atrium of heart
	Pulmonary trunk	R. and L. pulmonary arteries	Lobar arteries	Pulmonary capillaries	Pulmonary veins	

Systemic Circulation

Start	Level 1	Level 2	Level 3	Level 4	Level 5	End
L. ventricle of heart	Main vessel out of L. ventricle →	Vessels arising from Level 1 →	Vessels arising from Level 2 →	Vessels arising from Level 3 →	Vessels arising from Level 4 →	R. atrium of heart
	Aorta	Aortic Arch	Common Carotid	Capillary beds of head and upper limb	Superior Vena Cava	
			Subclavian			
		Thoracic Aorta	Capillary beds of mediastinum and thorax wall	Venous drainage/ Azygos system		
		Abdominal Aorta	Capillary beds of digestive viscera, spleen, pancreas, kidneys	Venous drainage	Inferior Vena Cava	

			Capillary beds of gonads, pelvis, and lower limbs			

B. The Aorta and Major Arteries of the Systemic Circulation: The aorta is the largest artery in the body and has discretely named regions that extend from the heart to the lower abdominal cavity. (pp. 730–731; Fig. 19.21; Table 19.

The Aorta and Major Arteries of the Systemic Circulation				
Level 1 Main Vessel	Divisions of Aorta	Level 2	Level 3	Area Served by Vessel
Aorta	Ascending aorta	R. and L. coronary arteries		Myocardium of heart
	Aortic arch	Brachio-cephalic artery	L. common carotid	L. side of head and neck
			L. subclavian artery	L. upper limb
		R. common carotid		R. side of head and neck
		R. subclavian artery		R. upper limb
	Thoracic aorta			Thorax wall and viscera
	Abdominal aorta	R. and L. common iliac arteries		R. and L. lower limb, pelvic cavity

C. Arteries of the Head and Neck: The common carotid arteries supply blood to the head and neck. (pp. 732–733; Fig. 19.22; Table 19.5)

Arteries of the Head and Neck					
Level 1 Main Vessel	Level 2	Level 3	Level 4	Level 5	Area Served by Vessel
Common carotid arteries (R. and L.)	External carotid arteries	Superficial temporal arteries			Parotid gland and scalp
		Facial arteries			Skin and muscles of face

	Internal carotid arteries	Anterior cerebral arteries			Frontal and parietal lobes of brain
		Middle cerebral arteries			Temporal, parietal, and frontal lobes of the brain
Subclavian arteries (R. and L.)	Vertebral arteries	Basilar artery	Posteri- or cere- bral arteries		Occipital and temporal lobes of the brain
				Anterior communicating artery	Arterial anastomosis connecting R. and L. anterior cerebral arter- ies (Circle of Willis)
				Posterior communicating arteries	Arterial anas- tomoses con- necting posterior cere- bral arteries to mid- dle cerebral arteries. (Circle of Willis)

D. Arteries of the Upper Limbs and Thorax: The subclavian arteries supply blood to the upper limbs. (pp. 734–735; Fig. 19.23; Table 19.6)

Arteries of the Upper Limbs and Thorax						
Level 1 Main Vessel	Level 2	Level 3	Level 4	Level 5	Level 6	Area Served by Vessel
Subclavian ar- teries (R. and L.)	Axillary arteries	Brachial arteries	Radial arteries	Deep palmar arches	Metacarpal arteries	Arm, forearm, hand, fin- gers
			Ulnar arteries	Superfi- cial pal- mar arches	Digital arteries	

E. Arteries of the Abdomen: The arteries supplying the abdomen arise from the abdominal aorta. (pp. 736–739; Fig. 19.24; Table 19.7)

Arteries of the Abdomen					
Level 1 Main Vessel	Level 2	Level 3	Level 4	Level 5	Area Served by Vessel
Abdominal aorta	Celiac trunk	Common hepatic artery	Hepatic artery		Liver
			Splenic artery	Left gastric artery	Stomach, spleen, pancreas
			R. gastric artery		Stomach
	Superior mesenteric artery				Small intestine, most of large intestine
	Suprarenal arteries				Adrenal glands
	Renal arteries				Kidneys
	Gonadal arteries				Ovaries/ testes
	Inferior mesenteric artery				Distal large intestine
	Common iliac Arteries				Lower limbs, pelvic cavity

F. Arteries of the Pelvis and Lower Limbs: The arterial blood supply to the pelvis and lower limbs is provided by the common iliac arteries, which branch from the distal end of the abdominal aorta. (pp. 740–741; Fig. 19.25; Table 19.8)

Arteries of the Pelvis and Lower Limbs						
Level 1 Main Vessel	Level 2	Level 3	Level 4	Level 5	Level 6	Area Served by Vessel
Common iliac arteries (R. and L.)	Internal iliac arteries					Pelvic wall, viscera, gluteal muscles
	External iliac arteries	Femoral arteries	Popliteal arteries	Anterior tibial arteries	Dorsalis pedis arteries	Ankle and foot

				Posterior tibial arteries	Fibular (peroneal) arteries	Lateral leg muscles

G. The Vena Cavae and the Major Veins of the Systemic Circulation: The vena cavae are the major veins that drain blood from the body back toward the heart. (pp. 742–743; Fig. 19.26; Table 19.9)

The Vena Cavae and the Major Veins of the Systemic Circulation

Area Drained by Vessel	Level 3	Level 2	Level 1 Main Vessel
Head and neck	Internal jugular veins	R. and L. brachiocephalic veins	Superior vena cava
Upper limbs	Subclavian veins		
Lower limbs		Common iliac veins	Inferior vena cava

H. Veins of the Head and Neck: Most of the blood drained from the head and neck is collected by three pairs of veins—the external jugular veins, the internal jugular veins, and the vertebral veins. (pp. 744–745; Fig. 19.27; Table 19.10)

Veins of the Head and Neck

Area Drained by Vessel	Level 6	Level 5	Level 4	Level 3	Level 2	Level 1 Main Vessel
Brain	Superior sagittal sinus	Straight sinus	Transverse sinuses	Sigmoid sinus	Internal jugular veins	Brachiocephalic veins
	Inferior sagittal sinus					
Deep face and neck				Superficial temporal veins		
				Facial veins		
Superficial face and neck				External jugular veins	Subclavian veins	
					Vertebral veins	

I. Veins of the Upper Limbs and Thorax: The deep veins of the upper limbs follow the same paths as the arteries of the same name; the superficial veins are larger than the deep veins and easily seen beneath the skin. (pp. 746–747; Fig. 19.28; Table 19.11)

Veins of the Upper Limbs and Thorax							
Area Drained by Vessel	Level 7	Level 6	Level 5	Level 4	Level 3	Level 2	Level 1 Main Vessel
Superficial forearm		Median cubital vein	Cephalic veins	Axillary veins	Subclavian veins	Brachiocephalic veins	Superior vena cava
			Basilic veins				
Deep upper limb	Deep and superficial palmar arches	Radial veins	Brachial veins				
		Ulnar veins					
Thoracic cavity and chest wall					R. intercostal veins	Azygos vein	
				L. intercostal veins	Hemiazygos vein		

J. Veins of the Abdomen: The inferior vena cava returns blood from the abdominopelvic viscera and abdominal walls to the heart. (pp. 748–748; Fig. 19.29; Table 19.12)

Systemic Circulation: Veins of the Abdomen						
Area Drained by Vessel	Level 6	Level 5	Level 4	Level 3	Level 2	Level 1 Main Vessel
Small intestine, first half of large intestine			Superior mesenteric vein	Hepatic portal vein	Hepatic veins	Inferior vena cava
Spleen, stomach, pancreas		Splenic vein				
Lower half of large intestine	Inferior mesenteric vein					
Adrenal glands					Suprarenal veins	
Kidneys					Renal veins	

Ovaries, testes		L. gonadal vein		
			R. gonadal vein	

K. Veins of the Pelvis and Lower Limbs: Most veins of the lower limbs have the same name as the arteries they accompany. (p. 750; Fig. 19.30; Table 19.13)

Systemic Circulation: Veins of the Pelvis and Lower Limbs							
Area Drained by Vessel	Level 7	Level 6	Level 5	Level 4	Level 3	Level 2	Level 1 Main Vessel
Pelvic cavity organs and wall						Internal iliac veins	Common iliac veins
			Posterior tibial veins	Popliteal veins	Femoral veins	External iliac veins	
	Dorsalis pedis veins	Anterior tibial veins					
		Fibular veins					
						Great saphenous veins	

Developmental Aspects of Blood Vessels (p. 751)

A. The vascular endothelium is formed by mesodermal cells that collect throughout the embryo in blood islands, which give rise to extensions that form rudimentary vascular tubes.
B. By the fourth week of development, the rudimentary heart and vessels are circulating blood.
C. Fetal vascular modifications include shunts to bypass fetal lungs (the foramen ovale and ductus arteriosus), the ductus venosus that bypasses the liver, and the umbilical arteries and veins, which carry blood to and from the placenta.
D. At birth, the fetal shunts and bypasses close and become occluded.
E. Congenital vascular problems are rare, but the incidence of vascular disease increases with age, leading to varicose veins, tingling in fingers and toes, and muscle cramping.
F. Atherosclerosis begins in youth, but rarely causes problems until old age.

G. Blood pressure changes with age: the arterial pressure of infants is about 90/55, but rises steadily during childhood to an average of 120/80, and finally increases to 150/90 in old age.