

CHAPTER 21

CARDIOVASCULAR SYSTEM: Peripheral Circulation and Regulation

CHAPTER OVERVIEW: This chapter describes the structure and function of arteries, veins and capillaries. The path of blood circulation through the body is traced and the physical properties governing blood flow are outlined. The generation and control of blood pressure is explained. The effects of exercise and shock are described.

OUTLINE (four or five fifty-minute lectures):
Seeley, A&P, 5/e

t. Topic Outline, Chapter 21	Figures & Tables	Transparen Acetates
I. General Features of Blood Vessel Structure, p. 647		
1. Vessels Branch, but System is Continuous		
2. Blood Flows		
a. From Heart to Capillaries in Arteries and Arterioles		
b. To Heart from Capillaries in Venules and Veins		
A. Capillaries	Fig. 21.1, p.647	TA-402
1. Structure		
a. Endothelium		
1). Single Sheet of Cells w/ Basement Membrane		
2). Scattered Pericapillary Cells Inside of Basement Membrane		
b. Adventitia		
1). Connective Tissue		
2). Outside of Basement Membrane		
c. Size 7-9 μ m Diameter		
2. Types of Capillaries		
a. Continuous Capillaries; Most Common Type		
b. Fenestrated Capillaries - Glomerular Capillaries in Kidney		
c. Sinusoidal Capillaries		
1). Sinusoids of Liver and Bone Marrow		
2). Venous Sinuses of Spleen		
d. Substances are Transported Across Endothelial Cell Membranes		
e. Substances Pass Through Fenestrae - 70-100 nm Diameter Holes		
f. Between Adjacent Capillary Cells		
3. Capillary Network	Fig. 21.2, p.648	TA-403
a. Metarterioles & Thoroughfare Channels		
b. Smooth Muscle Cells and Precapillary Sphincters		
B. Structure of Arteries and Veins		
1. General Features - Layers of the Wall	Fig. 21.3, p. 649	TA-403
a. Tunica Intima		
1). Endothelium		
2). Lamina Propria		
3). Internal Elastic Membrane		
b. Tunica Media		

1). Smooth Muscle		
a). Contraction = Vasoconstriction		
b). Relaxation = Vasodilation		
2). External Elastic Membrane		
c. Tunica Adventitia - Connective Tissue		
2. Large Elastic (Conducting) Arteries	Fig. 21.4a, p.650	TA-405
3. Muscular (Distributing) Arteries	Fig. 21.4b, p.650	
1). Smaller - Diameter 40-300 μ m		
2). Involved in Vasodilation & Vasoconstriction		
4. Arterioles		
5. Venules (40-50 μ m Diameter) and Small Veins (0.2 - 0.3 mm Diameter)		
a. Small Veins - 0.2 - 0.3 mm Diameter		
6. Medium-Sized and Large Veins	Fig. 21.4c, p.650	TA-405
7. Valves (in Veins of Diameter Greater than 2 mm.)	Fig. 21.4d, p.650	TA-262
	Clinical Note, p.651	
8. Vasa Vasorum of Tunica Adventitia and Tunica Media	Fig. 21.3, p.649	TA-403
9. Arteriovenous Anastomoses - Allow Direct Arterial to Venous Flow w/out Intervening Capillary		
a. Physiological Role in Temperature Regulation		
b. Pathological Condition Resulting from Some Tumors or Injuries		
C. Nerves	Fig. 21.3, p.649	TA-403
1. Unmyelinated Sympathetic Fibers to Tunica Media of Most		
2. A Few Also Receive Parasympathetic Fibers		
3. Response to Sympathetic Stimulation is Generally Vasoconstriction		
D. Aging of the Arteries		
1. Arteriosclerosis - Loss of Elasticity		
2. Atherosclerosis - Fatty Plaque Build-up	Fig. 21.5, p.652	TA-406
II. Pulmonary Circulation, p. 652	Fig. 21.6, p.653	TA-407
A. Single Pulmonary Trunk from R. Ventricle		
B. Branches into Two Pulmonary Arteries		
1. One to Each Lung		
2. Carry Deoxygenated Blood to Lungs		
C. Alveolar Capillaries = Site of Gas Exchange		
D. Collect into Four Pulmonary Veins		
1. Two from Each Lung		
2. Carry Oxygenated Blood Back to Heart		
III. Systemic Circulation: Arteries, p. 652	Fig. 21.6, p.653	TA-407
	Clinical Focus, p.681	
	Clinical Note, p.652	
A. Aorta		
1. From L. Ventricle		
2. Regions		
a. Ascending		
b. Arch		
c. Descending		

B. Coronary Arteries (Described in Chapter 20)	Table 21.1, p.656	
C. Arteries to the Head and Neck		
1. Branches off the Aortic Arch	Fig. 21.7, p.654	TA-408
a. Brachiocephalic A.		
b. L. Common Carotid A.		
c. L. Subclavian A.		
2. Blood Supply to the Head	Fig. 21.8, p.654	TA-409
	Predict Quest 1	
a. L. and R. Vertebral A.s		
b. Basilar A.		
c. L. and R., Ant. and Post. Cerebral A.s		
d. Ant. And Post. Communicating A.s		
e. Cerebral Arterial Circle (Circle of Willis)	Fig. 21.8, p.654	TA-409
	Fig. 21.9, p.655	TA-410
f. Sup. and Inf. Cerebellar A.s	Clinical Note, p.656	
D. Arteries of the Upper Limb	Table 21.2, p.657	
1. Branches of the Subclavian A.	Fig. 21.10, p.657	TA-411
	Fig. 21.11, p.658	TA-412
a. Axillary A.		
b. Brachial A.		
2. Blood Supply to Hand		
a. Supf. and Deep Palmar Arches		
b. Digital A.		
E. Thoracic Aorta and Its Branches	Table 21.3, p.658	
	Fig. 21.12a, p.659	TA-413
1. Visceral Branches		
2. Parietal Branches		
a. Intercostal A.s		
b. Sup. Phrenic A.s		
F. Abdominal Aorta and Its Branches	Table 21.3, p.658	
	Fig. 21.12b, p.659	TA-413
	Fig. 21.13, p.660	TA-414
1. Parietal Branches to Inf. Diaphragm and Abdominal Wall		
2. Visceral Branches		
a. Unpaired	Fig. 21.12, p.659	TA-413
b. Paired	Fig. 21.13, p.660	TA-414
G. Arteries of the Pelvis	Table 21.4, p.659	
	Fig. 21.13, p.660	TA-414
	Fig. 21.14, p.661	TA-415
1. At Level of Fifth Lumbar Vertebra the Common Iliac A.'s Branch		
2. Ext. Iliac A.'s Supply Lower Limbs		
3. Int. Iliac A.'s		
a. Visceral Branches		
b. Parietal Branches		
H. Arteries of the Lower Limb	Table 21.5, p.661	
	Fig. 21.14, p.661	TA-268
	Fig. 21.15, p.661	TA-416

1. Continuation of Ext. Iliac A. = Femoral A.
2. Popliteal A.
 - a. Ant. Tibial A. (Becomes Dorsalis Pedis in Foot)
 - b. Post. Tibial A. Becomes Fibular (Peroneal) A.

IV. Systemic Circulation: Veins, p. 660

Fig. 20.6c, p.613
Fig. 20.7b, p.613

TA-386

1. Coronary Sinus from Cardiac Veins of Heart Muscle
2. Superior Vena Cava from Upper Body and Thorax
3. Inferior Vena Cava from Lower Body and Abdomen

Fig. 21.16, p.662

TA-417

A. Veins Draining the Heart (Chapter 20)

B. Veins of the Head and Neck

1. Int. Jugular Veins From Brain and Face

Table 21.6, p.663

Fig. 21.17, p.663

TA-418

Clinical Note, p.663

- a. Venous Sinuses of Cranial Vault Formed by Spaces in Dura Mater

- b. Combine into Int. Jugular V.

2. Ext. Jugular V.'s From Post. Head

3. Ext. Jugular V.'s Join Subclavian V.'s

4. After Int. Jugular V.'s Join Subclavian V.'s to Form Brachiocephalic Veins

Table 21.7, p.664

Fig. 21.18, p. 664

TA-419

Fig. 21.19, p.665

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C. Veins of the Upper Limb

Table 21.8, p.665

Fig. 21.20, p. 665

TA-421

Fig. 21.21, p.666

TA-422

1. Branches of Axillary Vein

- a. Continuous with Subclavian V.

- b. After Passes Under Clavicle

2. Superficial Veins

- a. Cephalic V.

- b. Basilic V.

- c. Median Cubital V. and Median Antebrachial V.

3. Deep Veins

- a. Brachial V.

- b. Branches

D. Veins of the Thorax

Table 21.9, p.666

Fig. 21.22, p.667

TA-423

1. Three Major Veins Empty into Superior Vena Cava

2. R. and L. Brachiocephalic V.'s

- a. Int. Thoracic V.'s

- b. Ant. Intercostal V.'s

3. Azygous V.

a. Hemiazygos V.		
b. Post. Intercostal V.'s		
E. Veins of the Abdomen and Pelvis	Table 21.10, p.667	
	Fig. 21.23, p. 668	TA-424
	Fig. 21.25, p.669	TA-426
1. Ascending Lumbar V.'s Continuous with Hemiazygos and Azygos V.'s		
2. Paired Renal V.'s and Gonadal V.'s Empty Directly into Inferior Vena Cava		
3. Common Iliac V.'s		
a. Ext. Iliac V.s from Limbs		
b. Int. Iliac V.s from Pelvis		
4. Hepatic Portal System	Table 21.11, p.667	
	Fig. 21.24, p.668	TA-425
	Fig. 21.25, p.669	TA-426
a. Carriers Blood from Capillaries of Most Abdominal Organs to Sinusoids in Liver		
b. Hepatic Portal Vein to Liver		
c. Hepatic V.s to Inferior Vena Cava		
F. Veins of the Lower Limb	Table 21.12, p.670	
	Fig. 21.26, p.670	TA-427
	Fig. 21.27, p.671	TA-428
1. Deep Veins		
a. Ant. Tibial V.		
b. Post. Tibial V. Receiving Paired Fibular (Peroneal) V.'s		
b. Popliteal V.		
c. Femoral V.		
d. Ext. Iliac V.		
2. Superficial Veins		
a. Begin with Dorsal and Plantar Veins of Foot		
b. Great Saphenous V. - Medial		
c. Small Saphenous V. - Lateral		
V. Lymphatic Vessels, p. 671	Fig. 21.28, p.672	TA-429
A. Lymph Capillaries	Fig. 21.29, p.673	TA-430
1. Present in Most Tissues except CNS, Bone Marrow and Avascular Tissues		
2. Lack a Basement Membrane		
3. More Permeable than Blood Capillaries		
B. Lymph	Fig. 21.30, p.673	TA-431
C. Lymph Vessels Resemble Small Veins		
1. One-way Valves		
2. Movement of Lymph		
a. Skeletal Muscle Contractions - External Pressure		
b. Contraction of Smooth Muscle in Vessel Wall		

c. Pressure Changes in Thorax
During Respiration

D. Lymph Nodes

1. Round, Oval or Bean-shaped Collections of Cells along Lymphatic Vessels
2. Filter the Lymph Before it is Returned to Circulation

E. Pattern of Lymphatic Drainage

Fig. 21.31, p.673 TA-431
Fig. 21.28, p.672 TA-429
Predict Quest. 2

1. Thoracic Duct

- a. Empties into L. Subclavian V.
- b. Drains Remaining Lymph Vessels
- c. Abdominal Expansion Called the Cisterna Chyli

2. R. Lymphatic Duct

- a. Empties into R. Subclavian V.
- b. Drains Upper R. Quadrant

VI. Physics of Circulation, p. 674

A. Laminar and Turbulent Flow in Vessels

1. Laminar Flow - Central Layer Moves Most Swiftly

Fig. 21.32a, p.674 TA-432

2. Turbulent Flow

Fig. 21.32b, p.674

- a. Occurs Primarily in Heart - Normal Situation
- b. Produces Some Sound
- c. Can Indicate Abnormal Constriction in Arteries
- d. Increases Probability of Thrombosis Formation in Constricted Vessels

B. Blood Pressure

1. Force Exerted by Blood Against Vessel Walls - Measured in mm Hg

2. Direct Measurement by Cannulation

3. Indirect Measurement by Auscultatory Methods - w/in 10% of Accuracy of Direct Methods

- a. Sphygmomanometer
- b. Korotkoff Sounds

Fig. 21.33, p.675 TA-433

C. Rate of Blood Flow

Predict Quest. 3

1. Volume of Blood Moved per Unit Time

2. Directly Proportional to Pressure Difference

3. Inversely Proportional to Resistance to Flow

D. Poiseuille's Law

1. Flow Decreases when Resistance Increases

2. Vessel Factors Increasing Resistance to Flow

- a. Decreased Vessel Diameter
- b. Increased Vessel Length

E. Viscosity

1. Property of Fluid - Fluid's Own Resistance to Flow
2. Blood about 3 Times More Viscous than Distilled Water
3. Blood Viscosity Primarily Influenced by Hematocrit
4. Increased Viscosity of Blood Increases Workload on the Heart

F. Critical Closing Pressure and the Law of LaPlace

Formula, p.676

1. Minimum Blood Pressure to Keep Vessel from Collapsing
2. Law of LaPlace = Force on the Wall is Product of Diameter of a Vessel and the Pressure of the Vessel's Contents
 - a. Weakness in Vessel Can Lead to Aneurysms
 - b. Increased Diameter at Enlargement Increases Wall Pressure; Chance of Rupture Increases

G. Vascular Compliance

1. Tendency for Volume to Increase as Pressure Increases Formula, p.676
2. Venous Compliance is About 24 Times Greater than Arterial Compliance Table 21.13, p.677

VII. Physiology of Systemic Circulation, p. 676

A. Cross-Sectional Area of Blood Vessels

Fig. 21.34, p.677

TA-434

1. Inverse Relationship Between X-Sectional Area and Velocity of Blood Flow
2. Capillaries Have Greatest Total x-Sectional Area and Therefore Lowest Velocity of Blood Flow

B. Pressure and Resistance

Clinical Focus,
p.681

1. Arterial Pressure Varies with Cardiac Cycle
 - a. Highest Pressure (120 mm Hg) During Ventricular Systole
 - b. Lowest Pressure (80 mm Hg) During Ventricular Diastole

Table 21.14, p. 678

2. Pressure Falls Along Circulatory System
 - a. Drop Proportional to Resistance to Flow in the Vessels
 - b. Near 0 mm Hg in R. Atrium

Fig. 21.35, p.679

TA-434

C. Pulse Pressure

1. Numerical Difference Between Systolic and Diastolic Pressures ($120 - 80 = 40$ mm Hg)
2. Determined by
 - a. Stroke Volume (Direct Relation)

Matches Flow to Metabolic Requirements of Tissue
 b. Long-Term Increases in Metabolic Activity lead to Increased Diameter and Number of Capillaries in the Tissue
 c. Lack of O₂ Leads to Increased Vascularization; High O₂ Leads to Decreased Vascularization

B. Nervous Regulation of Local Circulation

1. Coordinates Rapid Routing of Blood with Changes in Tissue Activity

2. Controlled by Sympathetic Division of ANS

Predict Quest. 9;
 Fig. 21.38, p.684

TA-437

a. Innervate Most Blood Vessels Except Capillaries, Precapillary Sphincters and Metarterioles

b. Vasomotor Center of Medulla Oblongata Tonically Active

c. Resultant Partial Constriction = Vasomotor Tone

d. CNS Influences on Vasomotor Center

5, IX. Regulation of Mean Arterial Blood Pressure, p. 685

Table 21.14, p.678

A. Mean Arterial Blood Pressure

1. About 100 mm Hg; Slightly Lower than Average of Systolic and Diastolic Pressures

2. $MABP = CO \times PR$; or $MABP = HR \times SV \times PR$

B. Short-Term Regulation of Blood Pressure

1. Baroreceptor Reflexes

Fig. 21.39, p.686

TA-438

a. Sensory Receptors in Carotid Sinuses and Aortic Arch

Predict Quest. 10

Clinical Note p. 687

b. Constant Low Level of Activity

2. Adrenal Medullary Mechanism

Fig. 21.40, p.688

TA-439

a. Activated by Sympathetic Stimulation of Medulla

b. Medullary Hormones Affect Cardiovascular System

3. Chemoreceptor Reflexes

Fig. 21.41, p. 688

TA-440

a. Sensory Receptors in Carotid Bodies and Aortic Bodies

b. Stimulated by Marked Decrease in O₂, Increased CO₂, Increased H⁺

c. Increased Chemoreceptor Activity Leads to Increased Vasomotor Tone

4. Central Nervous System Ischemic Response

Fig. 21.42, p.689

TA-441

Fig. 21.43, p.690

TA-442

- a. Important when Arterial BP Falls Below 50 mm Hg
 - b. Triggered by High CO₂ and High H⁺
 - c. Stimulates Vasomotor Center and Vasoconstriction
- B. Long-Term Regulation of Blood Pressure
- 1. Renin-Angiotensin-Aldosterone Mechanism [Increases Blood Volume] Fig. 21.44, p.692 TA-443
 - 2. Vasopressin Mechanism [Increases Blood Volume and Vasoconstriction] Fig. 21.45, p.693 TA-444
 - 3. Atrial Natriuretic Mechanism [Decreases Blood Volume and Vasodilation] Predict Quest. 11
4. Fluid Shift and the Stress-Relaxation Response
- a. Both Help Compensate for Changes in BP Occurring Over Many Minutes
 - b. Fluid Shift Mechanism
 - c. Stress-Relaxation Response Fig. 21.46, pp.695-698 TA-445-446

IMPORTANT CONSIDERATIONS: Once again the decision needs to be made concerning how much of the anatomy is to be covered as lecture material. Even with five lecture sessions an instructor is going to have to make some decisions about which aspects of the peripheral circulation will be tackled in depth and which will be touched on more lightly or not at all. There are six basic topic areas; structure of vessels, arrangement of vessels in the body, physics of circulation, physiology of systemic circulation, control of blood flow in tissues, and regulation of mean arterial blood pressure.

A good understanding of the capillary network is essential to understanding gas exchange, filtration at the renal corpuscle, digestive absorption and many other important physiological processes to be discussed in later chapters. The concepts of vasoconstriction and vasodilation are very important. They can be discussed with the effect of nerves on vessels and the muscular layer of vessel walls. Students should realize that only vessels with muscle cells are involved in vasodilation or vasoconstriction.

Discuss vasomotor tone and compare and contrast sympathetic vasomotor tone with the parasympathetic vagal tone described in the last chapter on the heart. To a greater extent than students usually immediately appreciate, the individual tissues regulate their own blood flow. Students should be asked to think about the hypotheses for autoregulation and how autoregulatory mechanisms in combination with the generalized control mechanisms are responsible for ensuring that the metabolically active tissues are getting the most constant blood flow. It should be pointed out that under normal circumstances increased venous return is the most common way in which the cardiac output is increased to meet tissue demands.

SEE INSTRUCTOR'S MANUAL AND COURSE SOLUTIONS MANUAL FOR ADDITIONAL RESOURCES.