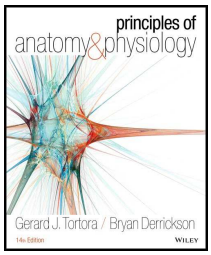


Principles of Anatomy and Physiology

14th Edition

CHAPTER 21

The Cardiovascular System: Blood Vessels and Hemodynamics

Introduction

The purpose of the chapter is to:

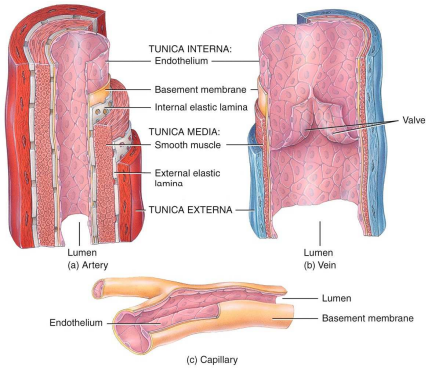
1. Discuss the development, structure, and function of our blood vessels
2. Examine the factors that affect blood flow
3. Discuss how the body controls blood pressure and blood flow
4. Compare and contrast the various circulatory routes in the body
5. Learn about shock, disorders, and disease associated with the blood vessels

Blood Vessel Structure

In general a blood vessel has 3 layers:

1. Tunica interna (a.k.a. tunica intima)
   - Innermost layer, adjacent to lumen
2. Tunica media
   - Middle layer, smooth muscle and elastic fibers
3. Tunica externa
   - Outermost layer, adjacent to surrounding tissue

Comparing Blood Vessel Structure



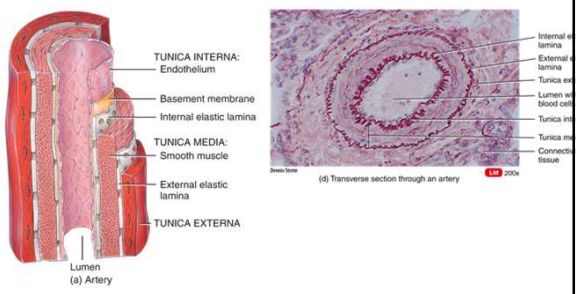
Vessels of the CV System

Anatomy Overview:

- The Cardiovascular System
  Arteries, arterioles, capillaries, venules, and veins

You must be connected to the Internet and in Slideshow Mode to run this animation.

Arteries & Arterioles



Arteries

Arteries carry blood away from the heart to the tissues

- The walls of the arteries are elastic which allows them to absorb the pressure created by ventricles of the heart as they pump blood into the arteries
- Because of the smooth muscle in the tunica media, arteries can regulate their diameter

Types of Arteries

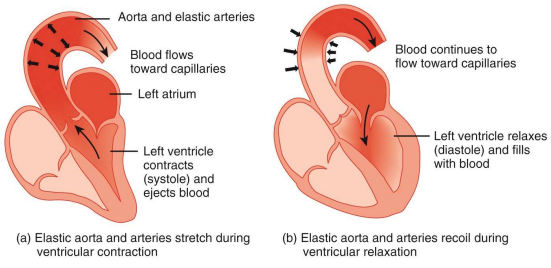
Elastic arteries (conducting arteries)

- Large diameter
- More elastic fibers, less smooth muscle
- Function as pressure reservoirs

Muscular arteries (distributing arteries)

- Medium diameter
- More smooth muscle, fewer elastic fibers
- Distribute blood to various parts of the body

Arteries as Pressure Reservoirs

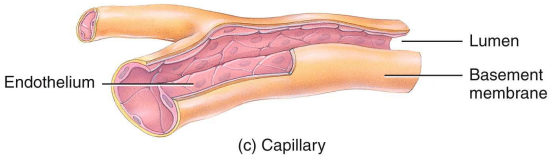


Anastomoses

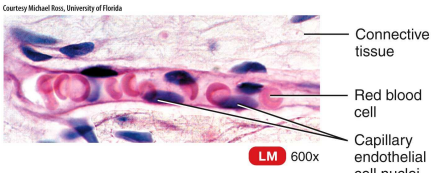
An anastomoses is the union of the branches of 2 or more arteries supplying the same region of the body

- This provides an alternate route for blood flow
- Arteries that do not form an anastomosis are called “end arteries”
  - If an end artery is blocked, blood cannot get to that particular region of the body and necrosis can occur

Capillaries



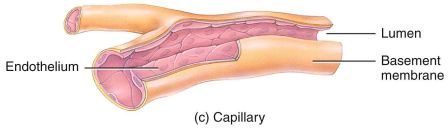
(c) Capillary



(e) Red blood cells passing through a capillary

Capillaries

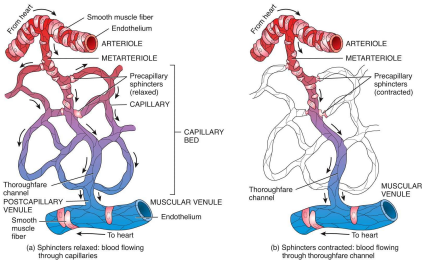
- Capillaries are microscopic vessels that usually connect arterioles and venules
- Capillary walls are composed of a single layer of cells and a basement membrane
  - Because their walls are so thin, capillaries permit the exchange of nutrients and wastes between blood and tissue cells



(c) Capillary

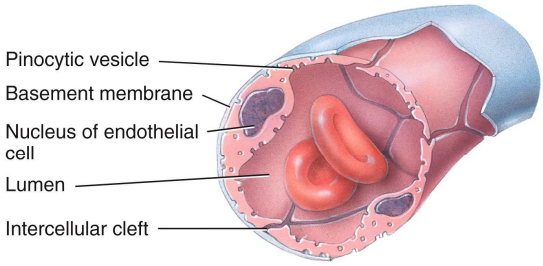
Blood Flow Through Capillaries

Capillaries branch to form an extensive capillary network throughout the tissues and are found near almost every cell in the body



Types of Capillaries

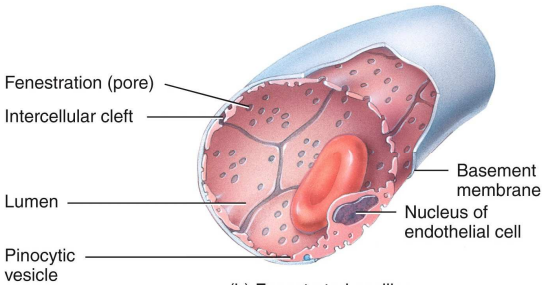
Continuous capillaries



(a) Continuous capillary formed by endothelial cells

Types of Capillaries

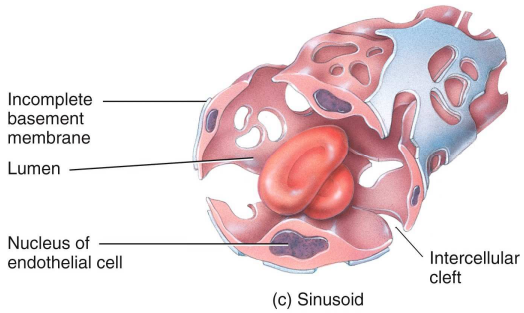
Fenestrated capillaries



(b) Fenestrated capillary

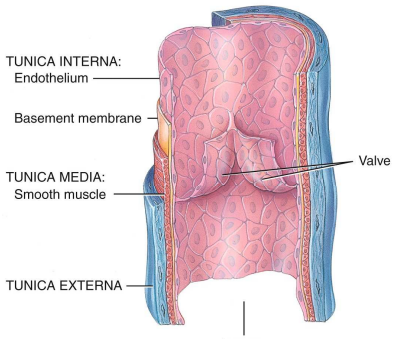
Types of Capillaries

Sinusoid capillaries



(c) Sinusoid

Veins & Venules



(b) Vein

Venules

- Venules are small vessels that are formed by the union of several capillaries
- Venules drain blood from capillaries into veins

Veins

- Veins are formed from the union of several venules
- Compared to arteries, veins have a thinner tunica interna and media and a thicker tunica externa
  - Veins have less elastic tissue and less smooth muscle than arteries
- Veins contain valves

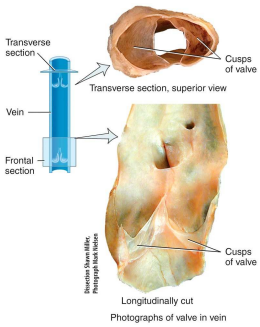


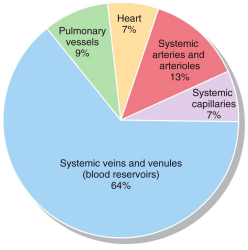
TABLE 21.1

Distinguishing Features of Blood Vessels

BLOOD VESSEL	SIZE	TUNICA INTERNA	TUNICA MEDIA	TUNICA EXTERNA	FUNCTION
Elastic arteries	Largest arteries in the body.	Well-defined internal elastic lamina.	Thick and dominated by elastic fibers; well-defined external elastic lamina.	Thinner than tunica media.	Conduct blood from heart to muscular arteries.
Muscular arteries	Medium-sized arteries.	Well-defined internal elastic lamina.	Thick and dominated by smooth muscle; thin external elastic lamina.	Thicker than tunica media.	Distribute blood to arterioles.
Arterioles	Microscopic (15–300 μm in diameter).	Thin with a fenestrated internal elastic lamina that disappears distally.	One or two layers of circularly oriented smooth muscle; distalmost smooth muscle cell forms a precapillary sphincter.	Loose collagenous connective tissue and sympathetic nerves.	Deliver blood to capillaries and help regulate blood flow from arteries to capillaries.
Capillaries	Microscopic; smallest blood vessels (5–10 μm in diameter).	Endothelium and basement membrane.	None.	None.	Permit exchange of nutrients and wastes between blood and interstitial fluid; distribute blood to postcapillary venules.
Postcapillary venules	Microscopic (10–50 μm in diameter).	Endothelium and basement membrane.	None.	Sparse.	Pass blood into muscular venules; permit exchange of nutrients and wastes between blood and interstitial fluid and function in white blood cell emigration.
Muscular venules	Microscopic (50–200 μm in diameter).	Endothelium and basement membrane.	One or two layers of circularly oriented smooth muscle.	Sparse.	Pass blood into vein; act as reservoirs for accumulating large volumes of blood (along with postcapillary venules).
Veins	Range from 0.5 mm to 3 cm in diameter.	Endothelium and basement membrane; no internal elastic lamina; contain valves; lumen much larger than in accompanying artery.	Much thinner than in arteries; no external elastic lamina.	Thickest of the three layers.	Return blood to heart, facilitated by valves in limb veins.

Blood Distribution

At rest, the largest portion of the blood is in systemic veins and venules (blood reservoirs)



Capillary Exchange

Substances cross capillary walls by:

- Diffusion
- Transcytosis
- Bulk flow

Capillary Exchange

Interactions Animation:

- Capillary Exchange

You must be connected to the Internet and in Slideshow Mode to run this animation.

Diffusion

Substances such as oxygen, carbon dioxide, glucose, amino acids, and some hormones cross capillary walls via *simple diffusion*

Transcytosis

Large, lipid-insoluble molecules (like insulin) cross capillary walls in vesicles via transcytosis

Bulk Flow

Bulk flow is a passive process in which large numbers of ions, molecules, or particles in a fluid move together in the same direction

- Bulk flow occurs from an area of higher pressure to an area of lower pressure, and it continues as long as a pressure difference exists

Bulk flow is more important for regulation of the relative volumes of blood and interstitial fluid

Filtration and Reabsorption

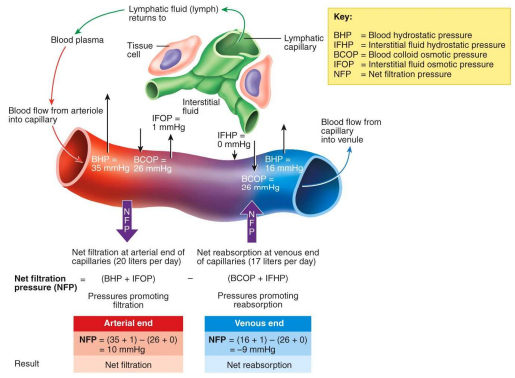
Filtration is pressure-driven movement of fluid and solutes from blood capillaries into interstitial fluid

- Blood hydrostatic pressure (BHP) and interstitial fluid osmotic pressure (IFOP) promote filtration

Reabsorption is pressure-driven movement of fluid and solutes from interstitial fluid into blood capillaries

- Interstitial fluid hydrostatic pressure (IFHP) and blood colloid osmotic pressure (BCOP) promote reabsorption

Dynamics of Capillary Exchange



Starling's Law of the Capillaries

Under normal conditions, the volume of fluid and solutes reabsorbed is almost as large as the volume filtered

- NFP = (BHP + IFOP) – (BCOP+ IFHP)

Factors Affecting Blood Flow

- Blood flow is the volume of blood that flows through any tissue in a given time period (in mL/min)
- Total blood flow is cardiac output (CO), the volume of blood that circulates through systemic (or pulmonary) blood vessels each minute
  - CO = heart rate (HR) × stroke volume (SV)
  - CO = mean arterial pressure (MAP) ÷ resistance (R)

Cardiac Output

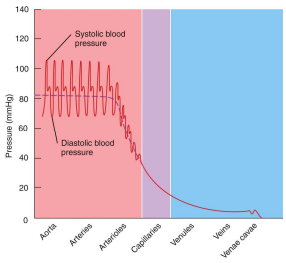
Interactions Animation:

- Cardiac Output

You must be connected to the Internet and in Slideshow Mode to run this animation.

Blood Pressure (BP)

- Contraction of the ventricles generates BP
- BP is determined by CO, blood volume, and vascular resistance
- The higher the BP, the greater the blood flow



Vascular Regulation

Interactions Animation:

- Vascular Regulation

You must be connected to the Internet and in Slideshow Mode to run this animation.

Vascular Resistance (R)

R is the opposition to blood flow due to friction between blood and the walls of blood vessels

- The higher the R, the smaller the blood flow

R depends on:

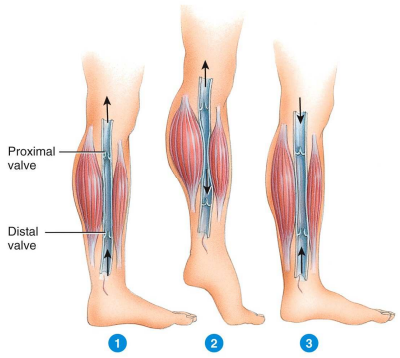
1. Size of the blood vessel lumen
2. Blood viscosity
3. Total blood vessel length

Venous Return

Venous return, the volume of blood flowing back to the heart through the systemic veins, occurs due to the pressure generated by contractions of the heart's left ventricle

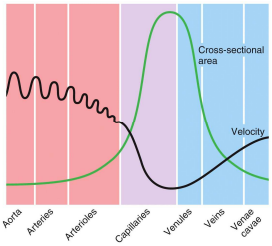
- Venous return is assisted by:
  - Valves
  - Respiratory pump
  - Skeletal muscle pump

Skeletal Muscle Pump

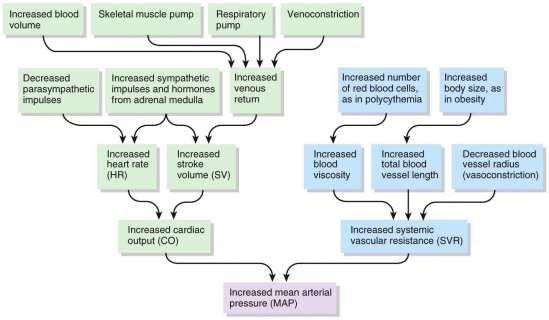


Velocity of Blood Flow

- Blood flow is the volume of blood that flows through a tissue in a given period of time
- Blood flow is inversely related to the cross-sectional area of blood vessels

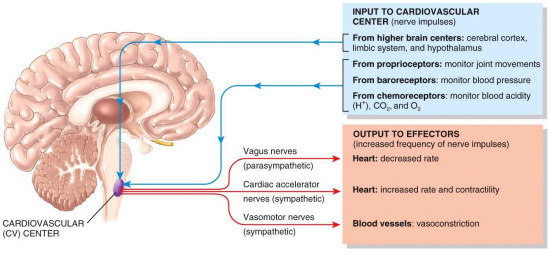


Factors That Affect BP



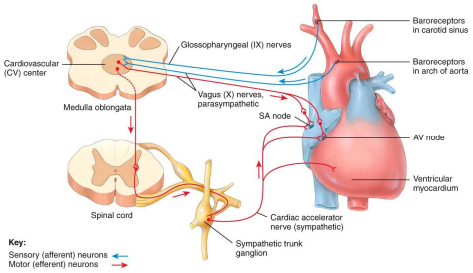
Control of BP and Blood Flow

The medulla oblongata contains a *cardiovascular center*, which is a group of neurons that regulate heart rate, contractility, and blood vessel diameter

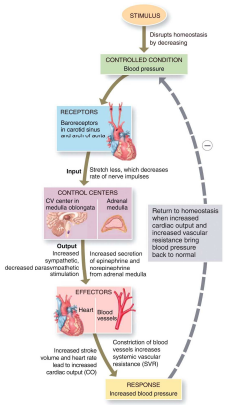


Control of BP and Blood Flow

Baroreceptors are important pressure-sensitive sensory neurons that monitor stretching of the walls of blood vessels and the atria



Negative Feedback Regulation of BP



Blood Pressure Regulation

Interactions Animation:

- Negative Feedback Regulation of Blood Pressure

You must be connected to the Internet and in Slideshow Mode to run this animation.

Hormonal Regulation of BP

TABLE 21.2

Blood Pressure Regulation by Hormones

FACTOR INFLUENCING BLOOD PRESSURE	HORMONE	EFFECT ON BLOOD PRESSURE
CARDIAC OUTPUT		
Increased heart rate and contractility	Norepinephrine, epinephrine.	Increase.
SYSTEMIC VASCULAR RESISTANCE		
Vasoconstriction	Angiotensin II, antidiuretic hormone (ADH), norepinephrine,* epinephrine.†	Increase.
Vasodilation	Atrial natriuretic peptide (ANP), epinephrine,† nitric oxide.	Decrease.
BLOOD VOLUME		
Blood volume increase	Aldosterone, antidiuretic hormone.	Increase.
Blood volume decrease	Atrial natriuretic peptide.	Decrease.

*Acts at α_1 receptors in arterioles of abdomen and skin.
†Acts at β_2 receptors in arterioles of cardiac and skeletal muscle; norepinephrine has a much smaller vasodilating effect.

Autoregulation of BP

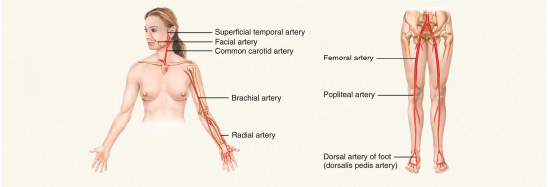
- Autoregulation is the ability of a tissue to automatically adjust its own blood flow to match its metabolic demand for delivery of oxygen and nutrients and removal of wastes
- Physical and chemical stimuli can lead to autoregulation

Checking Circulation

TABLE 21.3

Pulse Points

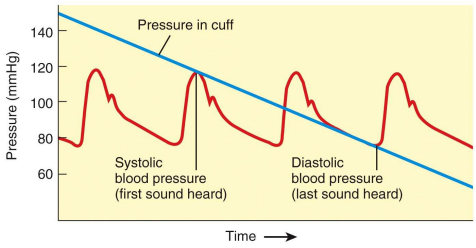
STRUCTURE	LOCATION	STRUCTURE	LOCATION
Superficial temporal artery	Medial to ear.	Femoral artery	Interior to inguinal ligament.
Facial artery	Mandible (lower jawbone) on line with corners of mouth.	Popliteal artery	Posterior to knee.
Common carotid artery	Lateral to larynx (voice box).	Radial artery	Lateral aspect of wrist.
Brachial artery	Medial side of biceps brachii muscle.	Dorsal artery of foot (dorsalis pedis artery)	Superior to instep of foot.



Checking Circulation

Measurement of BP

- Systolic blood pressure (SBP)
- Diastolic blood pressure (DBP)



Shock and Homeostasis

Shock is an inadequate CO that results in failure of the CV system to meet the metabolic demands of body cells

- Cell membranes dysfunction, cell metabolism is abnormal, and cell death may occur

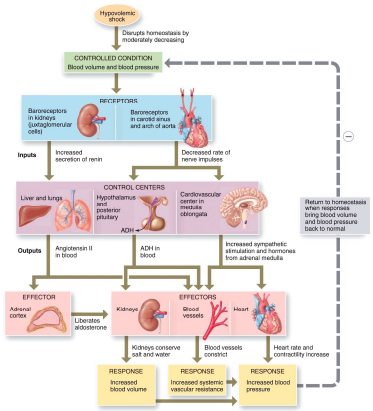
Types of shock:

1. Hypovolemic
2. Cardiogenic
3. Vascular
4. Obstructive

Homeostatic Responses to Shock

- Activation of the renin-angiotensin-aldosterone system
- Secretion of anti-diuretic hormone
- Activation of the sympathetic division of the autonomic nervous system
- Release of local vasodilators

Responses to Hypovolemic Shock



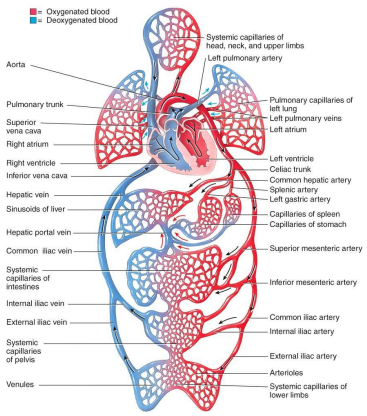
Signs and Symptoms of Shock

- Clammy, cool, pale skin
- Tachycardia
- Weak, rapid pulse
- Sweating
- Hypotension (SBP <90 mmHg)
- Altered mental status
- Decreased urinary output
- Thirst
- Acidosis

Circulatory Routes

- Systemic circulation
- Pulmonary circulation
- Hepatic portal circulation
- Fetal circulation

Circulatory Routes



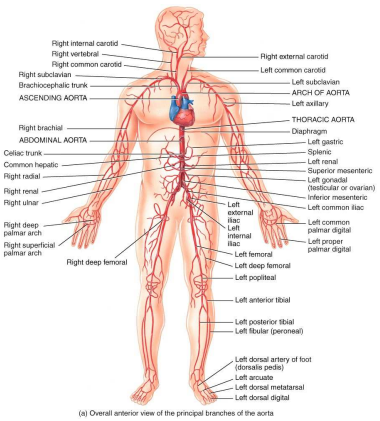
Vessels of the CV System

Anatomy Overview:

- The Cardiovascular System
  Arteries, arterioles, capillaries, venules, and veins

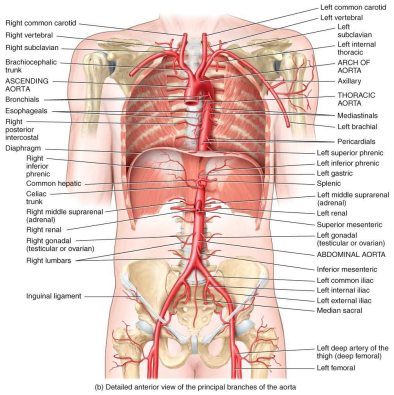
You must be connected to the Internet and in Slideshow Mode to run this animation.

Systemic Circulation



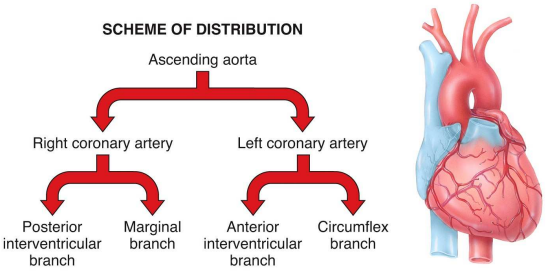
(a) Overall anterior view of the principal branches of the aorta

Systemic Circulation

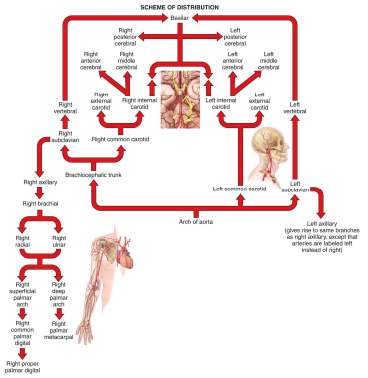


(b) Detailed anterior view of the principal branches of the aorta

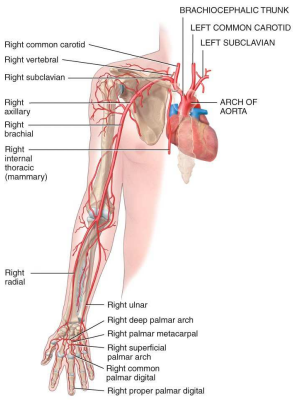
Systemic Circulation of the Heart



Systemic Circulation

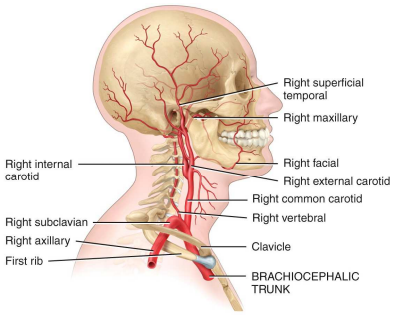


Systemic Circulation



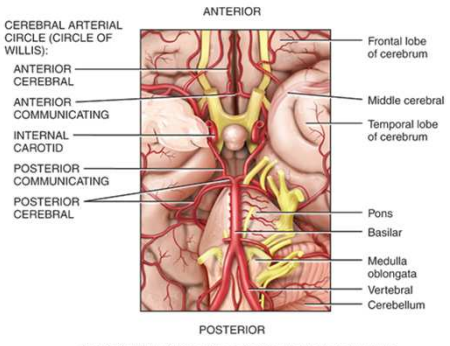
(a) Anterior view of branches of brachiocephalic trunk in upper limb

Systemic Circulation



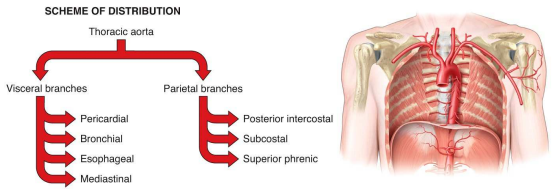
(b) Right lateral view of branches of brachiocephalic trunk in neck and head

Systemic Circulation

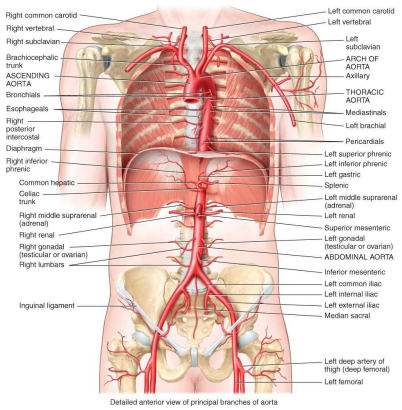


(c) Inferior view of base of brain showing cerebral arterial circle

Systemic Circulation

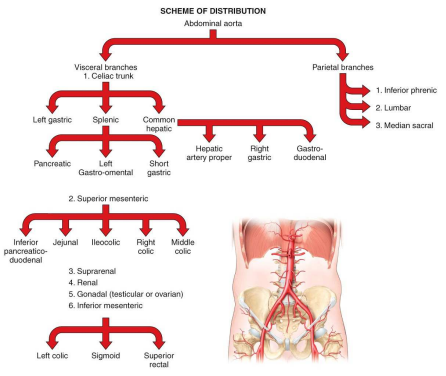


Systemic Circulation

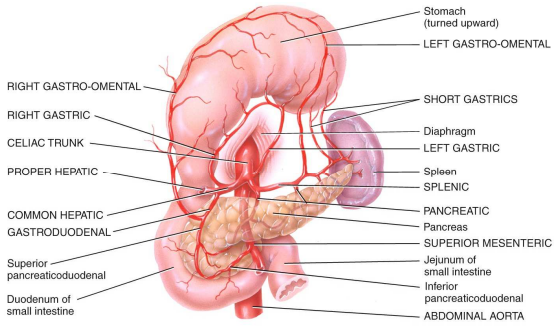


Detailed anterior view of principal branches of aorta

Systemic Circulation

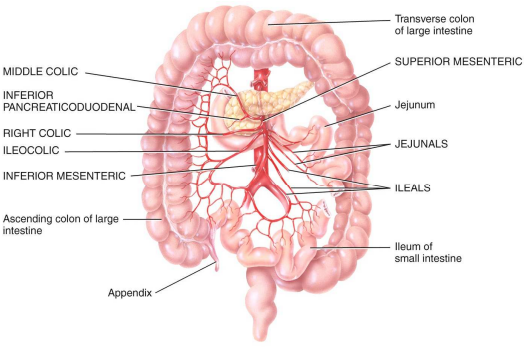


Systemic Circulation



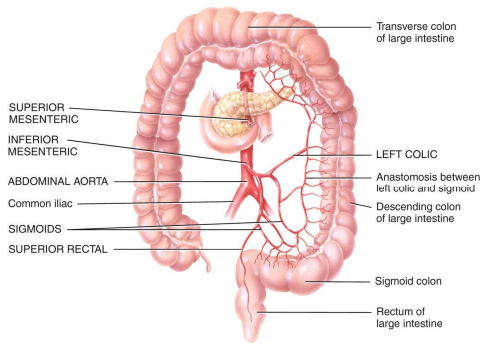
(a) Anterior view of celiac trunk and its branches

Systemic Circulation



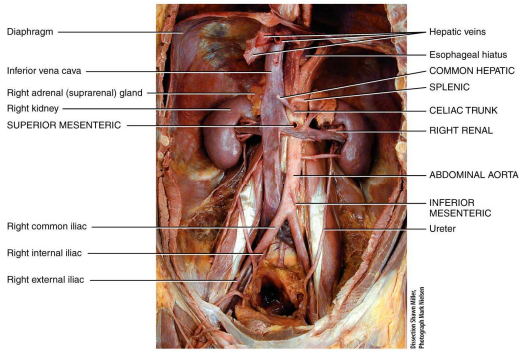
(b) Anterior view of superior mesenteric artery and its branches

Systemic Circulation



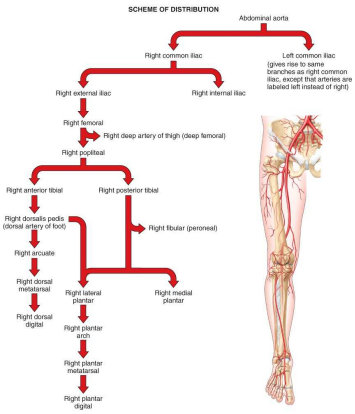
(c) Anterior view of inferior mesenteric artery and its branches

Systemic Circulation

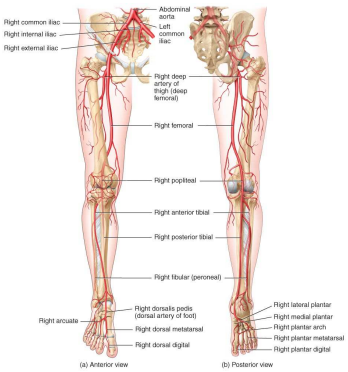


(d) Anterior view of arteries of abdomen and pelvis

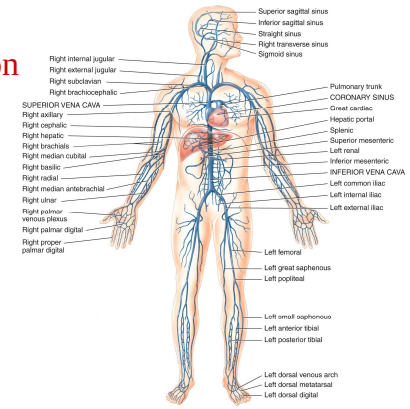
Systemic Circulation



Systemic Circulation

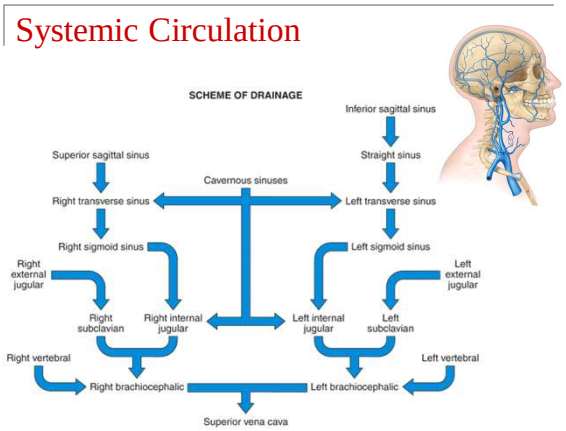


Systemic Circulation

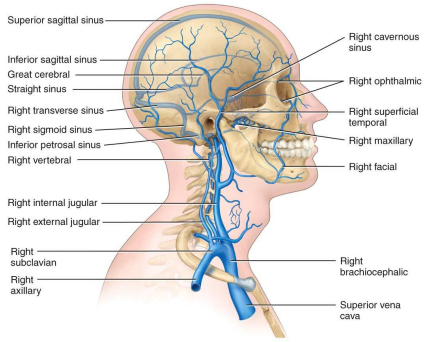


Overall anterior view of the principal veins

Systemic Circulation

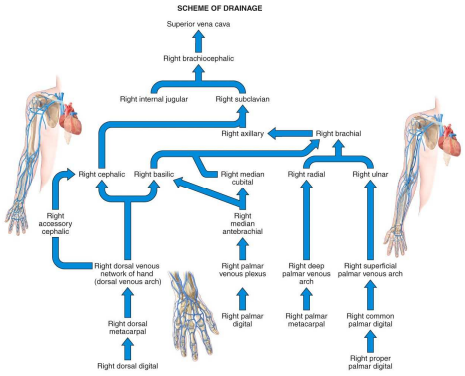


Systemic Circulation

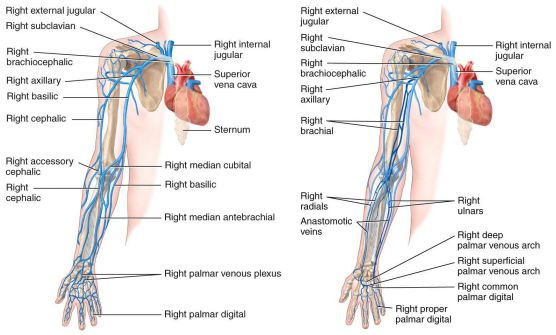


Right lateral view

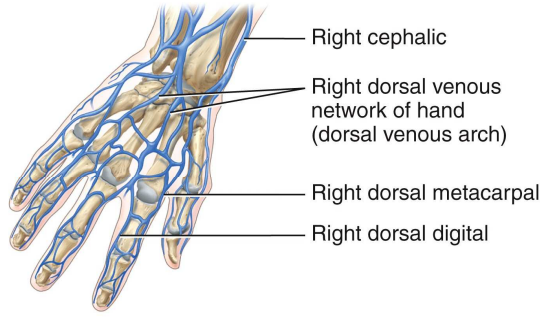
Systemic Circulation



Systemic Circulation

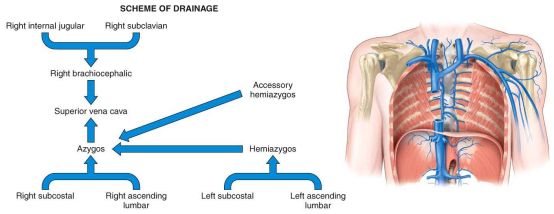


Systemic Circulation

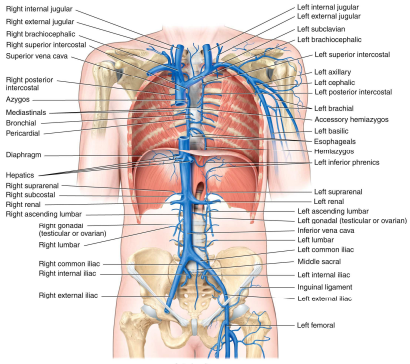


(c) Posterior view of superficial veins of hand

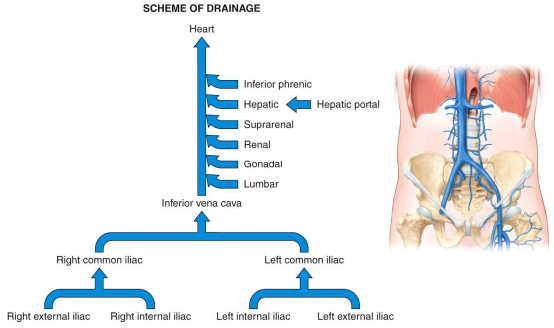
Systemic Circulation



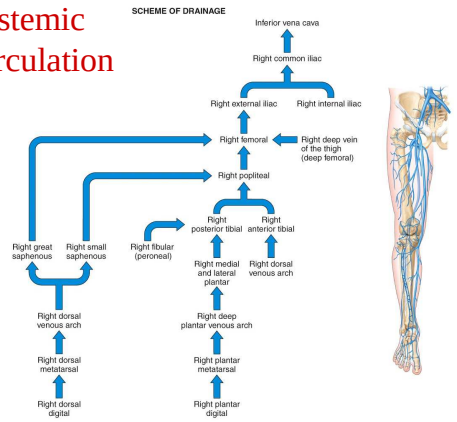
Systemic Circulation



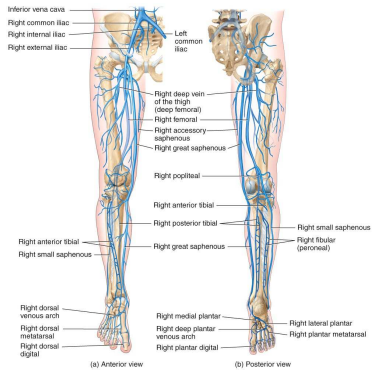
Systemic Circulation



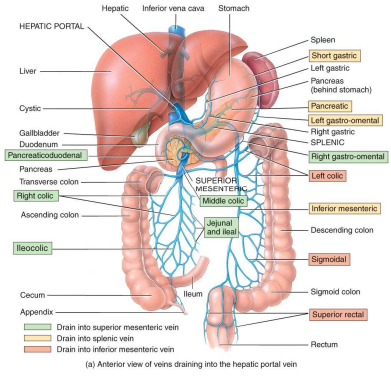
Systemic Circulation



Systemic Circulation

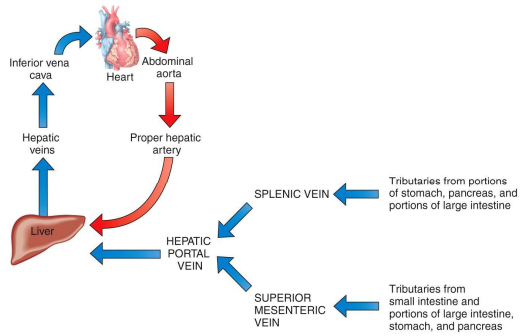


Hepatic Portal Circulation



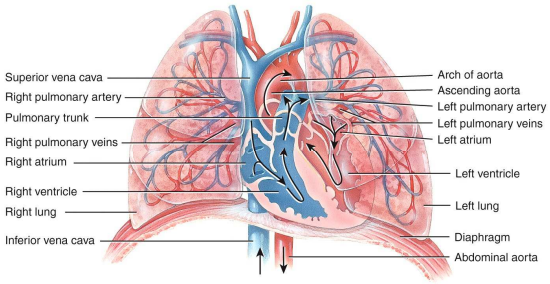
(a) Anterior view of veins draining into the hepatic portal vein

Hepatic Portal Circulation



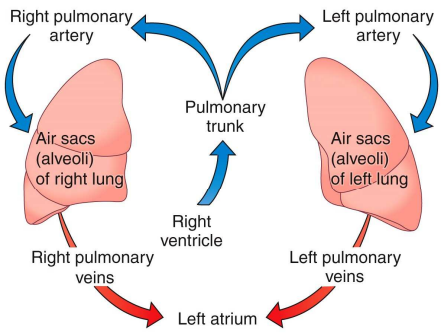
(b) Scheme of principal blood vessels of hepatic portal circulation and arterial supply and venous drainage of liver

Pulmonary Circulation



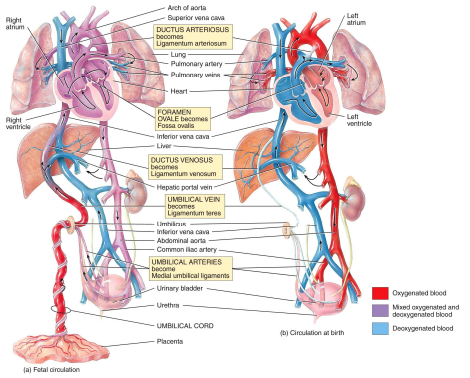
(a) Anterior view

Pulmonary Circulation

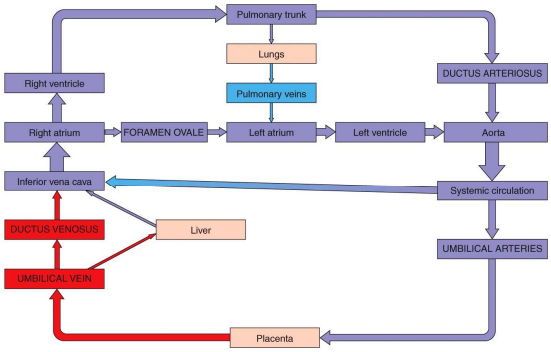


(b) Scheme of pulmonary circulation

Fetal Circulation



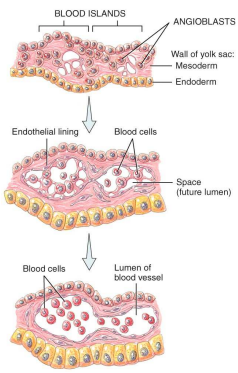
Fetal Circulation



(c) Scheme of fetal circulation

Development of Blood Vessels & Blood

Blood vessels develop from isolated masses of mesenchyme in the mesoderm called blood islands

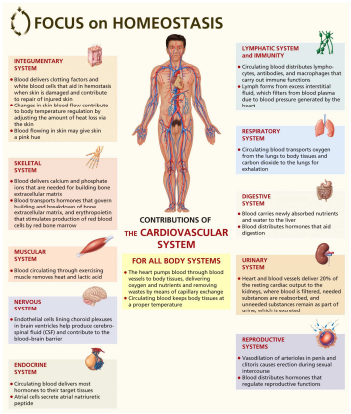


Aging and the CV System

Aging results in:

- Loss of compliance of the aorta
- Reduction in cardiac muscle fiber size
- Progressive loss of cardiac muscular strength
- Decline in maximum heart rate
- Increased systolic blood pressure

Homeostasis



Homeostatic Imbalances

- Hypertension
  - SBP > 140 mmHg
  - DBP > 90 mmHg
- Primary hypertension
- Secondary hypertension

End of Chapter 21