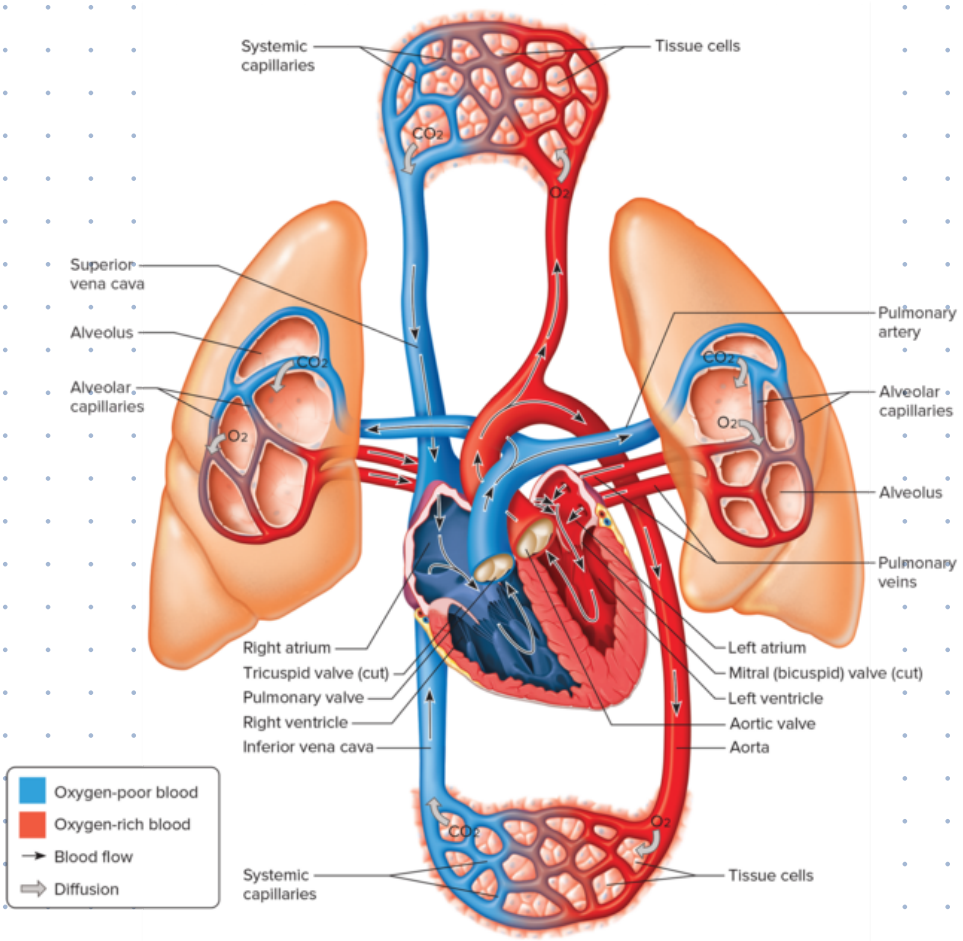
# Chapter 15.1

The heart is a muscular pump that generates the force required to move blood through the body's blood vessels. Along the way, oxygen & nutrients in the blood are distributed to tissue cells, while carbon dioxide & other waste products are removed & transported by the blood to various organs for disposal. Without circulation, deprived cells will begin irreversible change, which quickly leads to their death. The heart & blood vessels together constitute the cardiovascular system. During normal daily activities, the heart pumps the entire volume of blood approximately every minute.

- Veins carry blood toward the heart
- Arteries carry blood away from the heart
- Gas, nutrient, & waste exchange occur in microscopic blood vessels that lie between arteries & veins: capillaries.
- Cardiovascular system has 2 closed pathways/circuits of blood flow

Pulmonary circuit: system of blood vessels that transport blood between heart & lungs

- Sends deoxygenated blood

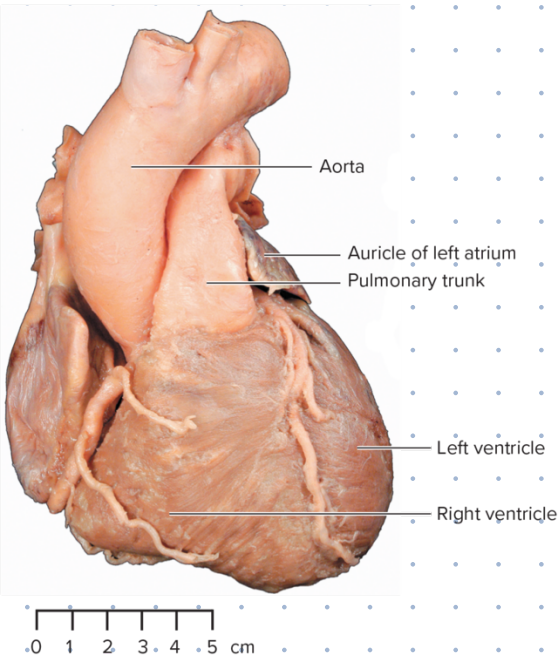


to lungs to unload carbon dioxide & pick up oxygen

**systemic circuit**: vessels that send oxygenated blood & nutrients to all body cells & removes wastes

- right side of heart pumps blood to pulmonary circuit & blood returns to right side of heart
- left side of heart pumps blood through systemic circuit & blood returns to right side of heart

# Chapter 15.2

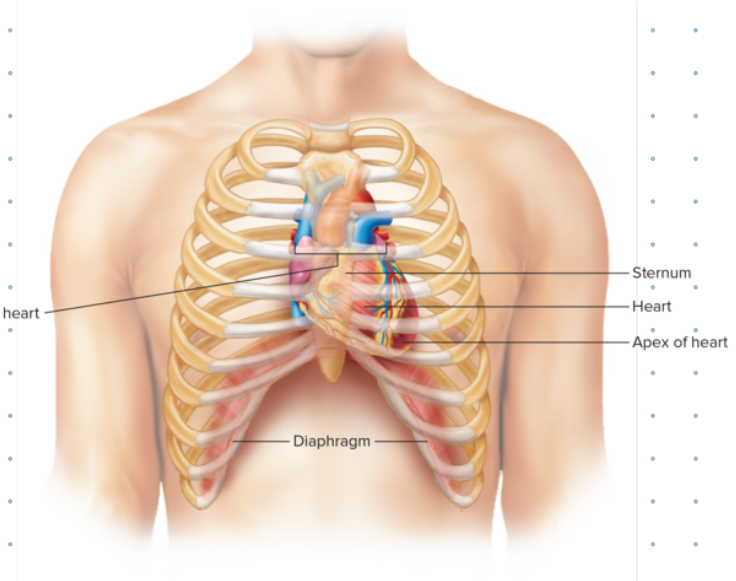



## size & location of heart

- outward heart appearance often referred to as cone-shaped
- hollow w a double pump divided into left & right
- typically size of fist but varies w body size
- average adult heart is 14 cm long & 9 cm wide
- located in the mediastinum of thoracic cavity
- just superior to the diaphragm
- laterally bordered by the lungs, posteriorly by vertebral column, anteriorly by sternum
- heart base (attaches to several large blood vessels) lies under second rib
- inferior and extends down & to the left, ending as a bluntly pointed apex at level of fifth intercostal space
- possible to detect apical heartbeat by feeling/listening to chest wall between fifth & sixth ribs, 7.5 cm to left of midline

## coverings of the heart

- **Pericardium** (pericardial sac) is membranous covering that encloses heart & proximal ends of large blood vessels it attaches to




**Fibrous pericardium**: outermost connective tissue that covers & anchors heart

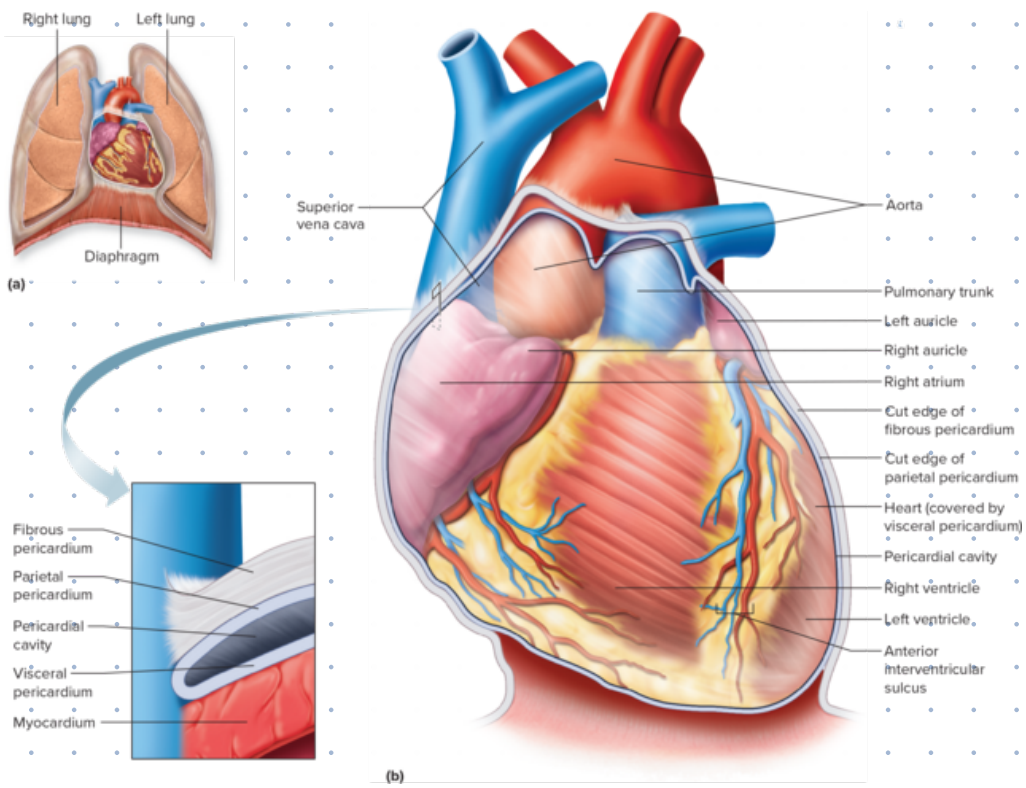
- **Attached to central portion of diaphragm, posterior of sternum, the vertebral column, & large blood vessels associated with heart**
- Pericardium surrounds delicate, double layered serous membrane

**Visceral pericardium**: inner serous membrane covering heart; also called epicardium

- At base of heart it turns back upon itself forming outermost serous membrane

**Parietal pericardium**: outer serous membrane covering heart

- Between parietal and visceral serous layers is pericardial cavity containing small amount of serous fluid (pericardial fluid) secreted by pericardial membranes
- Pericardial fluid reduces friction between membranes as heart moves within them




**Pericarditis**: inflammation of pericardium often due

to viral/bacterial infection, etc

**Cardiac tamponade**: characteristics sounds heard by stethoscope, sharp stabbing pain often felt posterior to sternum, fluid builds up in pericardial cavity and puts pressure on heart, interferes with heart movements restricting its ability to properly pump blood

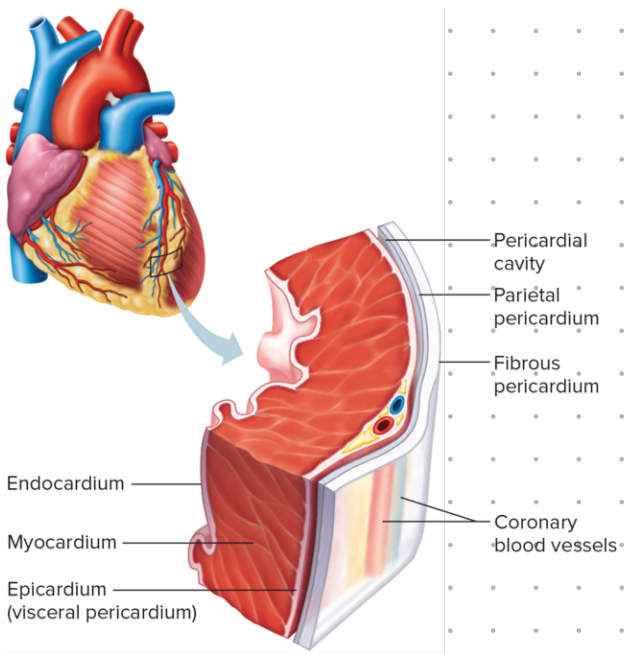
- Other symptoms include anxiety, rapid/difficulty breathing, lightheadedness, palpitations, pallor, & chest pain
- May be treated by inserting syringe into chest wall to remove accumulated pericardial fluid

## Wall of the Heart

The wall of the heart is composed of three distinct layers: an **outer pericardium**, a **middle myocardium**, and an **inner endocardium**.

**Epicardium**: visceral part of pericardium on heart's surface

- Corresponds to visceral pericardium
- Protects heart by reducing friction
- **Thin serous membrane**
- **Connective tissue covered by epithelium**
- **Connects capillaries & nerve fibers**
- Deeper portion typically contains adipose tissue




**Myocardium**: muscle layer of the heart

- Consists largely of cardiac muscle tissue that pumps blood out of heart chambers
- Muscle fibers lie in place separated by connective tissues supplied with blood

**TABLE 15.1 Wall of the Heart**

| Layer | Composition | Function |
|---|---|---|
| Epicardium (visceral pericardium) | Serous membrane of connective tissue covered with epithelium and includes blood and lymph capillaries and nerve fibers; adipose tissue around large blood vessels of the heart | Forms a protective outer covering; secretes serous fluid |
| Myocardium | Cardiac muscle tissue separated by connective tissue and includes blood and lymph capillaries and nerve fibers | Contracts to pump blood from the heart chambers |
| Endocardium | Membrane of epithelium and underlying connective tissue and includes blood vessels and specialized fibers | Forms a protective inner lining of the chambers and valves |

capillaries, lymph capillaries, & nerve fibers

**endocardium**: inner lining of heart chambers

- epithelium & underlying connective tissue that contains elastic & collagen fibers
- contains blood vessels & covers specialized cardiac cells called purkinje fibers
- lies in all chambers & covers all structures

**heart chambers & valves**

- heart is divided into four hollow chambers, two on each side
- upper chambers called atria have thin walls & receive blood returning to heart
- small, warlike projections called auricles extend anteriorly from atria & work to increase blood volume capacity of atria
- lower chambers called ventricles receive blood from atria & contract to force blood out of heart into arteries

**vena cava**: one of two large veins that conveys oxygen-poor blood to right atrium

- superior vena cava
- inferior vena cava
- smaller vein called coronary sinus also drains venous blood into right atrium from myocardium

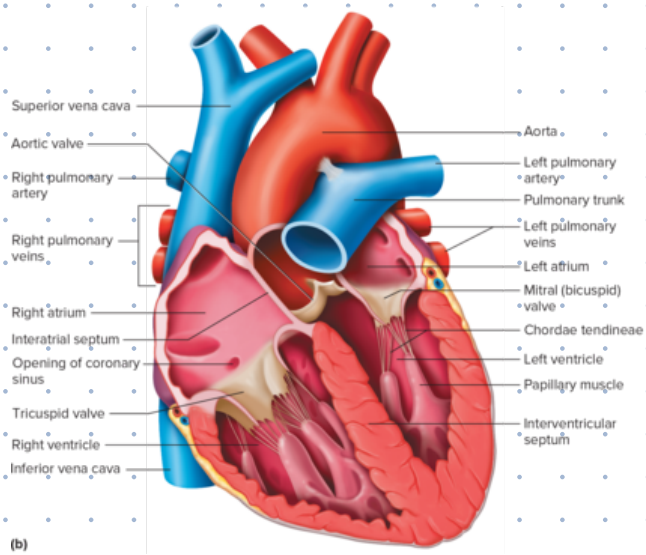
**atrioventricular valve** (AV valve): cardiac valve between an atrium & ventricle

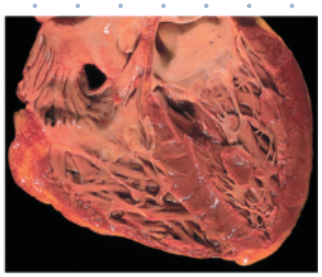
- atrium on each side communicates w it's corresponding ventricle through an opening guarded by AV valve
- this valve ensures one-way blood flow between atrium & ventricle on each side

**tricuspid valve** (right AV valve):heart valve between right atrium & right ventricle

- composed of three leaflets (cusps)
- permits blood to move from right atrium to right ventricle
- prevents blood from moving in opposite direction

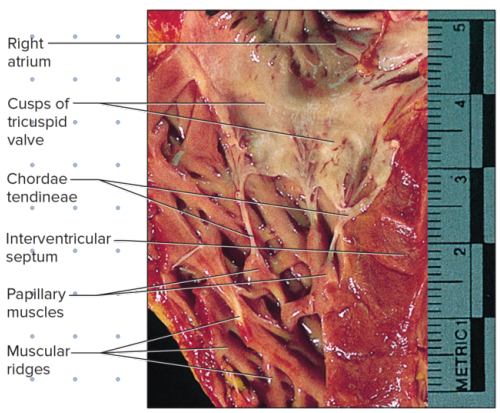
- cusps fold out of way against ventricular wall when blood pressure is greater on atrial side



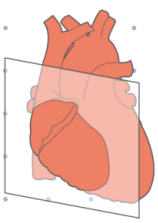

- cusps close when blood pressure is greater in ventricular side

**chordae tendineae**: strong, fibrous strings that attach to cusps of tricuspid valve & originate from small mounds of cardiac muscle tissue

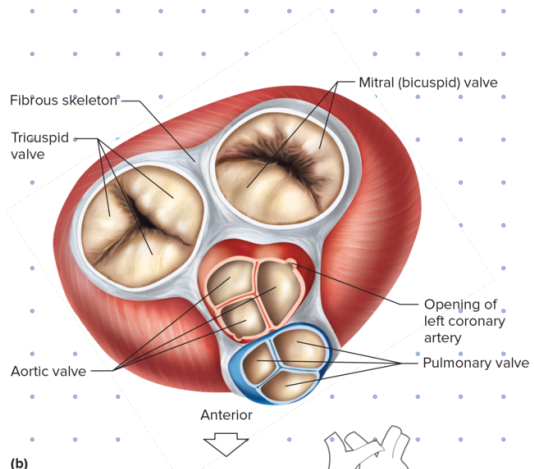



**papillary muscle**: any muscles that extend inward from the ventricular wall of the heart to which the chordae tendineae attach

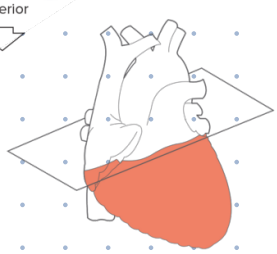
- **right ventricle has a thinner myocardium than left**
- **right chamber pumps blood a short distance to lungs against relatively blood flow resistance**
- left ventricle forces blood to all other body parts **against greater resistance to blood flow**



**pulmonary trunk**: divides to form left and right pulmonary arteries that lead to lungs




- **pulmonary valve**: valve leading from right ventricle to pulmonary trunk: pulmonary semilunar valve
- pulmonary valve is at **base of trunk** which consists of three cusps



- **left atrium receives blood from lungs** through four

pulmonary veins, two from right lung & two from left lung

**mitral valve**: valve between left atrium & left ventricle; bicuspid valve

- mitral valve prevents blood from flowing back into left atrium from left ventricle when ventricle contracts
- mitral valve prolapse (MVP) affects up to 6% of US population
- w MVP one/both mitral valve cusps stretches & bulges into left atrium during ventricular contraction
- symptoms of MVP: chest pain, palpitations, fatigue, & anxiety
- people w MVP are more susceptible to infective endocarditis

**aorta**: major systemic artery that receives blood directly from left ventricle

- aorta has many branches disturbing blood throughout body

**aortic valve**: valve in aorta near its origin that prevents blood from returning to left ventricle

- aortic valve consists of three cusps
- mitral & tricuspid valves also called atrioventricular valves bc they're between atria & ventricles
- pulmonary & aortic valves also called semilunar valves bc their half-moon shape of their cusps

**skeleton of the heart**

- rings of connective tissue surround pulmonary trunk & aorta at proximal ends
- rings provide attachments for heart valves & muscle fibers & prevent outlets if atria & ventricles from dilating during contraction
- fibrous rings along w connective tissue in part of septum between ventricles make the skeleton of the heart

**blood flow through the heart, lungs, & tissues**

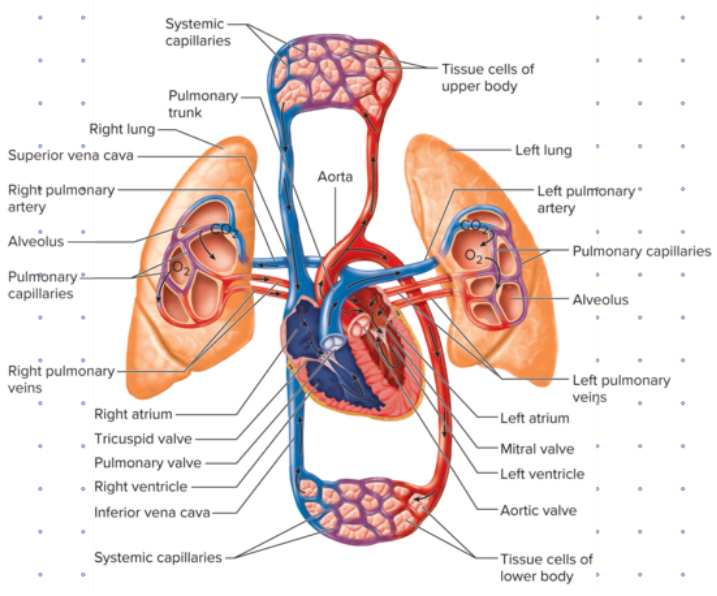
| TABLE 15.2 | Valves of the Heart | |
|---|---|---|
| **Valve** | **Location** | **Function** |
| Tricuspid valve | Opening between right atrium and right ventricle | Prevents blood from moving from the right ventricle into the right atrium during ventricular contraction |
| Pulmonary valve | Entrance to pulmonary trunk | Prevents blood from moving from the pulmonary trunk into the right ventricle during ventricular relaxation |
| Mitral valve | Opening between left atrium and left ventricle | Prevents blood from moving from the left ventricle into the left atrium during ventricular contraction |
| Aortic valve | Entrance to aorta | Prevents blood from moving from the aorta into the left ventricle during ventricular relaxation |

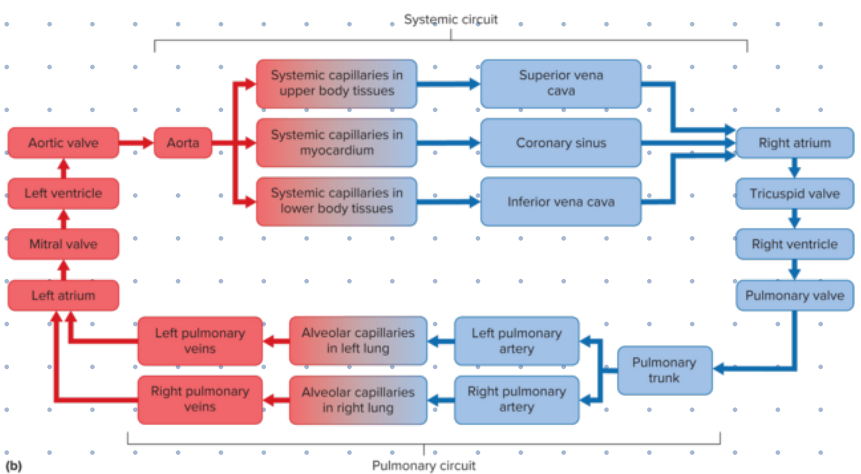
- Blood always flows in one-way direction through pulmonary & systemic circuits
- Deoxygenated blood & blood high in carbon dioxide enters right atrium through venal cavae & coronary sinus
- Gas exchange occurs between blood in capillaries & air in alveoli
- Carbon dioxide (metabolic waste produced by cells) leaves blood then exhaled

## Blood Supply to the Heart

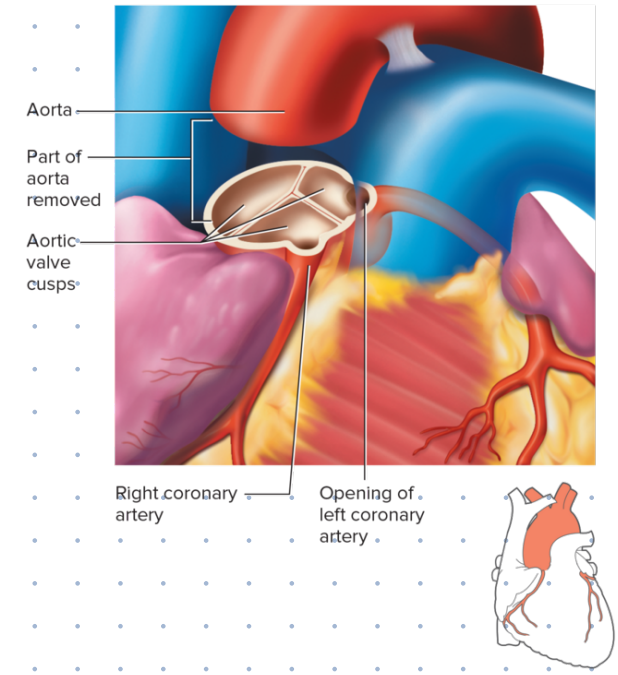
The first two branches of the aorta, called the right and left coronary arteries, supply blood to the tissues of the heart. Their openings lie just superior to the aortic valve.

- Right coronary artery passes along atrioventricular sulcus between right atrium & right ventricle
- Gives off two major branches: Posterior interventricular artery (travels along posterior interventricular sulcus & supplies posterior walls of both ventricles) & right marginal branch (passes along lower border of heart)

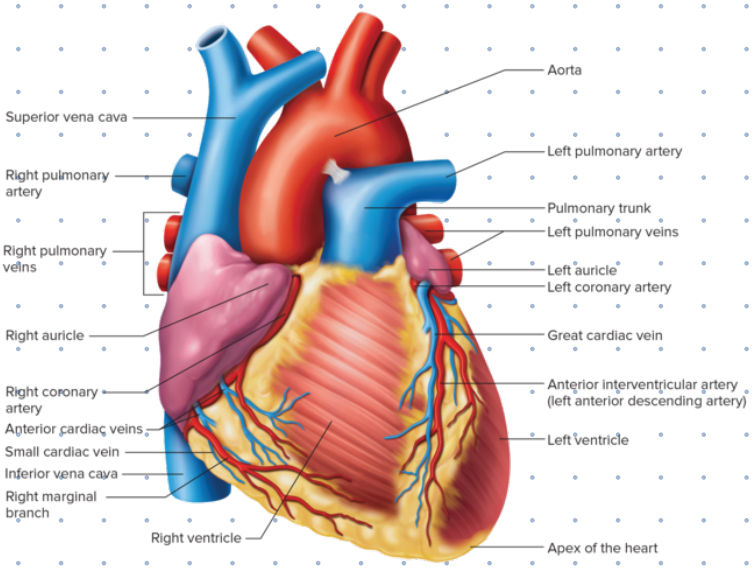


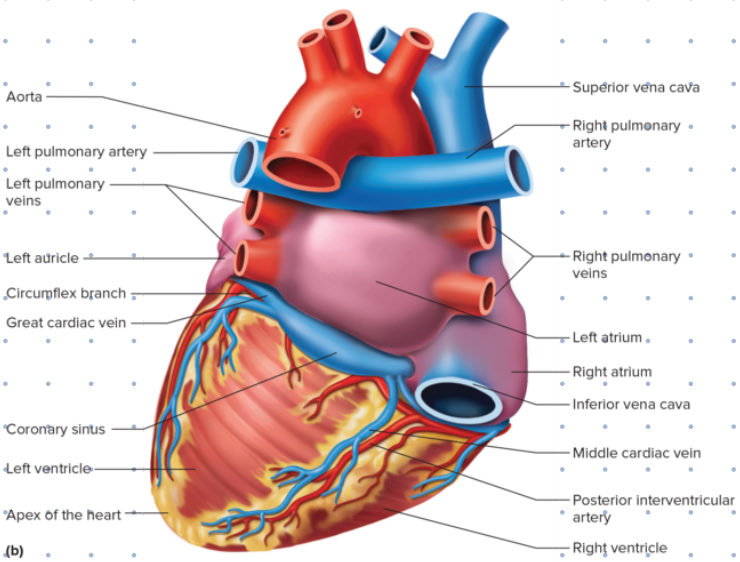



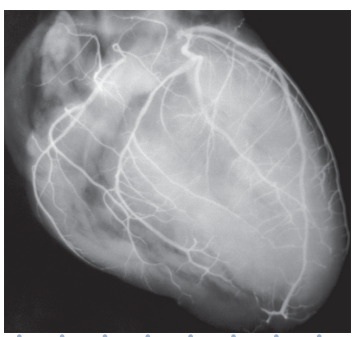
- right marginal branch supplies walls of right atrium & right ventricle
- circumflex branch (one branch of left coronary artery) follows atrioventricular sulcus between left atrium & encircles heart as it travels posteriorly
- anterior interventricular artery/left anterior descending artery is in the anterior interventricular sulcus & supplies the walls of both ventricles
- branches of coronary arteries feed myocardium capillaries
- smaller branches of these arteries usually have connections (anastomoses)




between blood vessels that provide alternate pathways for blood flow, also called collateral circulation



An angiogram (radiograph) of the coronary arteries is a diagnostic procedure used to examine specific blood vessels.

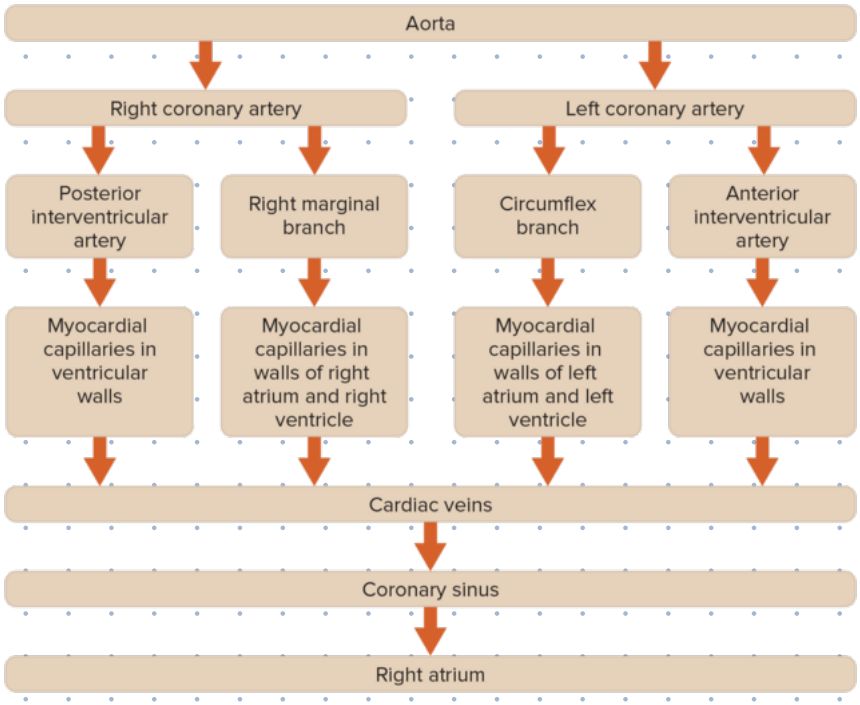
ischemia: thrombus/embolus that partially blocks/narrows coronary artery branch & causes a decrease in blood flow

- ischemia pain usually happens during physical activity when oxygen demand exceeds supply, rest usually solves this
- emotional disturbance may also trigger angina pectoralis
- angina pectoralis feels like heavy pressure, tightening, or squeezing in chest, usually behind the sternum/in anterior upper thorax & may radiate to neck, jaw, throat, left shoulder, left upper limb, back, or upper abdomen (profuse perspiration, difficultly breathing, nausea/vomiting is also possible)
- bloody clot may obstruct coronary artery (coronary thrombosis), killing that part of the heart
- death of myocardium is called myocardial infarction (MI), or heart attack
- blood flow in vessels of myocardium is poorest during ventricular contraction bc myocardium compresses blood vessels upon contraction which interferes w blood flow

cardiac vein: any blood vessels that returns blood from the venues of the myocardium to coronary sinus

- branches of cardiac veins drain blood that passed through capillaries of myocardium

coronary sinus: large vessel on posterior surface of heart into which cardiac veins form



# Chapter 15.3

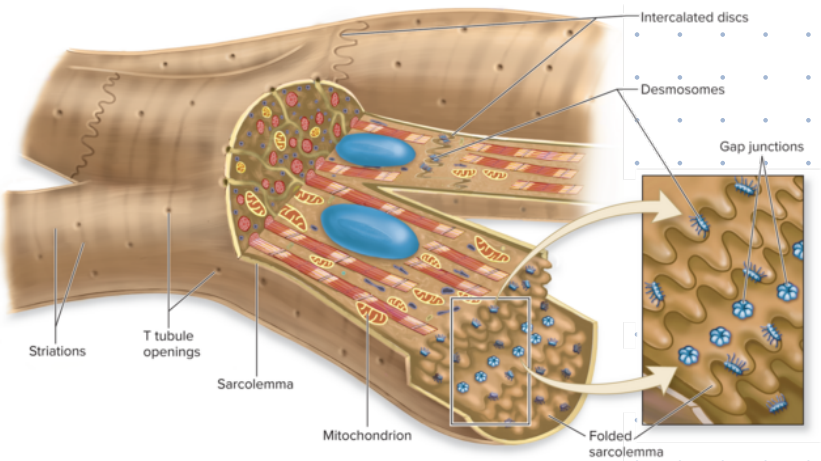
**systole**: phase of cardiac cycle when a heart chamber wall contracts

**diastole**: phase of cardiac cycle when a heart chamber wall relaxes

**cardiac cycle**: sequence of myocardial contraction & relaxation that constitutes a complete heartbeat

- during cardiac cycle, regular pattern of impulses are generated, & the electrical activity of the heart can be measured & recorded on an **electrocardiogram** (ECG, EKG)
- **two heart sounds associated w each cardiac cycle**

**cardiac muscle cells**



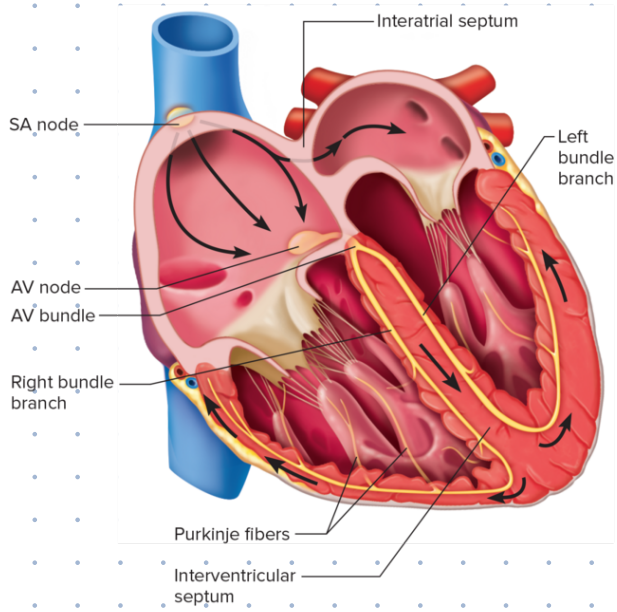

- intercalated discs connect adjacent cardiac muscle cells
- within intercalated discs are intercellular proteins called **desmosomes** that withstand tension & hold cells together
- gap junctions enable action potentials to spread through cell network

**functional syncytium**: mass of cells performing as a unit; those of the heart are joined electrically

- **two structures in heart: in atrial walls & in ventricular walls**
- in this region specialized conduction fibers connect the atrial syncytium & ventricular syncytium

## Cardiac conduction system

- throughout heart are clumps & strands of specialized cardiac muscle tissue
- instead of contracting, these specialized cells initiate & distribute action potentials (cardiac impulses) throughout myocardium
- fibers are self-ignitable (autorhythmic) & they make up the cardiac conduction system which coordinates cardiac cycle events




**Sinoatrial (SA) node**: mass of specialized, noncontractile cells beneath epicardium in right atrium near opening of superior vena cava

- cells of SA node are continuous w cells of atrial syncytium
- **SA node activity is rhythmic**: as cells initiate one impulse after another averaging 100 times a min in adults

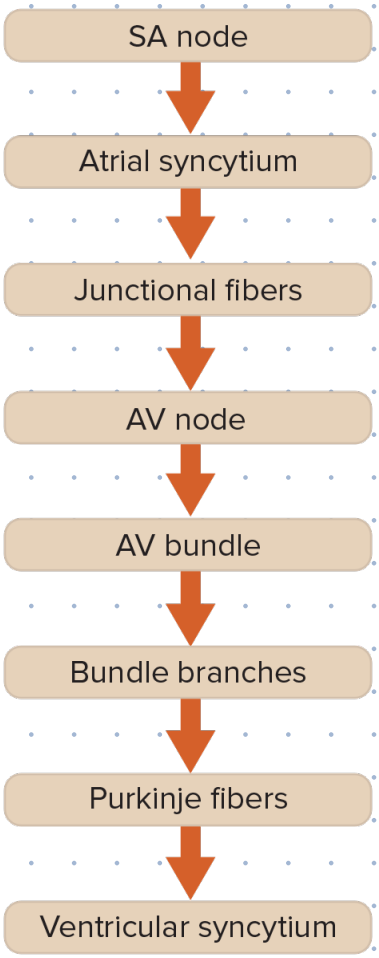
**Pacemaker**: mass of specialized cardiac muscle tissue that controls rhythm of heartbeat; sinoatrial node

- right & left atria contract almost simultaneously
- cardiac impulse passes along specialized noncontractile muscle cells called **junctions fibers** of the conduction system

**Atrioventricular (AV) node**: specialized mass of cardiac muscle fibers in the interstitial septum of the heart that conducts cardiac impulses from the sinoatrialnode to AV bundle: AV node

- bc fibrous skeleton is incapable of conducting an impulse, AV node provides only normal conductive pathway between atrial & ventricular syncytia

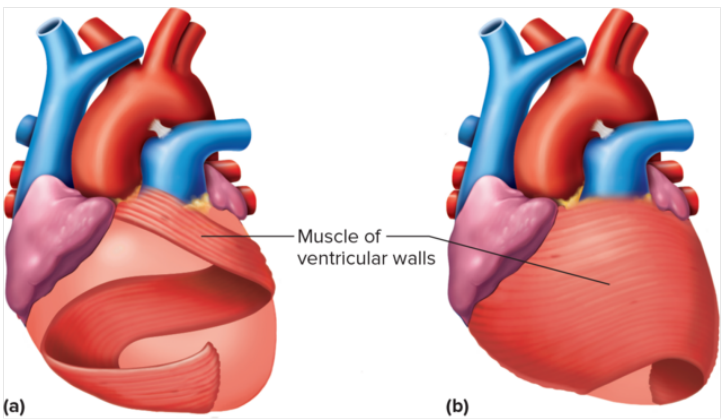
**Atrioventricular (AV) bundle**: group of specialized muscle fibers that conducts




impulses from the atrioventricular node to Purkinje fibers in ventricular muscle of the heart; AV bundle; bundle of His

**Purkinje fibers:** specialized cardiac muscle fibers that conduct cardiac impulse from AV bundle into ventricular walls, also called subendocardial conducting network

- cells of myocardium in ventricular walls form irregular whorls (spiral patterns)

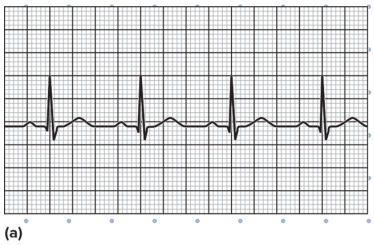



## Electrocardiagram

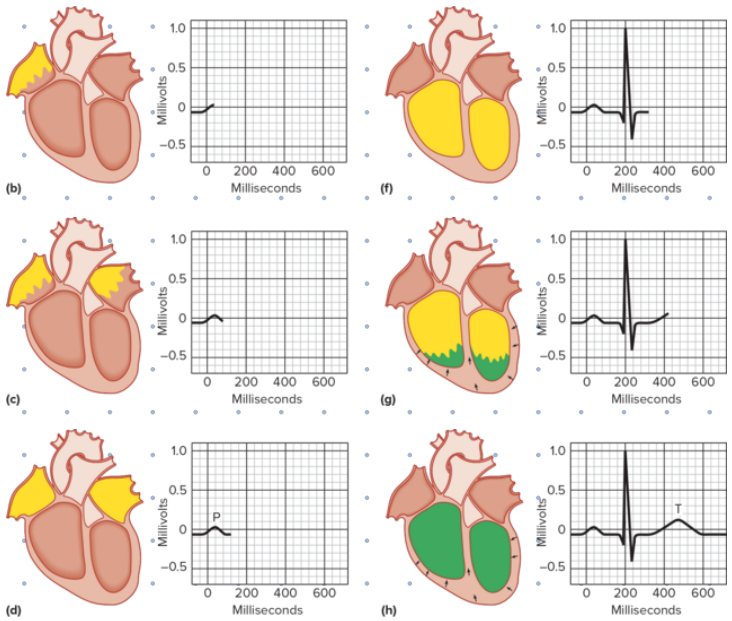
**Electrocardiogram:** recording if electrical activity associated w the cardiac cycle (ECG/EKG)

To record an ECG, electrodes are placed on the skin and & connected by wires to an instrument that responds to small electrical changes. These changes are recorded on an electronic device and may be displayed on a screen or printed on a moving strip of paper. A normal ECG pattern includes several deflections, or waves, during each cardiac cycle. Between cycles, the muscle cells remain polarized, with no detectible electrical changes. When the SA node initiates the cardiac impulse, the atrial cells depolarize, producing an electrical change. A deflection occurs, & at the end of the electrical change, the recording returns to the base line. This first deflection

produces a P wave, corresponding to a depolarization that spreads from the SA node through contractile cells of both atria that leads to atrial contraction.

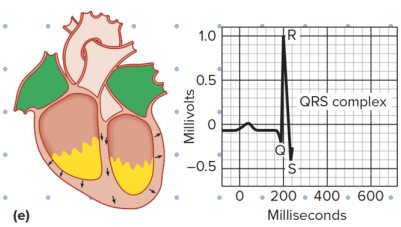


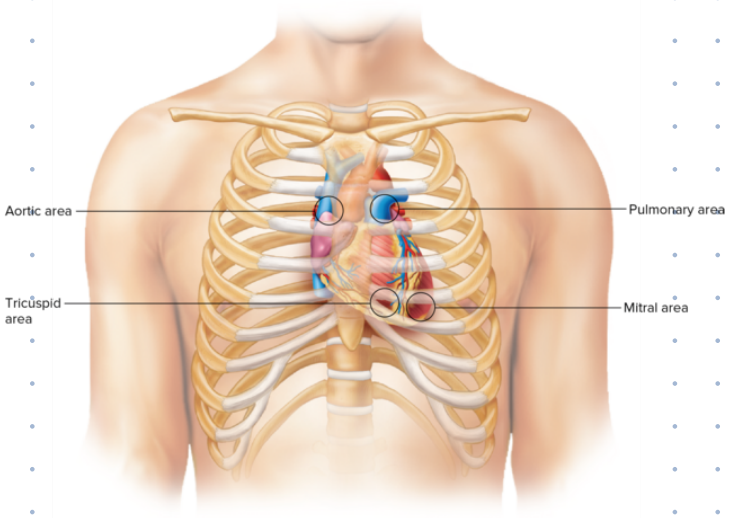

A normal ECG




## Heart sounds

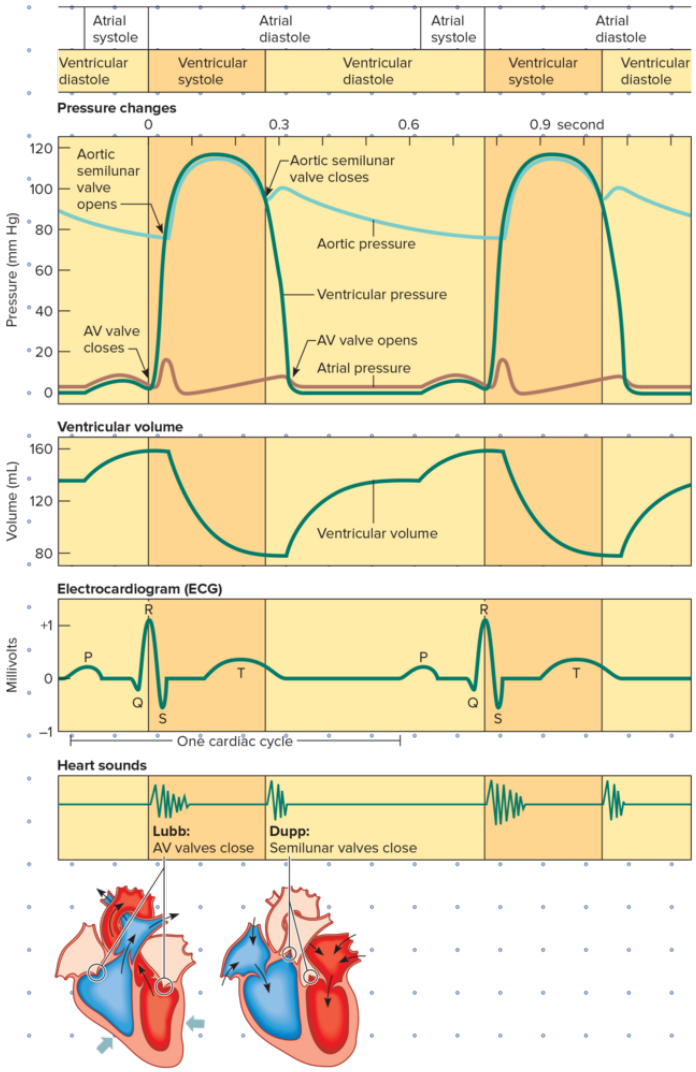
- heartbeat heard through stethoscope sounds like lubb-dupp
- heart sounds are due to vibrations in heart tissues associated w blood turbulence when heart valves close
- first heart sound, "lubb", occurs after ventricular systole begins, when AV valves close
- second heart sound associated w aortic & pulmonary valves are heard by listening from second intercostal space on either side of sternum
- aortic sound comes from right & pulmonic sound comes from left



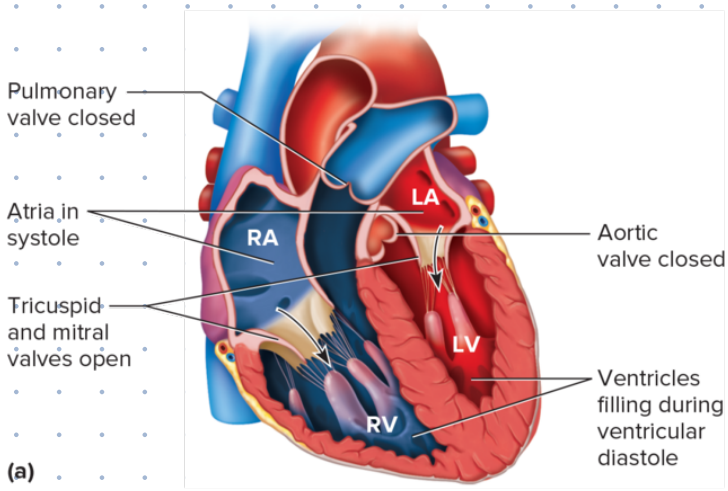



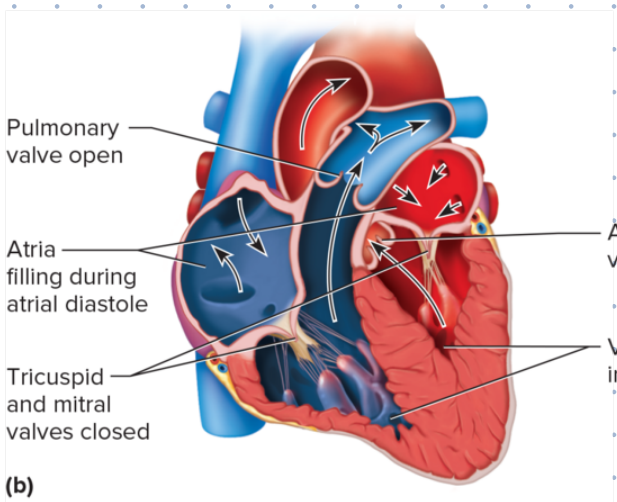

- sound associated w mitral valve can be heard from fifth intercostal space at nipple line on left
- sound of tricuspid valve can be heard at fifth intercostal space left of sternum

## Pressure & Volume Changes During a Cardiac Cycle




During a cardiac cycle, the pressure in the heart chambers rises and falls; pressure changes open and close the valves. Blood flow through the heart is driven by pressure changes, as blood flows down a pressure gradient. Early in ventricular diastole, ventricular pressure is lower than atrial pressure & AV valves open. Ventricles then fill w blood. 70% of returning blood enters ventricles before atria contraction, & the ventricular pressure increases. Following atrial depolarization, atrial systole forces remaining 30% of blood into ventricles, & ventricular pressure increases. When the ventricles have reached the end of their diastole, blood volume in ventricles has peaked. As the atria relaxes, the ventricles depolarize, ventricular contraction begins, & pressure within ventricles rises sharply. When the ventricular pressure exceeds atrial pressure, the AV valves close. At the same time, the papillary muscles contract. By pulling on the chordae tendineae, they prevent the cusps of the AV valves from bulging too far into the atria. During ventricular systole, the AV remains closed. Because the atria are relaxed, pressure within their chambers is low, even lower than venous pressure. As a result, blood flows into the atria from the attached veins. That is, as the ventricles are contracting, the atria are filling with blood, already preparing for the next cardiac cycle.

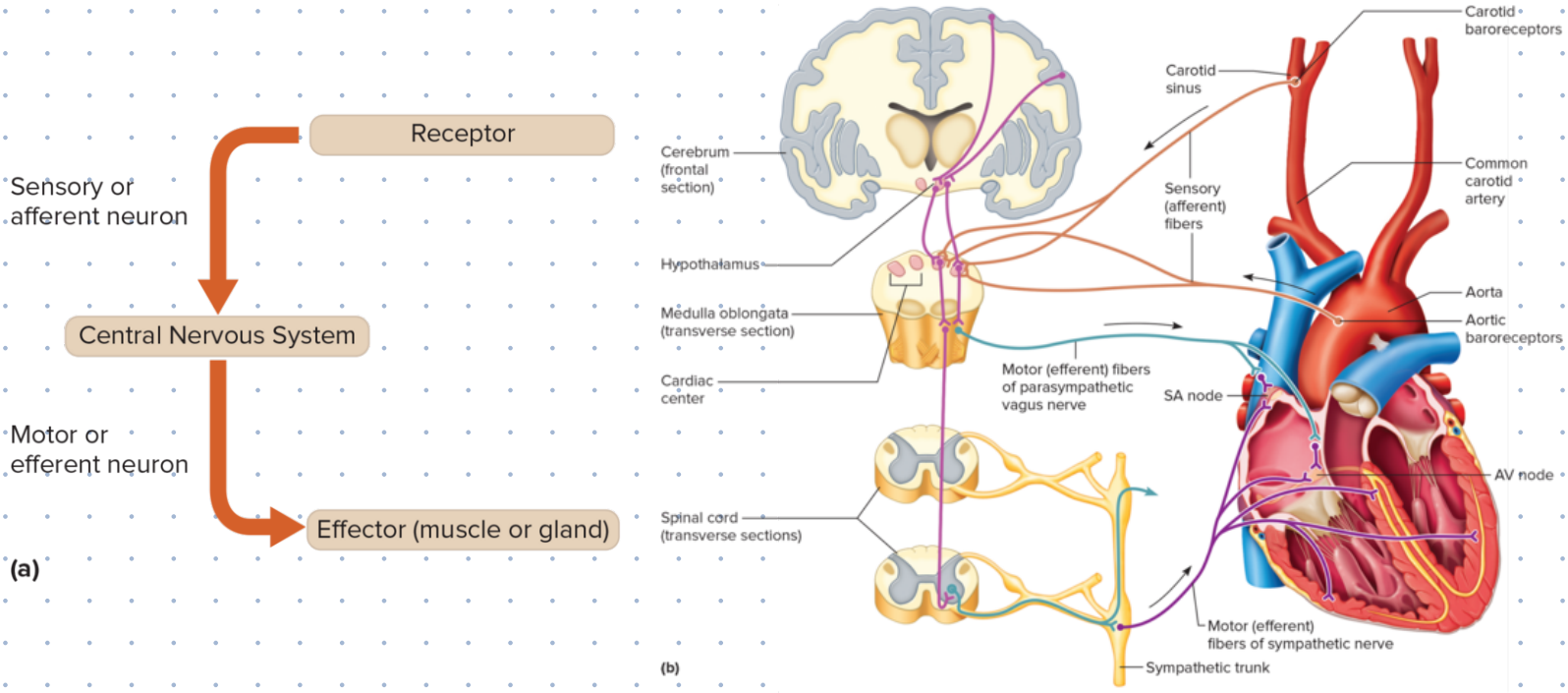



As ventricular systole progresses, ventricular pressure continues to increase until it exceeds the pressure in the pulmonary trunk (right side) & aorta (left side). The pressure differences open the pulmonary & aortic valves, & blood is ejected from each ventricle into its corresponding artery. As blood flows out of the ventricles, ventricular pressure begins to drop. Ventricular repolarization leads to ventricular diastole. Is the ventricles relax, pressure within then drops rapidly compared to the pressure of the order and pulmonary trunk, causing the closure of the semilunar valves. The ventricles continue to relax. As soon as ventricular pressure is less than atrial pressure, the AV valves open, and the ventricles begin to fill once more. During this filling phase, the atria and ventricles are in diastole. The systemic circuit has a high pressure compared to the low pressure of the pulmonary circuit. Although both ventricles eject the same volume of blood, the left ventricle needs a greater strength of contraction to force blood against this higher pressure, which is why the left ventricle has a thicker myocardium than the right ventricle.

## Regulation of the cardiac cycle

- cardiac center in the medulla oblongata is responsible for nervous system regulation of heart




- parasympathetic fibers that innervate heart arise from neurons in medulla oblongata & reach heart via vagus nerves
- sympathetic fibers reach heart by means if accelerator nerves

**hyperkalemia**: elevated blood potassium levels

**hypercalcemia**: excess of calcium ions in blood

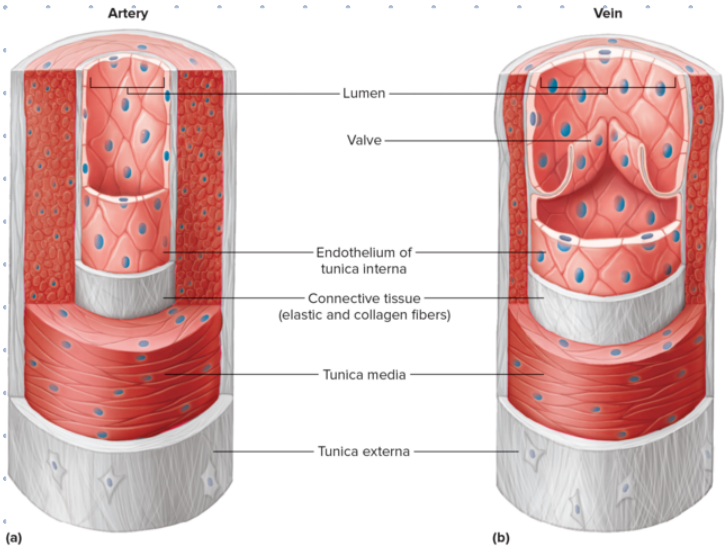
# Chapter 15.4

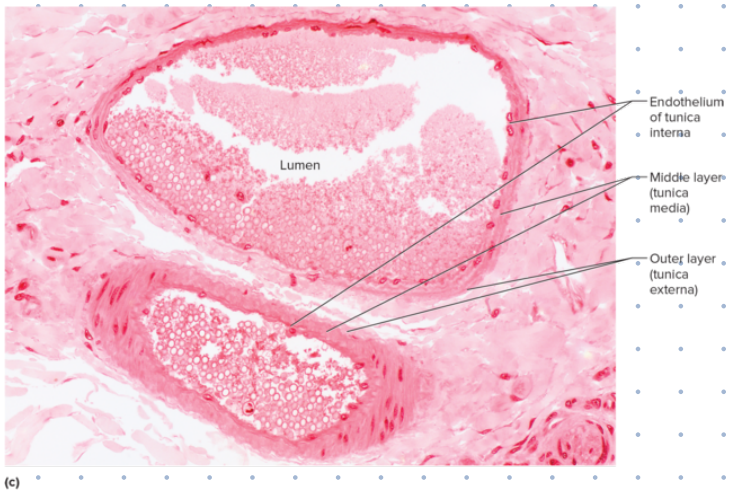
## Arteries & Arterioles

**arteries**: strong, elastic vessels adapted for transporting blood away from heart under relatively high pressure

**arterioles**: small branch of an artery that communicates w a capillary network

- artery wall consists of three layers/tunics: **tunica interna (intima)**, **tunica media**, & **tunica externa (adventitia)**
- **tunica interna is the innermost**, composed if layer of **simple squamous epithelium (endothelium)**, that rests on connective tissue mem. **rich in elastic & collagen fibers**



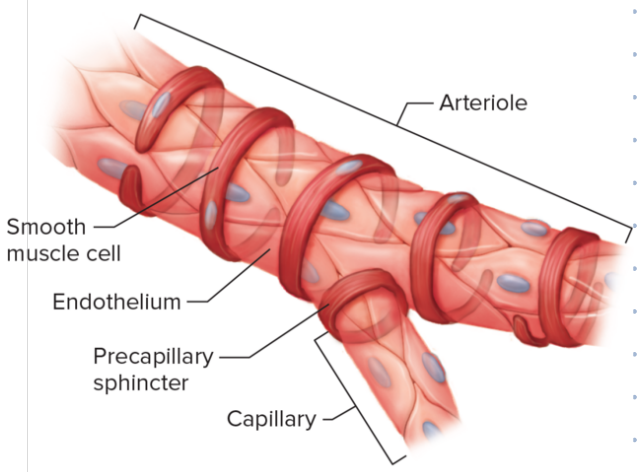



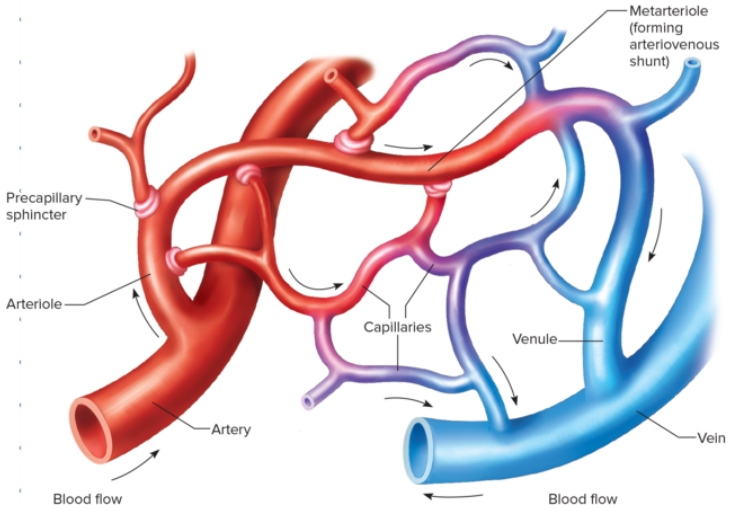

- tunica media is the middle layer & makes up bulk of arterial wall & contains smooth muscle cells that encircle tube & thick layer of elastic connective tissue
- tunica externa is the outermost layer that is relatively thin & chiefly consists of connective tissue w irregular elastic & collagen fibers

vasoconstriction: decrease in diameter of blood vessel

vasodilation: increase in diameter if blood vessel

- walls of larger arterioles have three layers similar to those of arteries but middle & outer layers thin as arterioles approach capillaries
- arterioles give off branches called metatrioles that join capillaries



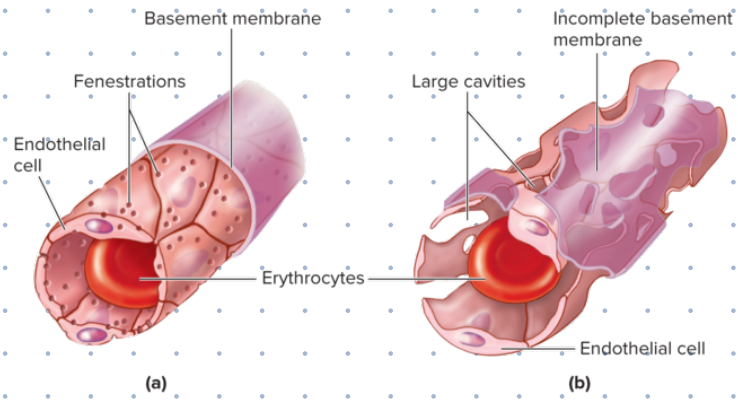



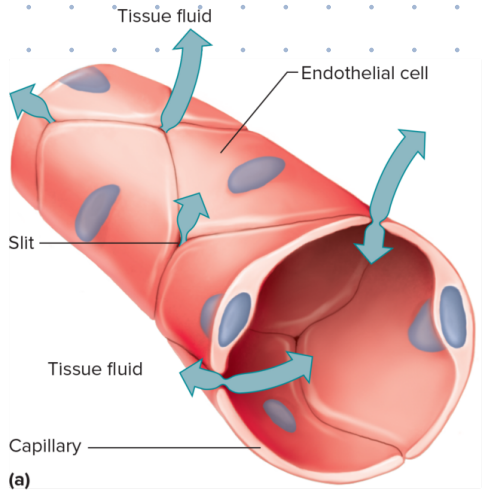

- some places metarterioles connect directly to venules, & blood entering them can bypass capillaries
- connections between arteriole & venous pathways are called arteriovenous shunts

# Capillaries

**Capillaries**: smallest-diameter blood vessels that most often connect smallest arterioles & smallest venules

- Capillaries are extensions of inner linings of arterioles in that their walls are endothelium

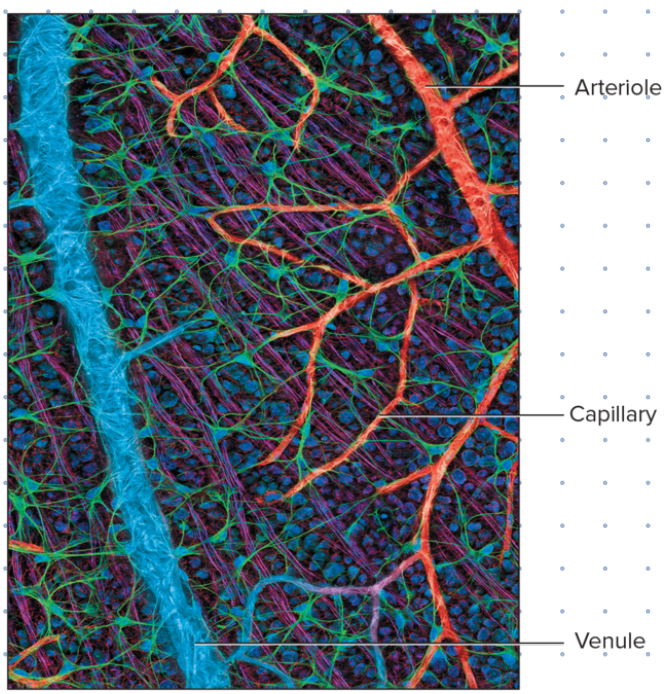



- Single layer of squamous epithelial cells
- Thin walls form semipermeable layer

**Continuous capillaries** associated w muscle tissue, most conn. & nervous tissue

**Fenestrated capillaries** associated w endocrine glands, kidneys, & small intestine lining




- Fenestarted capillaries have large holes within their plasma membranes & between endothelial cells which make them more "leaky"

**Sinusoidal capillaries** associated w liver, spleen, & red bone marrow have **largest openings**

- higher tissue's rate of metabolism, the denser its capillary networks
- if adult capillaries were unwound & lined end to end they would be 25,000-60,000 miles long

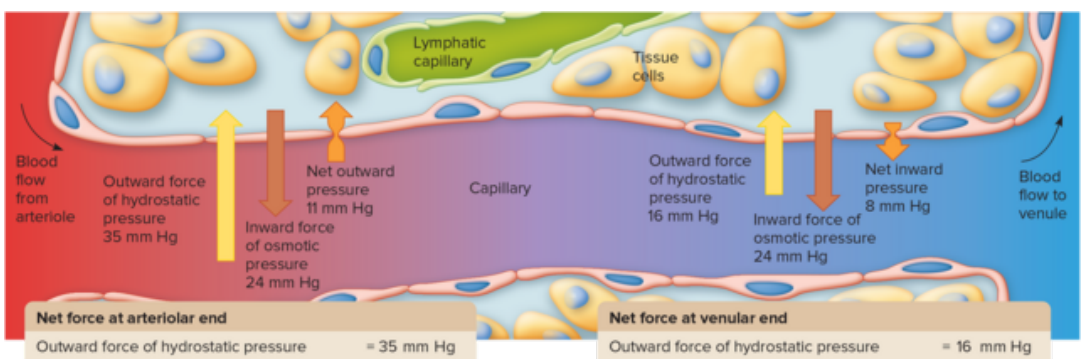
- during exercise blood is directed into capillary networks of skeletal muscles where more oxygen & nutrients is required & produces more metabolic waste (carbon dioxide)

**precapillary sphincter**: smooth muscle that encircles capillary where it branches off to an arteriole/metarteriole

- precapillary sphincter may close a capillary by contracting or open by relaxing

The vital function of **exchanging gases, nutrients, & metabolic by-products between the blood & the tissue fluid surrounding the cells takes place in the capillaries**. The biochemicals exchanged move through the capillary walls by **diffusion, filtration, osmosis, and transcytosis.**

- diffusion is most important means of transfer between blood & tissue fluid
- substances that are soluble in lipid,(oxygen, carbon dioxide, & fatty acids) can diffuse through most cell membrane areas bc they're mainly composed of phospholipids
- plasma proteins (albumins) generally remain in blood bc they're not lipid-soluble & they're too large to diffuse through membrane channels/openings between endothelial cells of most capillaries




| Net force at arteriolar end | |
|---|---|
| Outward force of hydrostatic pressure | = 35 mm Hg |
| Inward force of osmotic pressure | = 24 mm Hg |
| Net outward pressure | = 11 mm Hg |

| Net force at venular end | |
|---|---|
| Outward force of hydrostatic pressure | = 16 mm Hg |
| Inward force of osmotic pressure | = 24 mm Hg |
| Net inward pressure | = 8 mm Hg |

- in filtration, hydrostatic pressure forces molecules through a membrane
- force needed for filtration facilitated by blood pressure in capillaries generated when ventricle walls contract
- walls of arteries & arterioles are too thick to allow blood components to pass

through

- presence of an impermeant soluble on one side of cell membrane creates osmotic pressure
- colloid osmotic pressure describes osmotic effect due to plasma proteins
- at venular end, fluid reabsorption predominates
- histamine may increase blood flow to capillaries causing excess fluid to enter spaces between cells
- pulmonary edema (when lungs fill w too much fluid) can accompany a failing left ventricle/damaged mitral valve
- peripheral edema is when tissues swell

ascites: serous fluid accumulation in abdominal cavity

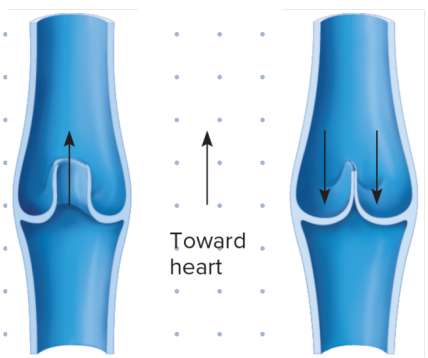
- ascites may occur when there's a decrease in plasma proteins (liver disease)

venules & veins

venules: vessel that transports blood from capillaries to a vein

vein: vessel that transports blood to the heart

- in terms of permeability the smallest of venules are similar to capillaries




- walls of veins are composed of three layers
- vein tunica media is less developed compared to that of the arterial wall
- veins have thinner walls that have less smooth muscle & less elastic connective tissue than comparable arteries (lumens have greater diameter)
- many veins particularly in upper & lower limbs have valves which project inward from their linings
- valves composed of the leaflets that close if blood backs up in a vein

- systemic veins function as blood reservoirs, useful in times of blood loss

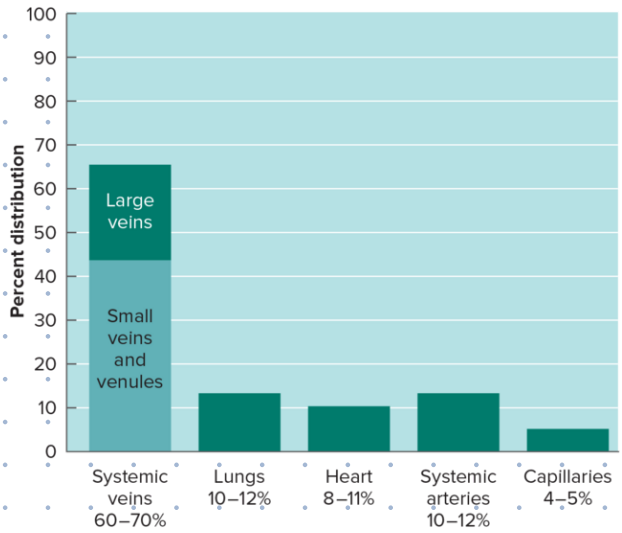



**TABLE 15.3 Characteristics of Blood Vessels**

| Vessel | Type of Wall | Function |
|---|---|---|
| Artery | Thick, strong wall with three layers—an endothelial lining, a middle layer of smooth muscle and elastic connective tissue, and an outer layer of connective tissue | Transports blood under relatively high pressure from the heart to arterioles |
| Arteriole | Thinner wall than an artery but with three layers; smaller arterioles have an endothelial lining, some smooth muscle tissue, and a small amount of connective tissue | Connects an artery to a capillary; helps control the blood flow into a capillary by vasoconstricting or vasodilating |
| Capillary | Single layer of squamous epithelium | Allows nutrients, gases, and wastes to be exchanged between the blood and tissue fluid; connects an arteriole to a venule |
| Venule | Thinner wall than an arteriole, less smooth muscle and elastic connective tissue | Connects a capillary to a vein |
| Vein | Thinner wall than an artery but with similar layers; the middle layer is more poorly developed; some have valves | Transports blood under relatively low pressure from a venule to the heart; valves prevent a backflow of blood; serves as a blood reservoir |

# Chapter 15.5

- term "blood pressure" refers to pressure in arteries supplied by branches of aorta (systemic arteries)

## Arterial Blood Pressure

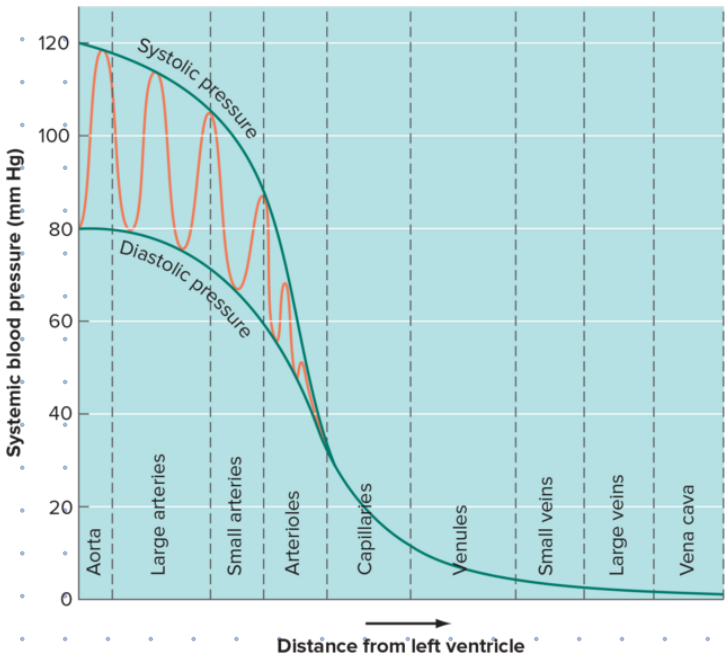
**systolic pressure**: highest arterial blood pressure during cardiac cycle; occurs in systole

**diastolic pressure**: lowest arterial pressure during cardiac cycle; occurs during diastole

**sphygmomanometer**: instrument used for measuring arterial blood pressure

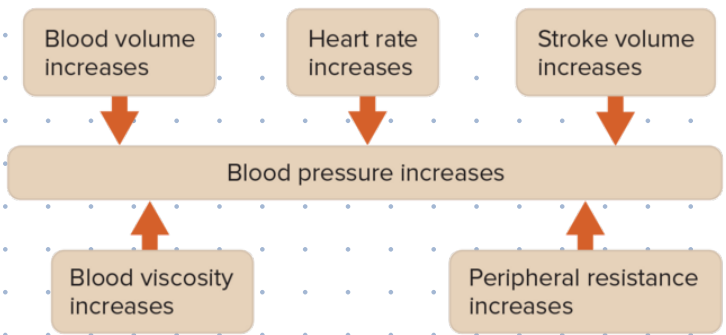
**pulse**: surge of blood pressure felt through artery walls dur to contraction of heart ventricles

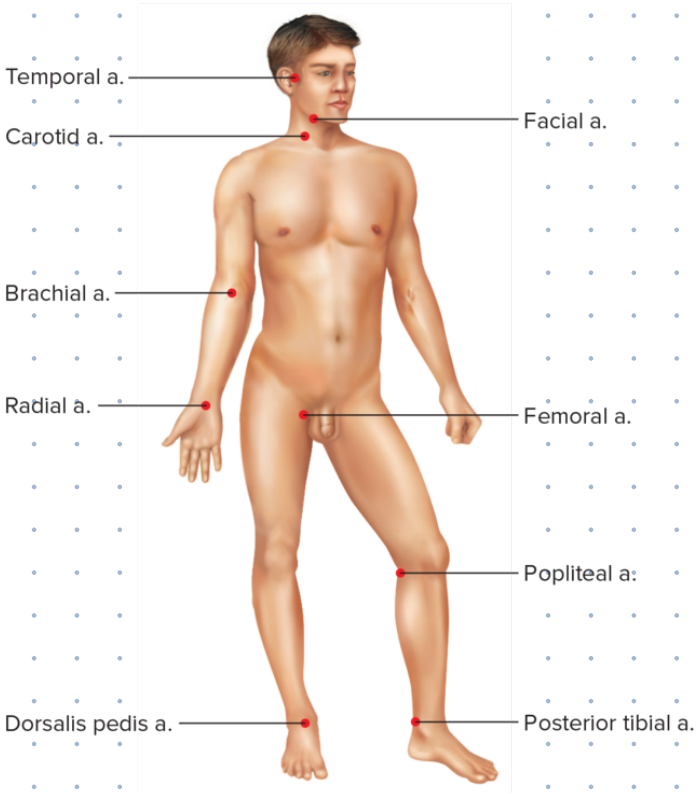
The difference between the **systolic & diastolic pressures (SP-DP)**, called the **pulse pressure (PP)**, is normally about **40 mm Hg**. The average pressure in the arterial system is also of interest because it **represents the average force throughout the cardiac cycle** driving blood to the tissues. To approximate this force, called the **mean arterial pressure**, add the diastolic pressure to one-third of the pulse pressure **(DP + 1/3 PP)**.




## Factors That Influence Arterial BP

- arterial BP depends on a variety of things **(cardiac output, blood volume, peripheral resistance, & blood viscosity)**




**Stroke volume**: volume of blood the ventricle discharges w each heartbeat; SV

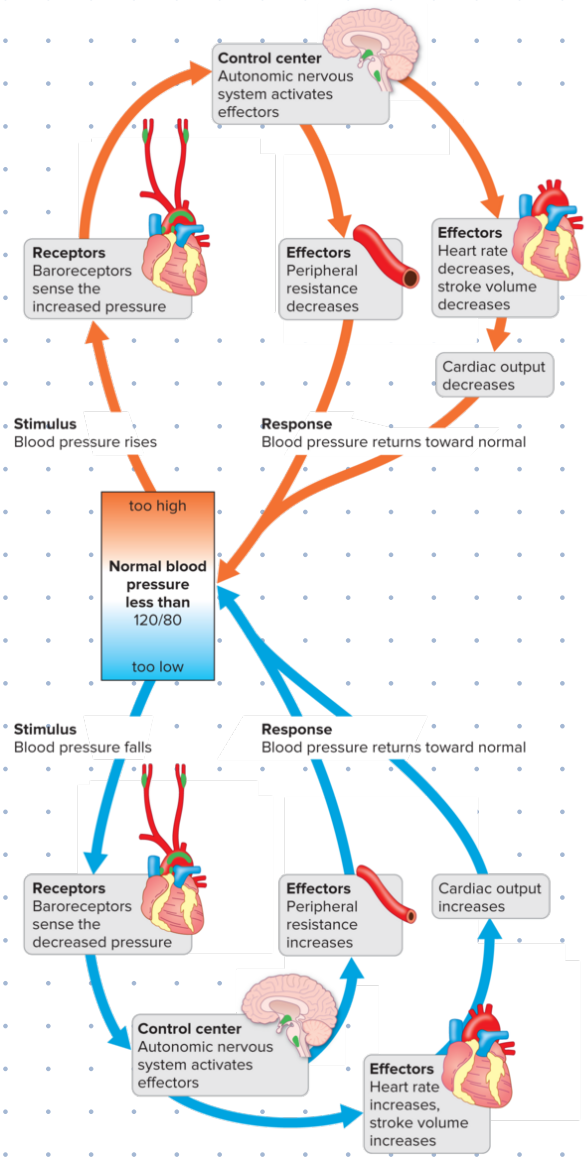
**Cardiac output**: volume of blood per minute that the heart pumps (stroke volume in milliliters multiplied by heart rate in bpm); CO

**Blood volume**: total amount of formed elements & plasma circulating within cardiovascular system

- Blood volume varies w age, body size, & sex (usually 5 liters for adults/8% of body weight in kilograms: 1 kg water = 1 liter)
- Blood vol. & blood pressure can be regulated by hormone release
- antidiuretic hormone (ADH) secreted by posterior pituitary gland in response to dehydration acting on kidneys to retain water

When low blood pressure is detected by the kidneys, the enzyme renin is secreted which begins a process called the renin-angiotensin-aldosterone system (RAAS) that leads to the production of angiotensin II. This hormone stimulates thirst in the hypothalamus & stimulates aldosterone secretion by the adrenal gland. Aldosterone is a hormone that increases sodium retention, & water follows.

Peripheral resistance: resistance to blood flow due to friction between blood & blood vessel walls




Viscosity: difficulty w which the molecules if a fluid flow past one another

Control of Blood Pressure

Blood pressure (BP) is determined by cardiac output (CO) & peripheral resistance (PR) according to this relationship:

- BP = CO x PR

End-diastolic volume: blood volume remaining in the ventricles at the end of ventricular diastole

End-systolic volume: blood volume remaining in the ventricles at the end of ventricular systole

Venous return: cardiac output limited by

amount of blood returning to ventricles

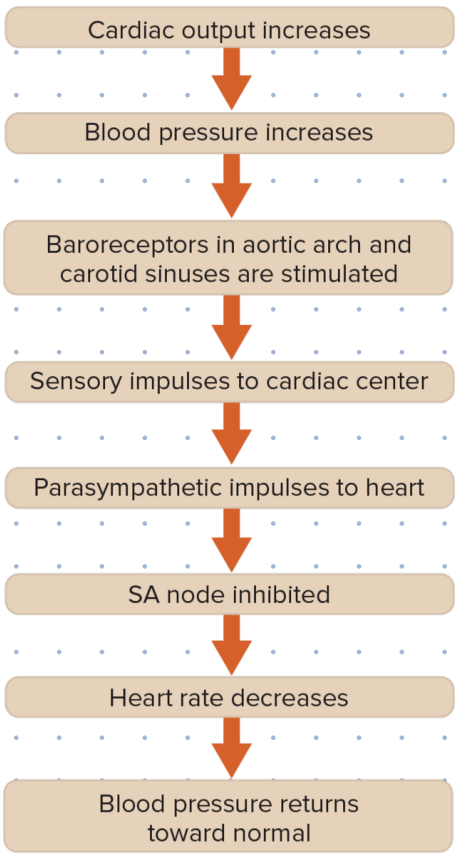
**Preload**: volume of blood filling relaxed ventricles prior to their contraction

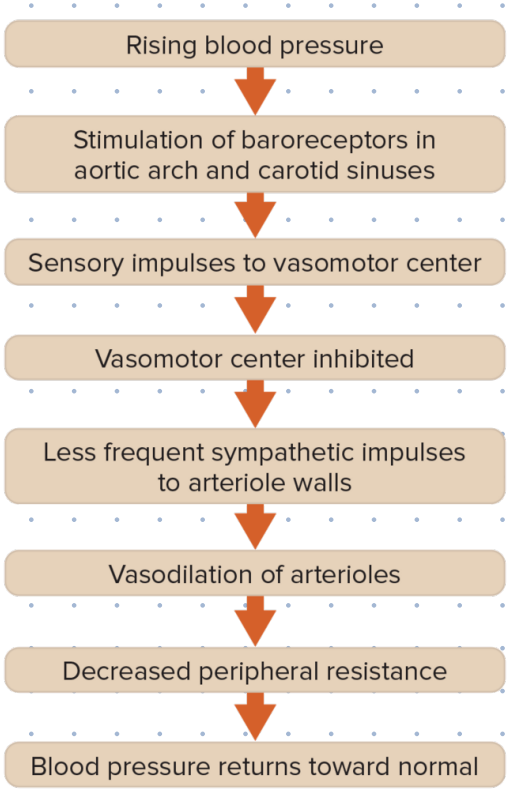
- relationship between cell length (due to stretching of cardiac muscle just before contraction) & force of contraction called **Frank-Starling law of the heart**

**Contractility**: measure if the force generated by contraction of the heart muscle when given volume of blood in the ventricles

**Afterload**: force required to open semilunar valves to eject blood from ventricles; determined largely by **arterial pressure**

- cardiac output & peripheral resistance are controlled in part by **baroreceptor reflexes**
- decreasing arterial BP initiates **cardioaccelerator reflex**, which **sends sympathetic impulses to SA node**




- vasomotor center of medulla oblongata continuously sends sympathetic impulses to smooth muscle in arteriole walls
- vasomotor center's control of vasoconstriction & vasodilation especially important in arterioles of abdominal viscera

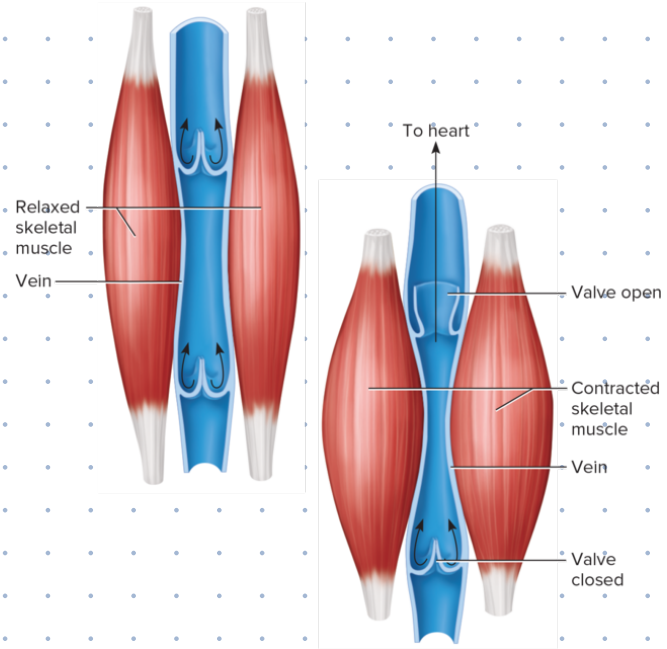
**Venous Blood Flow**

- blood flow through venous system only partially the direct result of heart action & depends on other factors to create a pressure gradient

- contraction of skeletal muscles helps push blood through venous system toward heart
- respiratory movements move venous blood

central venous pressure

- all veins (except those returning to heart from lungs) drain into right atrium
- pressure in right atrium called central venous pressure

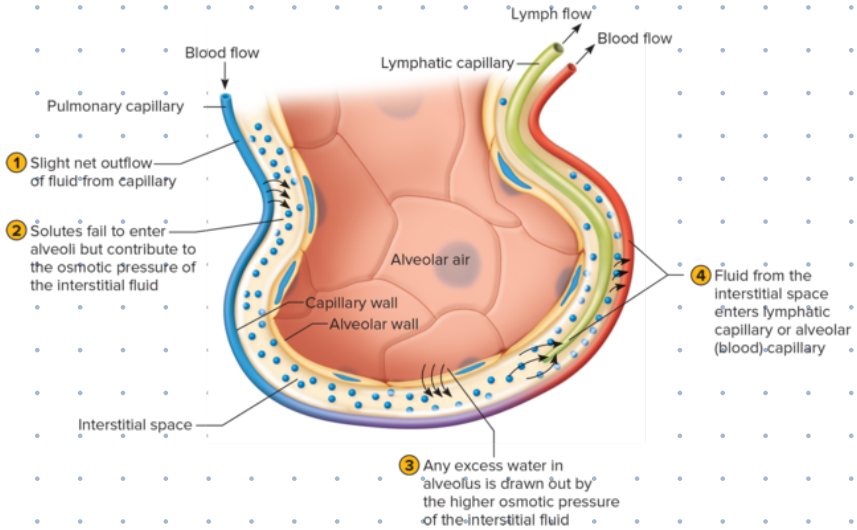



# Chapter 15.6

- two primary paths of circulation: pulmonary circuit & systemic circuit
- pulmonary circuit sends oxygen-poor blood to the lungs to pick up oxygen & unload carbon dioxide
- systemic circuit sends oxygen-rich blood & nutrients all body cells & removes wastes

pulmonary circuit

- in lungs, pulmonary arteries diverge into lobar branches (3 on right side, 2 on left)
- gases are exchanged between blood & air as blood moves through alveolar capillaries
- right ventricle contracts w less force than left
- arterial pressure in pulmonary circuit is less than systemic circuit: alveolar capillary pressure is low
- epithelial cells & alveoli are so tightly joined that sodium, chloride, & potassium ions, as well as glucose and urea, enter interstitial space but do not enter alveoli




- blood entering venules of pulmonary circuit is rich in oxygen & low in carbon dioxide
- four pulmonary veins (two from each lung) return blood to left atrium which completes vascular loop of pulmonary circuit

systemic circuit

oxygen-rich blood moves from the left atrium into the left ventricle. contraction of the left ventricle forces this blood into the systemic circuit, which includes the aorta & its branches that lead to all of the body tissues. The systemic circuit also includes the capillaries, venules, & veins that return blood to the right atrium.

# Chapter 15.7

aortic sinus: swelling in the aortic wall, behind each cusp of the semilunar valve

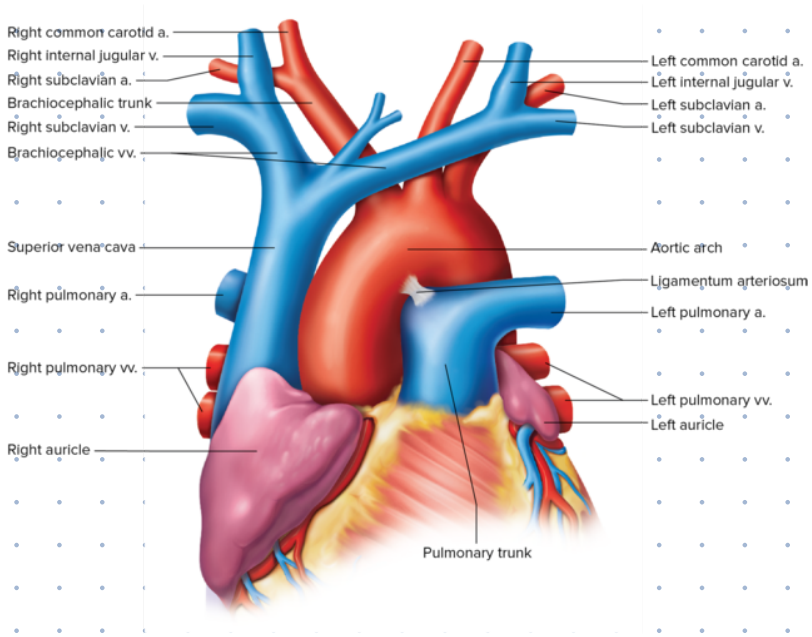
- right and left coronary arteries arise from two aortic sinuses
- three major arteries originate from the arch of the aorta (aortic arch): brachiocephalic trunk, left common carotid artery, & left subclavian artery

aortic bodies: structure associated w the wall of the aortic arch that contains chemoreceptors

The brachiocephalic trunk supplies blood to the tissues of the upper limb & head, as its name suggests. It is the first branch from the aortic arch & rises through the mediastinum to a point near the junction of the sternum in the right clavicle. There it divides, giving rise to the right common carotid artery, which supports blood to the

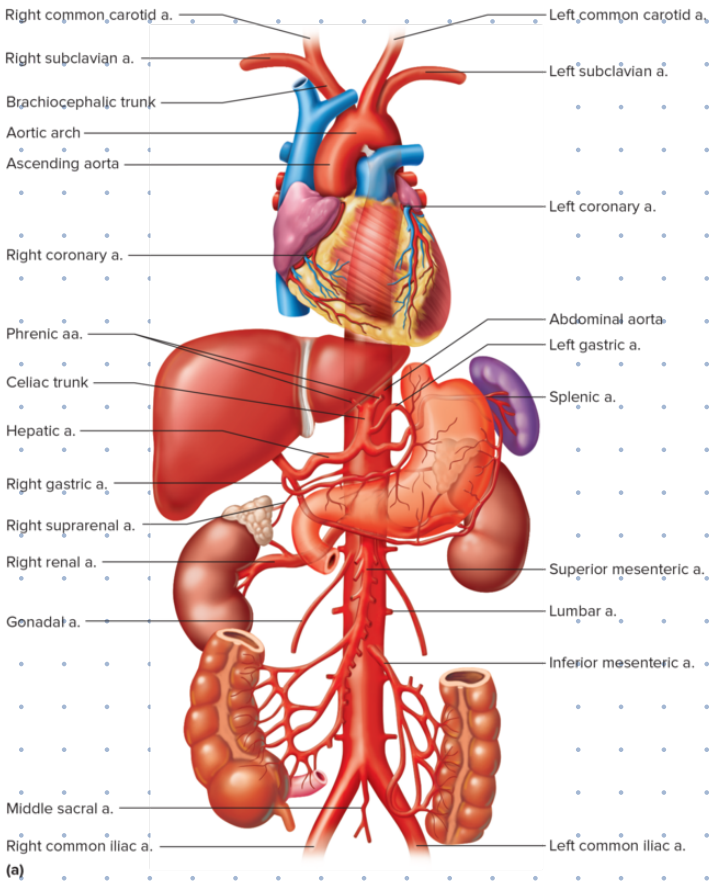
right side of the neck & head, & the right subclavian artery, which leads into the right arm. Branches of the subclavian artery also supply blood to parts of the shoulder, neck, & head.

- Left common carotid artery & left subclavian artery respectively are second & third branches of aortic arch
- Upper part of descending a order is left of midline but extends mediately & lies anterior to vertebral column at level of 12 thoracic vertebrae
- Part of descending aorta above diaphragm is thoracic aorta




Below the diaphragm, the descending aorta becomes the abdominal aorta, & it branches to the abdominal wall & several abdominal organs. These branches include the following:

1. Celiac trunk: Left gastric, splenic, and hepatic arteries which supply upper portions of the digestive tract, spleen, & liver, respectively
2. Phrenic arteries: Paired arteries that supply blood to diaphragm
3. Superior mesentric artery: Large unpaired vessel that branches to parts of intestinal tract & most of transverse colon of large intestine
4. Suprarenal arteries: Supply blood to adrenal glands
5. Renal arteries: Passed laterally from aorta to kidneys, where each artery will divide further in kidney
6. Gonadal arteries: In male & female, in female – paired ovarian arteries arise from aorta & pass into pelvis to supply ovaries; in male-spermatic arteries



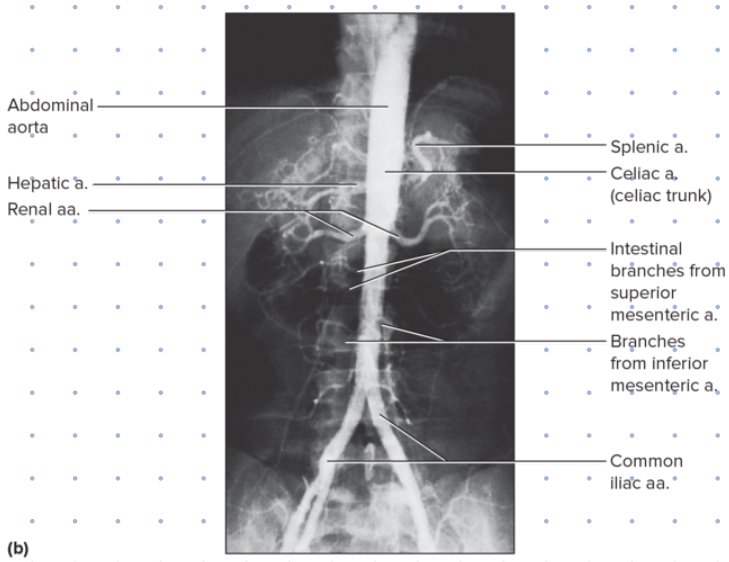

originate in similar locations & course downward and pass through body wall by way of inguinal canal to supply testes

7. **inferior mesenteric artery**: lead to remainder of transverse colon, descending colon, sigmoid colon, & rectum
8. **lumbar arteries**: arise from posterior surface of aorta in lumbar vertebrae region, these arteries supply muscles of skin & posterior abdominal wall
9. **middle sacra artery**: small vessel descends mediately from aorta along anterior surfaces of lower lumbar vertebrae, transports blood to sacrum & coccyx

- **abdominal aorta terminates near brim of pelvis, divides into right and left common iliac arteries**

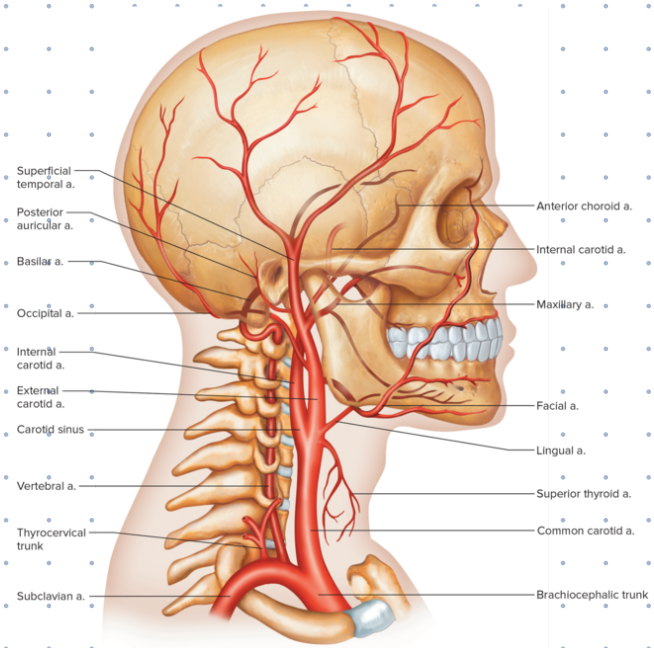
**TABLE 15.4 Major Branches of the Aorta**

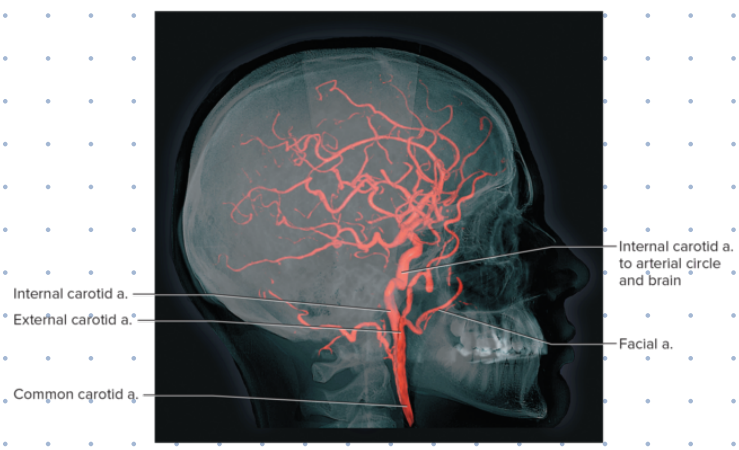
| Portion of Aorta | Branch | General Regions or Organs Supplied |
|---|---|---|
| Ascending aorta | Right and left coronary arteries | Heart |
| Arch of the aorta | Brachiocephalic trunk | Right upper limb, right side of head |
| | Left common carotid artery | Left side of head |
| | Left subclavian artery | Left upper limb |
| Descending aorta | | |
| Thoracic aorta | Bronchial artery | Bronchi |
| | Pericardial artery | Pericardium |
| | Esophageal artery | Esophagus |
| | Mediastinal artery | Mediastinum |
| | Posterior intercostal artery | Thoracic wall |
| Abdominal aorta | Celiac trunk | Stomach, spleen, liver |
| | Phrenic artery | Diaphragm |
| | Superior mesenteric artery | Portions of small and large intestines |
| | Suprarenal artery | Adrenal gland |
| | Renal artery | Kidney |
| | Gonadal artery | Ovary or testis |
| | Inferior mesenteric artery | Lower portions of large intestine |
| | Lumbar artery | Posterior abdominal wall |
| | Middle sacral artery | Sacrum and coccyx |
| | Common iliac artery | Lower abdominal wall, pelvic organs, and lower limb |

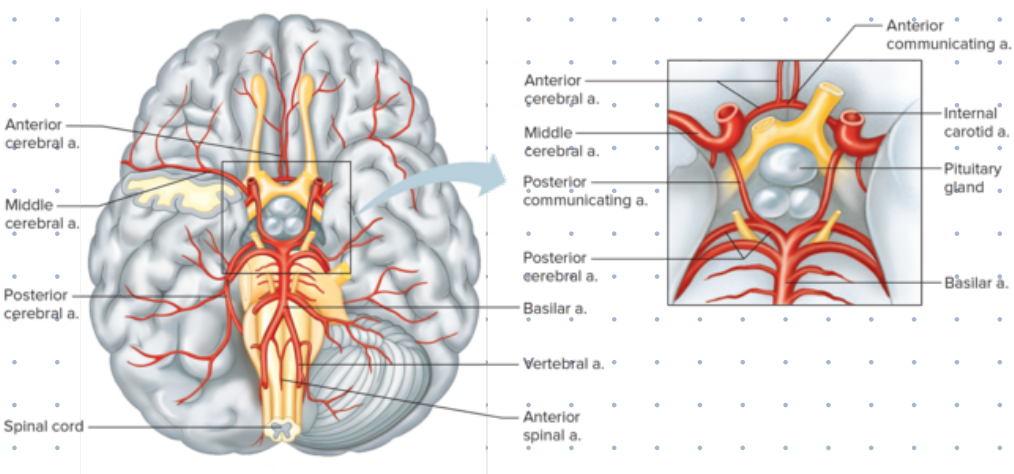


# Arteries to the Brain, Head, & Neck

- Branches of subclavian in common carotid arteries supply blood to brain, head, & neck structures
- Main divisions of subclavian artery to these regions are: vertebral, thyrocervical, & costocervical arteries
- Vertebral arteries arise from subclavian arteries in base of neck near tips of lungs
- In cranial cavity, vertebral arteries unite to form a single basilar artery
- Basilar artery terminates by dividing into two posterior cerebral arteries that supply occipital & temporal lobes of cerebrum
- Posterior cerebral arteries help form cerebral arterial circle (circle of Willis) at base of brain which connects vertebral artery & internal carotid artery systems
- The circle is complete and only 20%–30% of population




- Short vessels branch at thyrocervical axis to thyroid gland, parathyroid glands, larynx, trachea, esophagus, & pharynx, as well as to various muscles in neck, shoulders, & back

- costocervical arteries are third vessels to branch from subclavians, carry blood to muscles in neck, back, & thoracic wall

The left & right common carotid arteries ascend deeply in the neck on either side. At the level of the upper laryngeal border, they divide to form the internal & external carotid arteries.

The external carotid artery courses upward on the side of the head, giving off branches to structures in the neck, face, jaw, scalp, & base of skull. The main vessels that originate from this artery include the following:

1. superior thyroid artery to the hyoid bone, larynx, & thyroid gland
2. lingual artery to the tongue, muscles of the tongue, & salivary glands beneath the tongue
3. facial artery to the pharynx, palate, chin, lips, & nose
4. occipital artery to the scalp on the back of the skull, meninges, mastoid process, & various neck muscles
5. posterior auricular artery to ear & scalp over ear

The external carotid artery terminates by dividing into the maxillary and superficial temporal arteries. The maxillary artery supplies blood to the teeth, gums, jaw, cheek, nasal cavity, eyelids, & meninges. The superficial temporal artery extends to the parotid salivary gland into various surface regions of the face & scalp.

The internal carotid artery begins lateral to the external carotid artery, then extends mediately to follow a deep course upward along the pharynx to the base of the skull. Entering the cranial cavity, it provides the major blood supply to the brain. The major branches of the internal carotid artery include the following:

1. ophthalmic artery to eyeball & various muscles & accessory organs within orbit

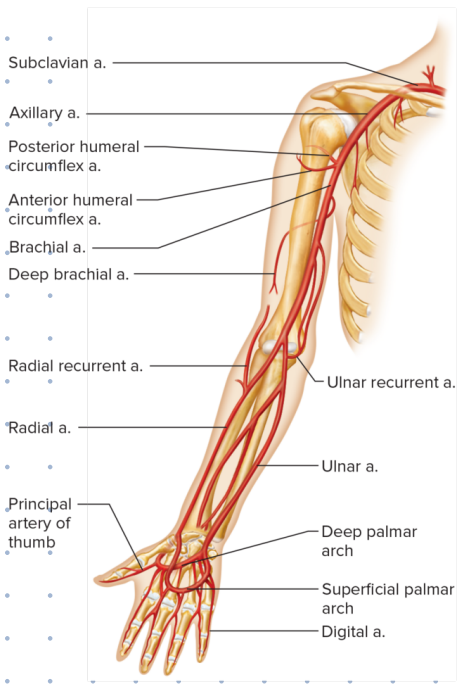
2. posterior communicating artery that forms part of the cerebral arterial circle
3. anterior carotid artery to the choroid plexus within the lateral ventricle of brain into nerve structures in brain

The internal carotid artery terminates by dividing into the anterior & middle cerebral arteries. The middle cerebral artery passes through the lateral tissue & supplies the lateral surface of the cerebrum, including the primary motor & sensory areas of the face & upper limbs, the optic radiation, in the speech area. The anterior cerebral artery extends anteriorly between the cerebral hemispheres & supplies the medial surface of the brain.

Near the base of each internal corroded artery is an enlargement called a carotid sinus that contain baroreceptors that control blood pressure. A number of small epithelial masses, called carotid bodies, are also in the wall of the carotid sinus. The carotid bodies have chemoreceptors that act with those of the aortic bodies in monitoring blood chemistry to regulate circulation & respiration.

## Arteries to the shoulder & upper limb

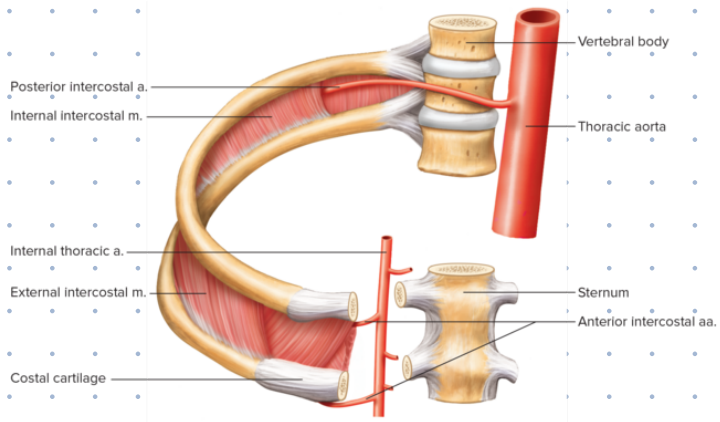
- subclavian artery continues into arm, passes between clavicle & first rib, & becomes axillary artery
- axillary artery supplies branches to structures in axilla & chest wall
- brachial artery courses along humerus to elbow, gives rise to deep brachial artery that curves around the humerus & supplies triceps brachii muscle
- ulnar artery leads downward on ulnar side of forearm to wrist
- radial artery (continuation of brachial artery) extends along radial side of



forearm to wrist

## Arteries to the Thoracic & Abdominal Walls

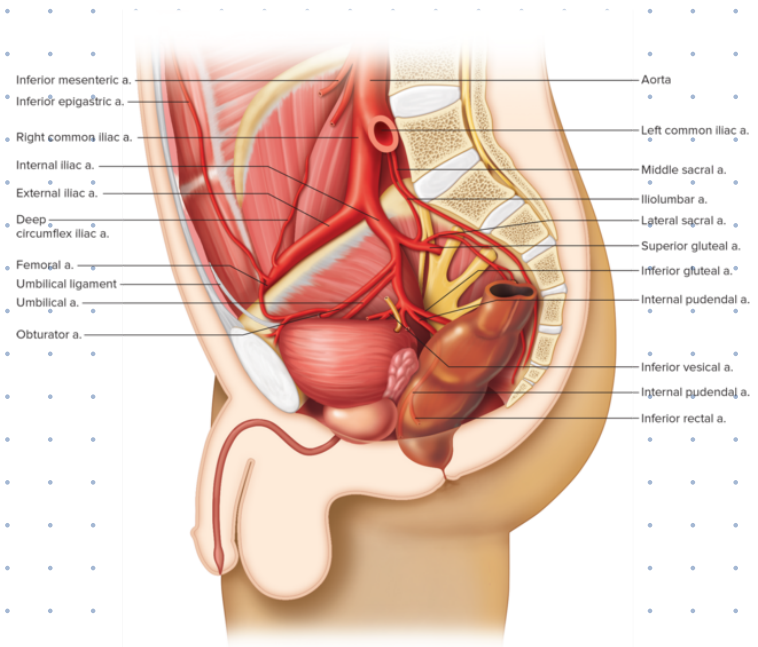
- Blood reaches thoracic wall through vessels including subclavian artery & thoracic aorta




- Subclavian artery contributes to supply through internal thoracic artery that originates in base of the neck & passes downward on pleura & behind upper six rib cartilage; gives off to interior intercostal arteries to upper six intercostal spaces
- Posterior intercostal arteries arise from thoracic aorta & enter intercostal spaces between 3rd-11th ribs & branch to supply intercostal muscles, vertebra, spinal cord, & deep muscles of back
- Internal thoracic & external iliac arteries provide blood to anterior abdominal wall: paired vessels originating from abdominal aorta including phrenic & lumbar arteries, supply blood to structures in lateral & posterior abdominal wall

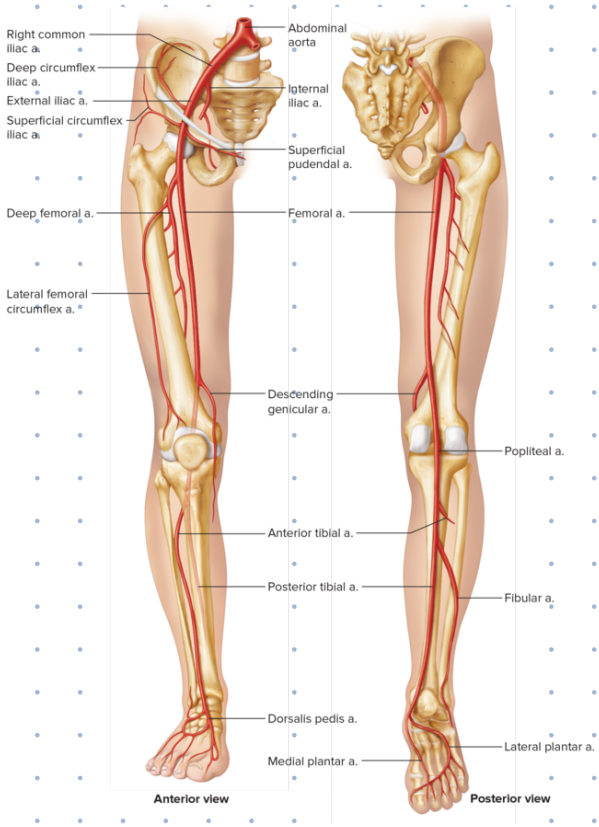
## Arteries to the Pelvis & Lower Limb

- Abdominal artery divides to form common iliac arteries at level of pelvis brim: vessels provide blood to pelvic organs, gluteal region, & lower limbs
- Internal iliac artery gives off many branches to various pelvic muscles & visceral structures, as well as two gluteal muscles and external genitalia



Important branches of this vessel include the following:

1. **iliolumbar artery** to ilium & muscles of the back
2. **superior and inferior gluteal arteries** to the gluteal muscles, pelvic muscles, & skin of buttocks
3. **interior pudendal artery** to muscles in the distal portion of the alimentary canal, external genitalia, and hip joint
4. **superior & inferior vesicle arteries** to the urinary bladder; in males, these vessels also supply the seminal vesicles & the prostate gland
5. **middle rectal artery** to the rectum
6. **uterine artery** to the uterus and vagina
7. **obturator artery** to the adductor muscles of the thigh



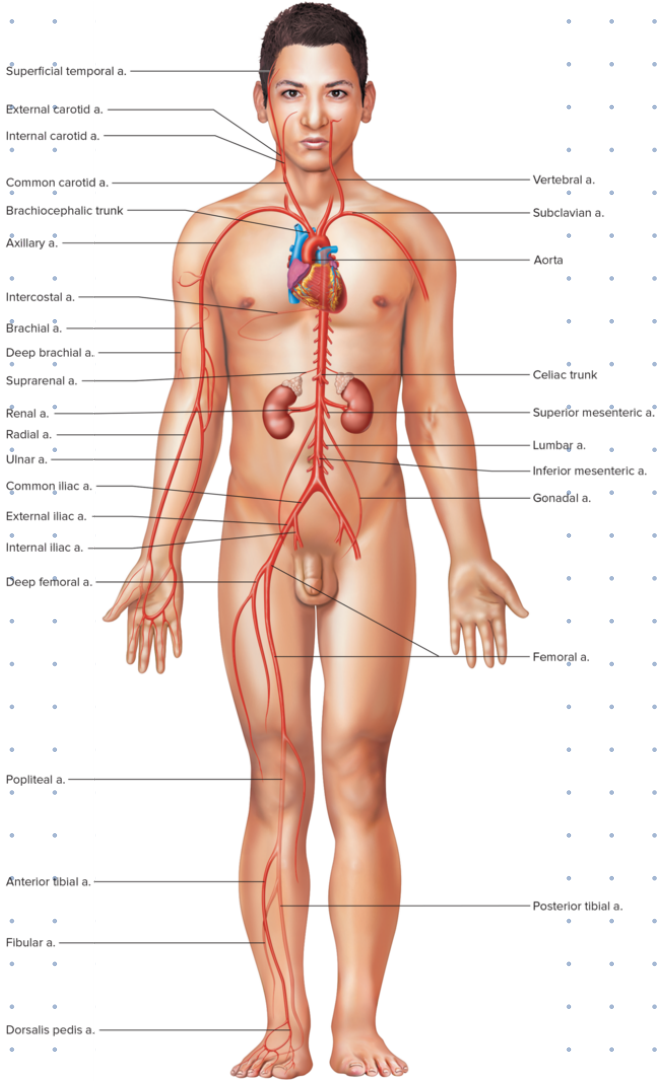

- **external iliac artery provides main blood supply to lower limbs**; passes downward along brim of pelvis & gives off two large branches: inferior epigastric artery & deep circumflex iliac artery
- midway between pubic symphysis & anterior superior iliac spine, the **external iliac artery becomes femoral artery**

The femoral artery, which passes fairly close to the anterior surface of the upper thigh, gives off many branches to muscles & superficial tissues of the thigh. These branches also supply the skin of the groin in the lower abdominal wall.

Important subdivisions of the femoral artery include the following:

1. **superficial circumflex iliac artery** to the lymph nodes & skin of the groin
2. **superficial epigastric artery** to the skin of the lower abdominal wall

3. superficial and deep external pudendal arteries to the skin of the lower abdomen & external genitalia
4. deep femoral artery (largest branch of the femoral artery) to the hip joint & muscles of the thigh
5. deep genocular artery to distal ends of thigh muscles & to an anastomosis around the knee joint



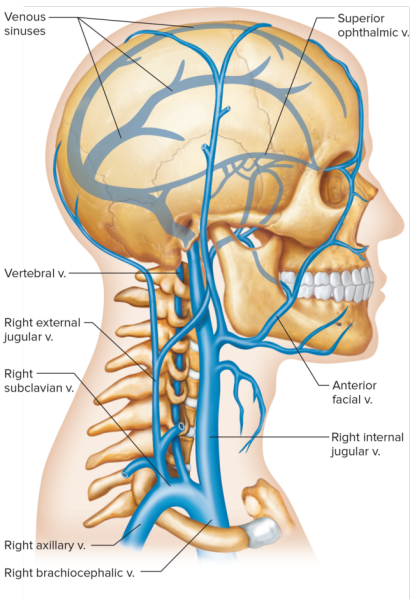

- as femoral artery passes behind medial distal femur & reaches proximal border of popliteal fossa, it becomes popliteal artery
- anterior tibial artery passes downward between tibia & fibula & continues into the foot as dorsalis pedis artery, supplying blood to instep & toes
- posterior tibial artery (larger of the two popliteal branches) descends beneath the calf muscles giving off branches to skin, muscles, & other tissues of the leg
- largest branch of posterior tibial artery is fibular artery, which extends downward along fibula & contributes to anastomosis of ankle

# Chapter 15.8

venous circulation returns blood to the heart after gases, nutrients, & waste are exchanged between the blood & body cells.

## Veins from the Brain, Head, & Neck

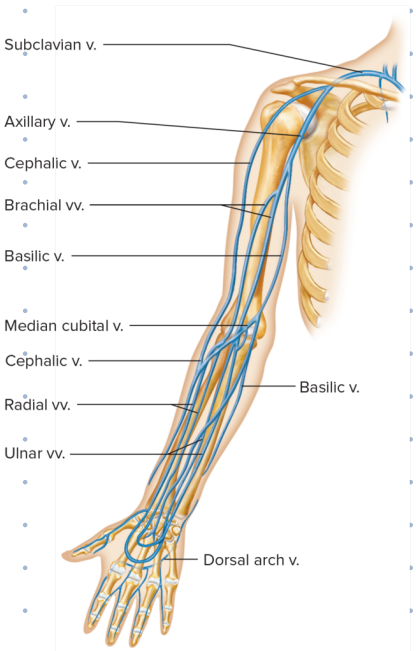
- External jugular veins drain blood from face, scalp, & superficial neck regions; they just found on either side of the neck, passing over the sternocleidomastoid muscles & beneath platysma, & empty into the right & left subclavian veins at neck base




- Internal jugular veins arise from many veins and venous sinuses of brain & from deep veins in parts of face & neck
- Unions of internal jugular and subclavian vein's form large brachiocephalic veins on each side, then merge in mediastinum & give rise to superior vena cava which enters the right atrium

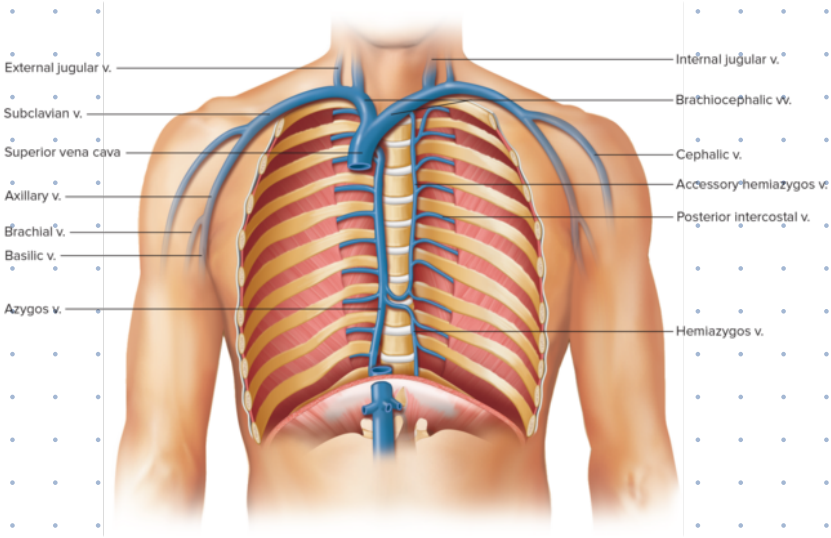
## Veins from Upper Limb & Shoulder

- Deep venous drainage of upper limbs begins in digital veins that drain into pairs of radial veins & ulnar veins, which merge to form a pair of brachial veins
- Basilic vein passes along back of forearm on ulnar side then curves forward to anterior surface below elbow
- Cephalic vein courses upward on lateral side of upper limb from hand to shoulder then pierces tissues & joins axillary vein, beyond the axilla becomes subclavian vein
- In elbow bend, median cubital vein ascends from cephalic vein on lateral side of forearm to basilic vein on medial side; large vein is usually visible beneath the skin & is often used as site for venipuncture when blood sample is needed




## Veins from the Abdominal & Thoracic Walls

- Tributaries of brachiocephalic & azygos veins drain abdominal & thoracic walls




- azygos vein originates in dorsal abdominal wall & ascends through mediastinum on right side of vertebral column to join superior vena cava
- posterior intercostal veins on right side drains intercostal spaces

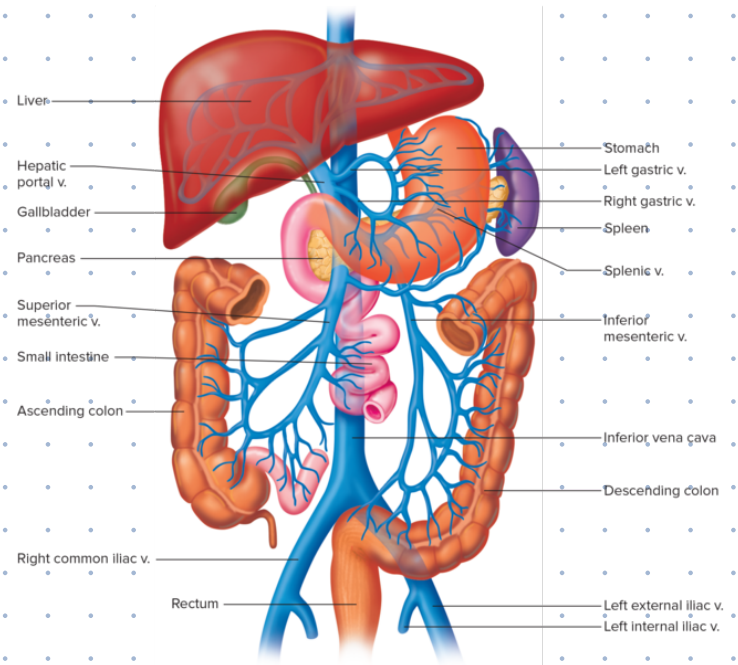
- superior & inferior hemiazygos veins receive blood from posterior intercostal veins on left
- right & left ascending lumbar veins w tributaries that include vessels from lumbar & sacral regions

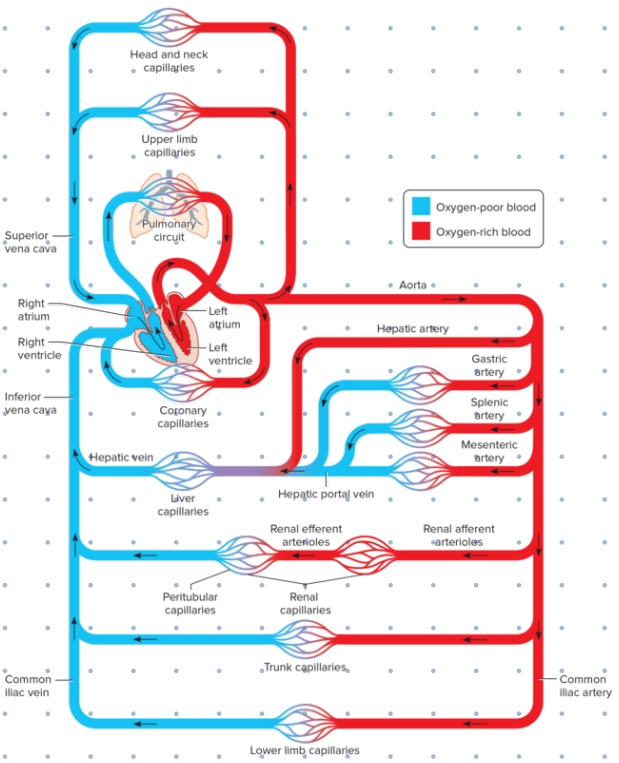
## veins from the abdominal viscera

**hepatic portal**: venous system that returns blood from digestive tract & spleen to liver

**hepatic sinusoids**: vascular channels in hepatic lobules

- hepatic portal system allows blood to flow from gastrointestinal organs to liver before returning to heart



The tributaries of the hepatic portal vein include the following vessels:

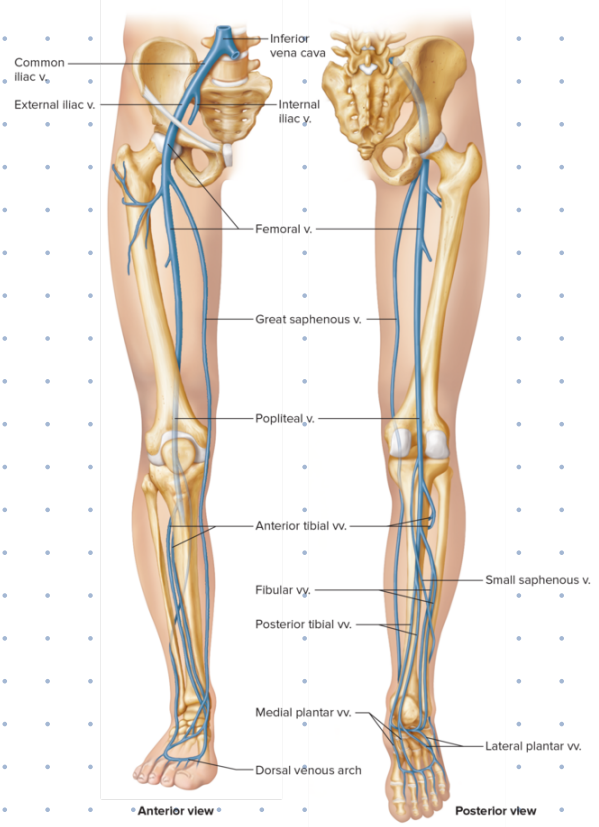
1. right and left gastric veins from stomach
2. superior mesenteric vein from small intestine, ascending colon, & transverse colon
3. splenic vein from a convergence of several veins draining the spleen, pancreas, & portion of stomach; as well as its largest tributary, inferior mesenteric vein from descending colon, sigmoid colon, & rectum

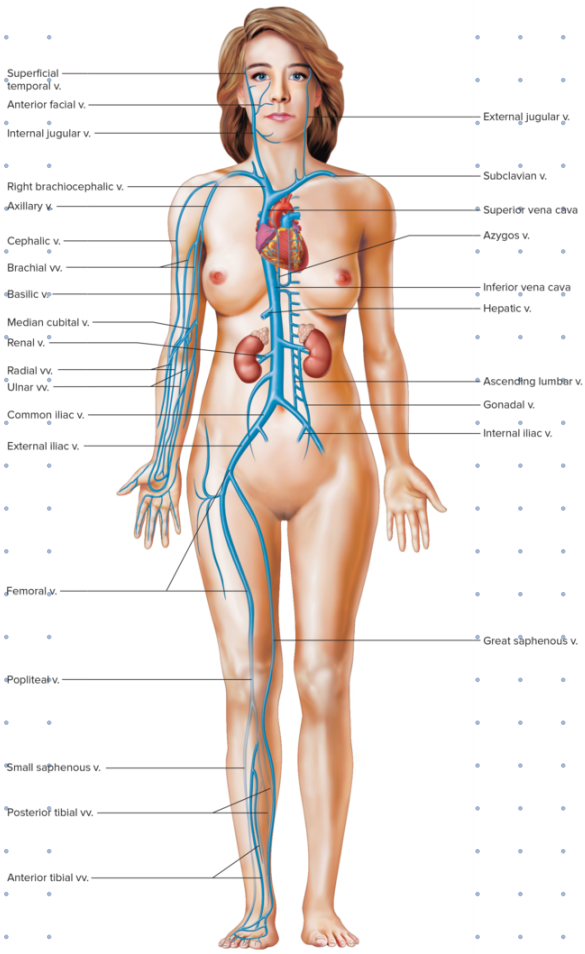
- about 80% of blood flowing to liver in hepatic portal system comes from capillaries in stomach & intestines
- liver helps regulate blood concentrations of recently absorbed amino acids and lipids by modifying them into forms that the cell can use, oxidizing them, or changing them into storage forms

hepatic vein: blood vessels that return low-oxygen blood from your liver back to the heart; these veins empty into the inferior vena cava

veins from the lower limb & pelvis

- at knee level, anterior & posterior tibial vein form single trunk: popliteal vein, which continues upward through thigh as femoral vein then becomes external iliac vein
- small saphenous vein begins in lateral portion of foot & passes upward between lateral malleolus, ascends back of calf, behind knee, & joins popliteal vein
- great saphenous vein (longest vein in body) originates on medial side of foot, ascends front






of medial malleolus, & extends up along medial side of leg & thigh

- in pelvic region, vessels leading to internal iliac veins transport blood away from organs of reproductive, urinary, & digestive systems
- these veins formed by tributaries corresponding to branches of internal iliac artery such as gluteal, pudendal, vesical, rectal, uterine, & vaginal veins
- internal iliac veins originate deep within pelvis and ascend to pelvic brim, then unite w right & left external iliac veins to form common iliac veins, then merge to produce inferior vena cava at level of 5th lumbar vertebra

# Chapter 15.8

- heart may normally shrink slightly with age, but disease may enlarge it
- in vascular system, age-related changes are most apparent in arteries
- veins may accumulate collagen & calcify but do not change as much with age as arteries

one study compared to vascular endothelial linings of athletic & sedentary individuals of various ages & found that the status of the vessels of the exercising elderly were very similar to those of either athletic or sedentary people in their 20s. many studies have correlated regular exercise to lowered heart disease risk in older people.