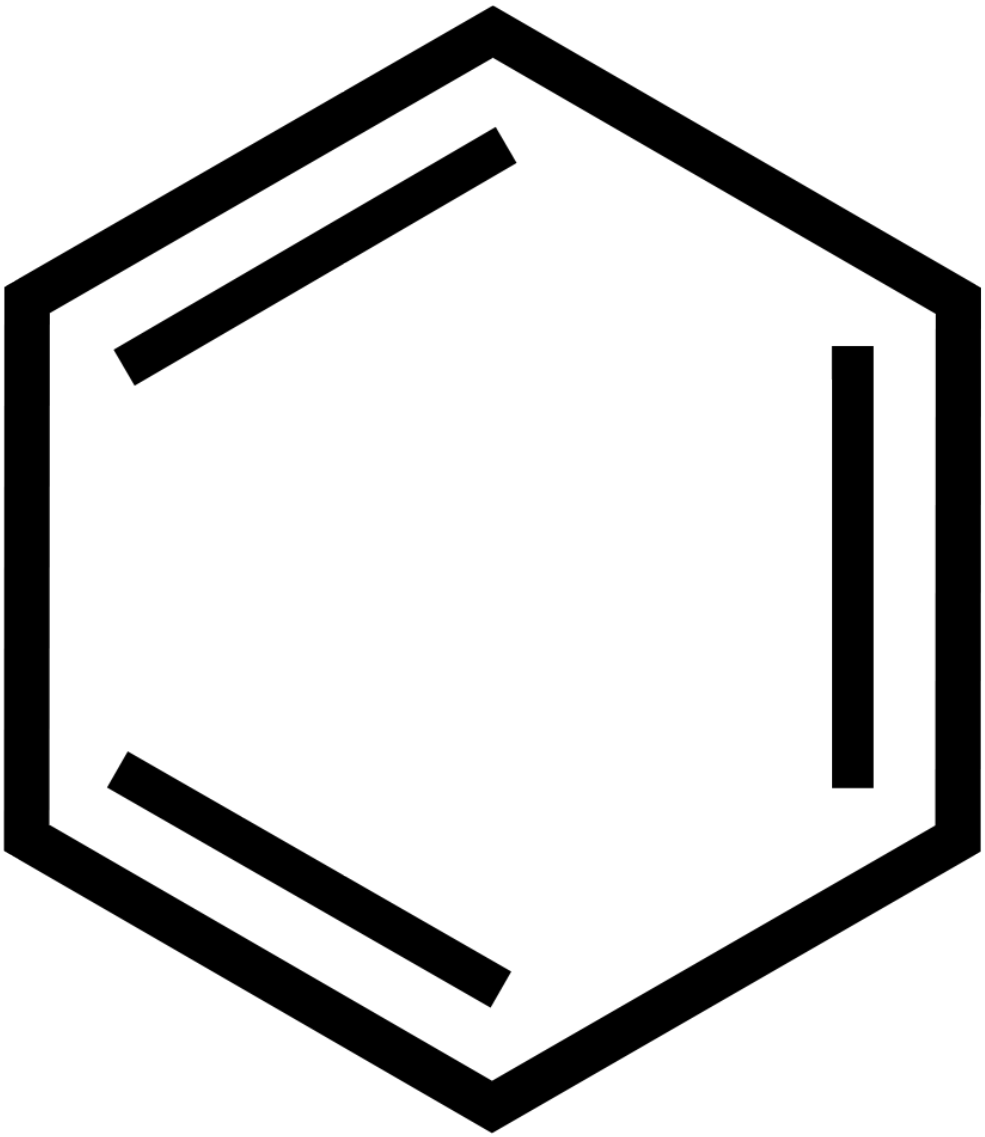

CLUTCH

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CONCEPT: BLOOD FLOW: OHM'S AND POISEUILLE'S LAWS

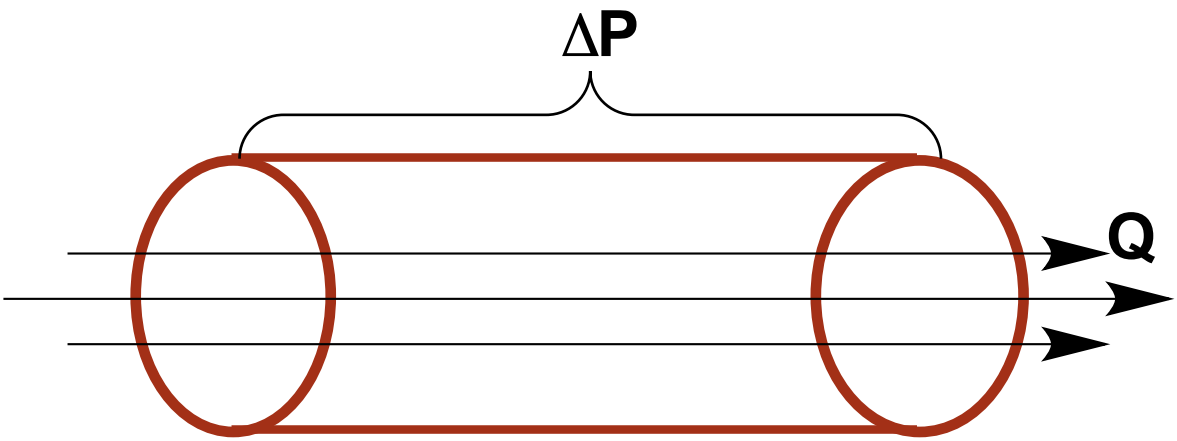
Ohm's Law for Blood Flow:

- Blood flows through blood vessels because of pressure gradients set up by the heart.
  - □ Flow from high pressure (in or near the heart) to low pressure (in the capillaries and veins).
- **Ohm's Law** describes blood flow as a result of pressure gradients.
  - □ $Q = \frac{\Delta P}{R}$

    Q= amount of flow (mL/min) ΔP=pressure gradient R= resistance to flow
  - □ Pressure gradient set by difference in pressure between arteries and veins.

    - $Q = \frac{(P_A - P_V)}{R}$

EXAMPLE: A visual of Ohm's Law for blood flow.

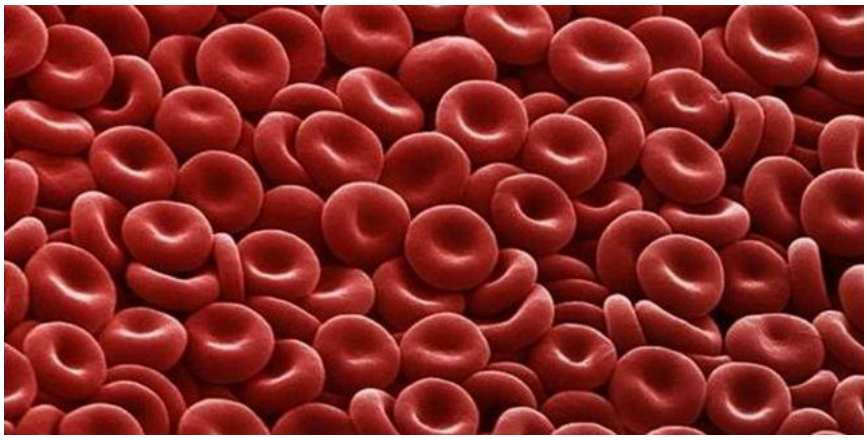


Poiseuille's Law and Resistance to Flow:

- **Poiseuille's Law** lets you determine the resistance to flow for a specific tube or blood vessel.
  - □ $R = \frac{8\eta\ell}{\pi r^4}$

    R= resistance η=viscosity (thickness) of fluid ℓ=length of tube r=radius of tube
- Possible to combine Ohm's and Poiseuille's to make an all-encompassing flow equation:
  - □ $Q = \frac{\Delta P \pi r^4}{8\eta\ell}$

EXAMPLE: Red blood cells are "sticky." Increasing hematocrit—the percentage of your blood that is RBCs—leads to a decrease in flow: ↑η→↑R→↓Q.



PRACTICE 1: Epinephrine is a hormone that binds to α_1 adrenergic receptors on smooth muscle cells in the walls of blood vessels. Binding of epinephrine to α_1 receptors activates an intracellular signaling cascade whose end effect is to cause contraction of the smooth muscle and, thus, constriction of the blood vessel. Which of the following correctly identifies the variable in Poiseuille's Law that will be directly affected by epinephrine binding to α_1 receptors *and* the resulting effect on blood flow through the affected vessels?

a) P | ↑Q
b) P | ↓Q
c) η | ↑Q
d) η | ↓Q
e) r | ↑Q
f) r | ↓Q

PRACTICE 2: Erythropoietin is a hormone that causes an increase in the production and release of red blood cells from the bone marrow. Which of the following correctly identifies the variable in Poiseuille's Law that will be directly affected by an erythropoietin-mediated increase in red blood cell volume *and* the resulting effect on blood flow through the affected vessels?

a) P | ↑Q
b) P | ↓Q
c) η | ↑Q
d) η | ↓Q
e) r | ↑Q
f) r | ↓Q

CONCEPT: THE BLOOD VESSELS

● As blood leaves the ventricle and makes its way back to atrium, it encounters three (general) types of blood vessels: *arteries*, *capillaries*, and *veins.*

□ Have different compositions to match their differing functions.

Arteries:

● **Arteries** carry blood _____ from the heart.

□ Oxygenated blood in systemic loop, deoxygenated blood in pulmonary loop.

● Blood just came from the pumping heart→blood is at a very high pressure.

□ Blood pressure is measured in arteries (more later).

● Arterial walls have lots of *smooth muscle*, which allows them to change their _____.

□ **Vasoconstriction**=vascular smooth muscle *contraction*→↓radius.

□ **Vasodilation**=vascular smooth muscle *relaxation*→↑radius.

□ Smooth muscle and other fibrous tissue makes walls tougher so don't rupture under high blood pressure.

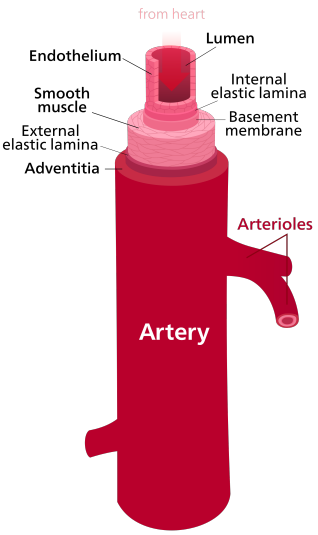
● **Arterioles** are small arteries close to capillary beds.

□ Have lots and lots of smooth muscle→can have big changes in radius.

-Sometimes called the "**Resistance Vessels**" because can change resistance to flow by changing radius.

-Important for promoting/shutting off flow into specific capillary beds.

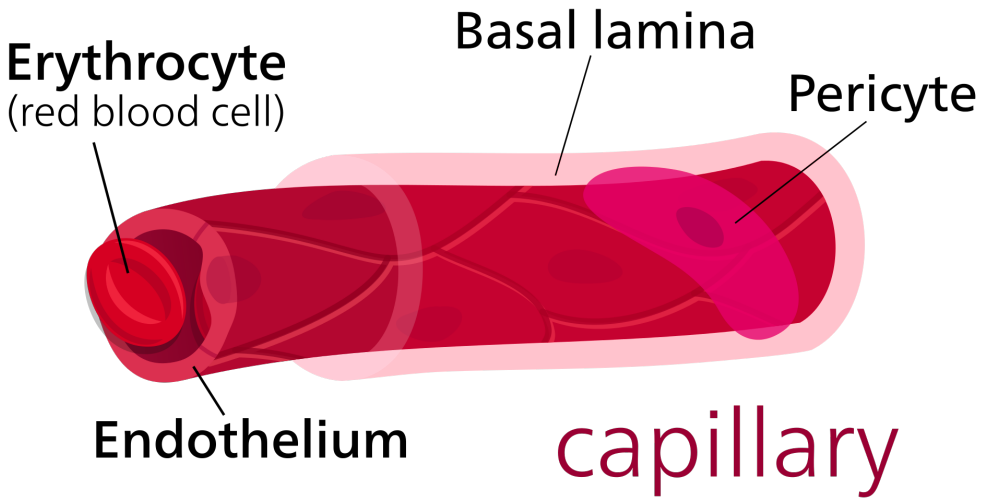
EXAMPLE: Diagram of an artery, showing high percentage of smooth muscle in arterial wall.



Capillaries:

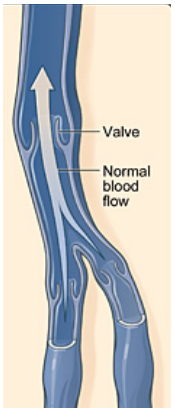
- **Capillaries** are the *only* place where the blood and tissues exchange materials.
    - □ Sometimes called "**Exchange Vessels."**
- Capillary walls are made *only* of one endothelial cell layer.
    - □ No smooth muscle, collagen, other fibrous tissue, etc.
        - -No smooth muscle→no vasoconstriction/vasodilation possible.
    - □ Thin wall allows for more efficient exchange.
- Diameter of a single capillary ≅ diameter of a single RBC.
    - □ RBCs run through capillary single-file, making exchange even more efficient.
- **Precapillary Sphincters**—rings of smooth muscle—control flow into some specific capillary beds.

EXAMPLE: Diagram of a capillary.



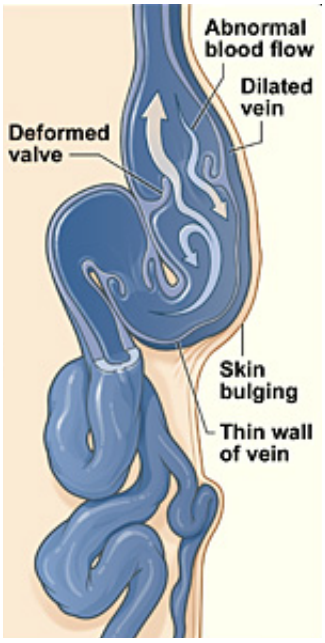
Veins:

- **Veins** carry blood *back to* the heart.
    - □ Deoxygenated in systemic loop, oxygenated in pulmonary loop.
- When in veins, blood has travelled a long distance. Distance, time, and friction reduce pressure.
    - □ Pressure in the veins is very _____ (close to 0 mmHg).
- Because pressure is so low, must be some other driving force to push blood through veins back to heart.
    - □ Veins have *valves*, which prevent backflow.
    - □ **Skeletal Muscle Pump**- Many veins run through middle of skeletal muscle.
        - -When muscle contracts, it squeezes on vein wall, pushing blood forward.



- Walls of veins are much more **compliant**—stretchy—than artery walls.
    - □ Don't have to withstand high pressure like arteries.
    - □ Makes it easier for skeletal muscle pump to work.
    - □ Have *some* smooth muscle, but less than arteries.

EXAMPLE: *Varicose veins* happen when valves become damaged, allowing venous blood to flow backward and pool.



PRACTICE 1: Epinephrine is a hormone that binds to α_1 adrenergic receptors on smooth muscle cells in the walls of blood vessels. Binding of epinephrine to α_1 receptors activates an intracellular signaling cascade whose end effect is to cause contraction of the smooth muscle and, thus, constriction of the blood vessel. Which of the following is the type of blood vessel that will be *most* affected by epinephrine?

a) Artery.
b) Arteriole.
c) Capillary.
d) Venule.
e) Vein.

PRACTICE 2: Epinephrine is a hormone that binds to α_1 adrenergic receptors on smooth muscle cells in the walls of blood vessels. Binding of epinephrine to α_1 receptors activates an intracellular signaling cascade whose end effect is to cause contraction of the smooth muscle and, thus, constriction of the blood vessel. Which of the following is the type of blood vessel that will be *least* affected by epinephrine?

a) Artery.
b) Arteriole.
c) Capillary.
d) Venule.
e) Vein.

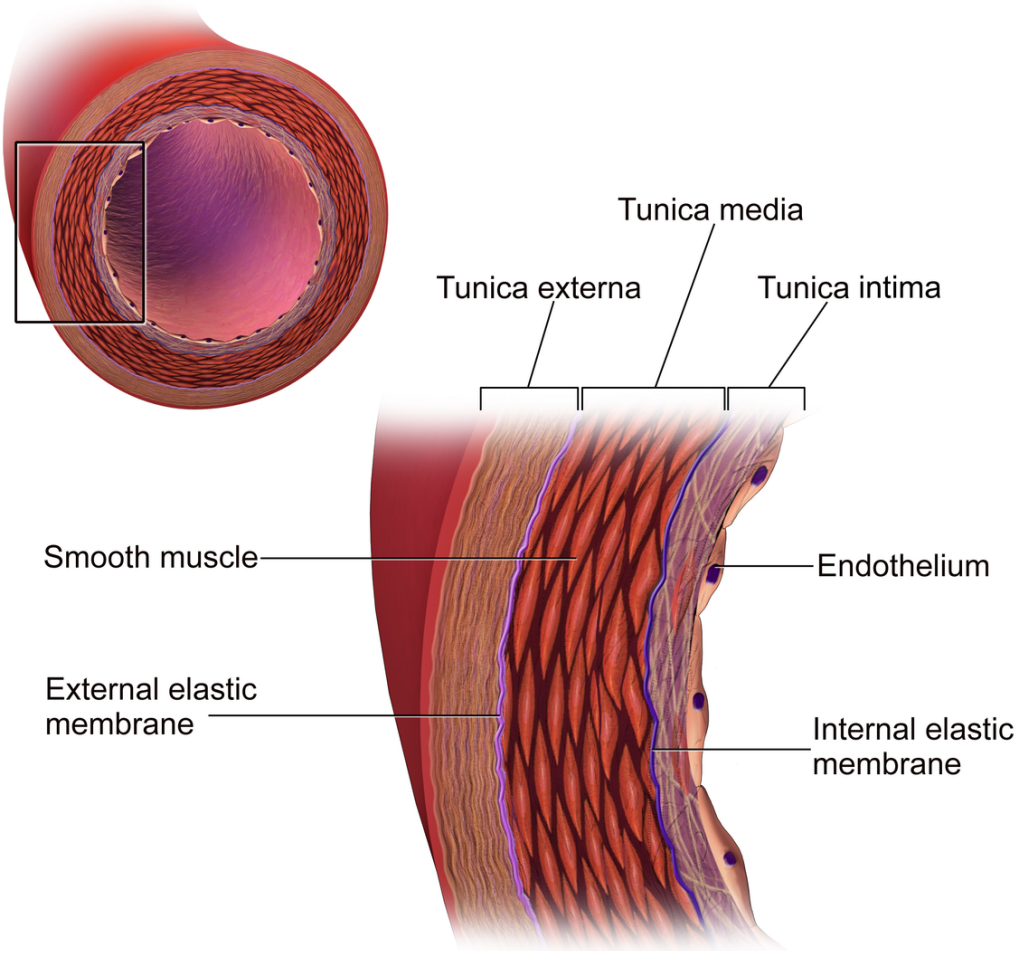
PRACTICE 3: Pregnancy causes a dramatic increase in intraabdominal pressure—the ambient pressure inside the abdomen, pushing from the outside of blood vessels. Which of the following is the type of blood vessel that will be *most* affected by the increase in intraabdominal pressure caused by pregnancy?

a) Artery.
b) Capillary.
c) Vein.

CONCEPT: STRUCTURE OF VESSELS

- Vessels are made up of **tunics** which surround an internal lumen, through which blood _____
  - The **tunic intima** (*tunica interna*) is the innermost tunic
    - Made of **endothelium** (simple squamous epithelium) and areolar connective tissue
    - Intima of veins are often folded to form valves
  - The **tunic media** is the _____ tunic
    - Made of smooth muscle
    - Arteries have a thicker tunica media and a narrow lumen
    - **Vasoconstriction** is a narrowing of the blood vessel lumen
    - **Vasodilation** is the widening of the blood vessel lumen
  - The **tunic externa** (*tunica adventitia*) is the outermost tunic
    - Areolar connection tissue with elastin and collagen fibers
    - Veins: have a thicker tunica adventitia and a larger lumen
    - If the blood vessel is _____, then the tunic externa needs its own blood supply
      - The **vasa vasorum** network of small arteries will supply tunic externa if needed

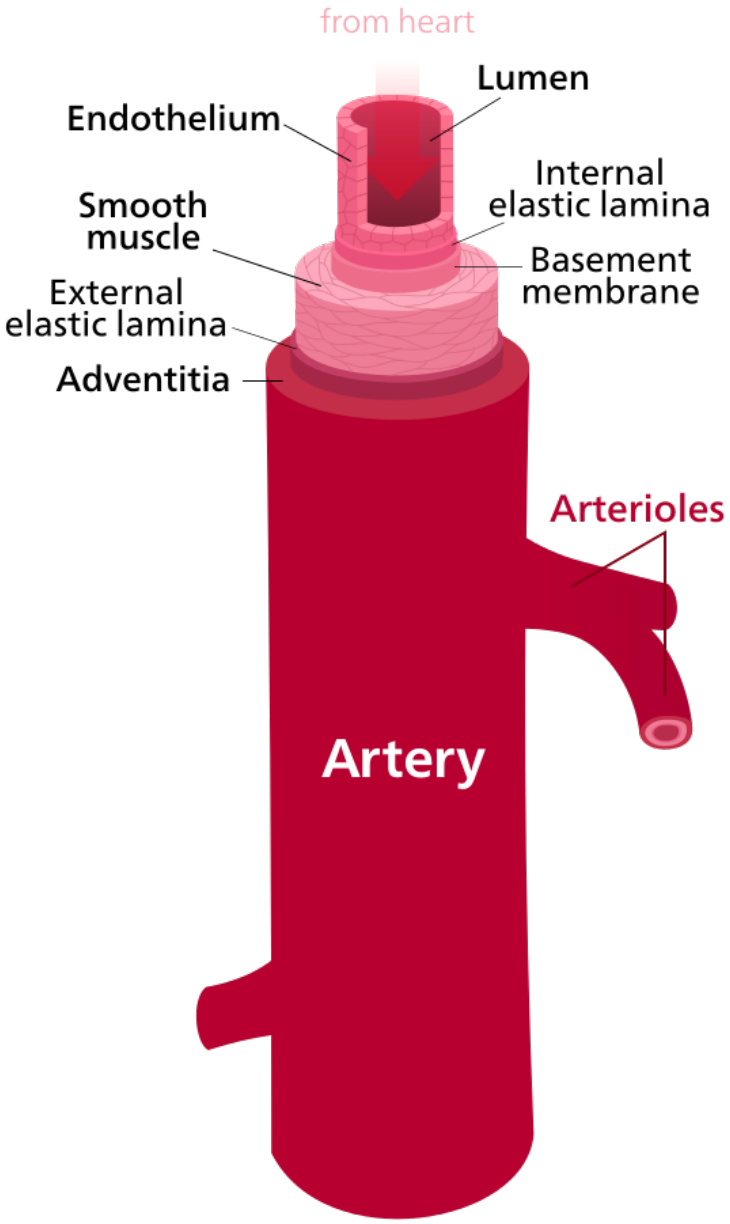
EXAMPLE:


Tunica media
Tunica externa
Tunica intima
Smooth muscle
Endothelium
External elastic membrane
Internal elastic membrane

CONCEPT: STRUCTURE OF ARTERIES

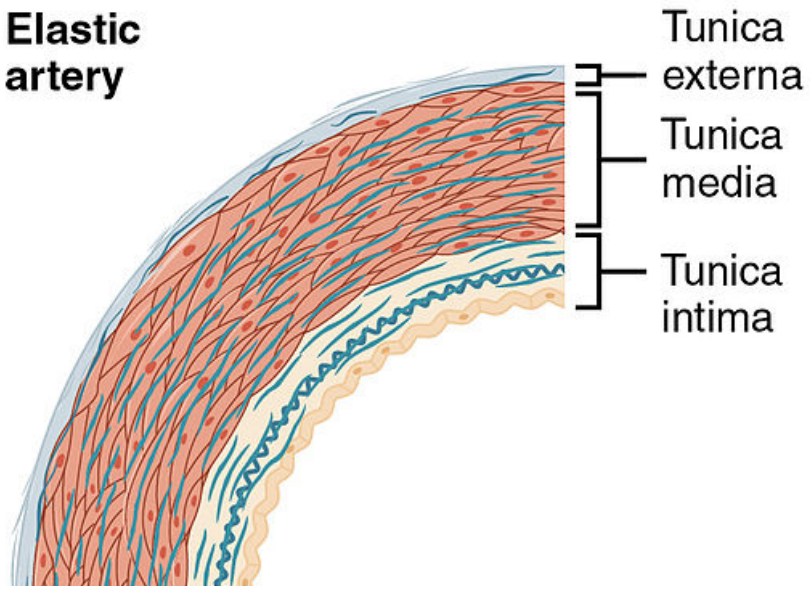
- Arteries near the heart are largest, and they branch into smaller vessels as they travel away from the heart
  - □ This change in size is due to a smaller lumen, and due to less elastin and collagen in the tunic walls
  - □ There are three types of arteries: elastic, muscular, and arterioles

EXAMPLE:



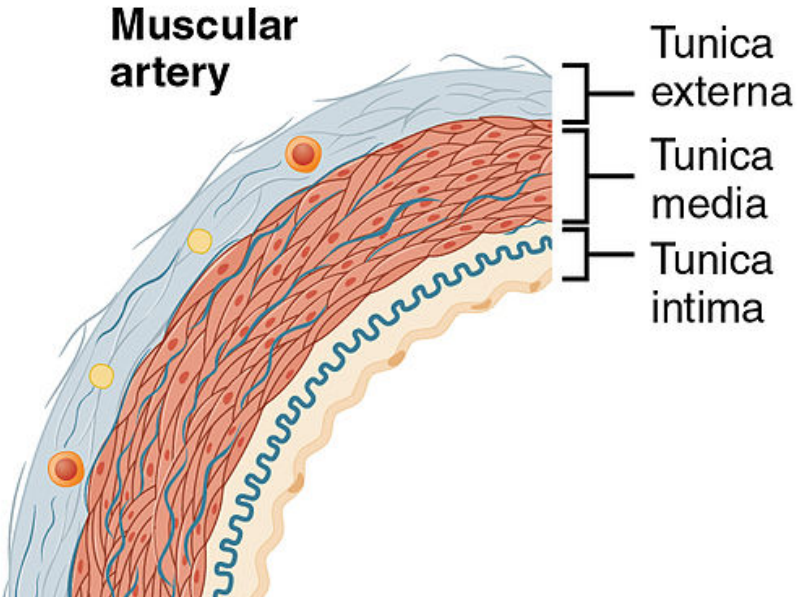
- The **elastic arteries** (conducting arteries) are the largest (2.5-1cm)
    - □ Transport blood from the heart to _____ arteries
    - □ Have a lot of elastic fibers, called **elastic lamellae**, which allow the artery to stretch and hold pumped blood
        - Ex: aorta, pulmonary trunk, and their largest branches

EXAMPLE:



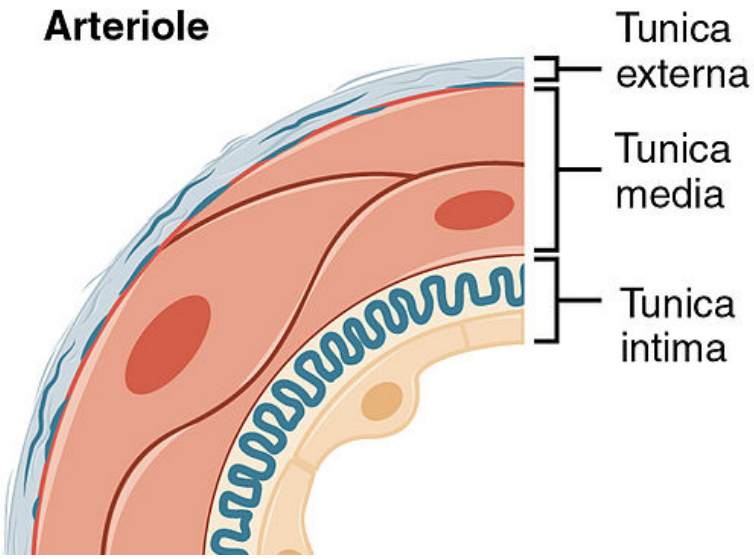
- The **muscular arteries** (distributing arteries) are the medium-sized arteries, range from 1cm-0.3mm
    - □ *Distribute* blood from elastic to body regions or organs
    - □ Have a thicker tunica media with more _____ muscle
        - Ex: brachial, anterior tibial, coronary, etc…
    - □ Elastic fibers are arranged into two sheets which allows for better vasoconstriction and vasodilation
        - **Internal elastic lamina** separates tunic media from tunic intima
        - **External elastic lamina** separates tunica media from tunica externa (only in large arteries)

EXAMPLE:



- The **arterioles** range from 0.3mm - 10μm and have no names
    - □ Regulate blood flow and pressure to different areas of the body
    - □ Their structure can be slightly different
        - Have < 6 layers of smooth muscle (tunica media)
        - Smaller arterioles have only tunica intima and 1- 2 layers of smooth muscle
    - □ The **vasomotor tone** is a partial state of contraction in arterioles
        - Constriction and dilation control blood flow into an area

EXAMPLE:



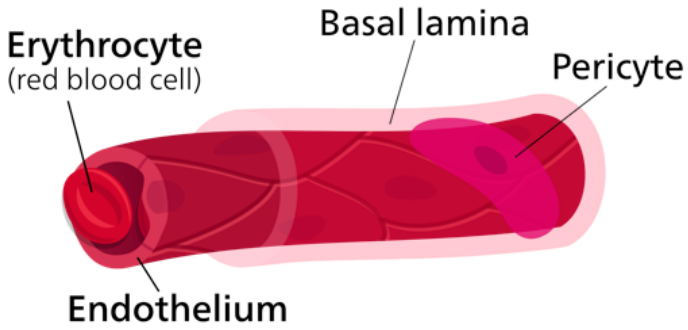
CONCEPT: STRUCTURE OF CAPILLARIES

● **Capillaries** connect arterioles to venules (smallest veins); they are the smallest blood vessels

□ Composed of a simple squamous endothelial layer on a basement membrane

□ The thin walls are perfect for the substance exchange between blood and body tissue

□ Erythrocytes travel inside in a single file, called **rouleau**



□ **Continuous capillaries** have a *continuous* endothelial lining around the lumen on a basement membrane

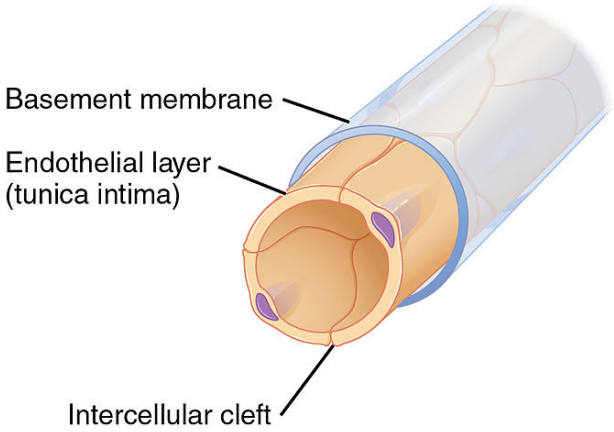
- Have tight junctions for minimal fluid leakage, but gaps, called **intercellular clefts**, exist

- Most common capillary and are found in muscle, skin, lungs, and CNS

- Molecules exchanged by diffusion or transcytosis

EXAMPLE:

Continuous

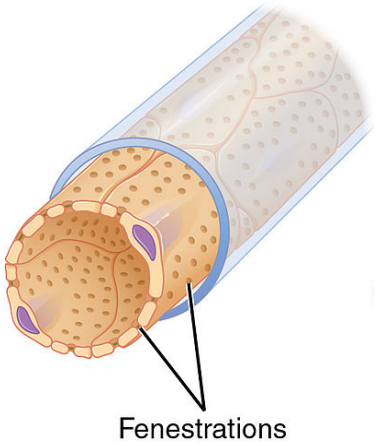


□ **Fenestrated capillaries** have a *continuous* endothelial lining around the lumen on a basement membrane

- **Fenestrations** (perforations) are small areas of endothelial cells that are extremely thin
  - Fenestrations can allow the passing of larger substances (including plasma proteins)
- Found most often in areas where there is a lot of fluid transport; ex: small intestine, eye, choroid plexus

EXAMPLE:

Fenestrated

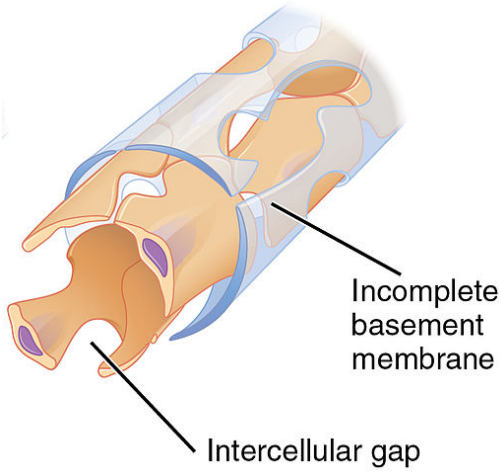


□ **Sinusoids** (discontinuous capillaries) *discontinuous* endothelial lining around the lumen on a basement membrane

- Large fenestration through the cells, lumen are usually wide
- Large substances including elements, and large plasma proteins, can pass
- Found in the red bone marrow, liver, spleen, and some endocrine glands

EXAMPLE:

Sinusoid



● **Capillary beds** are groups of capillaries that function together

□ A **metarteriole** is an arteriole branch that feeds a capillary bed

- Proximal part has smooth muscle, while distal part has no smooth muscle (**thoroughfare channel**)

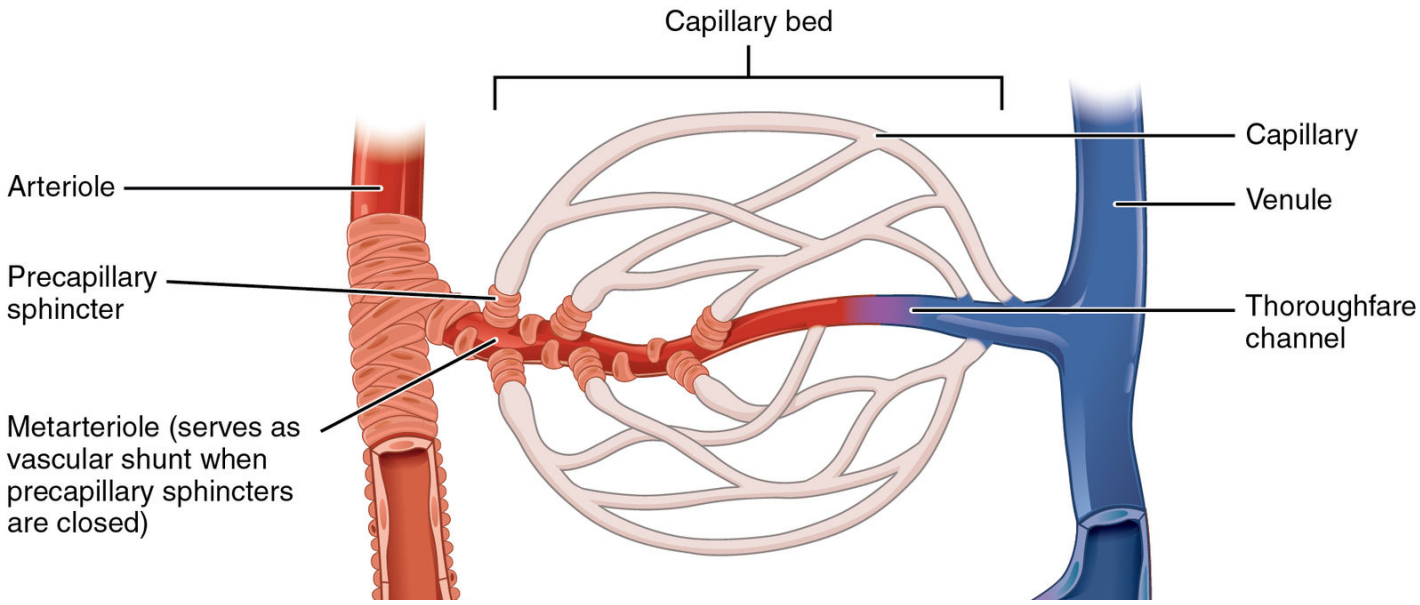
- Connects to the postcapillary venules

□ **True capillaries** branch from the metarteriole; bulk of capillary bed

- The **precapillary sphincter** is a ring of smooth muscles that controls blood flow into true capillaries

- Vasomotion is the cycling rate of contraction/relaxation that occurs 5-10 times a minute

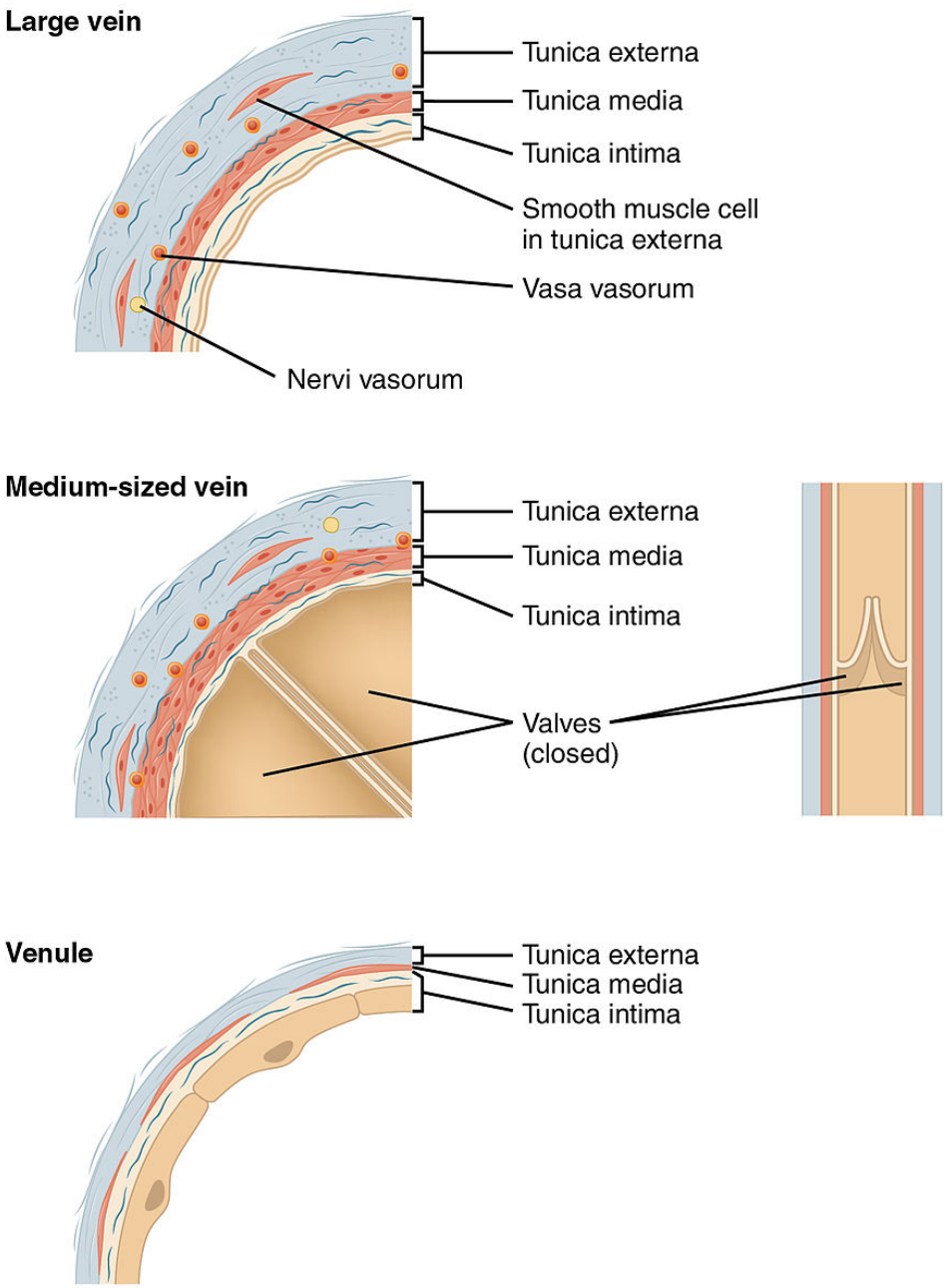
EXAMPLE:



CONCEPT: STRUCTURE OF VEINS

- **Veins** extend from capillaries to the heart
  - □ Veins are _____ and easily expand to accommodate blood; are called **blood reservoirs**
    - Approximately 55% of the body's blood is found in veins (11% is found in arteries)
  - □ **Venules**: are the companion vessels with arterioles, they merge to form veins
    - **Postcapillary venules** are the smallest veins (15-20μm) and receive blood from capillaries
    - **Muscular venules** are up to 1mm in diameter and receive blood from postcapillary venules
      - Recognizable tunic media
  - □ **Medium veins** are up to 10mm in diameter and receive blood from muscular venules
    - Veins contain **valves**, that assist the body in moving the blood against _____
      - Valves are made up of tunica intima
    - Companion vessels with muscular arteries
  - □ **Large veins** have a diameter of greater than 10mm
    - Large veins have some smooth muscle in all three tunics
    - Companion vessels with elastic arteries

EXAMPLE:


Large vein
Tunica externa
Tunica media
Tunica intima
Smooth muscle cell in tunica externa
Vasa vasorum
Nervi vasorum
Medium-sized vein
Tunica externa
Tunica media
Tunica intima
Valves (closed)
Venule
Tunica externa
Tunica media
Tunica intima

CONCEPT: BLOOD VESSEL PATHWAYS

- There are 5 ways that blood vessels are arranged
  - □ In the **simple pathway:** 1 single artery → arterioles → 1 single capillary bed → venule → 1 single vein
    - Ex: blood transport to and from spleen
    - **End arteries** provide only one pathway for blood to reach an organ
  - □ The **arterial anastomosis**: 2+ arteries → arterioles → 1 capillary bed → venule → 1 vein
    - F**unctional end arteries** occurs when you have an ineffectual anastomosis
  - □ The **venous anastomosis**: 1 artery → arterioles → 1 capillary bed → venule → 2+ veins
    - Ex: basilica, brachial, cephalic
  - □ The **arteriovenous anastomosis** (shunt): artery → vein
    - Ex: fingers, toes, palms, ears
  - □ The **portal system**: 1 artery → arterioles → *capillary bed* → portal vein → *capillary bed* → venule → 1 vein
    - Ex: hypophyseal portal system

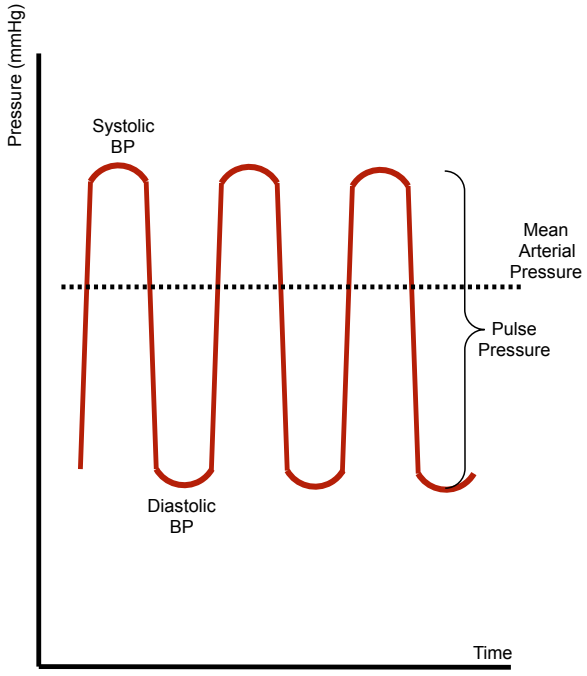
EXAMPLE:

CONCEPT: BLOOD PRESSURE: DEFINITIONS AND MEASUREMENTS

Blood Pressure Definitions:

- **Blood Pressure (BP)** is the pressure of blood pressing against the walls of *large, major arteries*.
  - □ Must measure in large, major arteries—pressure _____ as blood moves around the circulatory loop.
- BP varies over course of a cardiac cycle—↑ during heart contraction (systole), ↓ during during heart relaxation (diastole).
  - □ **Systolic Blood Pressure (SBP)** is the blood pressure during *systole.*
    - -Highest/peak pressure in the arteries.
  - □ **Diastolic Blood Pressure (DBP)** is the blood pressure during *diastole.*
    - -Lowest pressure in the arteries.
  - □ BP reported as "SBP/DBP." e.g. if SBP=120 mmHg and DBP=80 mmHg, BP=120/80.
- **Pulse Pressure (PP)** is the difference between SBP and DBP: PP=SBP-DBP.
  - □ The pressure generated by the heart during systole.
- **Mean Arterial Pressure (MAP)** is the *average* BP in the arteries.
  - □ $\text{MAP} = \text{DBP} + {}^{1}/_{3}\,(\text{SBP} - \text{DBP})$ or $\text{MAP} = \text{DBP} + {}^{1}/_{3}\,(\text{PP})$

EXAMPLE: SBP, DBP, PP, and MAP on a recording of pressure in a major artery.

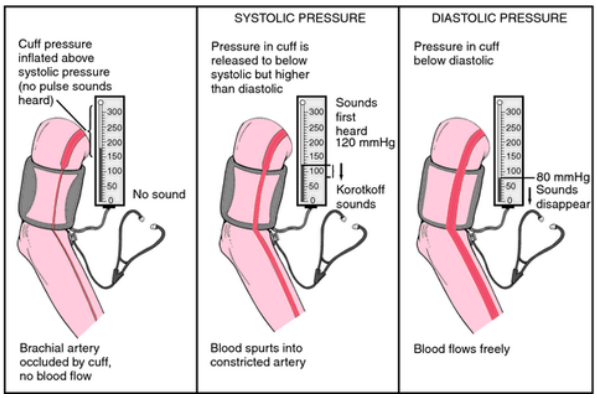


Measuring Blood Pressure:

- **Sphygmomanometer**- Cuff used to measure a patient's blood pressure. Has gauge to show pressure in the cuff.
- **Stethoscope**- A sound-amplifying device used to listen to internal sounds on a patient.
- To measure a patient's BP:

1. Place cuff on upper arm, inflate cuff so Cuff Pressure>SBP.
2. Place stethoscope head on brachial artery (inside of elbow).

    -Should hear nothing.
3. Begin to slowly deflate cuff.
4. When first hear tapping: Cuff Pressure=SBP.
5. Continue to deflate cuff.
6. When tapping stops (goes quiet): Cuff Pressure=DBP.



- **Korotkoff Sounds** are these tapping sounds caused by blood spurting through closed artery under cuff.
    - □ When Cuff Pressure>SBP→no flow through brachial artery→no noise.
    - □ When DBP<Cuff Pressure<SBP→flow through brachial artery only at high pressures→tapping noise.

        -Heart beats→blood spurts through artery under cuff→makes noise.

        -Heart relaxes→cuff pressure forces artery collapse→no noise.
    - □ When Cuff Pressure<DBP→continuous smooth flow through brachial artery→no noise.

EXAMPLE: A healthcare professional measuring a patient's blood pressure.

PRACTICE 1: A 65-year-old woman has a 10-year history of hypertension. During one cardiac cycle, the highest pressure recorded in her arteries is 160 mmHg, while the lowest pressure is 100 mmHg. Which of the following correctly identifies her systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse pressure (PP)?

a) SBP= 100 mmHg | DBP= 160 mmHg | PP= 60 mmHg
b) SBP= 160 mmHg | DBP= 100 mmHg | PP= 60 mmHg
c) SBP= 60 mmHg | DBP= 160 mmHg | PP= 100 mmHg
d) SBP= 160 mmHg | DBP= 100 mmHg | PP= 260 mmHg

CONCEPT: DIFFUSION

Diffusion, Qualitatively:

● **Diffusion** is the simple movement of solute from an area of higher concentration to an area of lower concentration.

□ Entirely passive—no _____ expenditure is required.

□ Happens from higher concentration→lower concentration.

- Net movement until concentrations are equal everywhere.

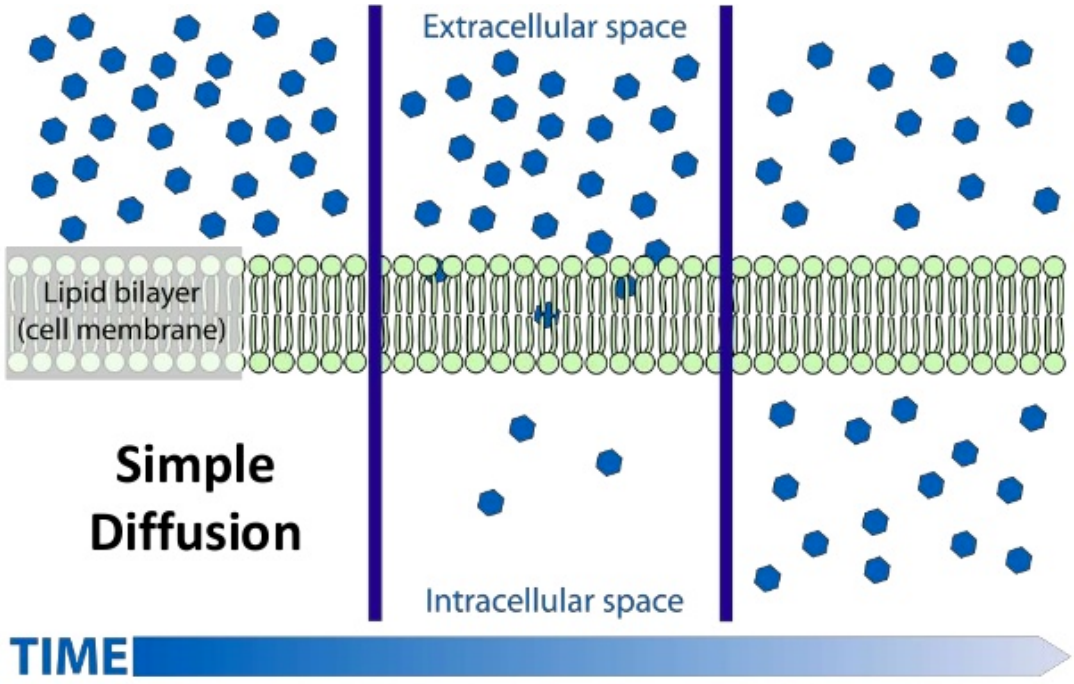
□ ↑Diffusion rate for ↑Temperature and ↓Molecular Size/Weight.

● Diffusion into and out of cells must happen across cell membranes, which are _____.

□ Lipophilic (i.e. nonpolar) solutes are the major solutes that enter cells via simple diffusion.

□ Hydrophilic (i.e. polar) solutes need to be transported across the membrane (more later).

EXAMPLE: Nonpolar solutes cross the cell membrane into cells via diffusion, moving from an area of higher concentration (the extracellular space) to an area of lower concentration (the intracellular space).



Diffusion, Quantitatively—Fick's Law:

● Mathematically, the rate of diffusion through membranes can be described by **Fick's Law: J=PA(ΔC)**, where:

□ J is the **flux** (the amount of solute moving per unit time) across the membrane.

□ P is the **permeability** of the membrane to the solute; if the solute can cross more easily, it crosses more quickly.

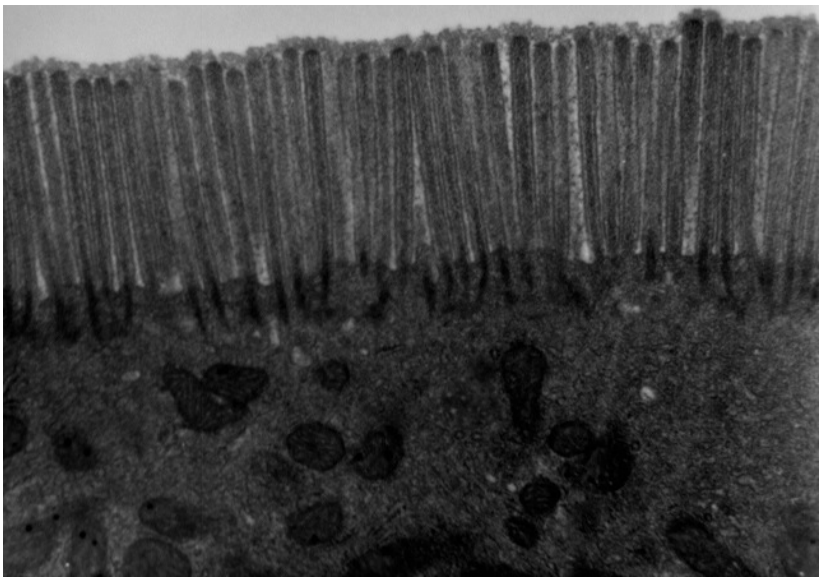
- A higher value of P means that the solute crosses more _____.

- Nonpolar molecules or molecules that can be transported typically have higher values of P.

□ A is the **surface area** of the membrane. More surface area means more "opportunity" for solute to cross.

□ ΔC is **concentration gradient** (the difference in solute concentration between the two side).

EXAMPLE: Microvilli that increase the available membrane surface area (↑A in Fick's Law), increasing the diffusion rate.



PRACTICE: The walls of capillaries—where all of the exchange between the blood and body takes place—are made of endothelial cells. Tight junctions are proteins that hold adjacent endothelial cells together and prevent too much from crossing. After injury, damaged cells release molecules that loosen tight junctions.

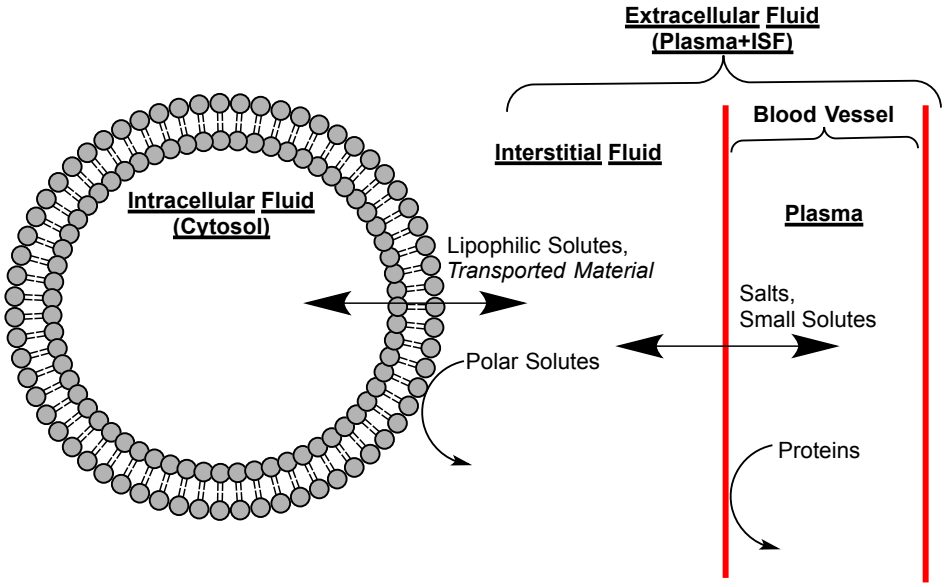
Which variable in Fick's Law is affected by injury? How will this affect flux (J)?

CONCEPT: CAPILLARY EXCHANGE II: BULK FLOW AND THE STARLING EQUATION OF ULTRAFILTRATION

Bulk Flow:

- *Vast* majority of individual nutrients—glucose, O_2, CO_2, etc.—move between capillaries and tissues by *diffusion*.
  - □ But, some nutrients and fluid move by *bulk flow.*
- **Bulk Flow** describes the movement of *fluid*—blood plasma and everything in it—across capillary walls.
  - □ **Interstitial Fluid (ISF)**=fluid surrounding cells but outside of blood vessels.
  - □ **Filtration**=capillaries→interstitial fluid. □ **Reabsorption**=interstitial fluid→capillaries.

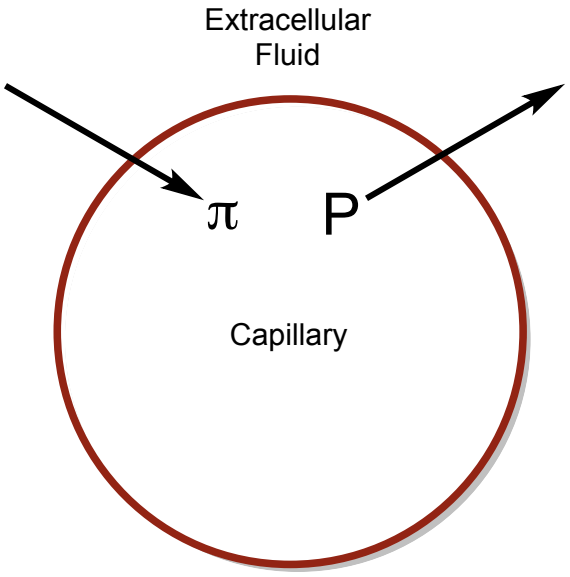
EXAMPLE: Bulk flow of fluid happens across capillary walls from blood to ISF.



Hydrostatic vs. Osmotic Pressures:

- Two kinds of "pressures" present in capillaries: *hydrostatic* pressure and *osmotic* pressure.
    - □ **Hydrostatic Pressure** (P) is the pressure of blood plasma/ISF *pushing* against walls of container.
    - □ **Osmotic Pressure** (π) *pulls* fluid toward itself as the result of a high concentration of solutes.

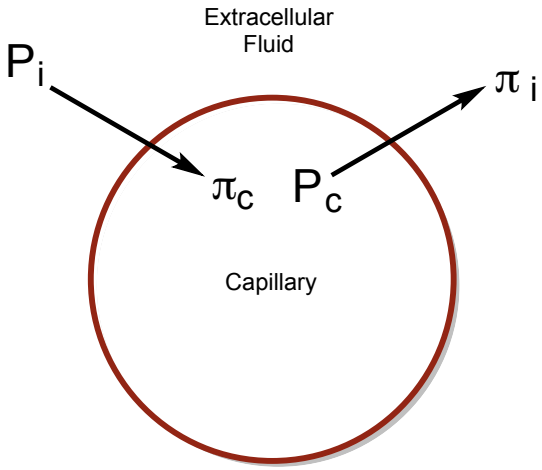
EXAMPLE: Hydrostatic pressure in the capillaries pushes fluid out; osmotic pressure pulls fluid back in.



The Starling Equation of Ultrafiltration:

- **Starling Equation of Ultrafiltration** describes the direction of bulk flow (filtration or reabsorption) in a capillary.
    - □ Push/pull between hydrostatic pressure (P) and osmotic pressure (π) in the capillary (c) and ISF (i).
- Two sets of forces:
    - □ Forces *out* of the capillary into ISF: P_c and π_i. □ Forces *in* to capillary from ISF: P_i and π_c.
- The equation: $\Phi=\mathcal{k}[(P_c+\pi_i)-(P_i+\pi_c)]$
    - □ If $\Phi>0\rightarrow$net *filtration*. □ If $\Phi<0\rightarrow$net *reabsorption.*
    - □ $\mathcal{k}$=filtration coefficient. How *easy* it is for fluid to cross capillary wall.

EXAMPLE: A visual of the forces out and forces in from the Starling Equation.

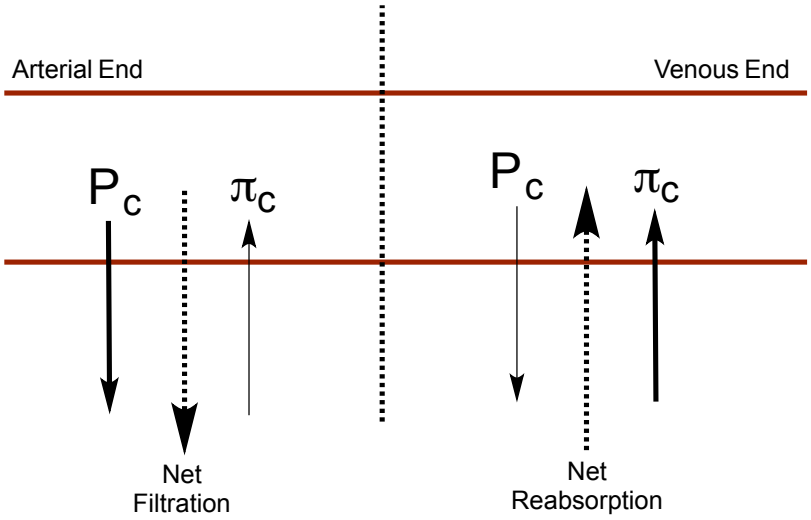


EXAMPLE: Starvation edema is the result of $\downarrow\pi_c\rightarrow\uparrow\Phi$.

Bulk Flow Along the Length of a Capillary:

- The balance of filtration and reabsorption changes along the length of a capillary.
    - □ Two most important Starling parameters are P_c and π_c.
        - $-P_i \cong 0$ mmHg, π_i is very small.
    - □ P_c favors filtration (force out); π_c favors reabsorption (force in).
- Hydrostatic pressure (P_c) decreases along the length of a capillary (because of friction, etc.), π_c remains ~constant.
    - □ At arterial side of capillary: $P_c > \pi_c \rightarrow$ forces out>forces in $\rightarrow$ net *filtration*.
    - □ At venous side of capillary: $P_c < \pi_c \rightarrow$ forces in>forces out $\rightarrow$ net *reabsorption*.

EXAMPLE: Filtration dominates at the arterial end and reabsorption dominates at the venous end because of $\downarrow P_c$.



PRACTICE 1: Which of the following variables in the Starling Equation favor flow *out* of the capillary into the interstitial space? (Choose all that apply.)

a) P_c
b) P_i
c) π_c
d) π_i
e) k

PRACTICE 2: A 23-year-old man is admitted to the hospital for an appendectomy. As part of the procedure he is given an intravenous infusion of normal saline (basically the same as blood plasma, with the same concentrations of all solutes as normal blood plasma). A mistake is made and the man is given 3 L of fluid, causing a huge increase in his blood plasma volume. Which of the following Starling Equation variables will be directly affected by this increase in plasma volume and how will it affect net bulk flow? (Recall that a positive value of Φ corresponds to net *outward* flow of fluid from the capillary to the interstitial space.)

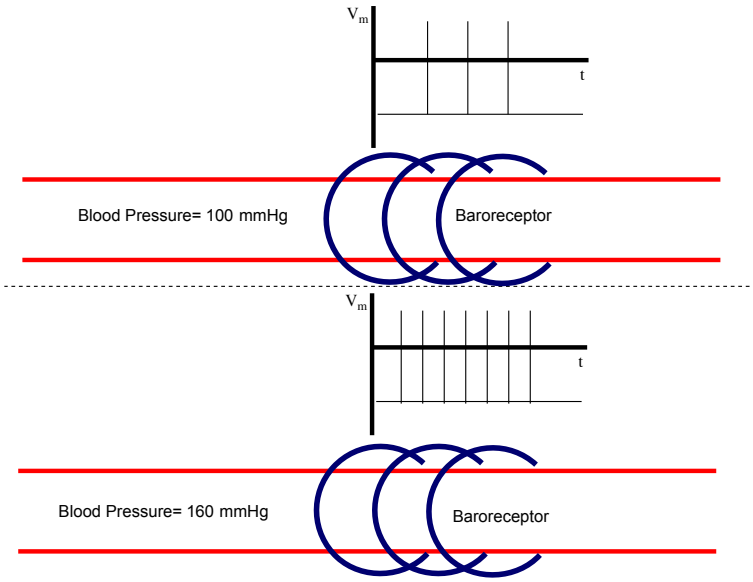
a) $P_c \mid \uparrow\Phi$
b) $P_i \mid \downarrow\Phi$
c) $\pi_c \mid \downarrow\Phi$
d) $\pi_i \mid \uparrow\Phi$

CONCEPT: SHORT-TERM REGULATION OF BLOOD PRESSURE—THE BARORECEPTOR REFLEXES

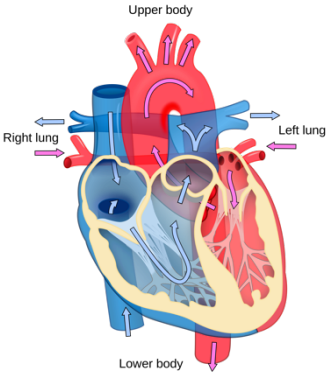
The Baroreceptors:

- **Baroreceptors**-Sensory neurons that wrap around blood vessels, monitoring blood _____.
  - □ *Tonic* Receptors: ↑BP→↑AP frequency and ↓BP→↓AP frequency.

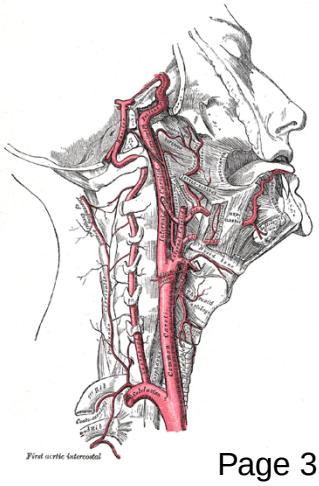
EXAMPLE: Baroreceptors increase their firing rate when BP increases.



Locations of the Baroreceptors:



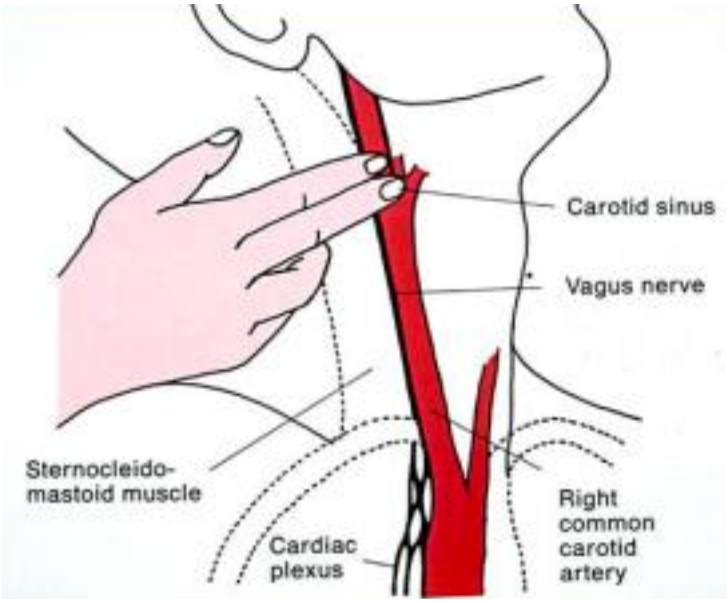
- Baroreceptors are located in just *two* (!) places in the body.
  - □ **Aortic Arch**—in the aorta immediately downstream of the left ventricle.
  - □ **Carotid Sinus**—in the carotid artery in neck, just below jawline.
- These locations allow for efficient BP monitoring at important checkpoints.
  - □ Aortic arch monitors blood flow and BP out of the heart to the entire body.
  - □ Carotid sinus monitors blood flow and BP specifically for the brain.



Effects of the Baroreceptor Reflex:

- **Baroreceptor Reflex** functions to increase BP and cardiac output to counter sudden changes in BP.
    - □ Works by stimulating or inhibiting the sympathetic or parasympathetic nervous system, as appropriate.
- In response to ↓BP, the baroreceptor reflex increases sympathetic nervous system activity. Effects:
    - □ Vasoconstriction→↑BP.
        - -↑Venous Return→↑EDV→↑SV→↑Cardiac Output→↑BP.
    - □ ↑HR→↑Cardiac Output→↑BP.
    - □ ↑Contractility→↑SV→↑BP.
- Response to ↑BP is the opposite: ↑PSNS activity and ↓SNS activity.

EXAMPLE: Carotid massage (artificially) increases baroreceptor activity. This can lead to a decrease in HR and BP.



PRACTICE 1: A 25-year-old woman presents to the emergency department after a car accident in which her right femoral artery—the major artery supplying her right leg—was cut by a piece of metal. She lost 2.5 L of blood en route to the hospital; her blood pressure is currently 80/50 mmHg. Which of the following do you expect to observe in this patient as a result of activation of her baroreceptor reflex? (Choose all that apply.)

a) Increased heart rate.
b) Decreased heart rate.
c) Vasoconstriction.
d) Vasodilation.
e) Increased myocardial contractility.
f) Decreased myocardial contractility.

CONCEPT: HORMONAL REGULATION OF BLOOD PRESSURE I: VASOPRESSIN/ANTI-DIURETIC HORMONE

Causes and Effects of Vasopressin Secretion:

- **Vasopressin** (aka **anti-diuretic hormone [ADH]**) is a peptide hormone secreted from the posterior pituitary.
- Vasopressin is secreted in response to:
    - □ ↓Blood Pressure (as sensed by baroreceptors in aortic arch and/or carotid sinus).
    - □ ↑Plasma Osmolarity (as sensed by **osmoreceptors** in the hypothalamus).
        - (This is a sign of dehydration.)
- Vasopressin/ADH has two names because of its two major effects.
    - □ On vascular smooth muscle→vasoconstriction→↑BP.
    - □ In kidney→↑Water reabsorption→↑Blood Volume→↓Plasma Osmolarity and ↑BP.

EXAMPLE: Vasopressin is secreted in response to, and temporarily combats the effects of, dehydration.

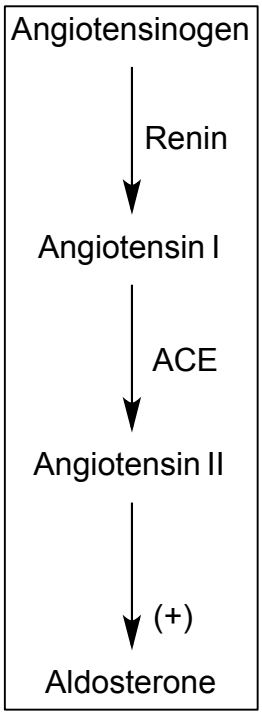
PRACTICE 1: A 20-year-old woman goes for a 10-mile run in the middle of a hot, humid Miami day. She sweats excessively and becomes dehydrated. Which of the following is expected to happen to the smooth muscle in her blood vessel walls?

a) Vasoconstriction.
b) Vasodilation.

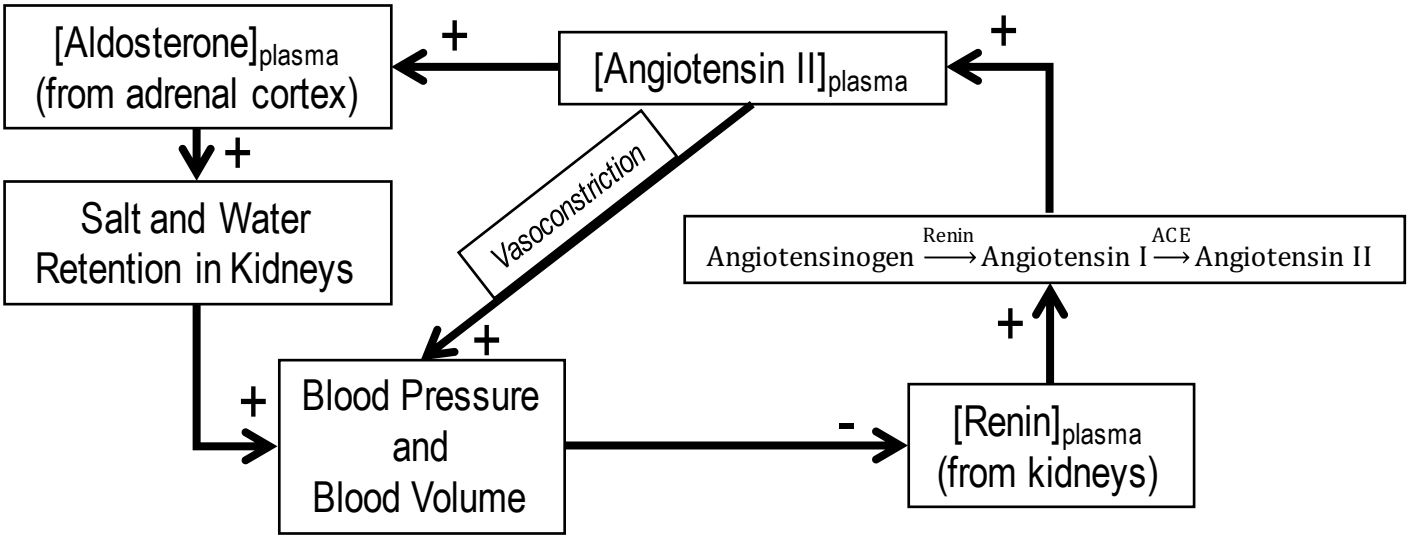
CONCEPT: HORMONAL REGULATION OF BLOOD PRESSURE II: THE RENIN-ANGIOTENSIN-ALDOSTERONE SYSTEM

Overview of the RAAS System:

- **Renin-Angiotensin-Aldosterone System (RAAS)** controls longer-term (weeks to months) blood volume and BP.
- **Renin** is an enzyme secreted by the kidneys in response to low blood pressure (and other factors).
- **Angiotensinogen** is a pro-hormone (an inactive precursor) tonically produced by the liver.
    - □ Renin converts angiotensinogen to **Angiotensin I (ATI)**.
- Angiotensin I is converted to **Angiotensin II (ATII)** by **Angiotensin-Converting Enzyme (ACE)**.
    - □ On its own, ATI does nothing.
- ATII has two major effects.
    1) Directly excites vascular smooth muscle→vasoconstriction→↑BP.
    2) Causes the release of *aldosterone* from the adrenal cortex.
- **Aldosterone** is a steroid hormone that acts on the kidneys.
    - □ Aldosterone→↑Salt and Water Retention→↑Blood Volume→↑Blood Pressure.



EXAMPLE: A feedback loop summary of the RAAS system.



PRACTICE 1: Lisinopril is a drug that inhibits angiotensin converting enzyme (ACE). Which of the following is the expected effect of lisinopril on the level of angiotensin II (ATII) in the bloodstream?

a) Increased ATII.
b) Decreased ATII.
c) No change in ATII.

PRACTICE 2: Lisinopril is a drug that inhibits angiotensin converting enzyme (ACE). Which of the following is the expected effect of lisinopril on the excitation of vascular smooth muscle?

a) Increased excitation→vasoconstriction.
b) Decreased excitation→vasodilation.
c) No change in vascular smooth muscle excitation.

PRACTICE 3: Lisinopril is a drug that inhibits angiotensin converting enzyme (ACE). Which of the following is the expected effect of lisinopril on circulating levels of aldosterone?

a) Increased aldosterone.
b) Decreased aldosterone.
c) No change in aldosterone.

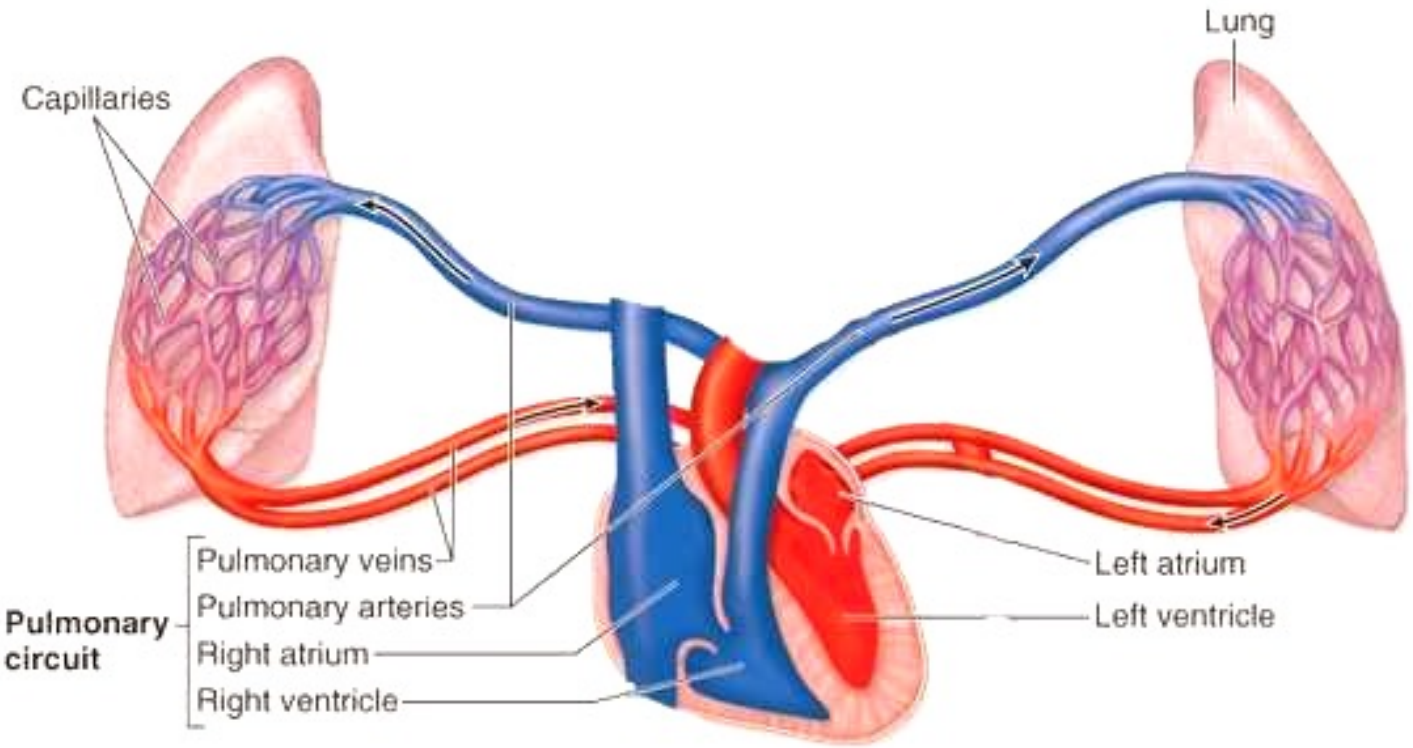
PRACTICE 4: Lisinopril is a drug that inhibits angiotensin converting enzyme (ACE). Which of the following is the expected effect of lisinopril on blood pressure?

a) Increased blood pressure.
b) Decreased blood pressure.
c) No effect on blood pressure.

CONCEPT: PULMONARY CIRCULATION

- **Pulmonary circulation** takes deoxygenated blood and transports it to the lungs, oxygenates it, and returns it to the heart
  - □ *Deoxygenated blood*: R. atrium → R. ventricle → **pulmonary trunk** → splits into L. and R. **pulmonary artery** → smaller arteries → arterioles → pulmonary capillaries (where gas exchange occurs)
  - □ *Oxygenated blood:* pulmonary capillaries → venules → L. and R. **pulmonary veins** → L. atrium → L. ventricle
  - □ Blood pressure is _____ in pulmonary circulation
    - Right ventricle: systolic pressure: 15-25 mm Hg
    - Pulmonary trunk/arteries: systolic pressure: 10 mm Hg
    - Pulmonary veins → left atrium: nearly 0 mm Hg

EXAMPLE:



CONCEPT: BLOOD FLOW OUT AND IN THE HEART

● Major vessels supplying _____ blood to the body

□The **left** and **right coronary arteries** supply the heart wall with blood, other arteries supply the rest of the body

□ Left ventricle → ascending aorta → aortic arch → three branches come off the aortic arch

- The **brachiocephalic trunk** → bifurcates into:

- Right common carotid artery: supplies to right side of head and neck

- Right subclavian artery: supplies to right upper limb and thoracic

- The **left common carotid artery**: supplies to the left side of the head and neck

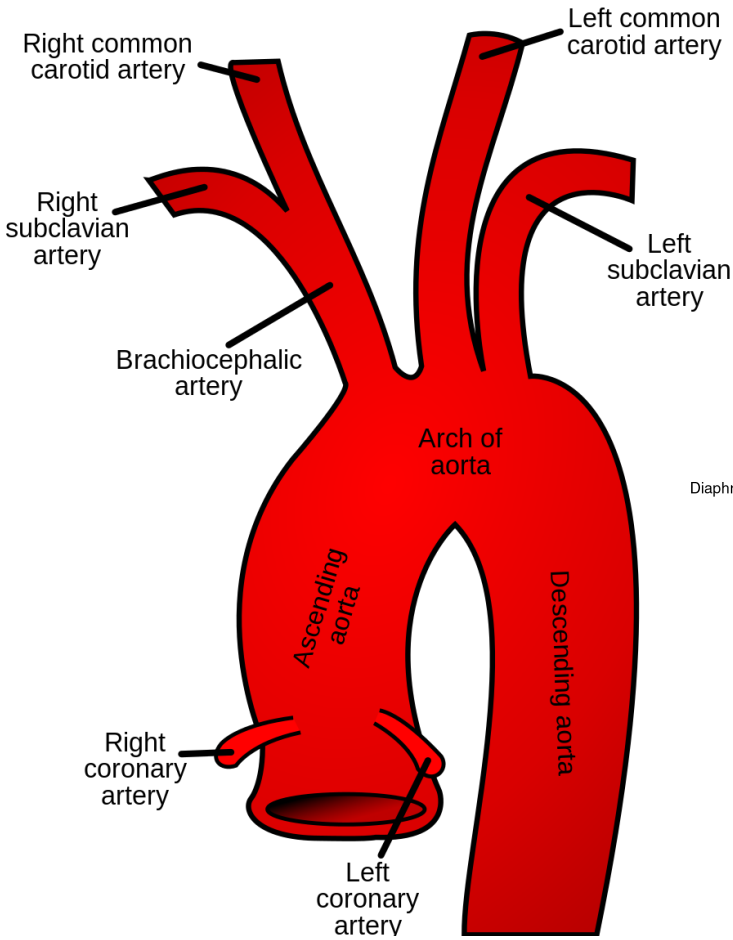
- The **left subclavian artery**: supplies to left upper limb and thoracic

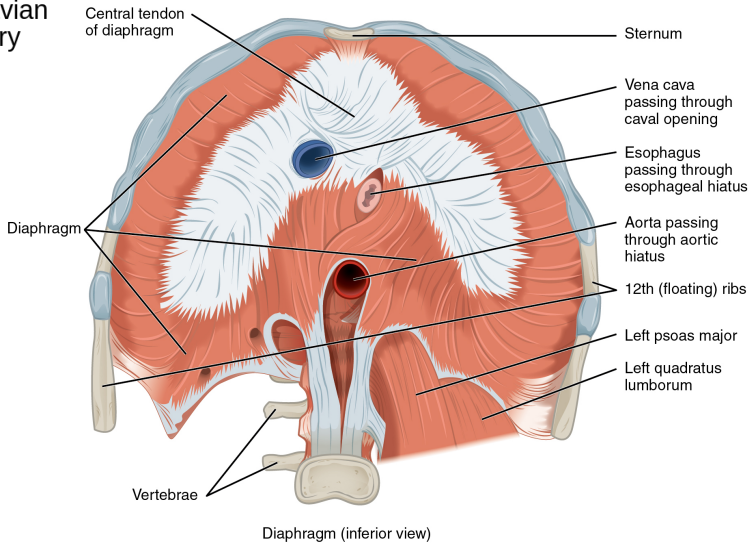
□ As the aortic arch travels _____, it becomes the **descending thoracic**

□ As it goes through the aortic hiatus in the diaphragm it becomes **descending abdominal aorta**

- It then bifurcates into **left** and **right common iliac arteries,** which further divide.

EXAMPLE:





Diaphragm (inferior view)

● Major vessels draining deoxygenated blood from the body and returning it to the right atrium of the heart

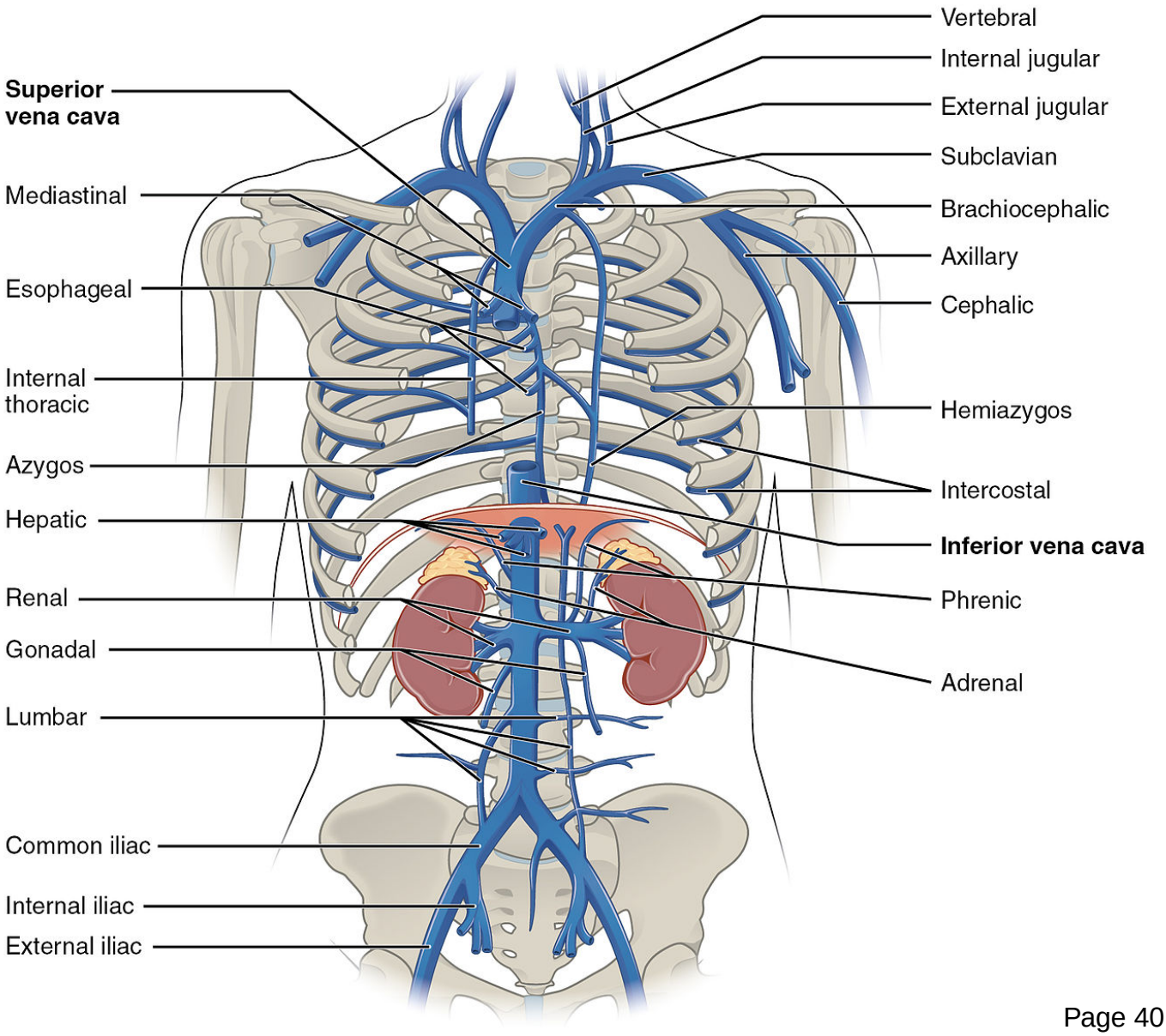
□ The draining of the head, neck, upper limbs, thoracic and abdominal walls is by the L. and R. brachiocephalic veins → merge to form the **superior vena cava**

□ The draining of the lower limbs, pelvis, and perineum is by the abdominal veins → merge to form the **inferior vena cava**

- Runs on the right side of the descending aorta, passing through the caval opening of the _____

□ The **coronary sinus** carries deoxygenated blood from myocardium to the right atrium

EXAMPLE:



CONCEPT: HEAD AND NECK CIRCULATION

● Branches of the aortic arch supply the head and neck

□ The **common carotid artery** supplies _____ of the blood in the head and neck

- The **external carotid artery** supplies external skull structures

  - Branches: *superior thyroid, ascending pharyngeal, lingual, facial, occipital, posterior auricular, maxillary artery and superficial temporal artery*

- The **internal carotid artery** supplies internal _____ structures and orbit; branches after it enters the skull

  - Branches: *anterior cerebral, middle cerebral, ophthalmic*

□ Branches of the **subclavian artery** provides additional blood to the head and neck

- The **vertebral arteries** supply the pons and cerebrum

  - Travels through the cervical vertebrae transverse foramina – enters skull via foramen magnum

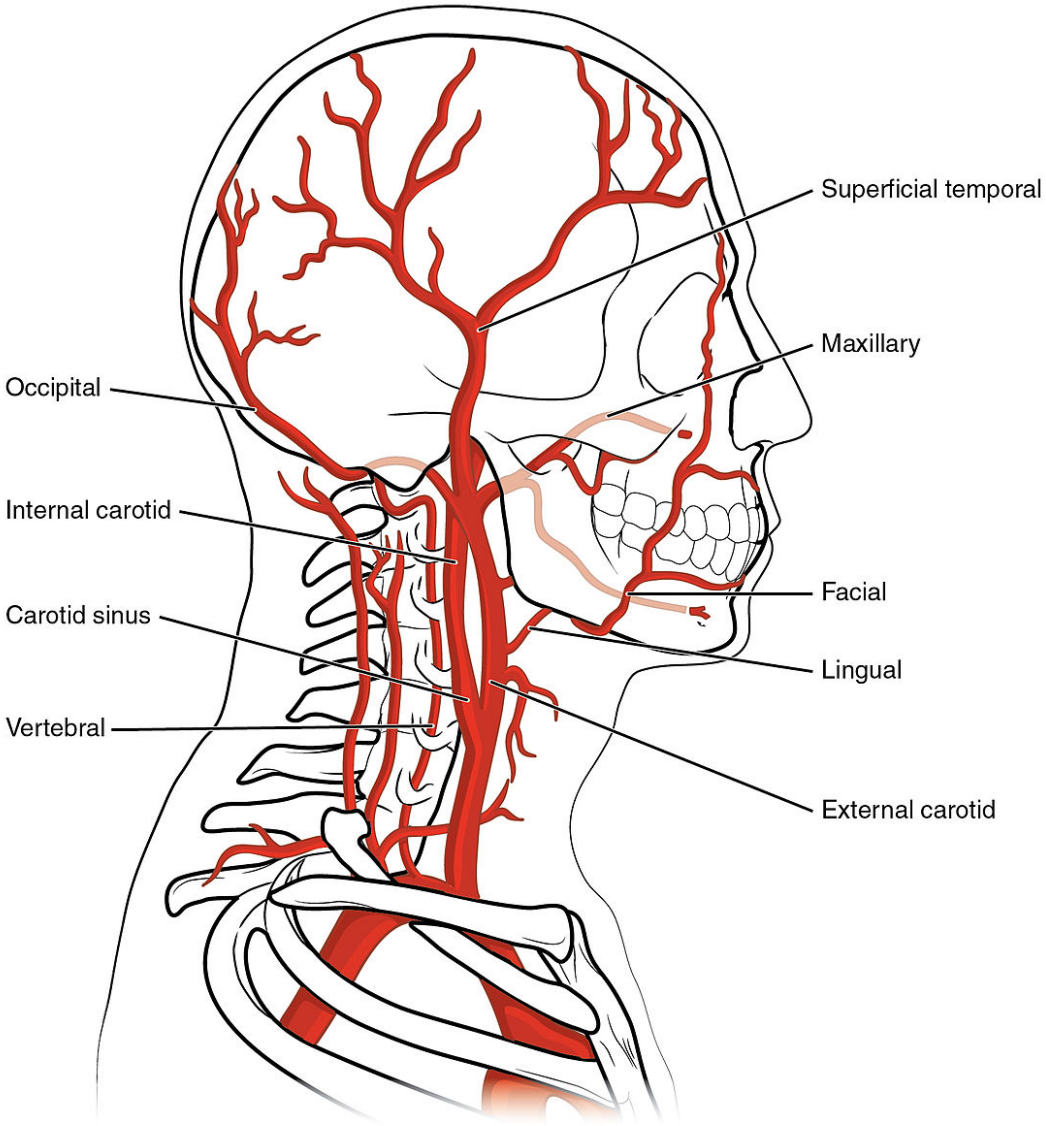
  - Merge to form **basilar artery**, which _____ into **posterior cerebral arteries**

- The **cerebral arterial circle** stabilized blood pressure and can provide a route around a blocked vessel

  - The cerebral arterial circle is an _____ around the sella turcica

  - Formed by: *posterior cerebral, posterior communicating, internal carotid, anterior cerebral, & anterior communicating arteries*

EXAMPLE:


Superficial temporal
Maxillary
Occipital
Internal carotid
Facial
Carotid sinus
Lingual
Vertebral
External carotid

● The jugular and brachiocephalic veins drain the head and neck

□ Three primary vein _____ drain the head and neck

- The **vertebral vein** empties into subclavian vein

- The **external jugular vein** empties into subclavian vein from superficial head and neck structures

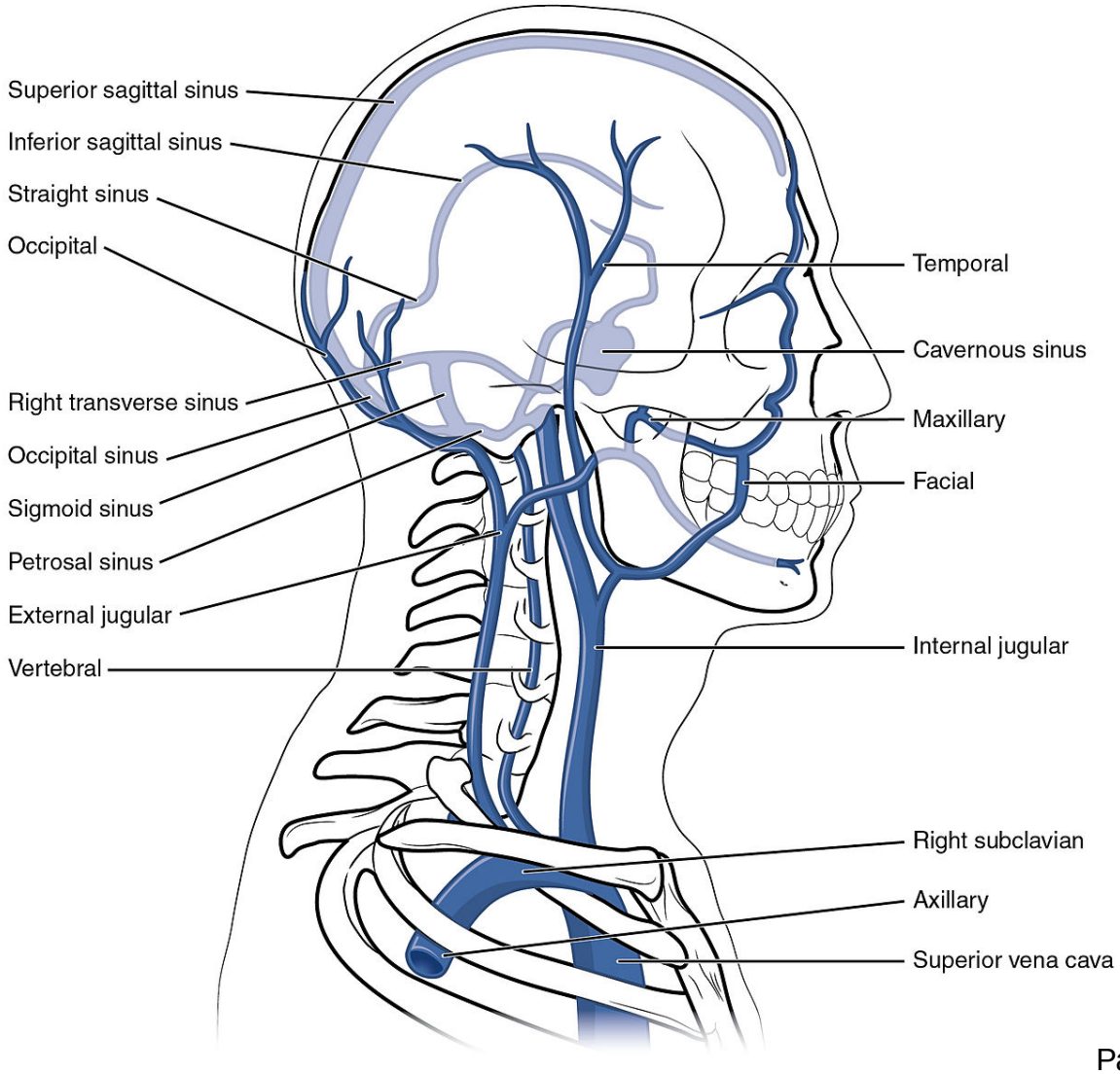
- The **internal jugular vein** drains blood from from cranial cavity

- Joins the subclavian vein to form **brachiocephalic vein** → superior vena cava

□ **Dural venous sinuses** are large, modified veins that drain most cranial venous blood into internal jugular vein

- Are found between the dura mater layer receiving blood and excess _____

EXAMPLE:



CONCEPT: THORACIC CIRCULATION

● The thoracic and abdominal walls are supplied by complex paired vessels with several _____

□ Several small pairs of arteries branch off the thoracic aorta, divided into two groups:

- The **visceral branches** send arteries to _____

- The **pericardial arteries** supply the pericardial sac, that surrounds the heart

- The **bronchial arteries** supply lung tissue, from beginning of the brachial tree to alveolar ducts

- The **esophageal arteries** supply the esophagus

- The **mediastinal arteries** supply lymph nodes and tissues of mediastinum

- The **parietal branches** send arteries to the body _____

- The **posterior intercostal arteries** supply the skin, muscle, and ribs of thoracic wall

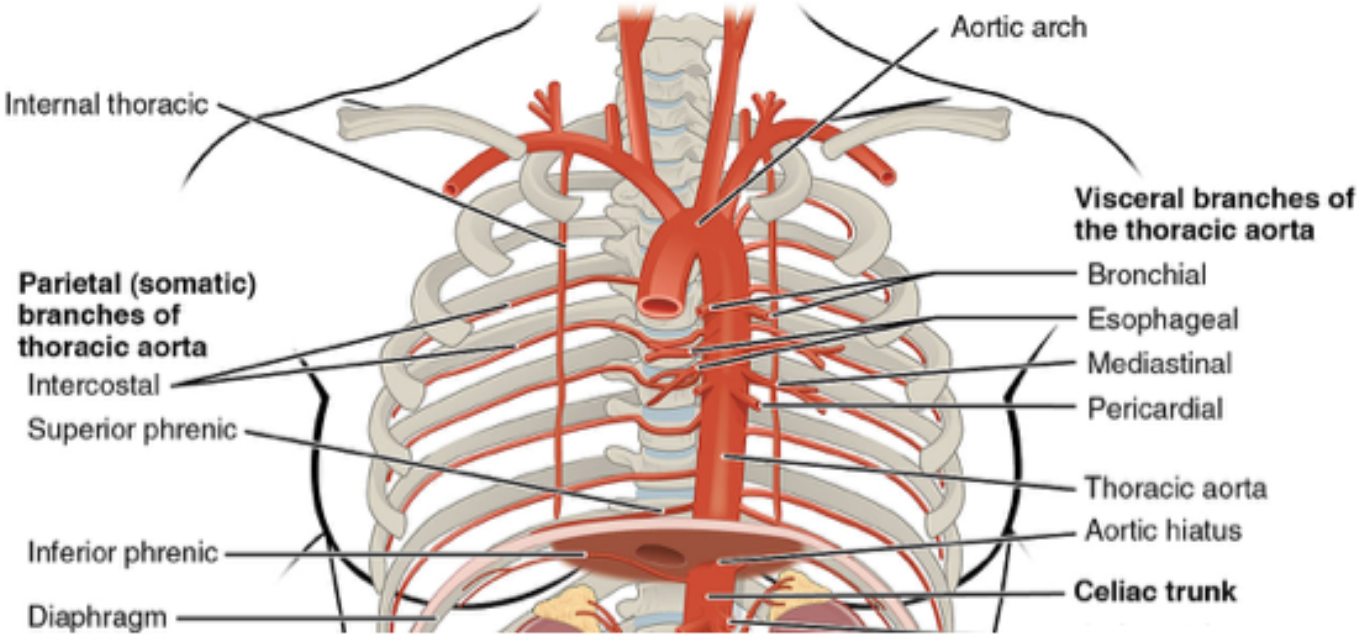
- Usually 9 pairs that branch from the posterolateral thoracic aorta

- The **subcostal arteries** supply the lower thoracic region, including skin, muscles, ribs, vertebrae

- Runs inferiorly to the 12th rib, lowest branches of the thoracic aorta

- The **superior phrenic arteries** runs on the superior surface of the diaphragm, supplying it

EXAMPLE:



● The venous drainage of the thoracic and abdominal walls is more _____ than the arterial supply

□ The **brachiocephalic veins** drain the head, neck, upper limbs, mammary glands, and superior thorax

- Created by the _____ of the subclavian and jugular vein

- The union of two brachiocephalic veins create the superior vena cava

□ The azygous system drains most of the thoracic and abdominal walls, emptying it into the superior vena cava

- The **azygos vein** drains the right thoracic wall, right thoracic viscera, and posterior abdominal wall

  - Begins at the merging of right lumbar and subcostal veins, ends by _____ the SVC

  - Branches: *R. posterior intercostal, hemiazygos, accessory hemiazygos, esophageal, mediastinal, pericardial, and bronchial veins*

- The **hemiazygos vein** drains the left thoracic wall, thoracic viscera, and posterior abdominal wall

  - Begins at the merging of left lumbar and subcostal veins, ends by joining the azygos vein

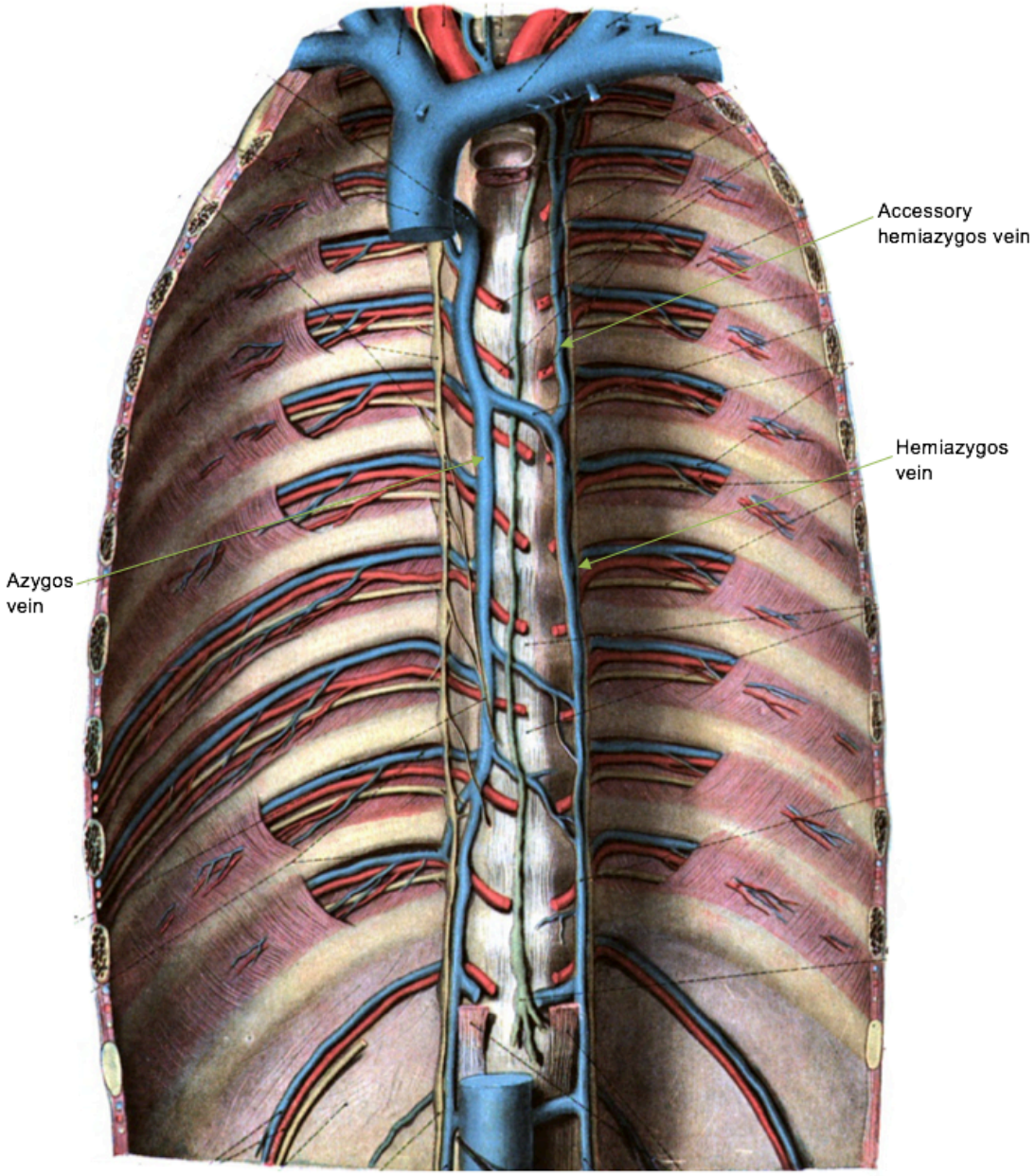
  - Branches: *L. posterior intercostal, esophageal, mediastinal, accessory hemiazygos veins*

- The **accessory hemiazygos vein** drains the left upper thoracic wall and thoracic _____

  - Begins at 4th intercostal space, ends by joining the azygos vein

  - Branches: *L. posterior intercostal veins, L. bronchial, and mediastinal veins*

EXAMPLE:

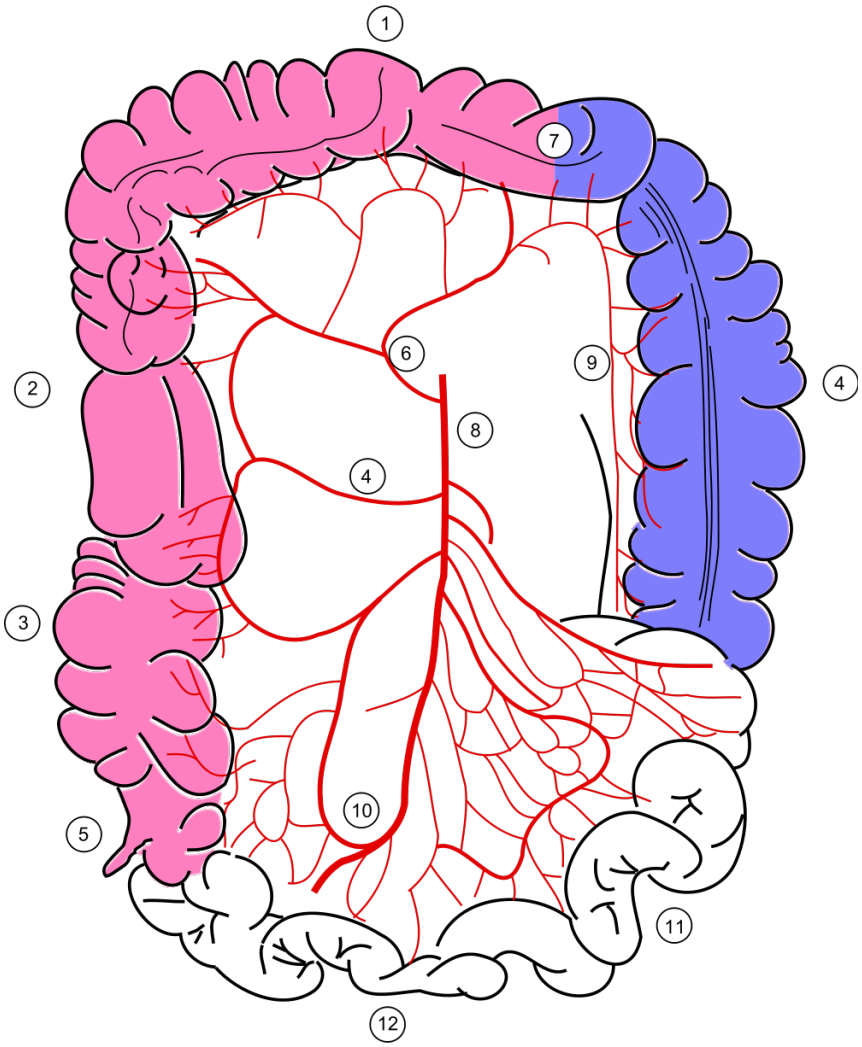


Organ	Artery	Vein
Lungs	**Bronchial arteries** from descending thoracic aorta	**Bronchial veins** drain into azygos system and pulmonary veins
Esophagus	**Esophageal arteries** and **branches** from descending thoracic aorta	**Esophageal veins** drain into either the azygos vein or left gastric vein
Diaphragm	**Superior phrenic arteries** from descending thoracic aorta and **inferior phrenic arteries** from descending abdominal aorta	**Superior phrenic** and **inferior phrenic** veins drain into inferior vena cava and **musculophrenic drains** into internal thoracic veins

CONCEPT: GASTROINTESTINAL TRACT

- The GI tract is supplied by three unpaired arteries from the abdominal aorta and drained by the hepatic portal system
  - □ The **celiac trunk** emerges inferior the to aortic opening in the diaphragm; has _____ branches
    - **Left gastric artery** (stomach), **splenic artery** (spleen, pancreas), and **common hepatic artery**
      - The common hepatic artery branches into **hepatic artery proper** and **gastroduodenal artery**
  - □ The **superior mesenteric artery** is inferior to the celiac trunk; supplies small intestine, _____, pancreas, cecum
    - Branches into: **intestinal arteries** (18-20), **middle colic artery**, **right colic artery**, and **ileocolic artery**
  - □ The **inferior mesenteric artery** is located around the L_3 vertebra; supplies the colon and rectum
    - Branches into: **left colic artery**, **sigmoid arteries**, and **superior rectal artery**

EXAMPLE:



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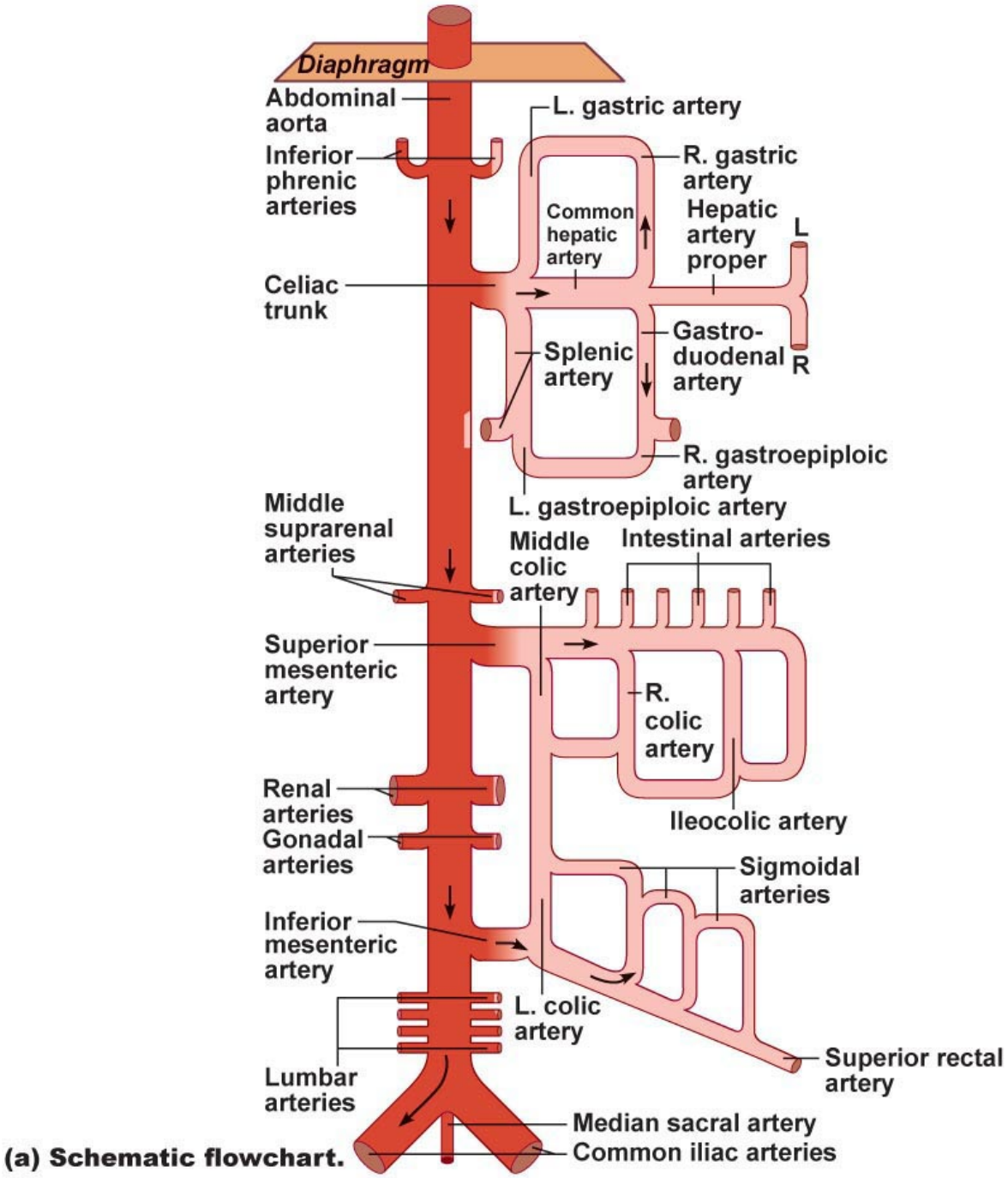


(a) Schematic flowchart.

□ Blood from _____ organs is drained into the **hepatic portal system**

- The hepatic portal system drains blood into the liver, then the inferior vena cava

- It is part of the body's filtration system, preventing harmful substances from going back to the heart

- Main function is to deliver de-oxy blood to the liver for detoxification

- Receives _____ erythrocytes from the spleen, goes to the liver for recycling

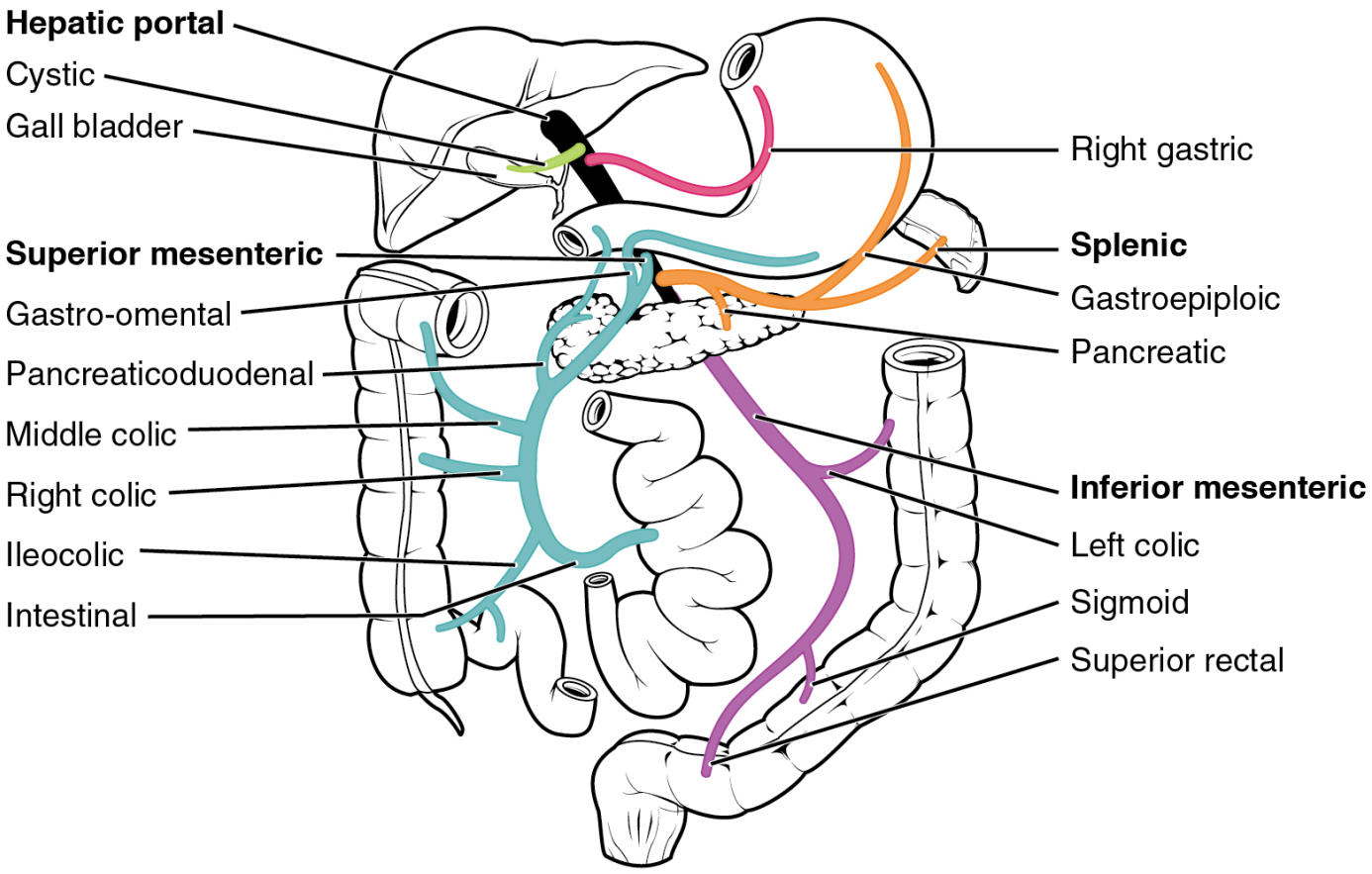
□ Blood from digestive organs drain into three branches

- The **splenic vein**, the **inferior mesenteric vein**, and the **superior mesenteric vein**

□ All three branches drain into **hepatic portal vein**, which drains blood to the liver

□ Blood leaves the liver through the **hepatic veins** into the inferior vena cava

EXAMPLE:



CONCEPT: POSTERIOR ABDOMINAL ORGANS

● The posterior abdominal area is supplied by branches from descending abdominal aorta and **internal iliac arteries**

□ The posterior abdominal organs are supplied and drained by _____ of the descending aorta:

- The **middle suprarenal artery** supplies the adrenal gland and the **middle suprarenal vein** drains it

- The **renal artery** supplies the kidneys, and the **renal veins** drains them

- The **gonadal artery** supplies the gonads, and the **gonadal vein** drains them

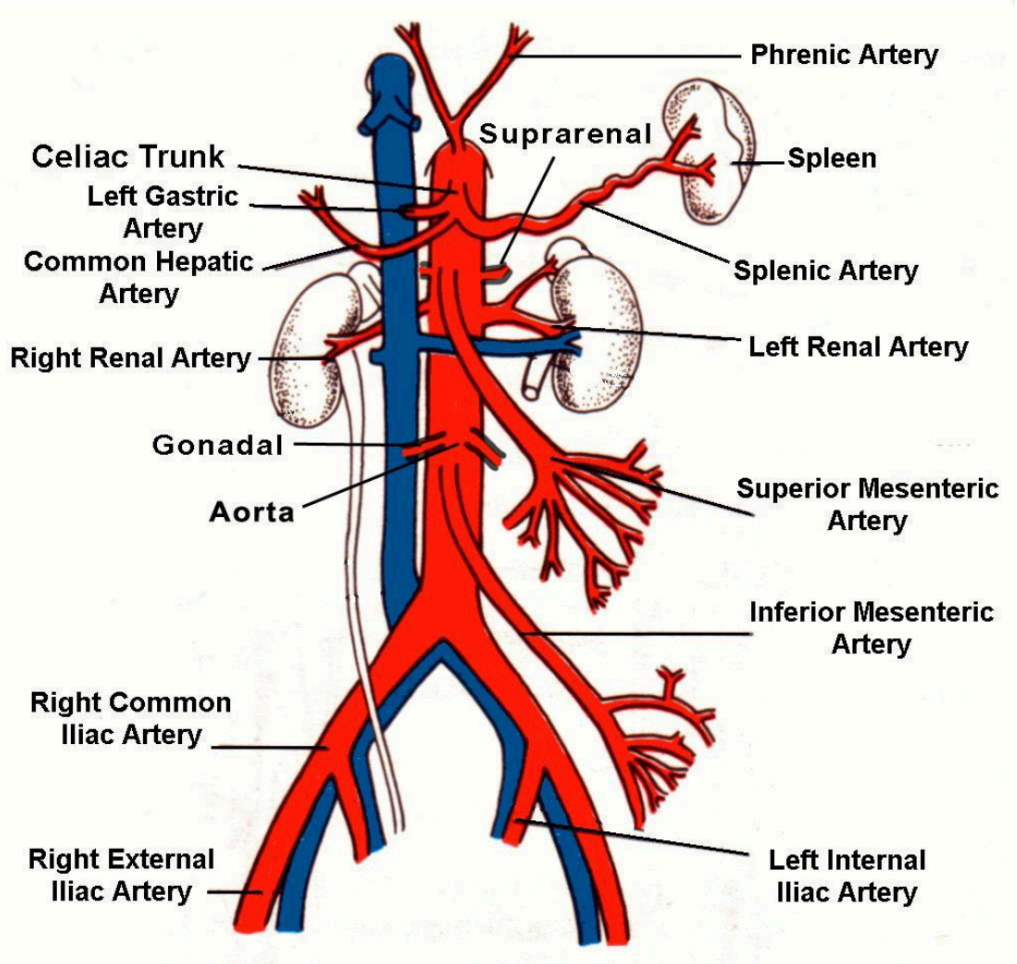
□ The inferior end of the descending aorta bifurcates into the **right** and **left common iliac**

- The common iliac further _____ into internal and external iliac artery

□ The pelvis and perineum are supplied the **internal iliac artery** and drained by the **internal iliac vein**

- Branches include: **superior** and **inferior gluteal, superior vesical, middle rectal, vaginal, uterine, internal pudendal, obturator** arteries

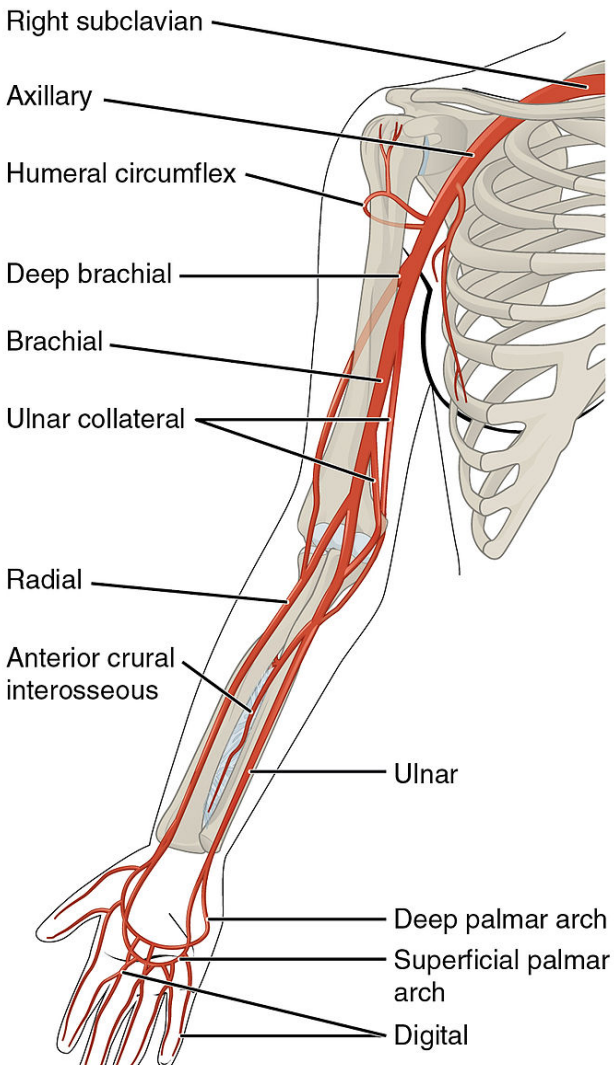
EXAMPLE:



CONCEPT: UPPER LIMB CIRCULATION

- The **subclavian artery** supplies blood to the upper limbs and the **subclavian vein** drains the upper limb
  - □ The **left subclavian artery** comes from the aortic arch, the **right subclavian artery** comes from brachiocephalic
  - □ Prior to entering the arm, the subclavian artery _____ to supply the upper body region
  - □ The subclavian artery gets renamed when it passes certain _____
    - As it crosses over the 1st rib, it becomes the **axillary artery** that supplies the shoulder/thoracic regions
    - At the inferior border of the teres major muscle, it becomes the **brachial artery**
  - □ The brachial artery then branches off to supply different areas of the _____
    - At the ventral elbow region, it splits into the **radial artery** (lateral) and **ulnar artery** (medial)
      - They anastomose and form two arterial arches in palm: **Deep palmar** and **superficial palmar arch**
        - The **digital arteries** emerge from the arches to supply the digits

EXAMPLE:



● All these veins will converge on the axillary vein and then drain into the subclavian vein

□ Drainage depends on-both the superficial and deep veins

□ Superficial drainage beings in the _____ of the hand, which drains into:

- The **basilica vein** (medial) and the **cephalic vein** (lateral)

- Basilic vein drains into the brachial vein

- Cephalic vein drains into the axillary vein

- The **median cubital vein** connects the cephalic and basilica veins

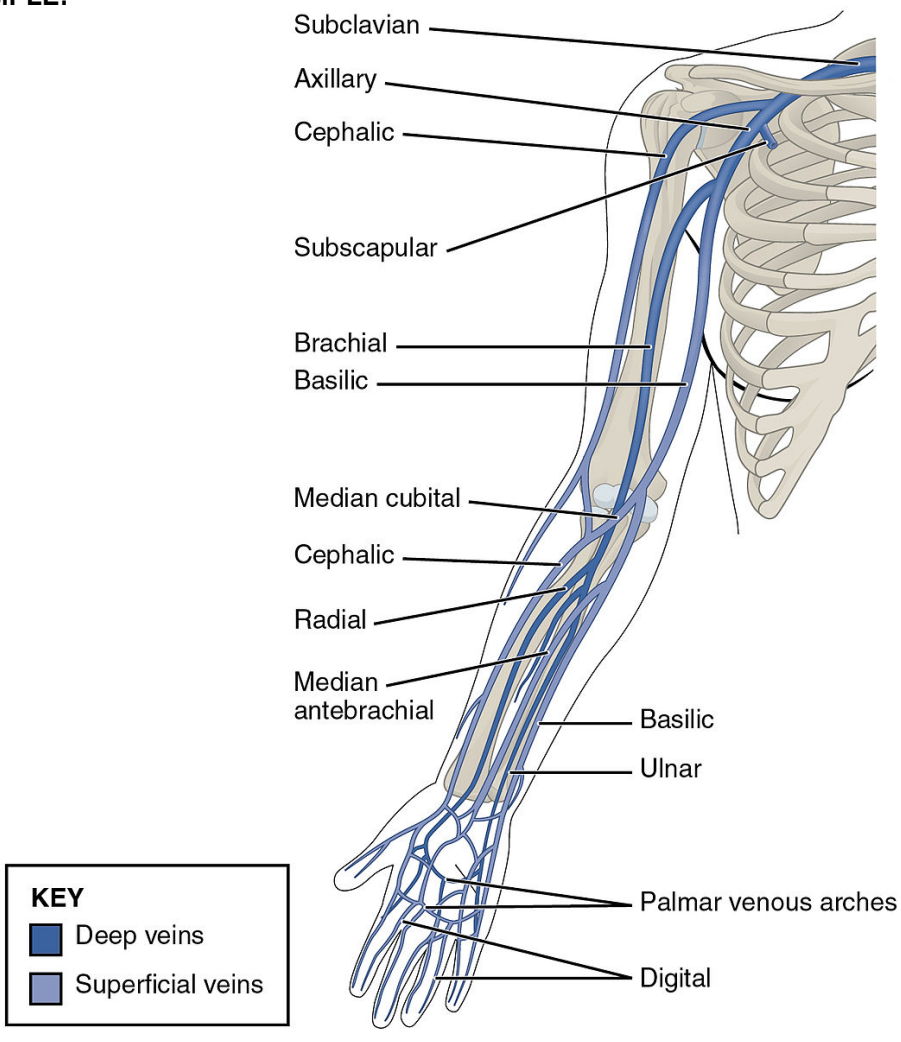
□ Deep drainage beings in the _____

- The **digital veins** and **deep** and **superficial palmar venous arches** drain into:

- A pair of **radial** and **ulnar veins**, which merge to form a pair of **brachial veins**

- Brachial veins merge to form **axillary vein**, which then becomes the **subclavian vein**

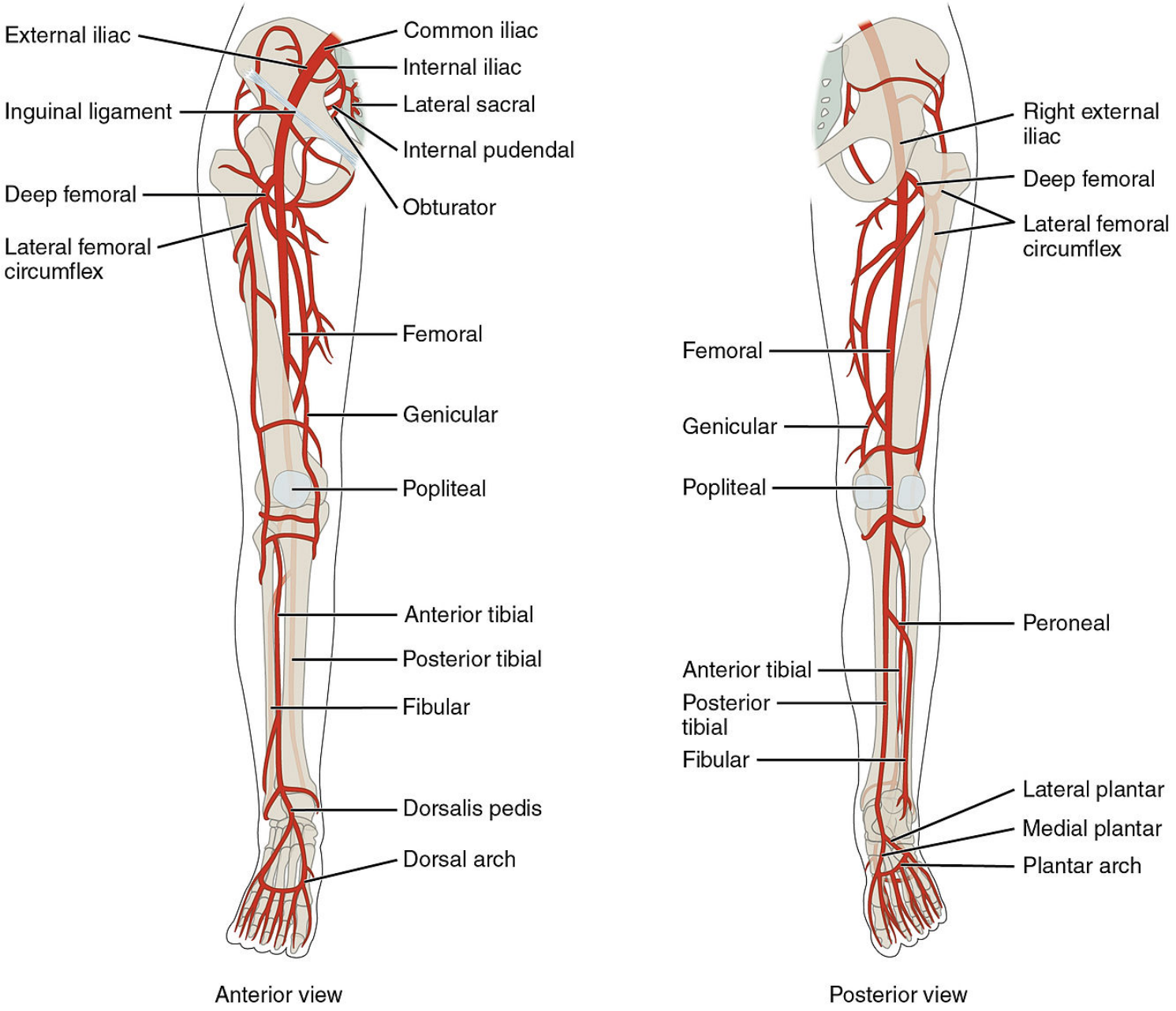
EXAMPLE:



CONCEPT: LOWER LIMB CIRCULATION

- The lower limb circulation is similar to the upper limb circulation
  - □ The **external iliac artery** becomes the **femoral artery** at the inguinal ligament
    - The **deep femoral artery** then emerges and supplies the _____ joint and posterior thigh via the:
      - **Media**l and **lateral femoral circumflex arteries**
  - □ At the popliteal fossa, the femoral artery becomes the **popliteal artery**
    - Supplies the knee joint and muscles regions, bifurcating into the anterior and posterior tibial arteries
  - □ The **anterior tibial artery** supplies the anterior leg
    - At the ankle it becomes the **dorsalis pedis** which branches into:
      - **Plantar arterial arch** and **digital arteries** to supply the plantar arch and _____
  - □ The **posterior tibial artery** supplies the posterior leg
    - Gives off a branch called **fibular (peroneal) artery** which supplies the lateral leg
    - Continues to the sole of the foot where the **medial** and **lateral plantar arteries** branch off

EXAMPLE:


External iliac
Common iliac
Internal iliac
Inguinal ligament
Lateral sacral
Internal pudendal
Deep femoral
Obturator
Lateral femoral circumflex
Femoral
Genicular
Popliteal
Anterior tibial
Posterior tibial
Fibular
Dorsalis pedis
Dorsal arch
Anterior view
Right external iliac
Deep femoral
Lateral femoral circumflex
Femoral
Genicular
Popliteal
Peroneal
Anterior tibial
Posterior tibial
Fibular
Lateral plantar
Medial plantar
Plantar arch
Posterior view

● Drainage of lower limb is also through superficial and deep veins

□ Superficial drainage begins in the dorsum of the foot and drains into the **great** and **small saphenous veins**

- The great saphenous vein

  - Arises in the medial ankle, running up medial surface of lower limb, draining into the **femoral vein**

- The small saphenous vein

  - Arises at the lateral ankle, running along _____ calf, draining into the **popliteal vein**

□ The deep drainage begins in the digits

- The deep and **digital veins** of the foot, drain into pairs of **medial** and **lateral plantar veins**

- The plantar veins join the **fibular veins** and together they drain into the **posterior tibial veins**

- The **posterior** and **anterior tibial veins** drain into the **popliteal vein**

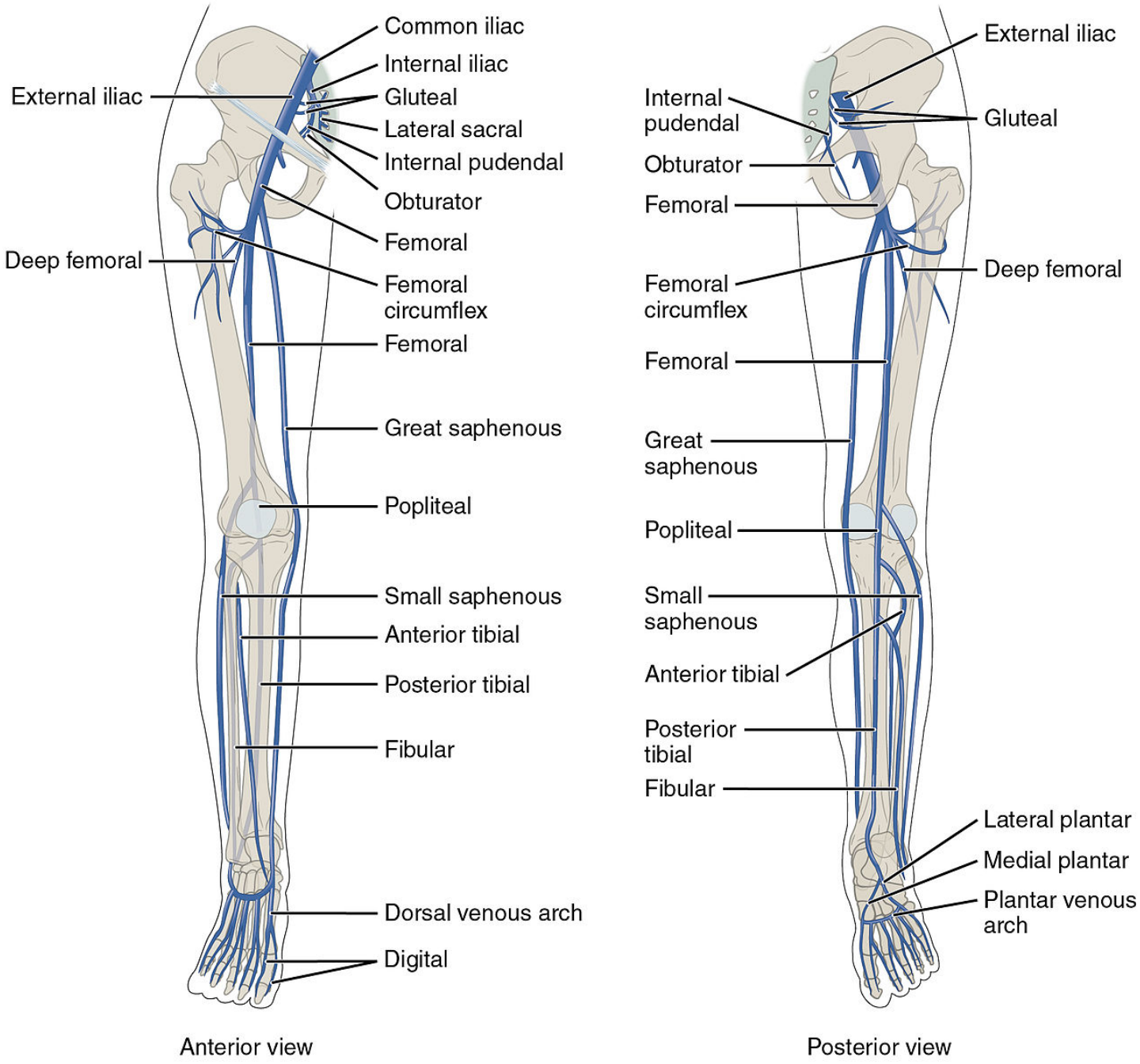
- At the _____ cap, the popliteal vein crosses from posterior to anterior thigh

  - Becomes the **femoral vein** on the anterior thigh

- When the femoral vein passes superiorly to the inguinal ligament, it becomes the **external iliac vein**

- The external and internal iliac then merge in pelvis forming the **common iliac vein→ inferior vena cava**

EXAMPLE:


Common iliac
Internal iliac
External iliac
Gluteal
Lateral sacral
Internal pudendal
Obturator
Femoral
Deep femoral
Femoral circumflex
Femoral
Great saphenous
Popliteal
Small saphenous
Anterior tibial
Posterior tibial
Fibular
Dorsal venous arch
Digital
Anterior view
External iliac
Internal pudendal
Gluteal
Obturator
Femoral
Deep femoral
Femoral circumflex
Femoral
Great saphenous
Popliteal
Small saphenous
Anterior tibial
Posterior tibial
Fibular
Lateral plantar
Medial plantar
Plantar venous arch
Posterior view