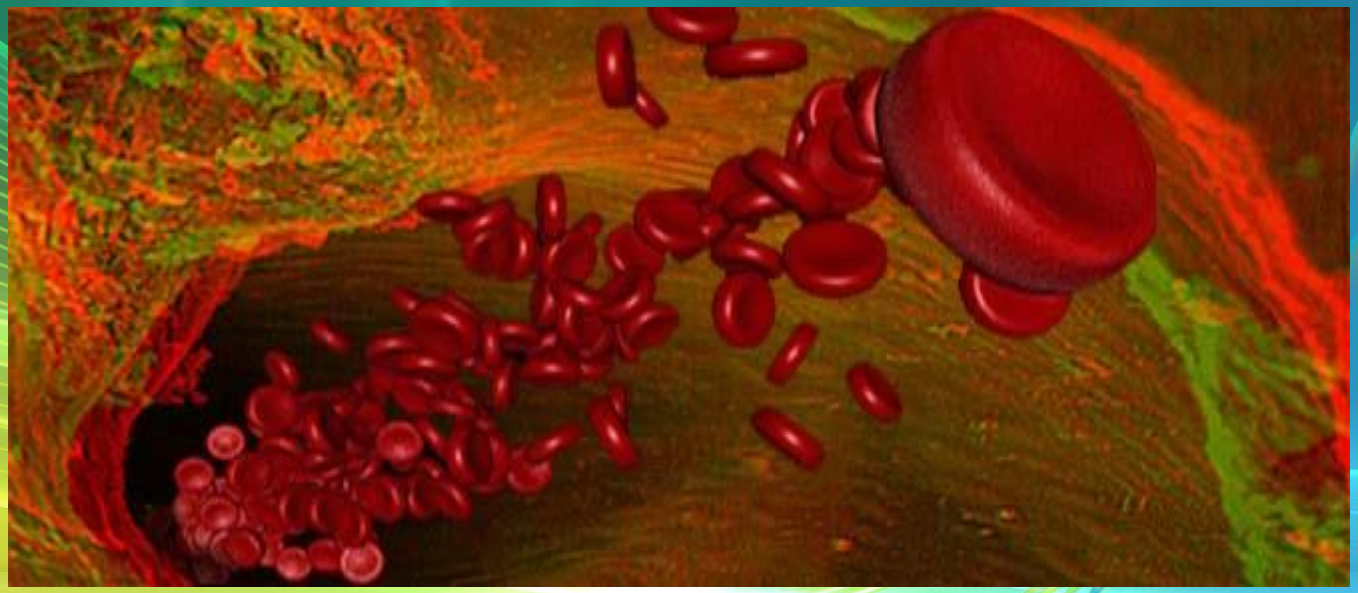
Saladin Ch. 20

Blood Vessels



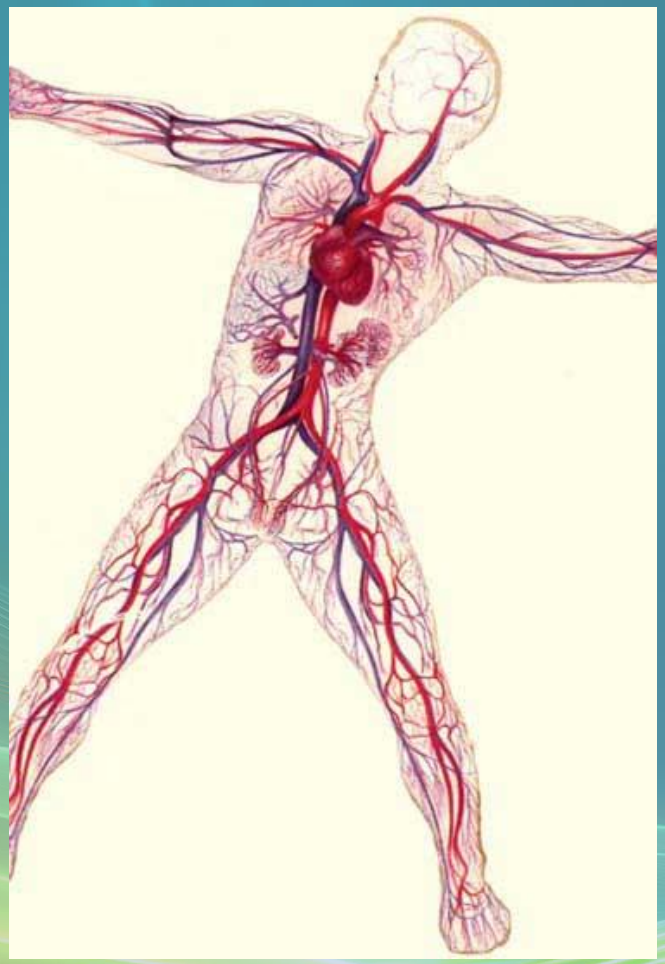
Anatomy of Blood Vessels:

- Types:
  - Arteries - carry away from heart
  - Arterioles - deliver blood to capillaries; regulate blood flow and blood pressure

Anatomy of Blood Vessels:

- Types:
  - Capillaries - exchange gases and nutrients/wastes
  - Venules - remove from capillaries
  - Veins - carry back to heart

Anatomy of Blood Vessels:



Anatomy of Blood Vessels:

- Layers:
  - Tunica interna [ti] - simple squamous epithelium, basement membrane, elastic [tissue = elastic lamina. Selectively permeable, secretes vasoactive chemicals.

Anatomy of Blood Vessels:

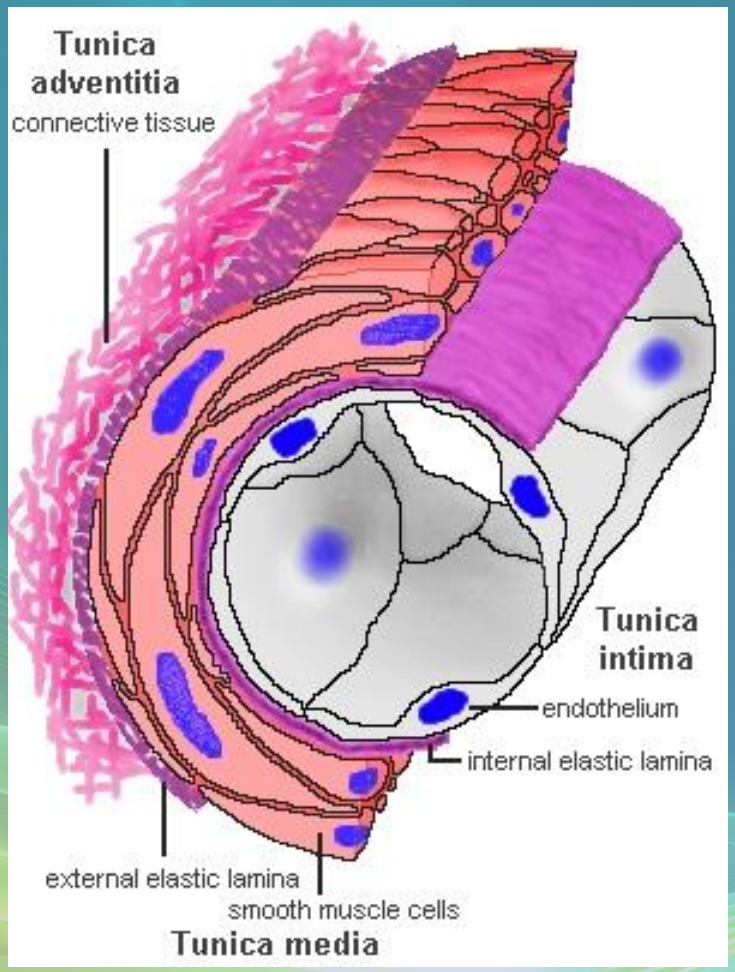
- Layers:
  - Tunica media [tm] - middle coat - thickest layer - elastic fibers and smooth muscle around lumen - allows significant expansion. Smooth muscles contractions - innervated by the sympathetic nervous system

Anatomy of Blood Vessels:

- Layers:
  - Tunica media [tm]
    - Vasomotion = If stimuli increase, fibers contract more - get vasoconstriction
    - If stimuli decrease, fibers relax - get vasodilation

Anatomy of Blood Vessels:

- Layers:
  - Tunica externa [tunica adventitia] [te] [separated from tm by external elastic lamina] mainly collagen & elastic fibers. Anchors & provides passage for nerves.


Tunica adventitia
connective tissue
Tunica intima
endothelium
internal elastic lamina
external elastic lamina
smooth muscle cells
Tunica media

Anatomy of Blood Vessels:

- Layers:
  - Tunica externa
    - Vasa vasorum - found in large vein and arteries such as the aorta and its branches. These small vessels serve to provide blood supply and nourishment .

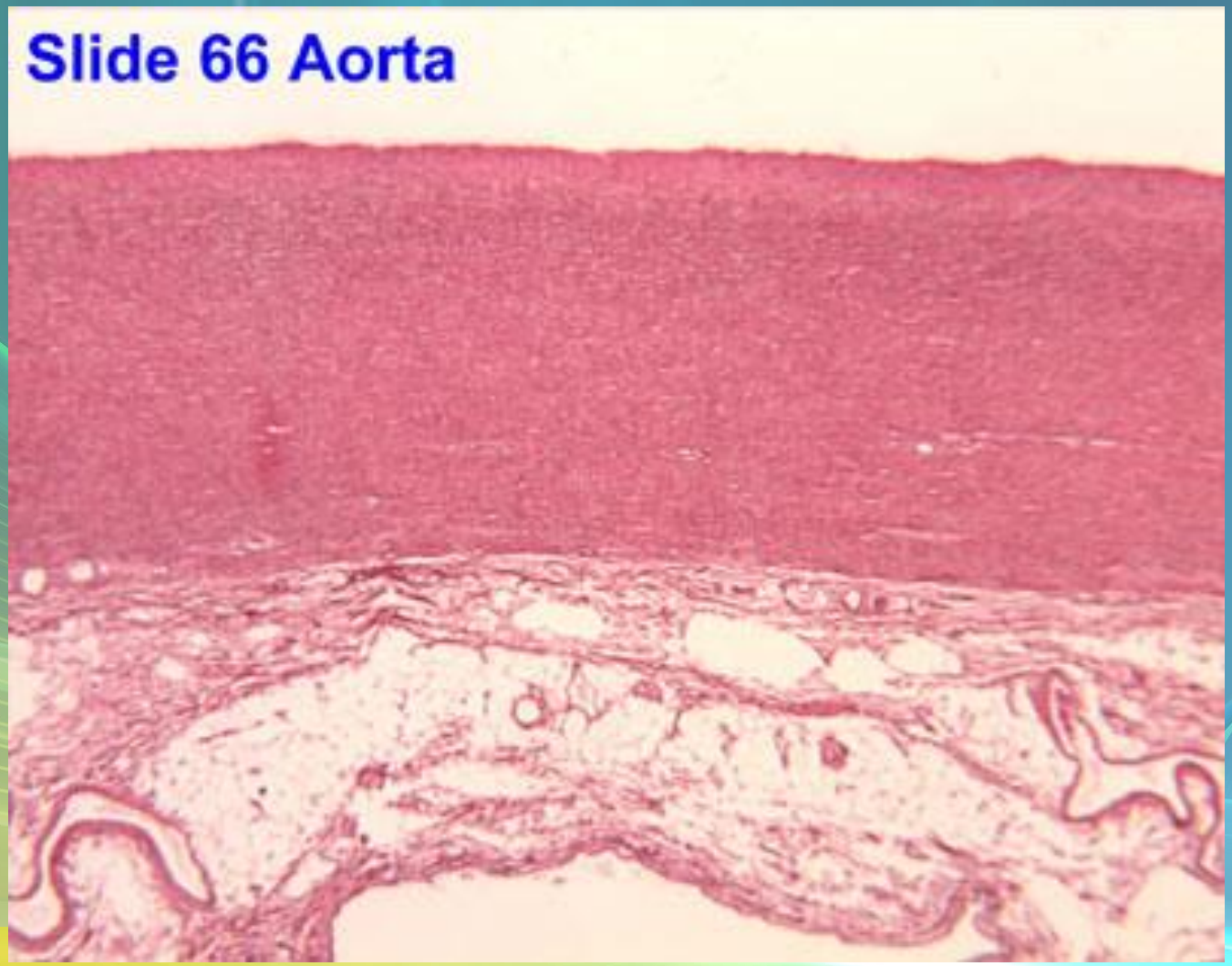
Anatomy of Blood Vessels:

- Arteries - have all three layers - resist high blood pressure
  - The thickest layer is the tm - lots of resilience to pressure and volume changes - helps move blood along during ventricular diastole.

Anatomy of Blood Vessels:

- Elastic arteries - largest diameter
  - Also called conducting arteries
  - Lots of elastic fibers, and thin walls → allows easy expansion during systole, recoil propels blood along during diastole.

Anatomy of Blood Vessels:



Anatomy of Blood Vessels:

- Distributing [muscular] arteries- medium sized
  - Tm has more smooth muscle, less elastic fibers
  - Can do greater dilation and constriction

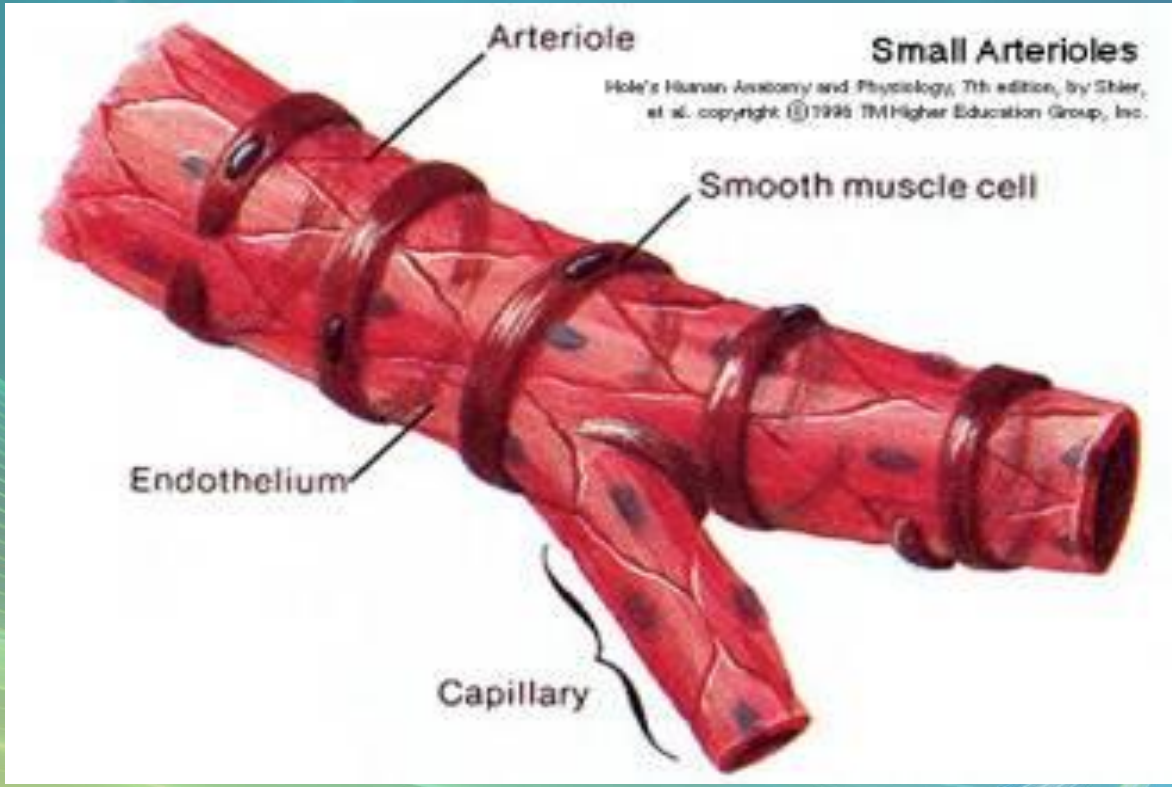
Anatomy of Blood Vessels:

- Arterioles - very small
  - Deliver to capillaries
  - Largest have 3 layers, smallest have only endothelium and a few muscle fibers

Anatomy of Blood Vessels:

- Arterioles - very small
  - Have a role in regulation of blood pressure and blood flow
  - Metarterioles link arterioles & capillaries - have precapillary sphincters that can allow or block flow into capillary beds.

Anatomy of Blood Vessels:



Anatomy of Blood Vessels:

- Arterial sense organs - monitor Bp and blood chemistry.
  - Carotid sinuses - baroreceptors - measure Bp
  - Carotid bodies - chemoreceptors - sense pH, CO_2, O_2
  - Aortic bodies - chemoreceptors like carotid bodies

Anatomy of Blood Vessels:

- Capillaries – microscopic
  - Connect arterioles to venules
  - Exchange nutrients and wastes
    - 1 cell thick - simple squamous epithelium -no tm or te

Anatomy of Blood Vessels:

- Location
  - None in epithelium or cartilage
  - Few in ligaments and tendons
  - Lots where metabolic activity is high - muscle, liver, kidney, nervous tissue

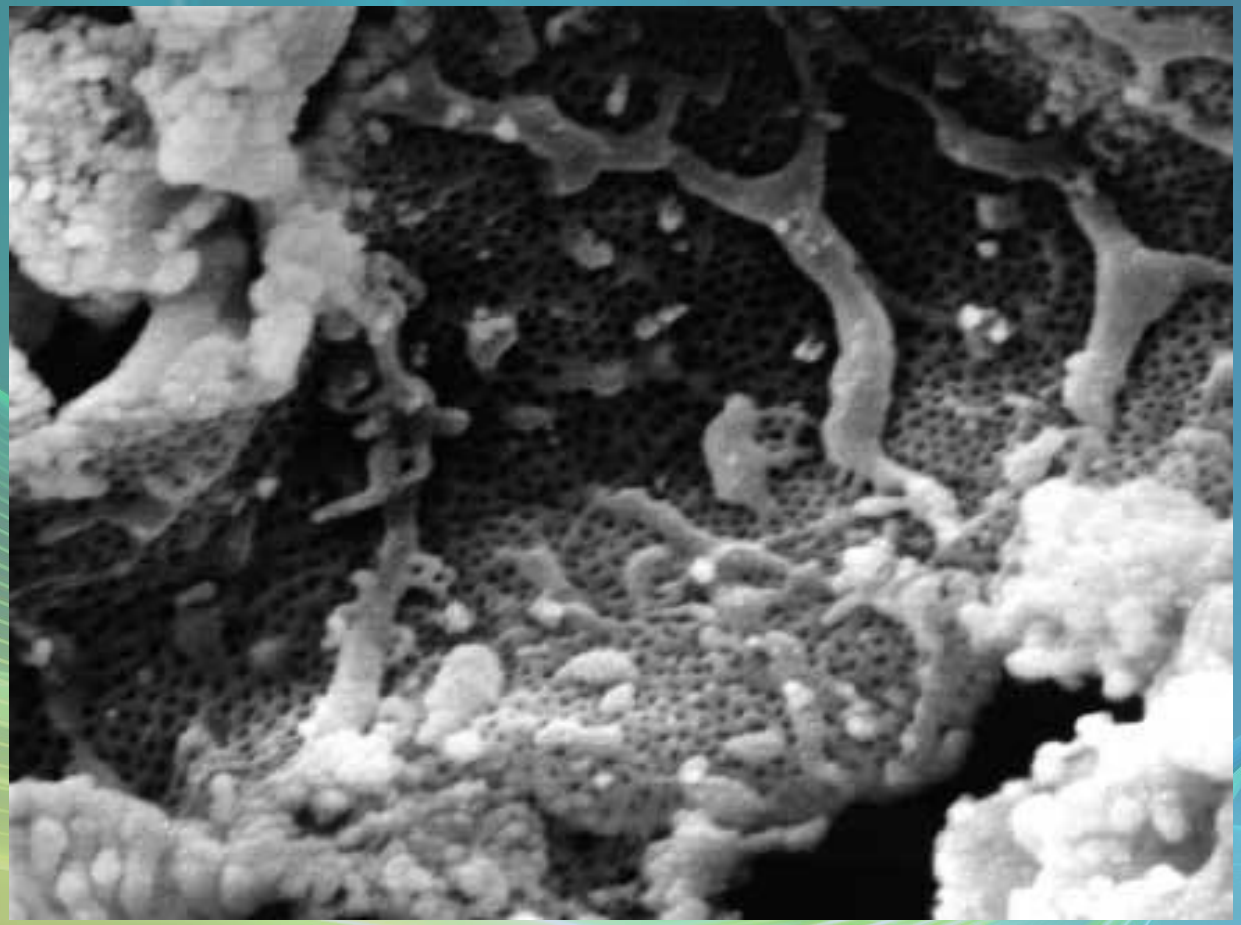
Anatomy of Blood Vessels:

- Types of capillaries
  - Continuous - uninterrupted endothelium - intercellular clefts = gaps between neighboring cells. Found in skeletal and smooth muscle, connective tissue and the lungs.

Anatomy of Blood Vessels:

- Fenestrated - endothelial cells have holes in plasma membranes = fenestrations. Found in kidney, small intestine, choroid plexuses, ciliary bodies - allow large amounts of material to flow in or out.

Anatomy of Blood Vessels:



Fenestrated

Anatomy of Blood Vessels:

- Sinusoids - wide, winding. Large fenestrations, large intercellular clefts, incomplete basement membranes. Contain tissue-specific lining cells. Can allow even blood cells to pass. Liver, bone marrow, lymphoid tissue, endocrine organs.

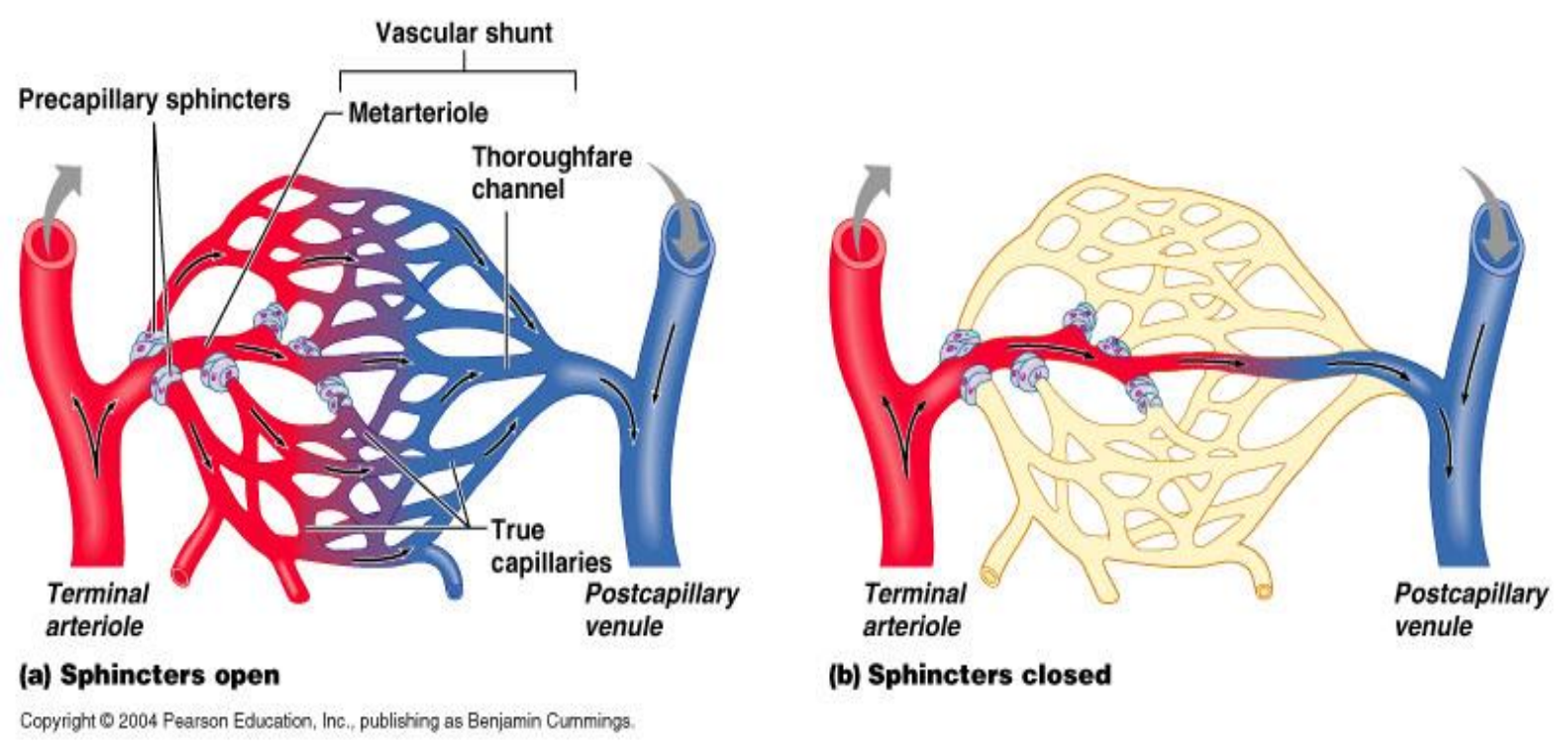
Anatomy of Blood Vessels:

Anatomy of Blood Vessels:

- Capillary bed structure - 10-100 capillaries
  - Blood flows from arterioles into metarterioles, also called **shunts**.
  - Metarterioles either pass the blood to a true capillary or bypass the capillary and pass it directly to a venule [thoroughfare channel]pathway is determined by the opening or closing of precapillary sphincters [smooth muscle].

Anatomy of Blood Vessels:

– When the sphincters are relaxed, blood flows into the capillary, when contracted, blood bypasses the capillary.

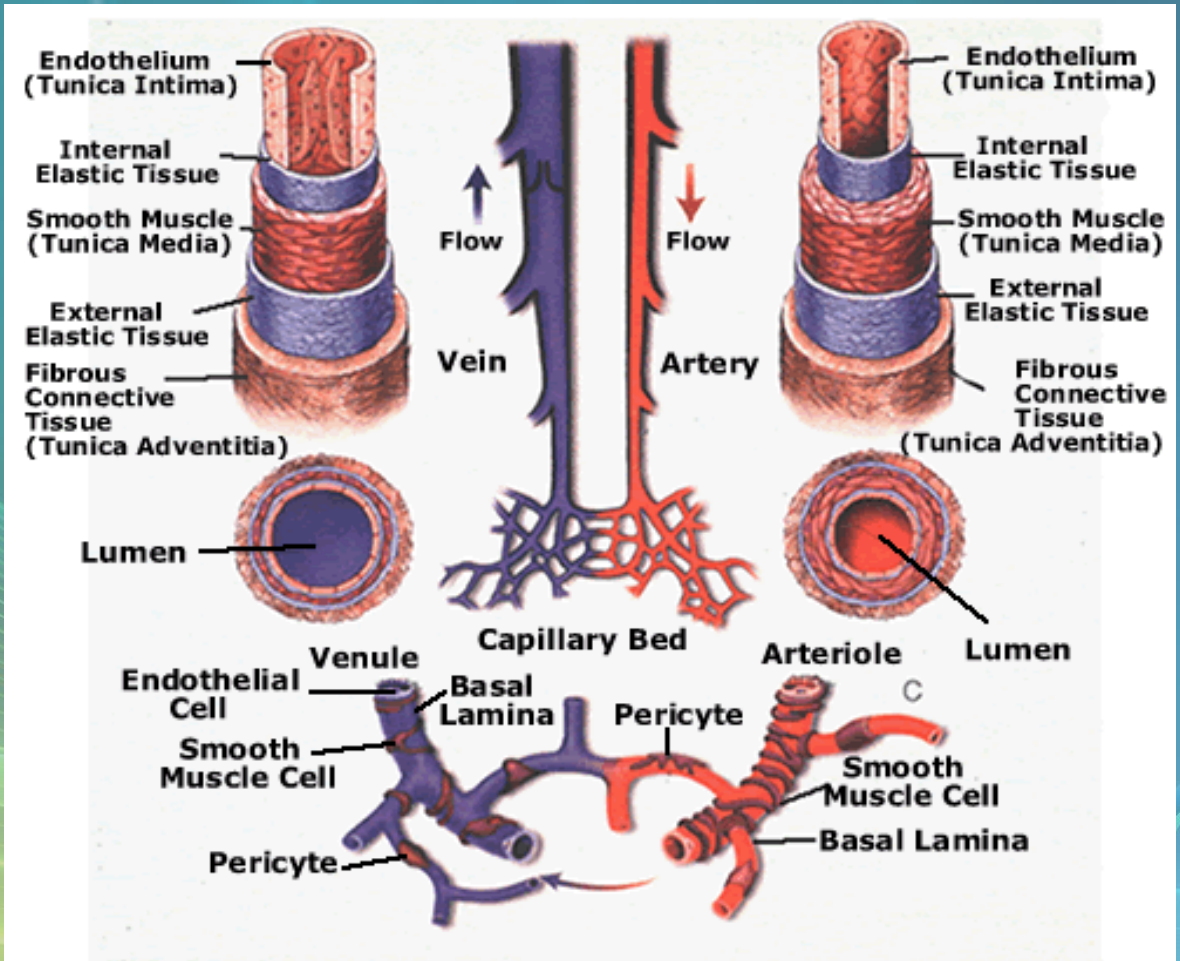


Veins

- Venules - ti and tm are thin. Venules are very porous. Large venules have a te.

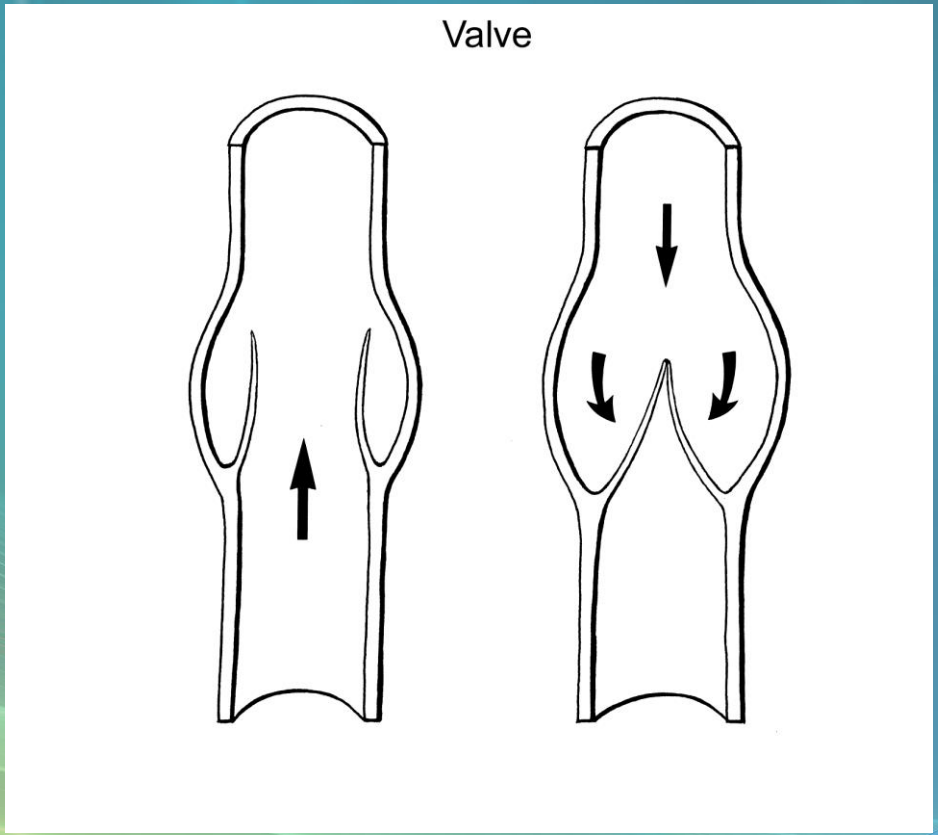
- Veins – capacitance vessels or blood reservoirs [hold up to 65% of blood - 54% at rest]
  - Layers - same 3, different thicknesses
    - Ti thinner than arteries
    - Tm much thinner than artery - little smooth muscle or elastic fibers

Veins


Endothelium
(Tunica Intima)
Internal
Elastic Tissue
Smooth Muscle
(Tunica Media)
External
Elastic Tissue
Fibrous
Connective
Tissue
(Tunica Adventitia)
Lumen
Flow
Vein
Flow
Artery
Endothelium
(Tunica Intima)
Internal
Elastic Tissue
Smooth Muscle
(Tunica Media)
External
Elastic Tissue
Fibrous
Connective
Tissue
(Tunica Adventitia)
Lumen
Capillary Bed
Venule
Endothelial
Cell
Basal
Lamina
Smooth
Muscle Cell
Pericyte
Pericyte
Arteriole
Smooth
Muscle Cell
Basal Lamina

Veins

- Larger lumens than arteries
- Valves - flaps of ti - prevent backflow
- Vascular [venous] sinus - vein lacking smooth muscle. Surrounding connective tissue replaces the tm - get a ballooning chamber.
  - Coronary sinus [heart], dural sinuses [brain].


Valve

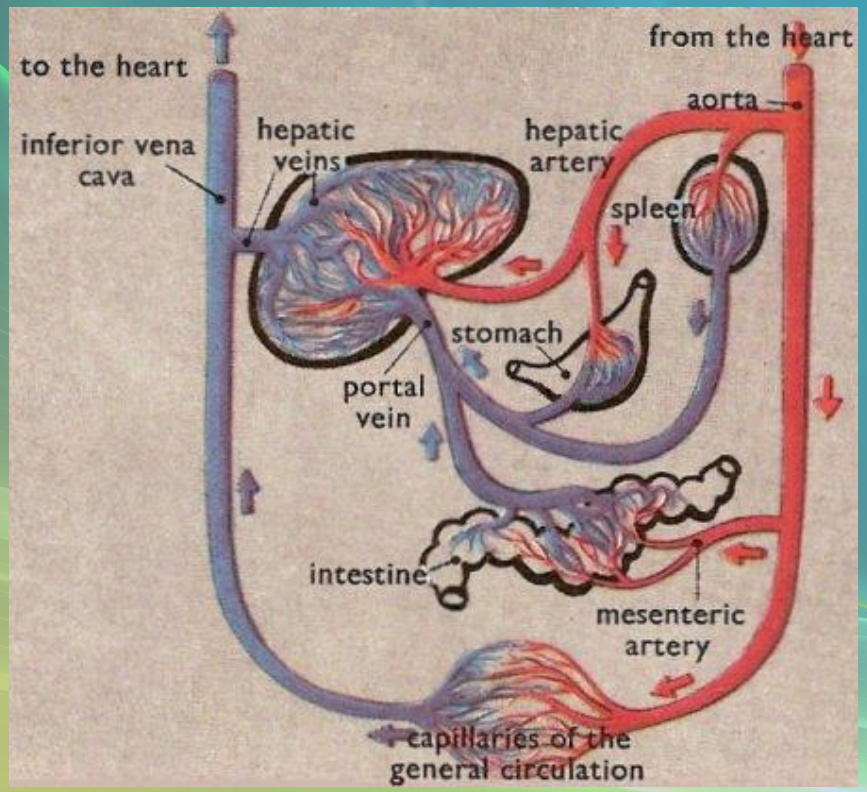
Veins

- Vessel Homeostatic Imbalances: Varicose Veins

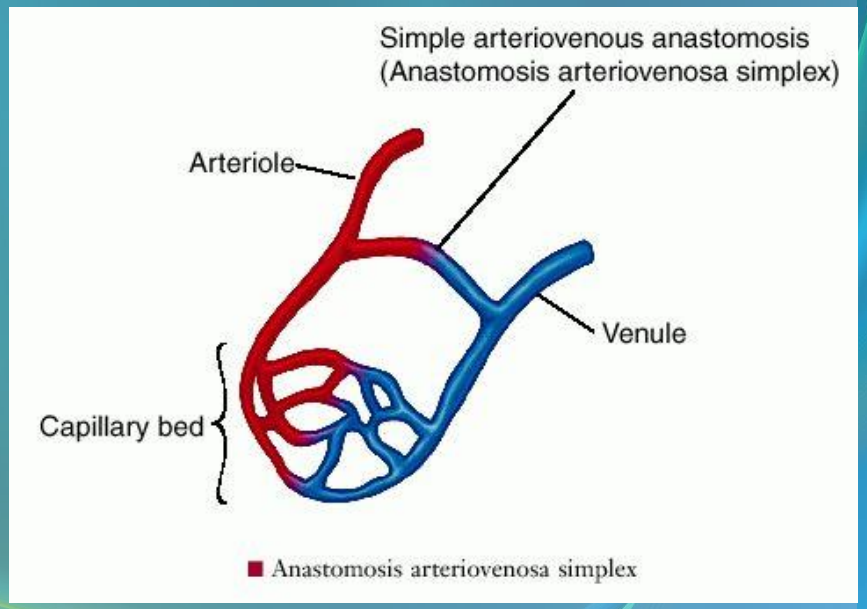
Circulatory Routes

- Usual - one capillary bed Heart --> arteries -->capillaries --> veins --> heart
- Portal system - 2 consecutive capillary beds
- Anastomoses - alternate routes - 2 or more arteries or veins supplying the same region; shunts - artery --> vein [no capillary bed]

Portal System



Anastomosis



Blood Pressure and Resistance

- **Blood flow**
  - From Ch. 19 → CO = SV X HR
  - **Blood Flow** – the amount of blood moving through something in a unit time.
  - **Perfusion** - flow per given volume or mass of tissue

Blood Pressure and Resistance

- **Blood pressure - force blood exerts on a vessel wall**
  - Arterial Blood Pressure – related to stretch of elastic arteries and CO
    - Varies with heart rate
    - Highest at ventricular systole
    - Lowest at diastole

Blood Pressure and Resistance

- Pulse Pressure = S-D
- Mean Arterial Pressure = D + [1/3] PP

Blood Pressure and Resistance

- Measuring Blood pressure - sphygmomanometer
  - Use Korotkoff sounds
    - Use stethoscope and/or pulse - pump up cuff until no sound/pulse.
    - Release pressure slowly 'til get sound [fairly loud] - record the pressure = systolic

Blood Pressure and Resistance

- Continue to release pressure 'til sounds become faint/stop - record pressure = diastolic

- Normal - systolic < 100-140, diastolic 70- 80

- Alterations in Bp:
  - » Hypotension - systolic , 100.
  - » Hypertension

Blood Pressure and Resistance

- Normal increases with fever, exercise and emotional upset.
- 30% of those over 50 are hypertensive.

Blood Pressure and Resistance

Blood Pressure and Resistance

- CO, volume & resistance determine Bp
  - Blood flows down a pressure gradient – if there is none, there is no flow
- Blood pressure also depends on total blood volume
  - Small decreases are compensated for by usual homeostatic mechanisms

Blood Pressure and Resistance

- Large losses [10% +] result in a decrease in pressure
- Water retention, etc. result in increases in blood pressure

Blood Pressure and Resistance

- **Peripheral Resistance** [mostly friction]
  - Depends on vessel average radius, blood viscosity and total vessel length
  - As viscosity [internal resistance to flow in a fluid] increases, resistance increases [mostly due to rbc count and albumin].

Blood Pressure and Resistance

- As total length increases, resistance increases [gain 300 Km of vessel length per pound – this is the main issue with weight gain and pressure increases].

Blood Pressure and Resistance

– Blood vessel radius – peripheral arteries.

- Systemic vascular resistance = total peripheral resistance

- Controlled mostly by arterioles - vasoconstriction & vasodilation

Blood Pressure and Resistance

- Laminar flow - faster toward center of tube [less friction], slower toward walls [more]

- As average radius decreases, resistance increases: $F \alpha r^4$ so radius changes have major effects on velocity.

Blood Pressure and Resistance

- Bernoulli's principle – the velocity of a fluid increases as the ***net*** diameter of the tube[s] decrease. As velocity of a fluid increases, its pressure decreases.

Blood Pressure and Resistance

Energy per unit volume before = Energy per unit volume after

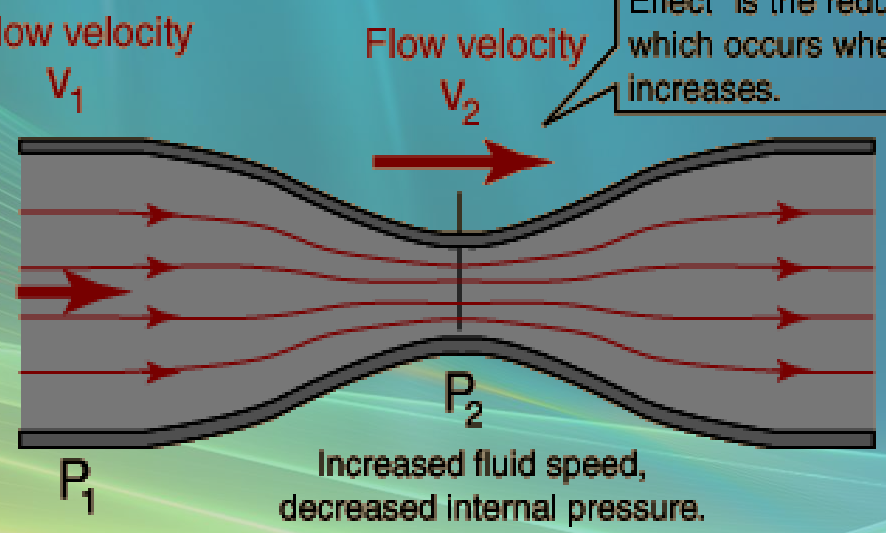
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Pressure Energy

Kinetic Energy per unit volume

Potential Energy per unit volume

The often cited example of the Bernoulli Equation or "Bernoulli Effect" is the reduction in pressure which occurs when the fluid speed increases.



$A_2 < A_1$

$v_2 > v_1$

$P_2 < P_1$!

Blood Pressure and Resistance

- As arteries branch, the net diameters of the branches is greater than the diameter of the original artery. Therefore, velocity drops and pressure increases.

- As veins unite, the reverse holds, therefore velocity increases and pressure drops.

Blood Pressure and Resistance

- The average velocity at the aorta is 1200 mm/s. At a capillary, it is 0.4 mm/s. At the vena cavas, it is 80 mm/s

- Small constriction or dilation => a large resistance change.

Regulation of Blood Pressure & Flow

- **Neural Control**
  - CV center of medulla oblongata affects vessel diameter & CO
    - Input from cortex, limbic system, hypothalamus
    - Contains nuclei for heart rate, contractility, vessel diameter
    - Receives sensory input – proprioceptors, baroreceptors, chemoreceptors

Regulation of Blood Pressure & Flow

- CV output – sympathetic and parasympathetic ANS
  - Sympathetic to heart – via cardiac accelerator nerves – increase heart rate.
  - Parasympathetic to heart – via the vagus nerve [CX] – decreases rate.
  - Sympathetic to vessel walls – vasomotor nerves.

Regulation of Blood Pressure & Flow

- “Vasomotor tone” is maintained by regular stimulation of vessels, yielding a moderate degree of continuous contraction.

Regulation of Blood Pressure & Flow

– Baroreceptor reflex

- Receptors in walls of carotid and aortic sinuses [proximal internal carotid, aortic arch and ascending aorta]
- Mechanoreceptors - stretch stimulates
- Send impulses to medulla oblongata - the carotid by CXI, aortic by CX

Regulation of Blood Pressure & Flow

- As blood pressure decreases - get fewer stimuli
  - Response - CV decreases parasympathetic stimulation and increases sympathetic stimulation - which also increases secretion of epinephrine and norepinephrine
  - Effect - increase in heart rate and force of contractions, vasoconstriction

Regulation of Blood Pressure & Flow

- As blood pressure increases - get more stimuli - CV increases parasympathetic and decreases sympathetic stimulation - epinephrine and norepinephrine decrease

– Carotid sinus massage and syncope - pressure applied to carotid sinus produces response - decrease in blood pressure - may cause fainting[Think Vulcan].

Regulation of Blood Pressure & Flow

– Chemoreceptor reflex - carotid and aortic bodies

- Detect H^+, O_2 and CO_2
- Hypoxia [low oxygen] acidosis [high H^+] or hypercapnia [high CO_2] stimulate
- CV - increase sympathetic stimulation of vessels - produces vasoconstriction which increases blood pressure.

Regulation of Blood Pressure & Flow

- Medullary Ischemic Reflex
  - Response to a drop on brain perfusion → increase HR & force of contraction, also → vasoconstriction. Can respond to emotions.

Regulation of Blood Pressure & Flow

- **Hormonal Control**
  - Epinephrine/norepinephrine - adrenal medulla
    - Increase CO by increasing heart rate & force of contractions. Epinephrine also causes vasodilation of arterioles in cardiac and skeletal muscle. Both cause vasoconstriction of arterioles & veins in skin & abdominal organs.

Regulation of Blood Pressure & Flow

- ADH causes vasoconstriction & water retention.

- Atrial natriuretic peptide - from atrial walls - decreases blood pressure by increasing
  - vasodilation and promoting salt & water

- Angiotensin II [Renin-angiotensin pathway] vasoconstricton & release of aldosterone.
  - ACE [angiotensin-converting enzyme] needed for formation – blocked by ACE inhibitors.

Vasomotion & Routing Blood Flow

- Automatic adjustment of flow to tissues based on need

- Arterioles & Beds make automatic adjustments of vasoconstriction and dilation to match local O_2 demand = auto-regulation

- Physical changes - warming results in vasodilation, etc. Muscle stretching decreases when blood flow decreases

Capillary Exchange:

- Exchange mechanisms – diffusion, transcytosis, filtration, reabsorption
  - Diffusion - most goes this way
  - Transcytosis - via pinocytic vesicles [fatty acids, albumins, some hormones]
  - Filtration & Resorption

Capillary Exchange:

- **Filtration** = pressure-driven flow out of capillaries into IF – at arteriolar end, capillary hydrostatic pressure and a “drawing” pressure from IF → net 33 mm Hg outward force.

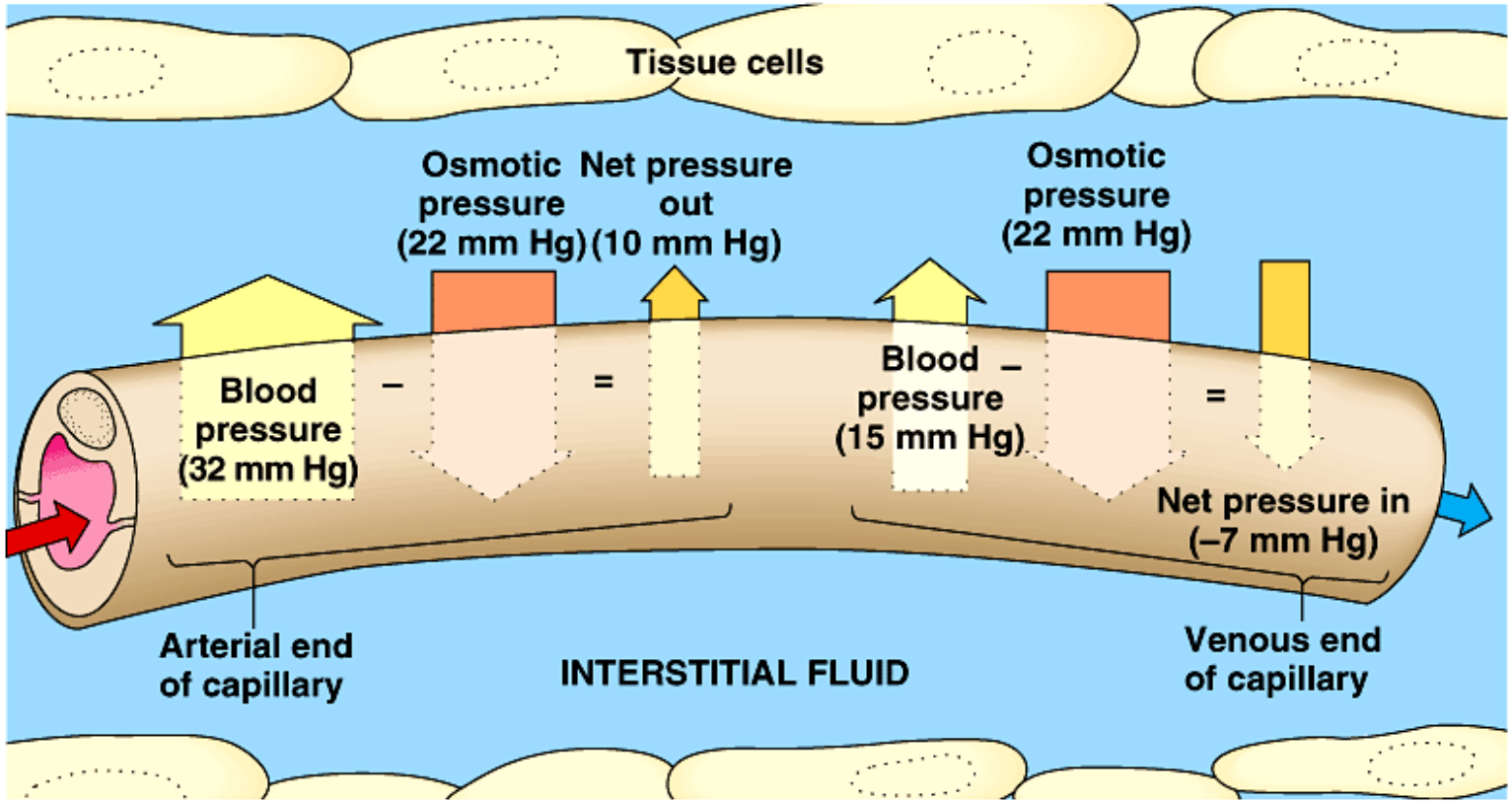
Capillary Exchange:

- **Filtration** = Colloid osmotic pressure [due to number of pieces of solute] draws water into capillary [~ 20 mmHg inward]. Net filtration pressure = 33 – 20 = 13

- **Resorption** = pressure-driven flow into capillaries [see fig. 20.17] Blood pressure has dropped to 10 mm Hg, + 3 mm from "drawing" force → 13 mm Hg outward, but still have 20 inward, so net at venule end is 20 – 13 = 7 mm Hg inward.

Capillary Exchange:

– **Bulk flow** = solvent drag – stuff in water moves



Capillary Exchange:

- Edema
  - Fluid exits faster than re-enters → swelling, inadequate waste removal, hypoxia, etc.
  - Increased capillary filtration – kidney failure, hear failure, histamine reactions
  - Reduced reabsorption – deficient serum protein due to liver failure or damage – related to famine
  - Obstructed lymphatic drainage

Venous Return & Shock

- Harvey demonstrated valve action – one way flow
- Venous return = volume of blood flowing back to heart veins – 5 factors
  - Velocity – increases as vessels get larger
  - Venous Blood Pressure –favors return to heart.

Venous Return & Shock

- Gravity
- Respiratory pump – inhale – diaphragm drops, squeezes abdominal vessels, while pressure on thoracic vessels drops.
- Exhale – diaphragm goes up, releases pressure on abdomen, applies it to thoracic vessels.

Venous Return & Shock

- Skeletal muscle pump – contractions of muscles squeeze vein, close lower valve, open upper – blood squirted up.

Venous Return & Shock

- Relaxation backflow closes upper valve, lower opens and blood flows into region because of pressure reduction above.

- Cardiac suction

Venous Return & Shock

Venous Return & Shock

- Circulatory Shock = failure of cardiovascular system to deliver enough O_2 and nutrients to meet cellular metabolic needs. Caused by inadequate blood flow.

- Velocity – increases as vessels get larger
  - Venous Blood Pressure – pressure gradient from 7 – 13 mmHg throughout system – favors return to heart.

Venous Return & Shock

- Types:
  - Hypovolemic - decreased volume - hemorrhage, dehydration, diabetes.
  - Cardiogenic - poor heart function – MI
  - Vascular - inappropriate dilation - toxins, allergins, neurologic, tumors, etc.

Venous Return & Shock

- Circulatory Shock
- Homeostatic responses
  - Renin-angiotensin- aldosterone
  - ADH

Venous Return & Shock

- Homeostatic responses
  - Sympathetic ANS acts on CV center
  - Release of local dilators

Venous Return & Shock

- Circulatory Shock

- Signs and symptoms
  - Weak, rapid pulse – tachycardia
  - Clammy pale cold skin
  - Sweats - sympathetic stimulus

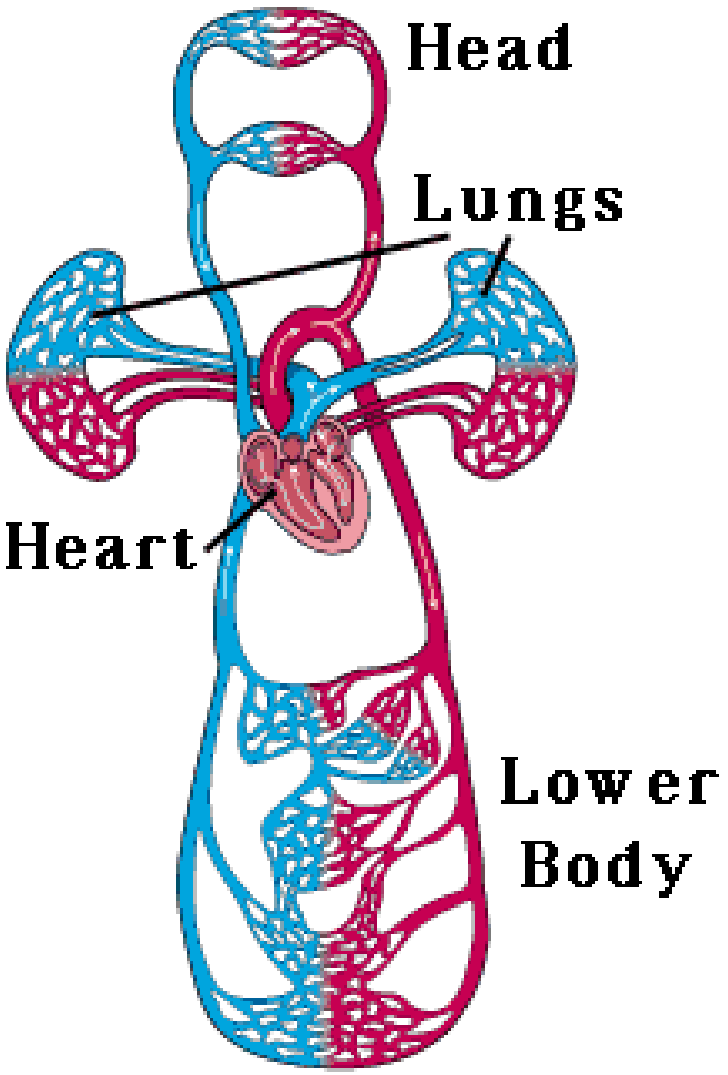
Venous Return & Shock

- Urine reduction
- Thirst
- Acidosis - lactate accumulation
- Nausea - circulation to digestive system reduced
- Altered mental state

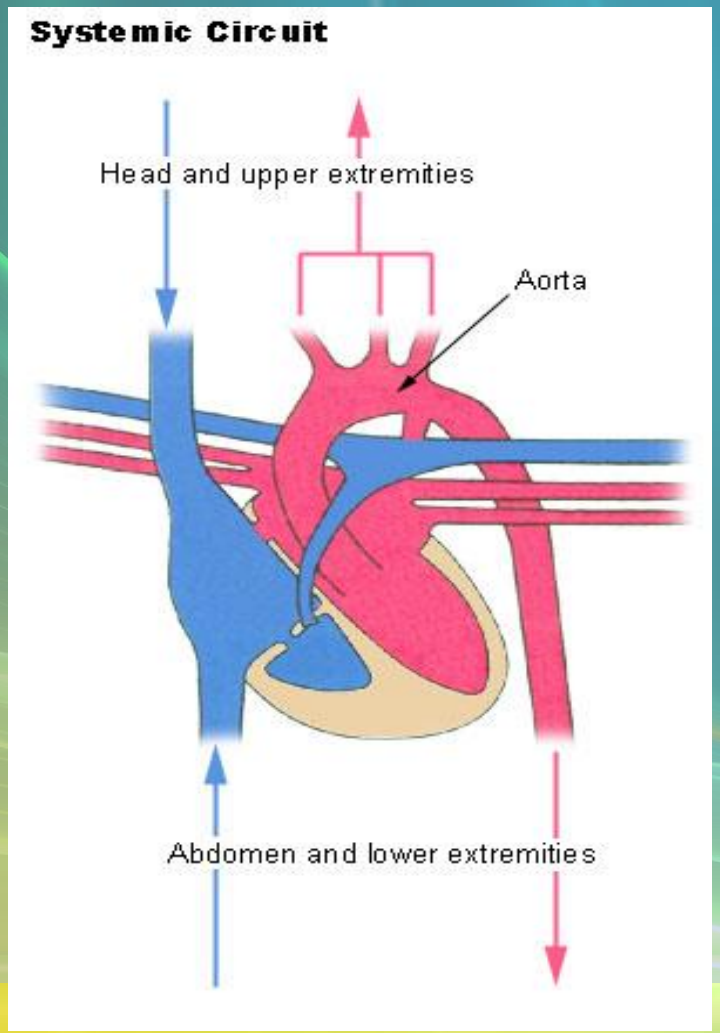
Circulatory Routes: Omit text sections except for the following:

- **Systemic** - out L. Ventrical, in R. Atrium

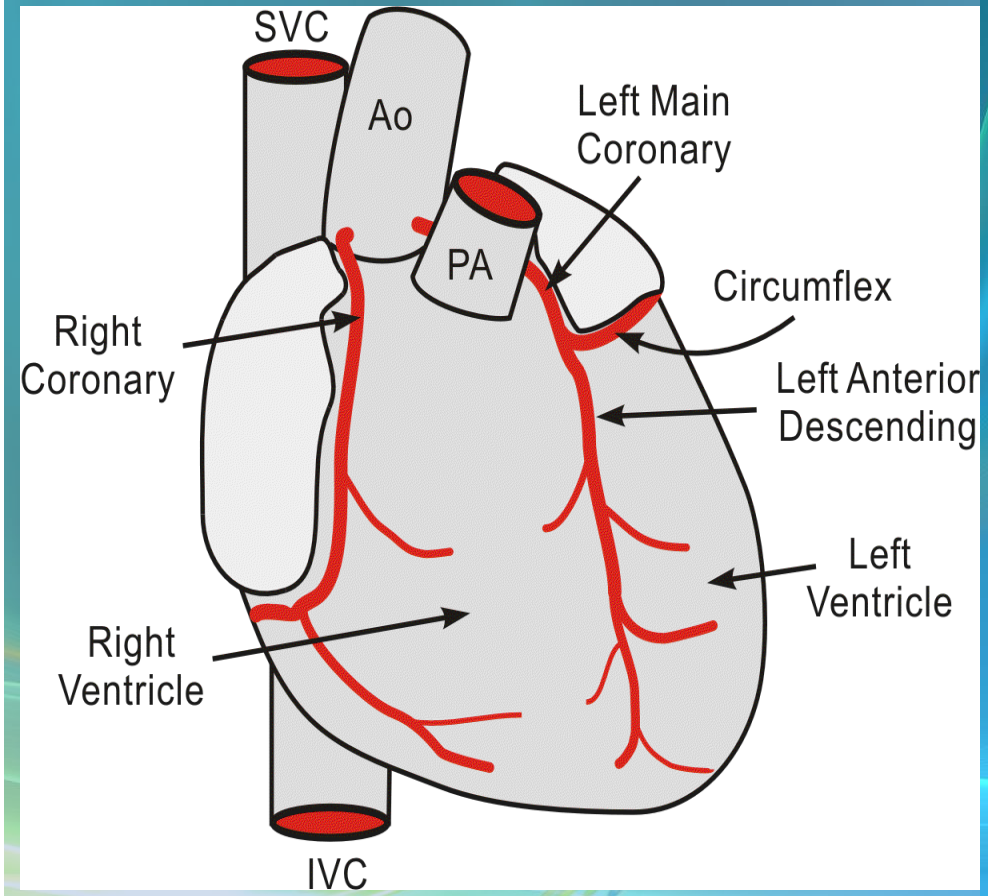
- **Coronary** - from ascending aorta into L. and R. coronary arteries to coronary sinuses to R. atrium [review from chapter 19]


Head
Lungs
Heart
Lower
Body

Circulatory Routes: Omit text sections except for the following:



Coronary



Circulatory Routes: Omit text sections except for the following:

- **Hepatic Portal** Circulation [a portal system carries blood between two capillary networks]
  - Carries blood from capillaries of GI tract to sinusoids of liver
  - Nutrients absorbed in GI are stored and/or processed in liver

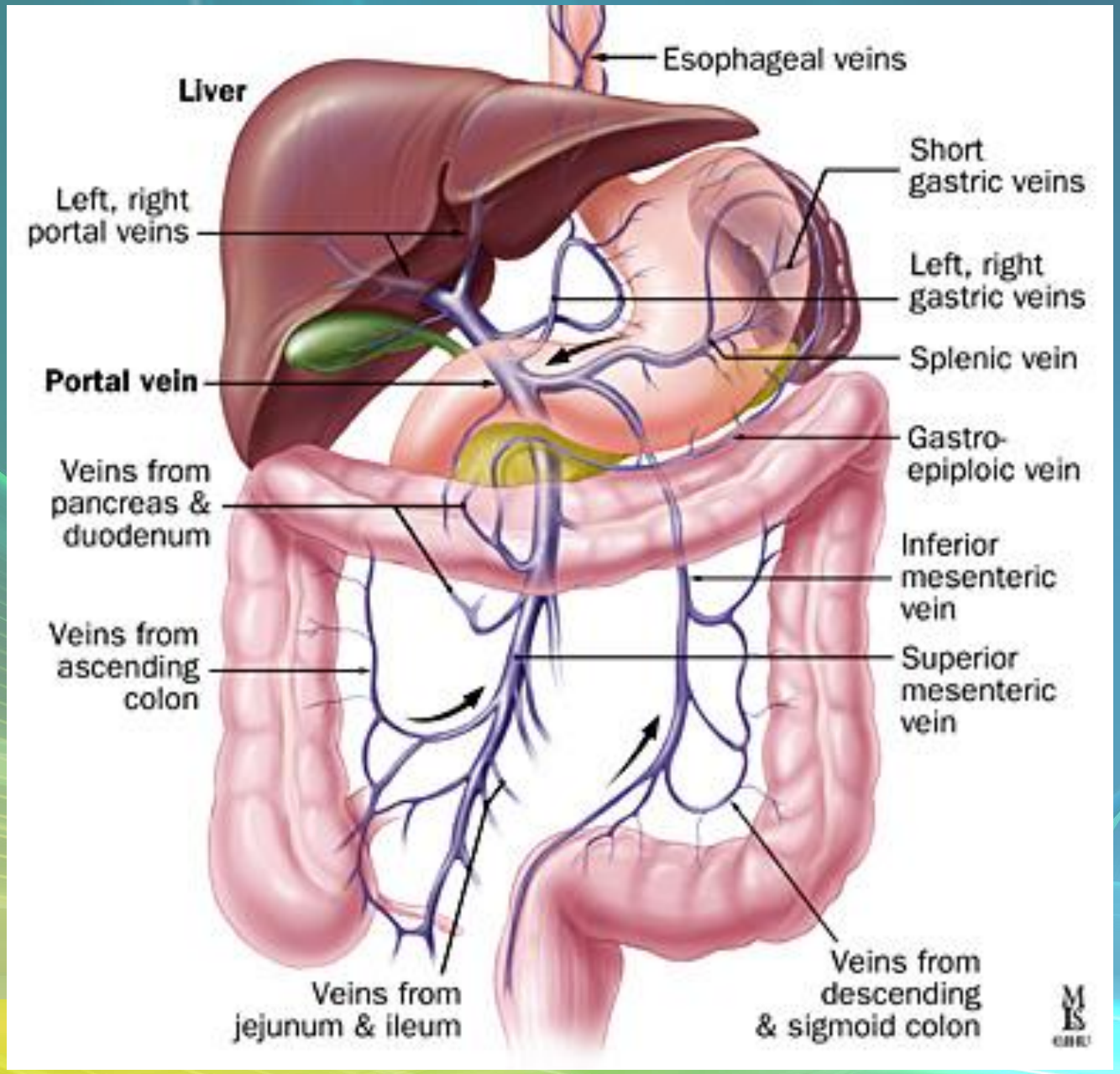
Circulatory Routes: Omit text sections except for the following:

- Harmful substances absorbed in GI are detoxified
- Bacteria are destroyed by liver macrophages
- Circuit:
  - **Hepatic portal vein** is formed from union of **superior mesenteric vein**[small intestine, some large intestine, stomach and pancreas] & **splenic veins** [stomach, pancreas, some large intestine].

Circulatory Routes: Omit text sections except for the following:

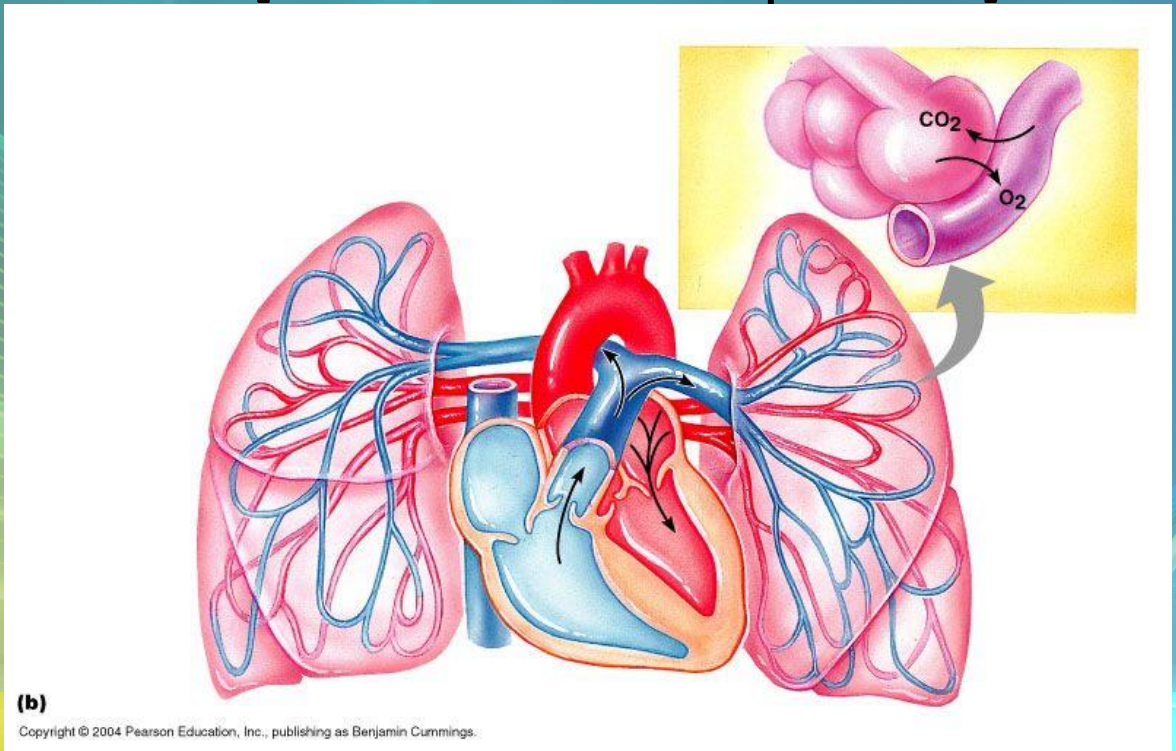
- The **inferior mesenteric vein** → splenic. The **right & leftgastric veins** from the stomach → hepatic portal vein directly. C**ystic vein** from gallbladder →hepatic portal directly also.

- These bring deoxygenated, nutrient rich blood into liver. **Proper hepatic artery** → to liver. All blood ***leaving*** liver goes through **hepatic veins**, → inferior vena cava.


Esophageal veins
Liver
Short gastric veins
Left, right portal veins
Left, right gastric veins
Splenic vein
Portal vein
Gastro-epiploic vein
Veins from pancreas & duodenum
Inferior mesenteric vein
Veins from ascending colon
Superior mesenteric vein
Veins from jejunum & ileum
Veins from descending & sigmoid colon

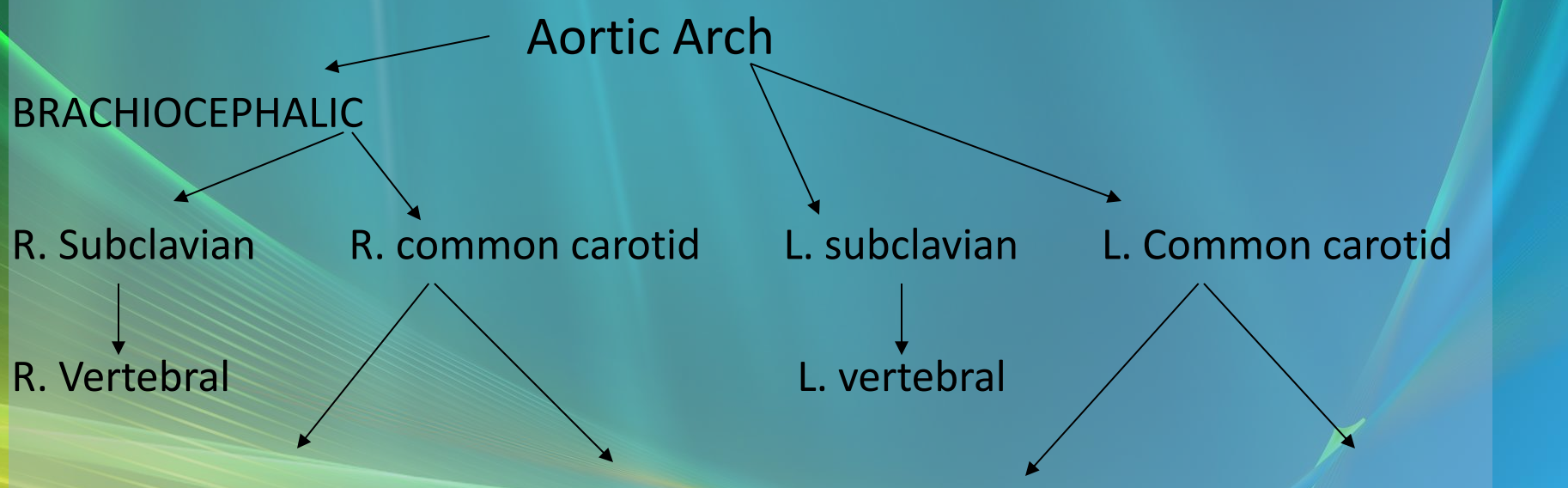
Circulatory Routes: Omit text sections except for the following:

- **Pulmonary circulation** - Pulmonary trunk → pulmonary arteries → capillaries → pulmonary veins → left atrium [review from chapter 19]



Circulatory Routes: Omit text sections except for the following:

- **Cephalic Circulation**



Circulatory Routes: Omit text sections except for the following:

- All flow into the cerebral arterial circle of Willis [a collection of vessels]. This provides multiple alternate paths and equalizes cephalic blood pressure.

Circulatory Routes: Omit text sections except for the following:

- **Fetal Circulation**
  - Oxygen and nutrients are delivered to the fetus from maternal blood via the placenta.
  - All exchange occurs in intervillous spaces in the placenta by diffusion

Circulatory Routes: Omit text sections except for the following:

- Blood from the fetus to the placenta - the abdominal aorta → common iliac artery, → internal iliac arteries. These branch →umbilical arteries → through the umbilicus to the placenta where they pick up oxygen and nutrients.

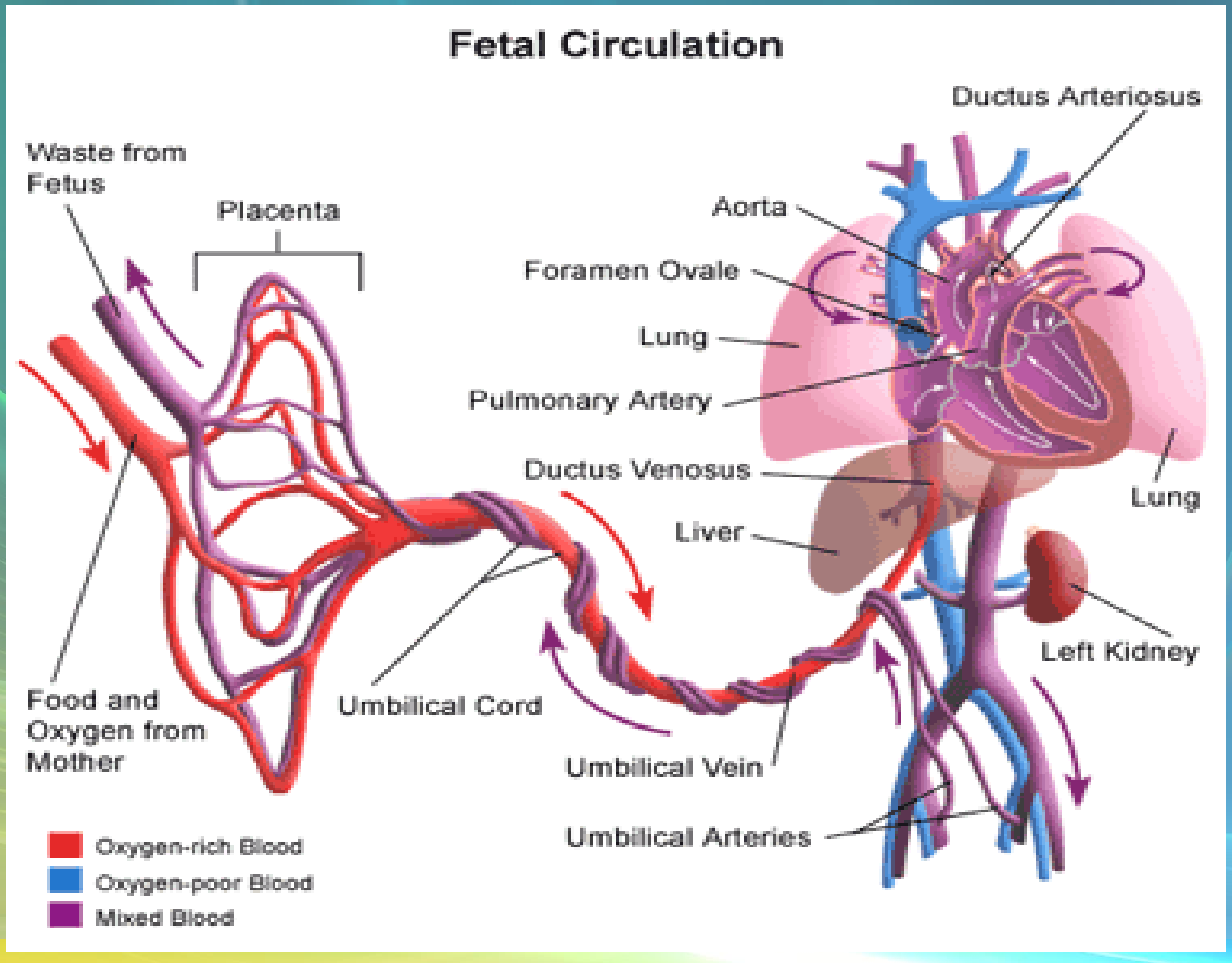
Circulatory Routes: Omit text sections except for the following:

- From the placenta to the fetus - → through the umbilical vein, →. Here it branches into the hepatic portal vein and the ductus venosus, → inferior vena cava. Deoxygenated blood from the lower fetus mixes with the ductus venosus blood in inferior vena cava and moves into right atrium.

Circulatory Routes: Omit text sections except for the following:

- From the placenta to the fetus - Deoxygenated blood from the upper fetus goes directly into the superior vena cava and into the right atrium.

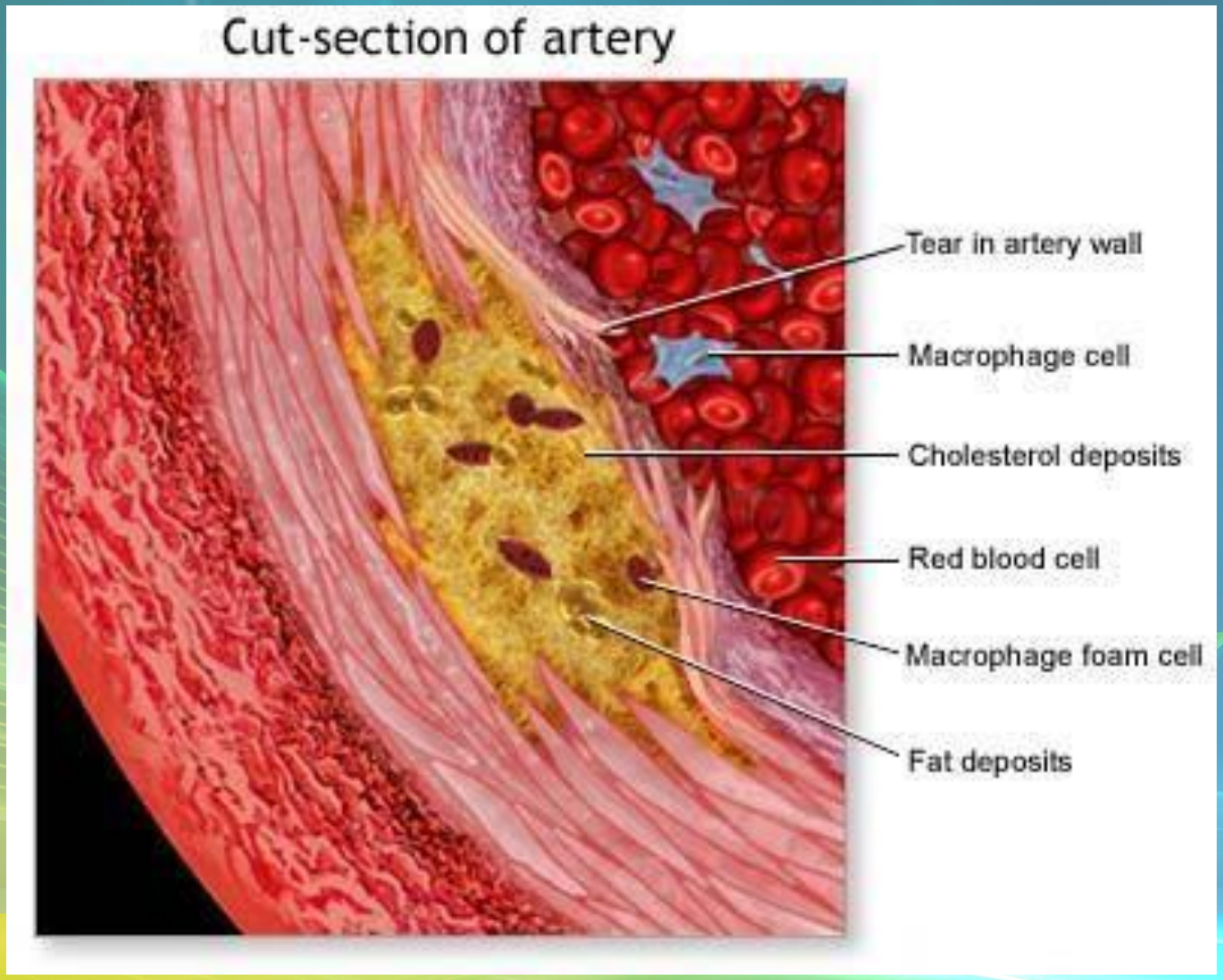
- From the right atrium, blood passes either through the foramen ovale into the left atrium, or through the ductus arteriosus into the aorta.


Fetal Circulation
Ductus Arteriosus
Waste from Fetus
Placenta
Aorta
Foramen Ovale
Lung
Pulmonary Artery
Ductus Venosus
Lung
Liver
Left Kidney
Food and Oxygen from Mother
Umbilical Cord
Umbilical Vein
Umbilical Arteries
Oxygen-rich Blood
Oxygen-poor Blood
Mixed Blood

Homeostatic Imbalances:

- **Atherosclerosis:**
  - Vessel walls thicken and intrude into the vessel lumen. Aorta and coronary arteries most commonly affected.
  - Plaques form in vessel walls in stages.

Homeostatic Imbalances:



Homeostatic Imbalances:

- Possible cause[s] – irritation of the vessel walls by bacteria, etc. triggers inflammatory response.

- Additive – multiple events over time.

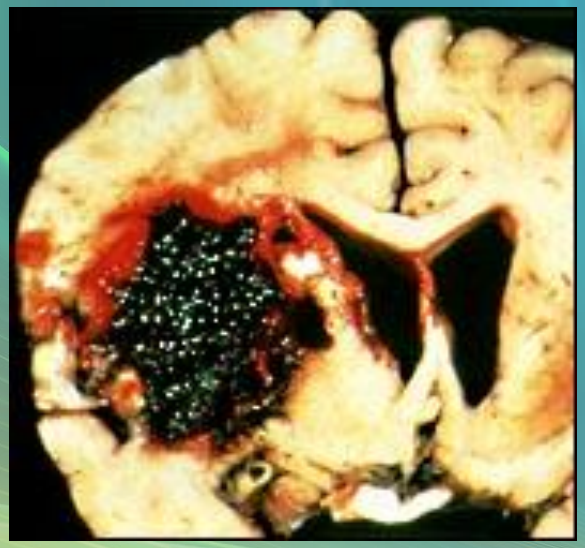
Homeostatic Imbalances:

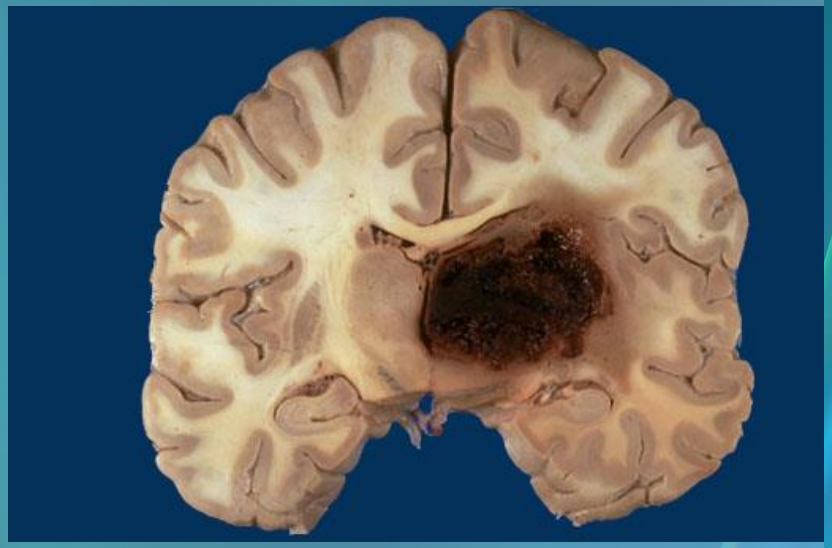
- **Atherosclerosis:**

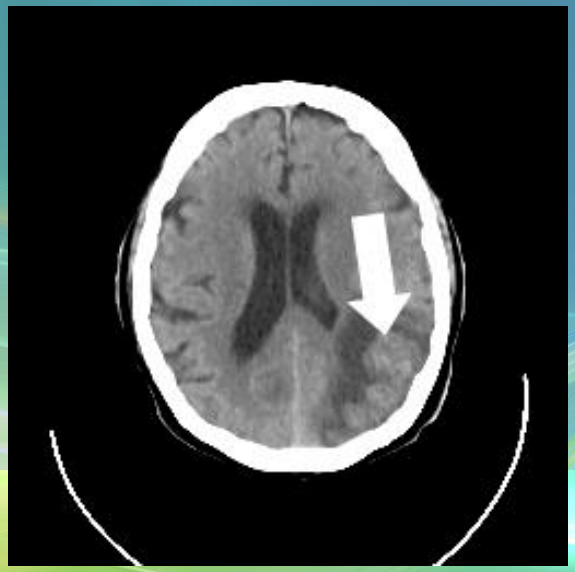
Homeostatic Imbalances:

- **Stroke [Cerebrovascular accident – CVA**
  - Circulation to the brain is blocked & brain tissue dies.
  - Most common cause – blockage of a cerebral artery by a clot.
  - Also caused by atherosclerosis & brain compression from hemorrhage or edema.

Homeostatic Imbalances:







Homeostatic Imbalances:

Pulmonary Embolism