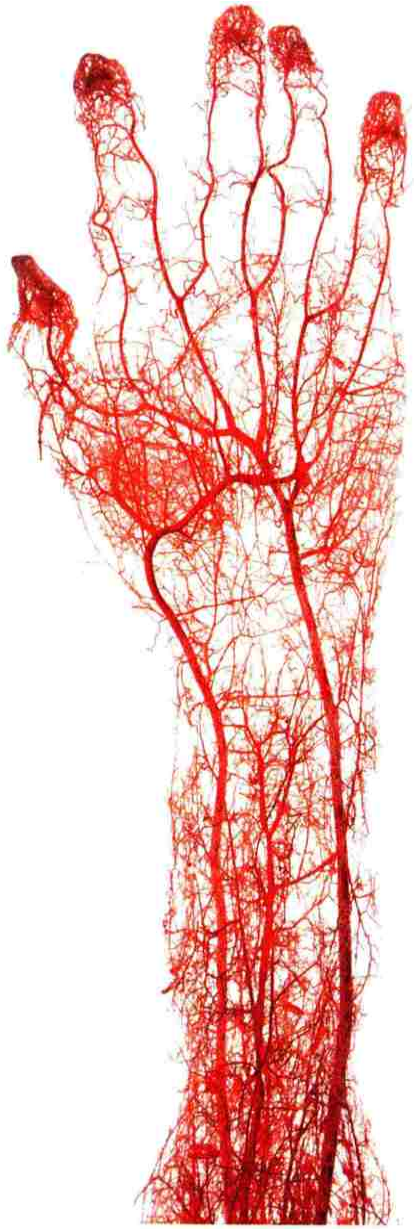
Blood Vessels & Hemodynamics



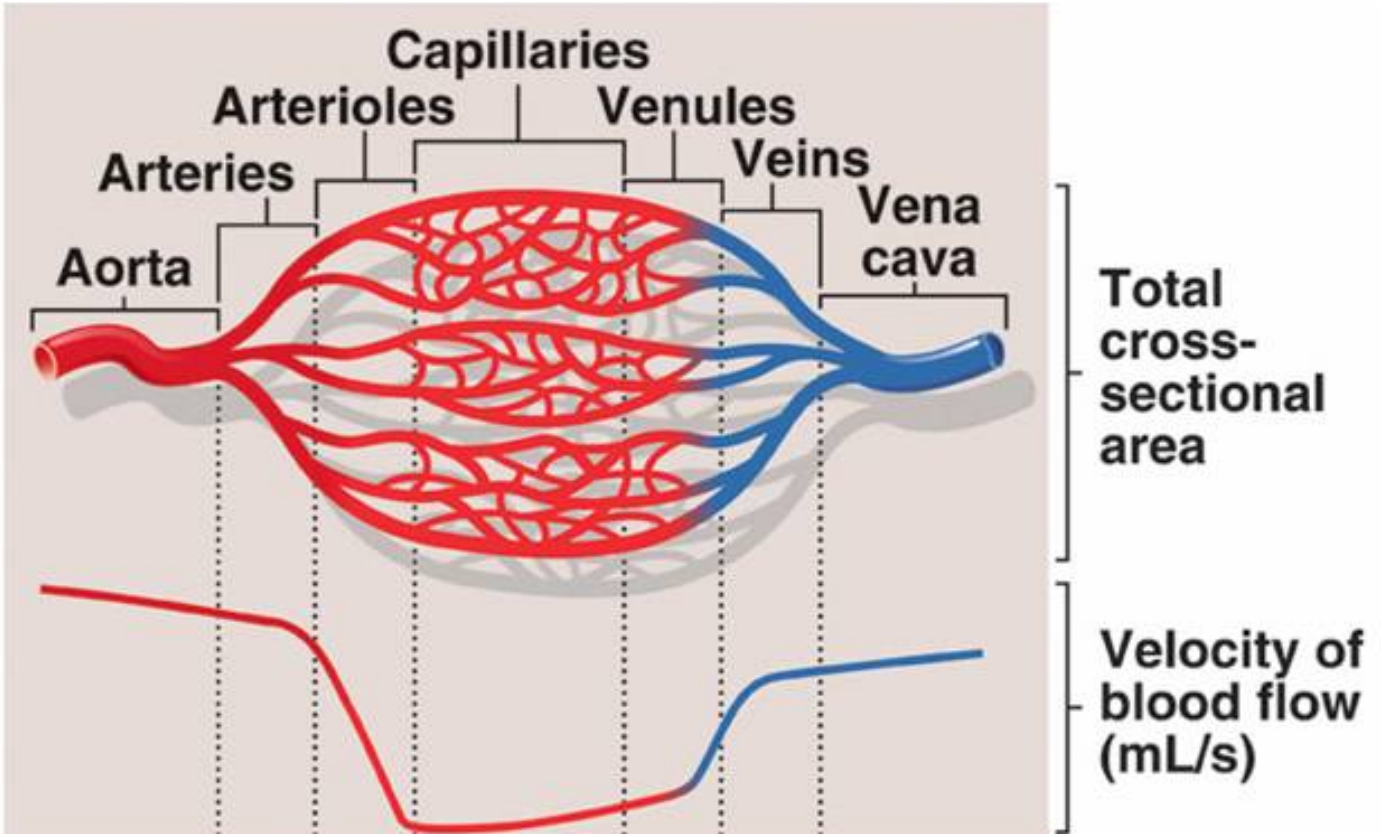
"Hemo" = blood, "Dynamics" = power

*Forces involved in **circulating** blood throughout the body*

What do Blood vessels do?

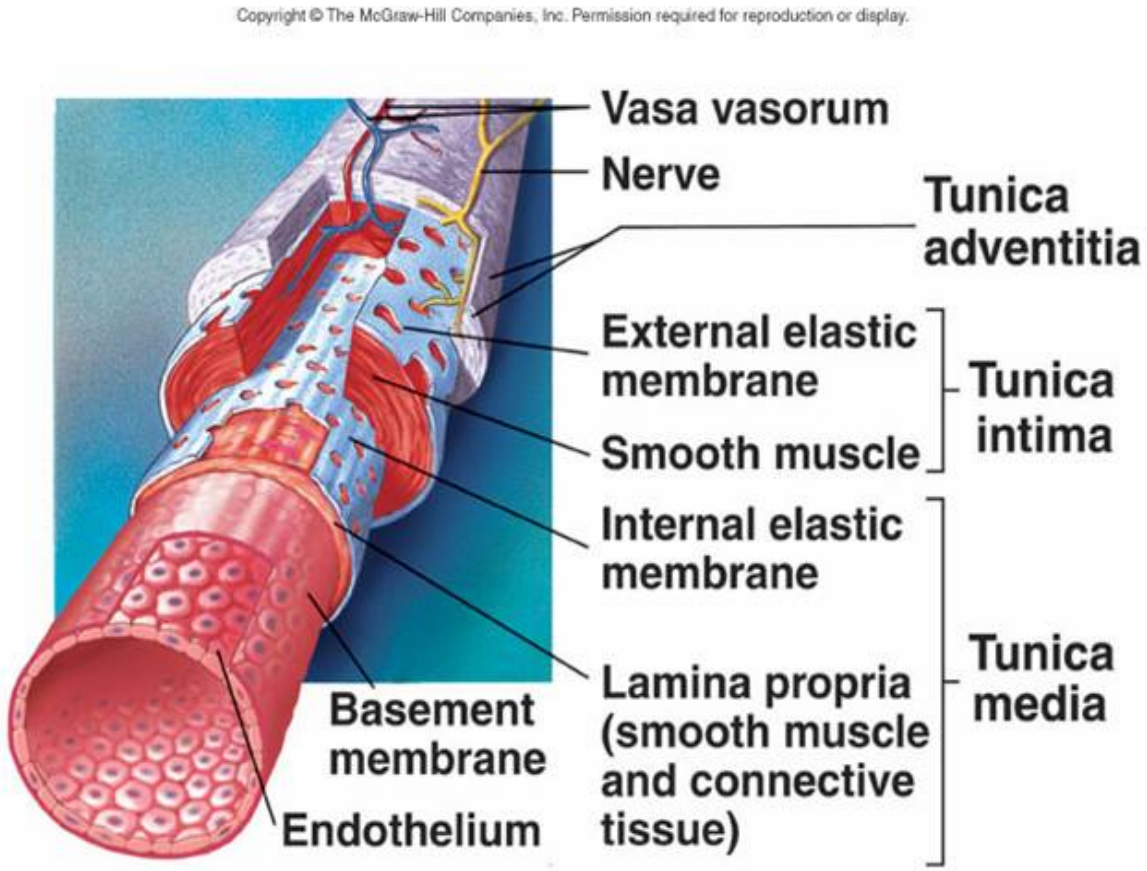
- Adjust velocity & volume of blood flow
- Transport & exchange of substances absorbed from the outside world & those produced by the deepest, tiniest tissues of our bodies
  - Eg O2, CO2, nutrients, cellular metabolic wastes, hormones etc.

5 Types of Blood Vessels



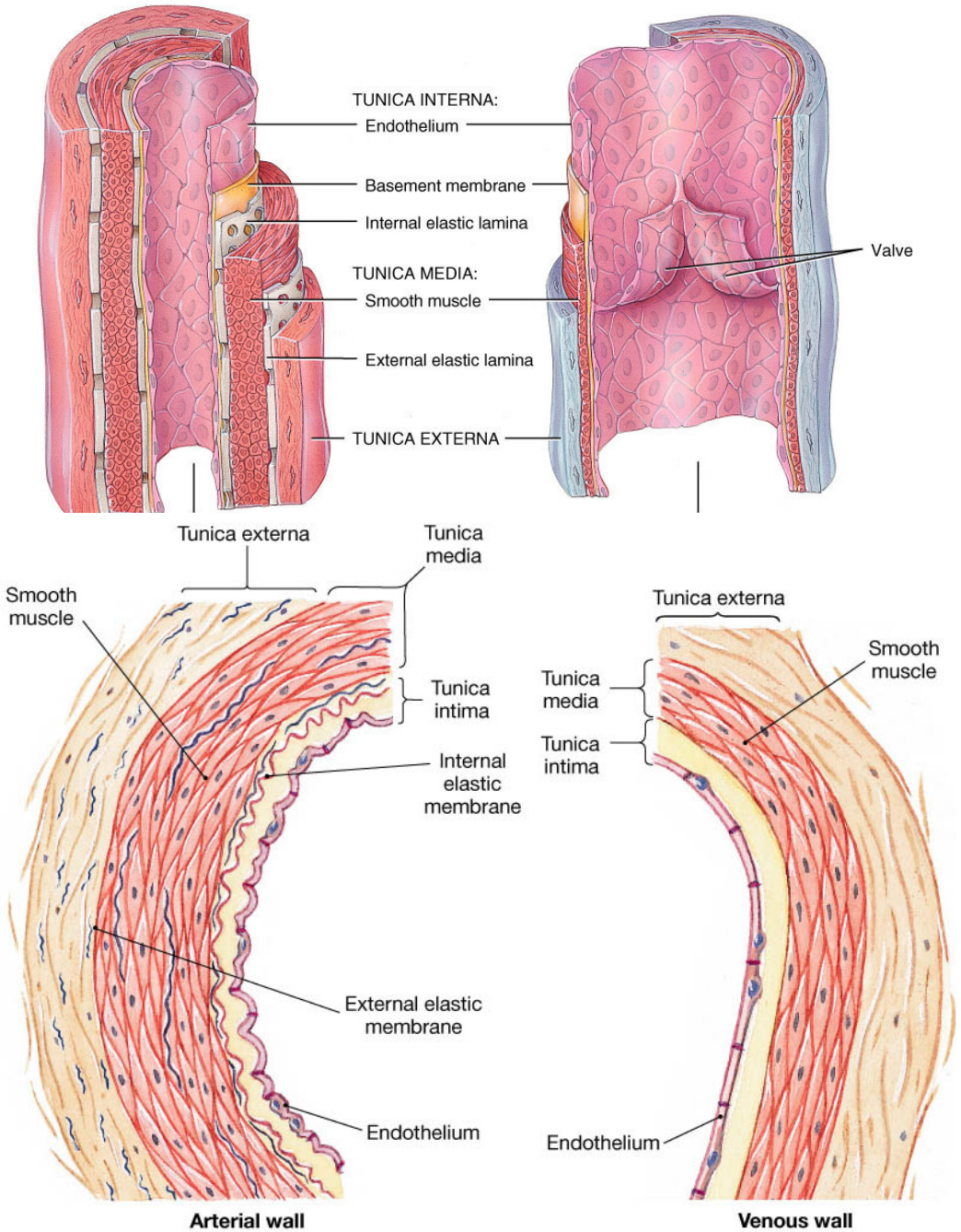
1. **Arteries**: carry blood **away** from the heart
2. **Arterioles**: very small arteries
3. **Capillaries:** tiniest vessels. allow **exchange** of substances between blood and body tissues
4. **Venules**: very small veins
5. **Veins**: carry blood back **to the heart**

Vasa Vasorum, Blood vessel of the blood vessel



- Larger blood vessels require smaller blood vessels to supply oxygen and nutrients to their smooth muscle tunica media
- *Vasa Vasorum* means ‘blood vessels of the blood vessels’
  - Small vessels located within larger vessels

Arteries and Veins have 3 Tunics (Coats)



1. The **Tunica Interna (intima)**, also called the *endothelium.* The innermost layer is only 1-cell thick and made of flat cells.

2. The **Tunica Media** has **smooth muscle** cells + **Elastic fibers** for regulating the **diameter** of the lumen

3. The **Tunica Externa** is made of *collagen* + *elastic fibers*. This outermost covering contains nerves, vasa vasorum, and anchors the vessel to the surrounding tissue

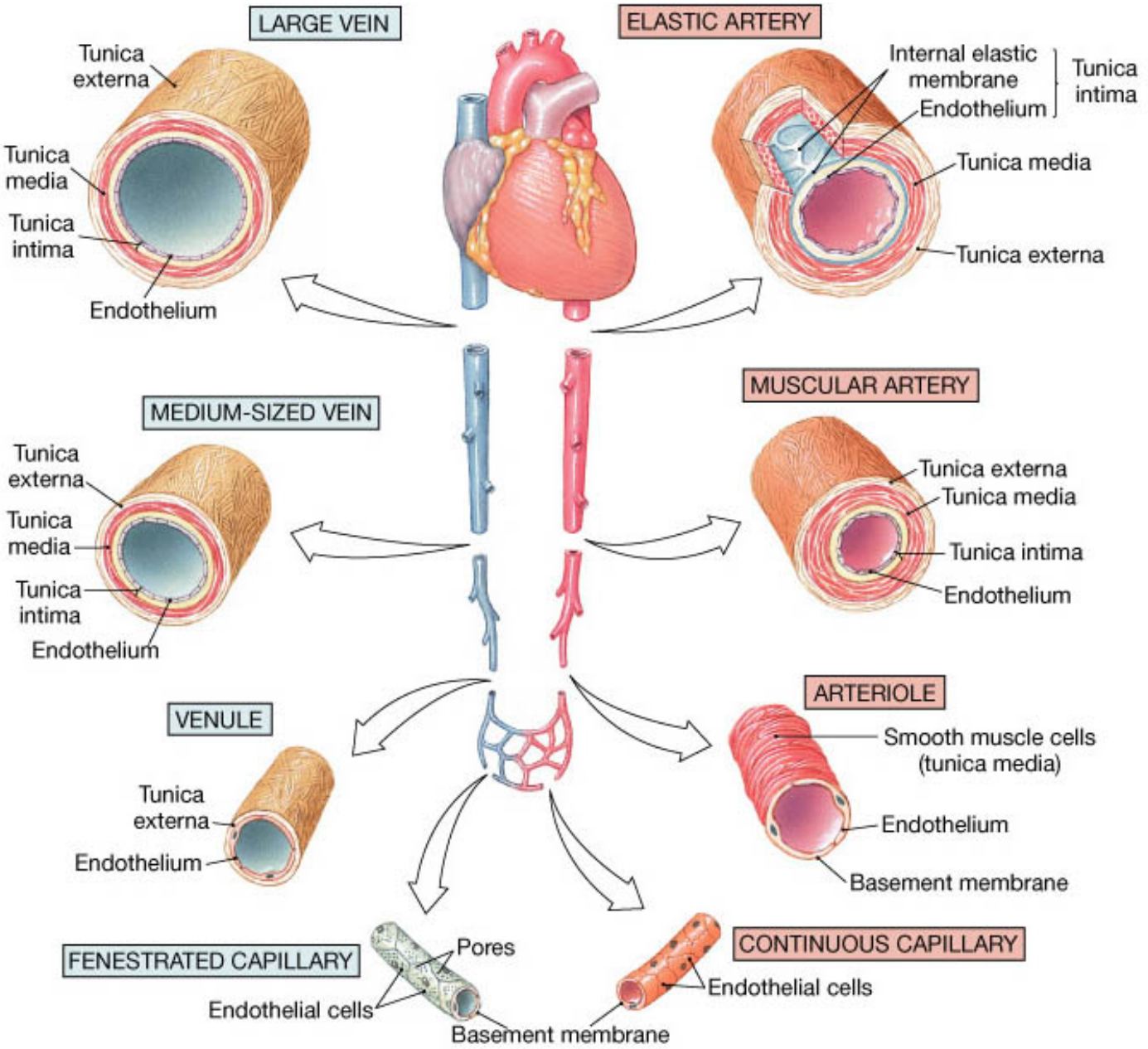
Elastic = Conducting Arteries

Muscular = Distributing Arteries

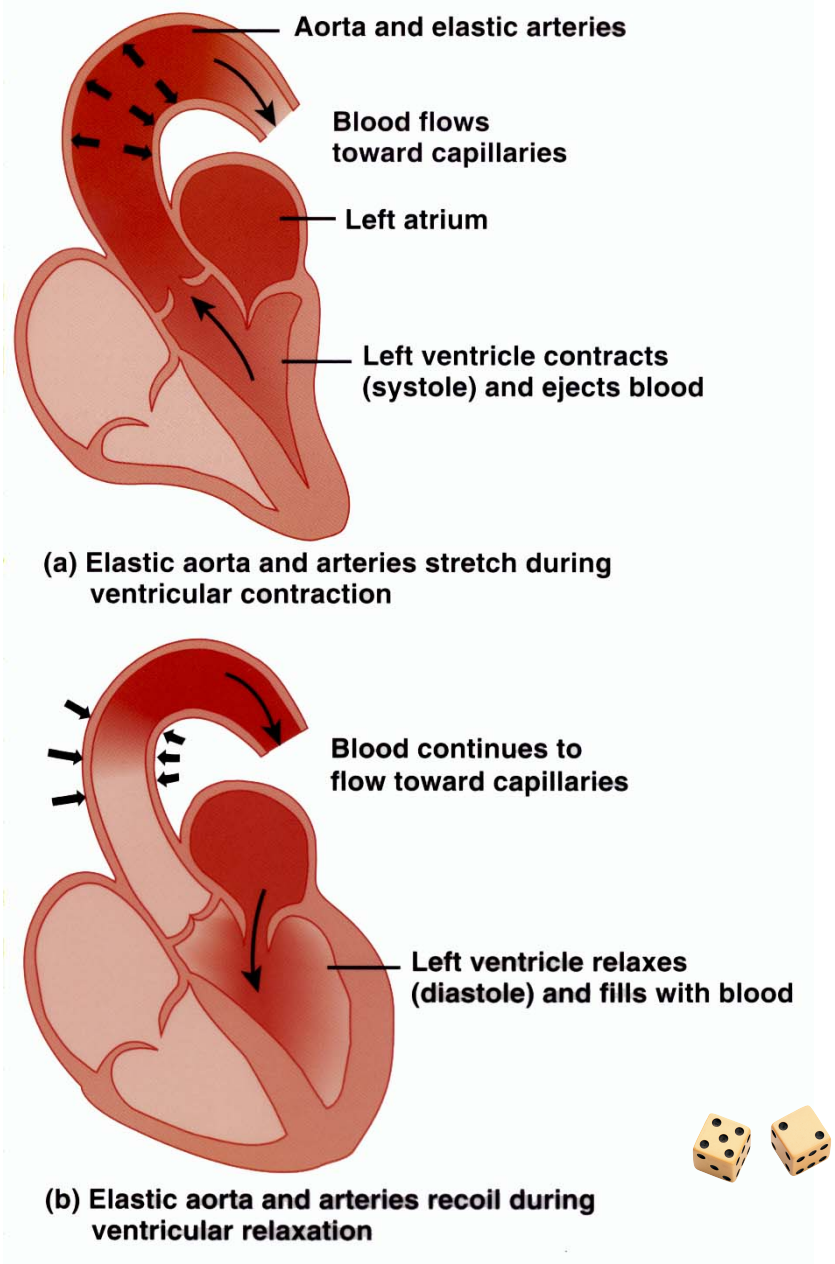
Resistance Arterioles

ARTERIES

Blood vessel types and functions

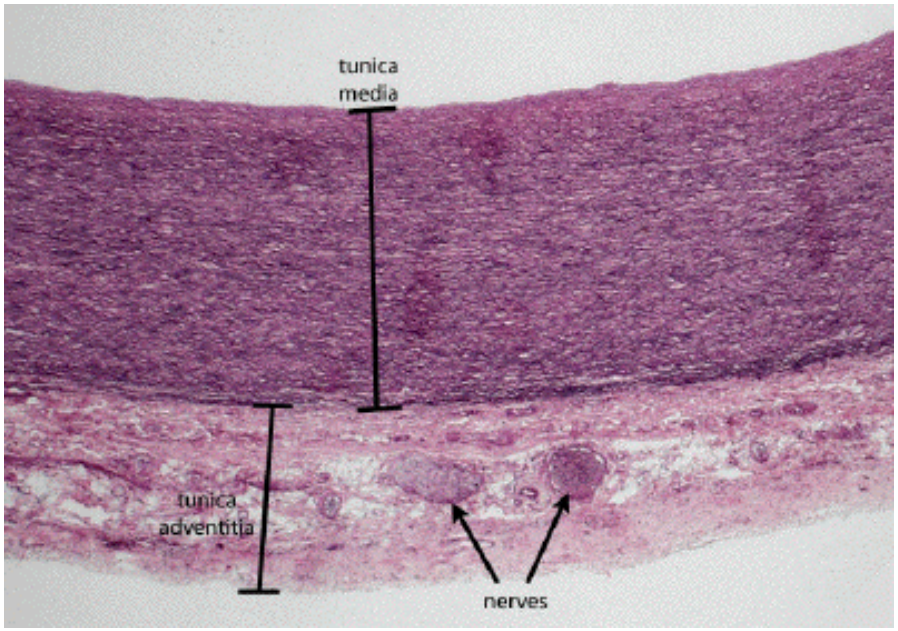


Largest arteries:ELASTIC ARTERIES



- Have the largest diameter, but their walls are relatively thin. Examples: the **aorta** or **pulmonary artery**
- They function as a **PRESSURE RESERVOIR:**
  - They **stretch** when the ventricle pumps blood into them.
  - ** when the ventricles relax, they **recoil, propelling blood forward**
- Also called ***conducting*** arteries because they *conduct blood from the heart to the medium-sized arteries*

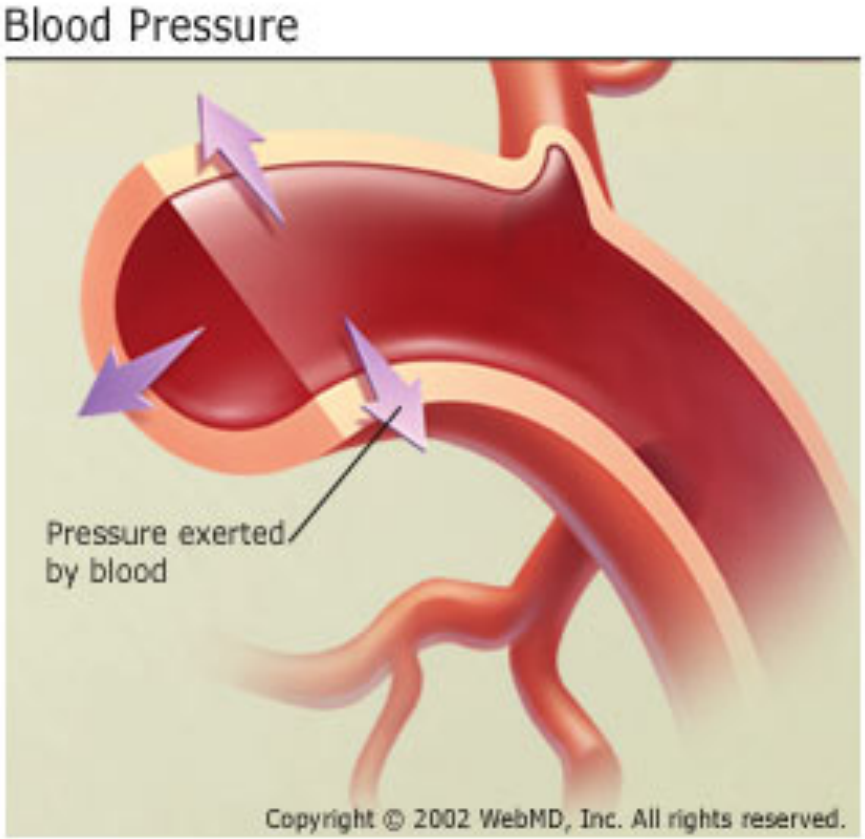
Elastic lamellae



- Layers of elastic fibers in the **tunica media, elastic lamellae,** make elastic arteries able to **stretch & RECOIL** which ***maintains diastolic blood pressure***.

- Elastic fibers give arteries high ***<u>compliance</u>***, the ability to stretch in response to pressure without tearing

Blood Pressure generation



'Blood Pressure' refers to the ***Hydrostatic pressure exerted by blood on the wall of a blood vessel***

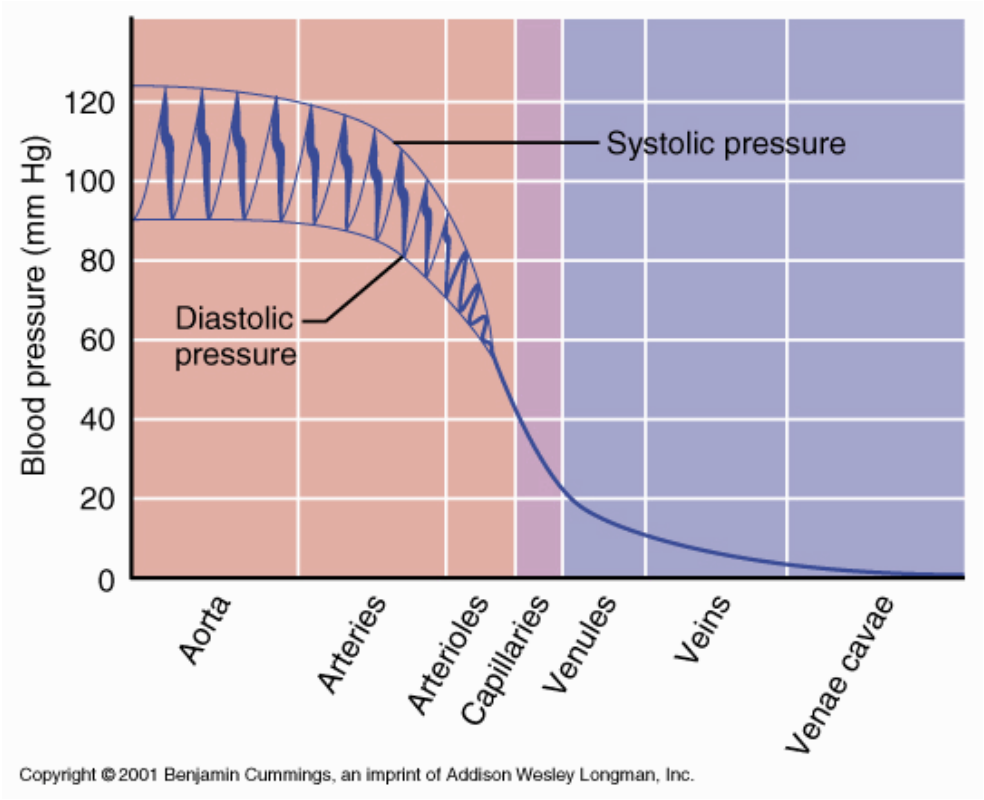
Blood Pressure depends on:

1. **Cardiac Output**
2. **Vascular Resistance**
3. **Total Blood Volume**

Blood Pressure =
Cardiac Output x Resistance

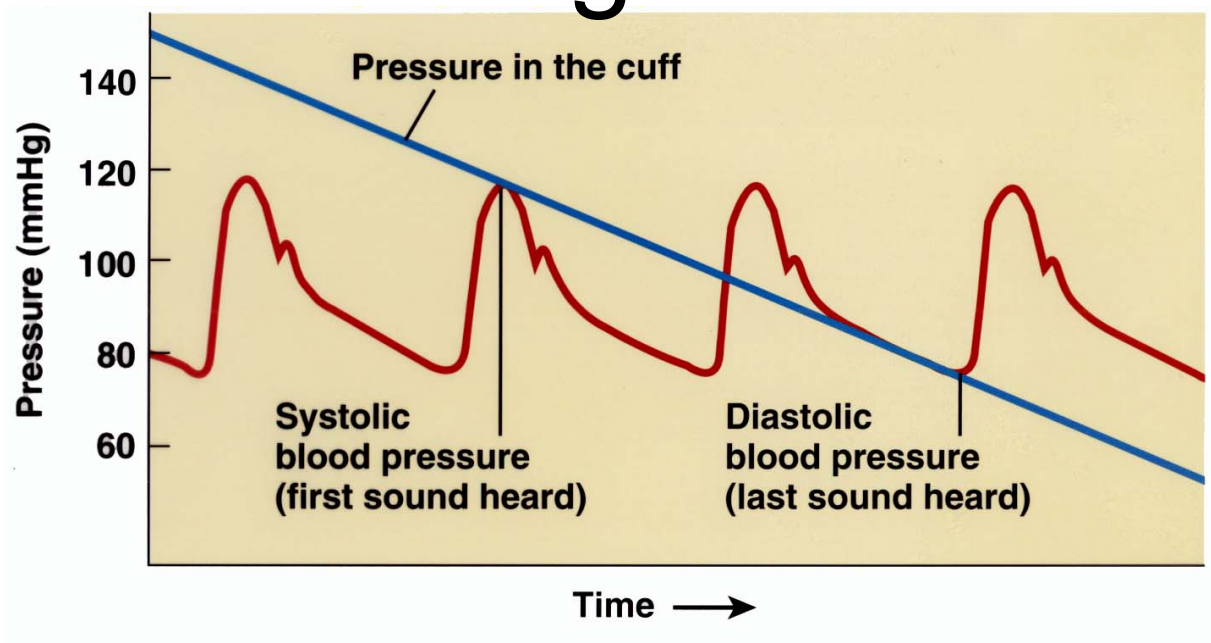
- The elastic vessels cushion the pulsations generated by the heart

Systolic and Diastolic Pressure



- **Initial blood pressure is generated by contraction of the Left Ventricle & CO (eg. 120mm Hg)**
- **Systolic BP**: the **highest** pressure attained in the arteries during **systole**
- **Diastolic BP**: the **lowest** arterial pressure during **diastole**
- BP falls progressively with distance from left ventricle. BP **is 0 at Right ventricle**

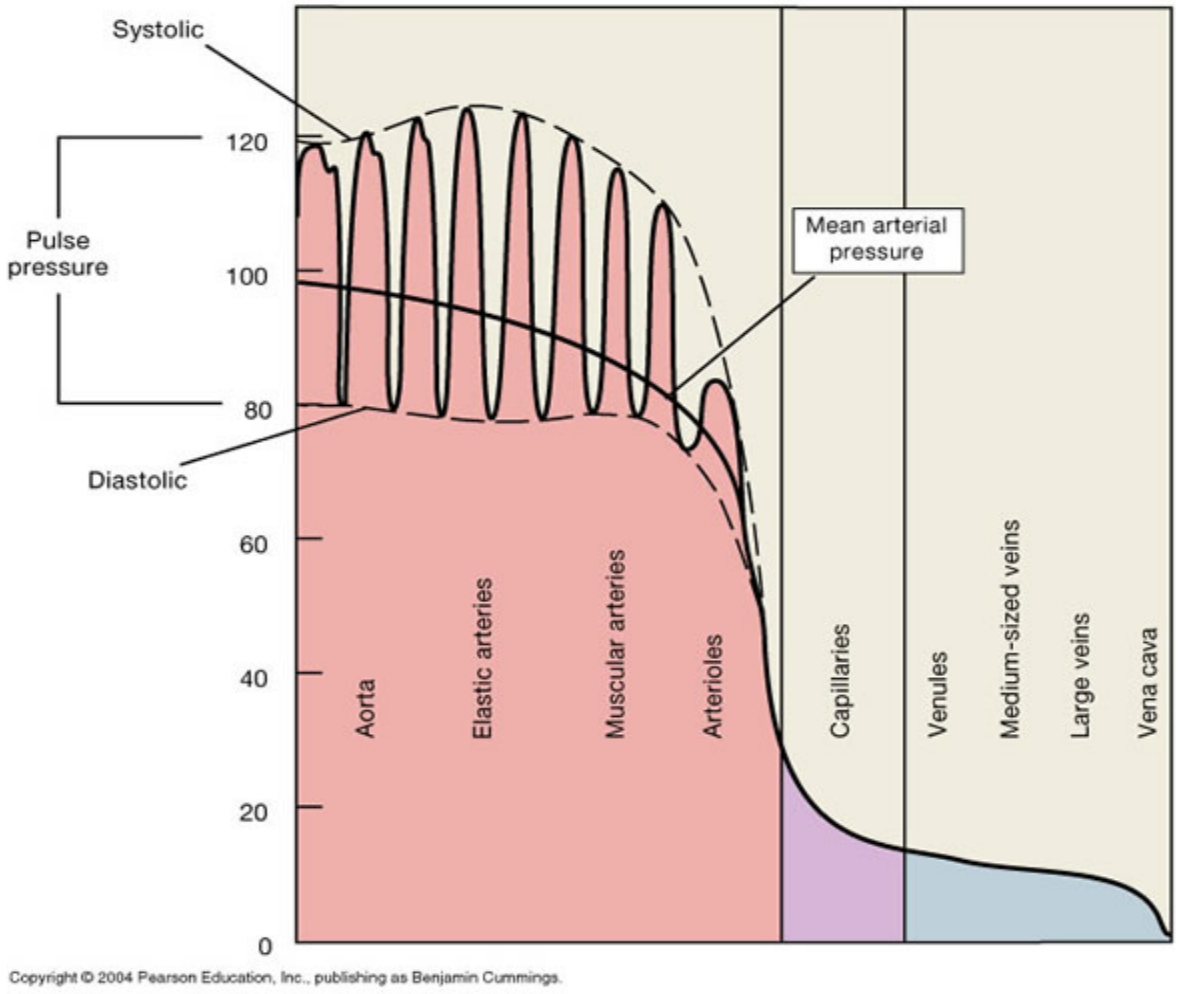
Checking BP & Pulse



- **Pulse:** stretch & recoil of elastic arteries create the wave
- Heart rate creates the rate
  - Normal: 70-80 bpm
  - Tachycardia: >100 bpm
  - Bradycardia: < 50 bpm

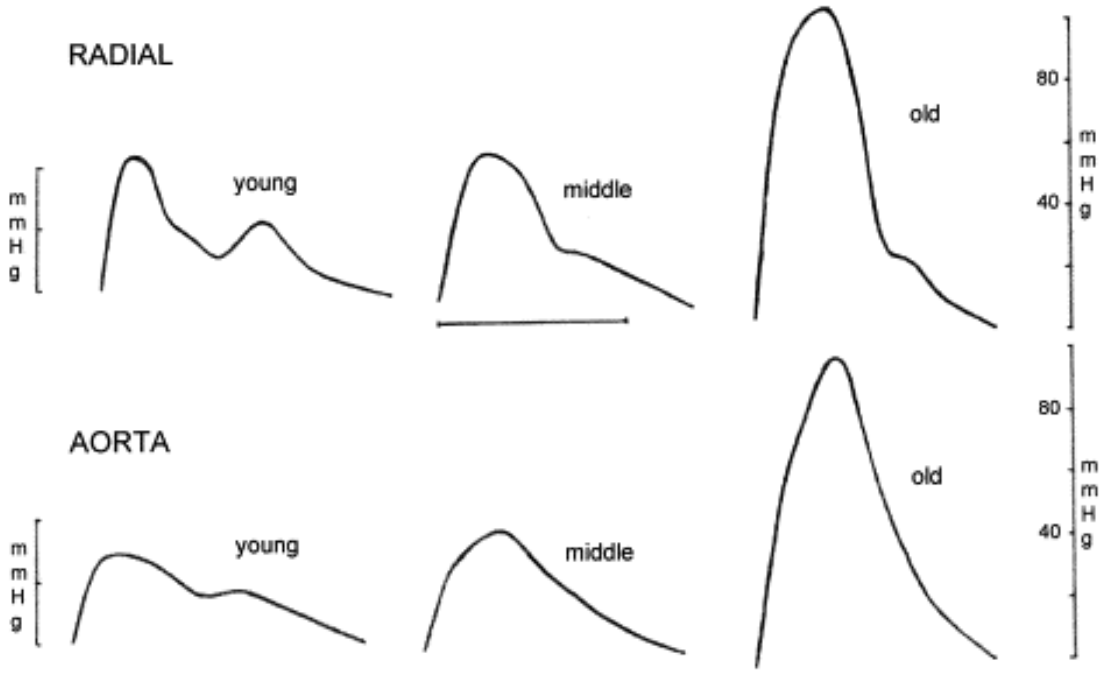
- **BP cuff & stethoscope:. Cut off circulation to the arm with a BP cuff.** listen for Karotkoff sounds as you release and reduce the pressure in the cuff
  - First sound heard = systolic BP, Last sound heard = diastolic BP

Pulse Pressure vs Mean Arterial Pressure (MAP)

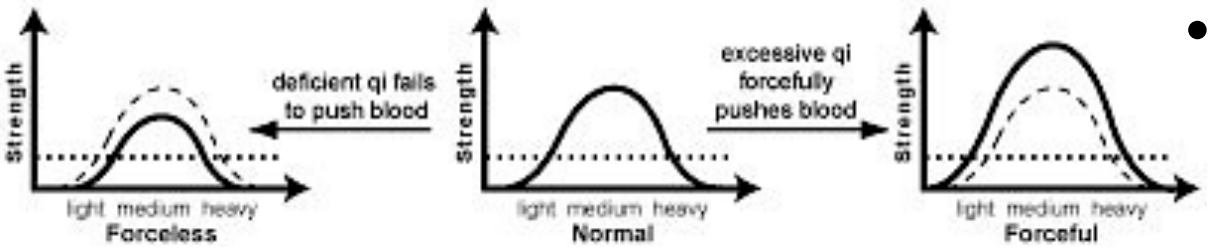


- **The difference** between systolic & diastolic pressure is called the **pulse pressure**
- **The average** of the systolic and diastolic pressures is called the **mean arterial pressure**

(FYI) Pulse pressure: young vs old

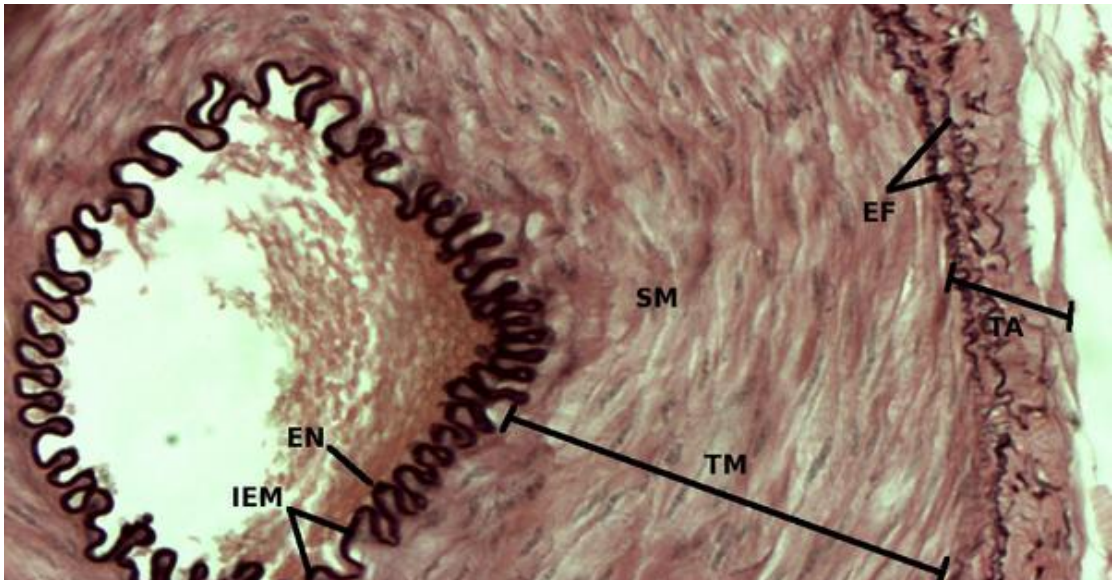


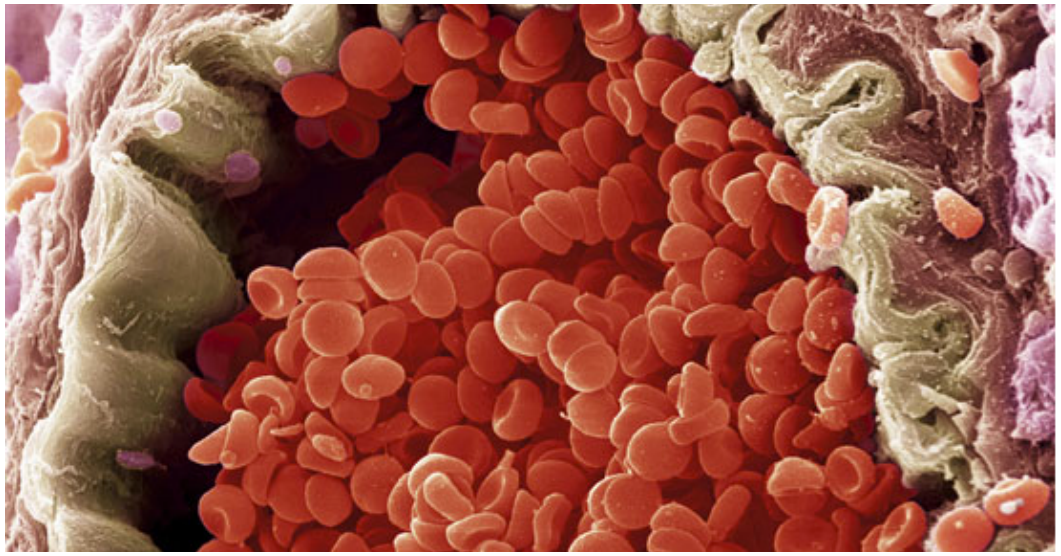
- As we age, vessels become harder and more dilated.
- The can no longer cushion the wave



- So, both pulse pressure and pulse wave velocity increase

Medium sized **Muscular Artery**

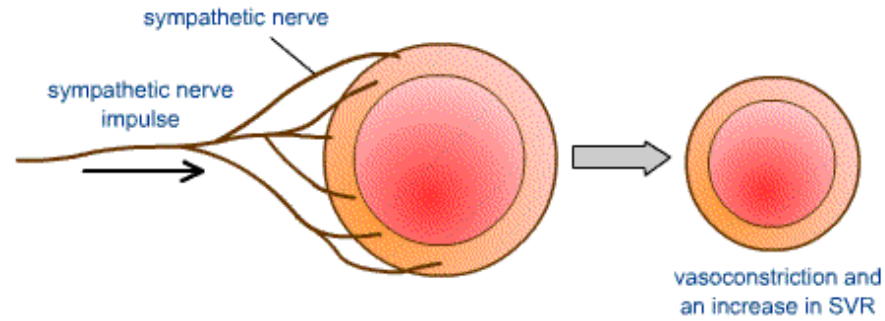


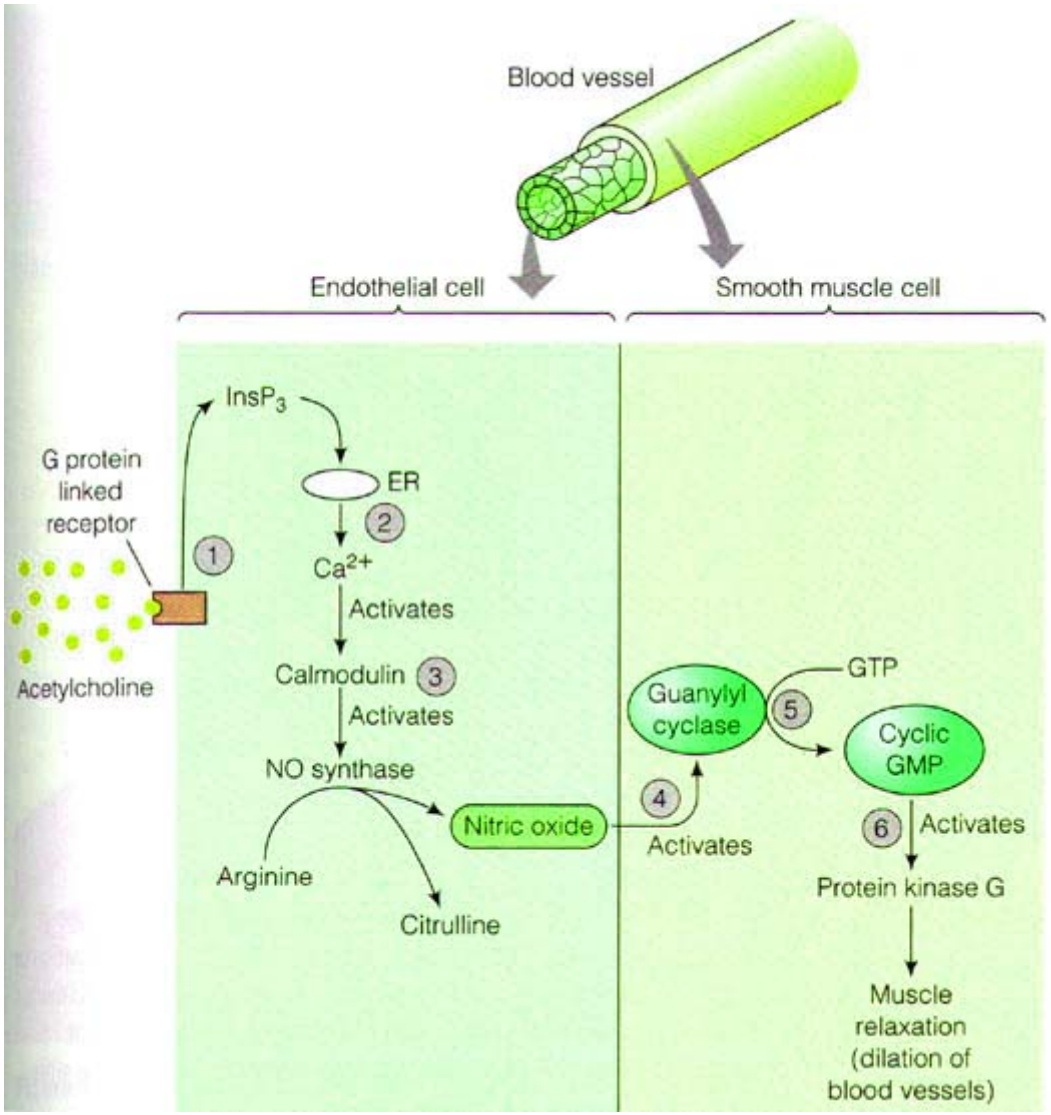


- Capable of **great vasoconstriction / vasodilation** to adjust vessel pressure & thus rate of blood flow

- **Muscular arteries have more smooth muscle**, fewer elastic fibers in the tunica media

Changes Vessel Diameter

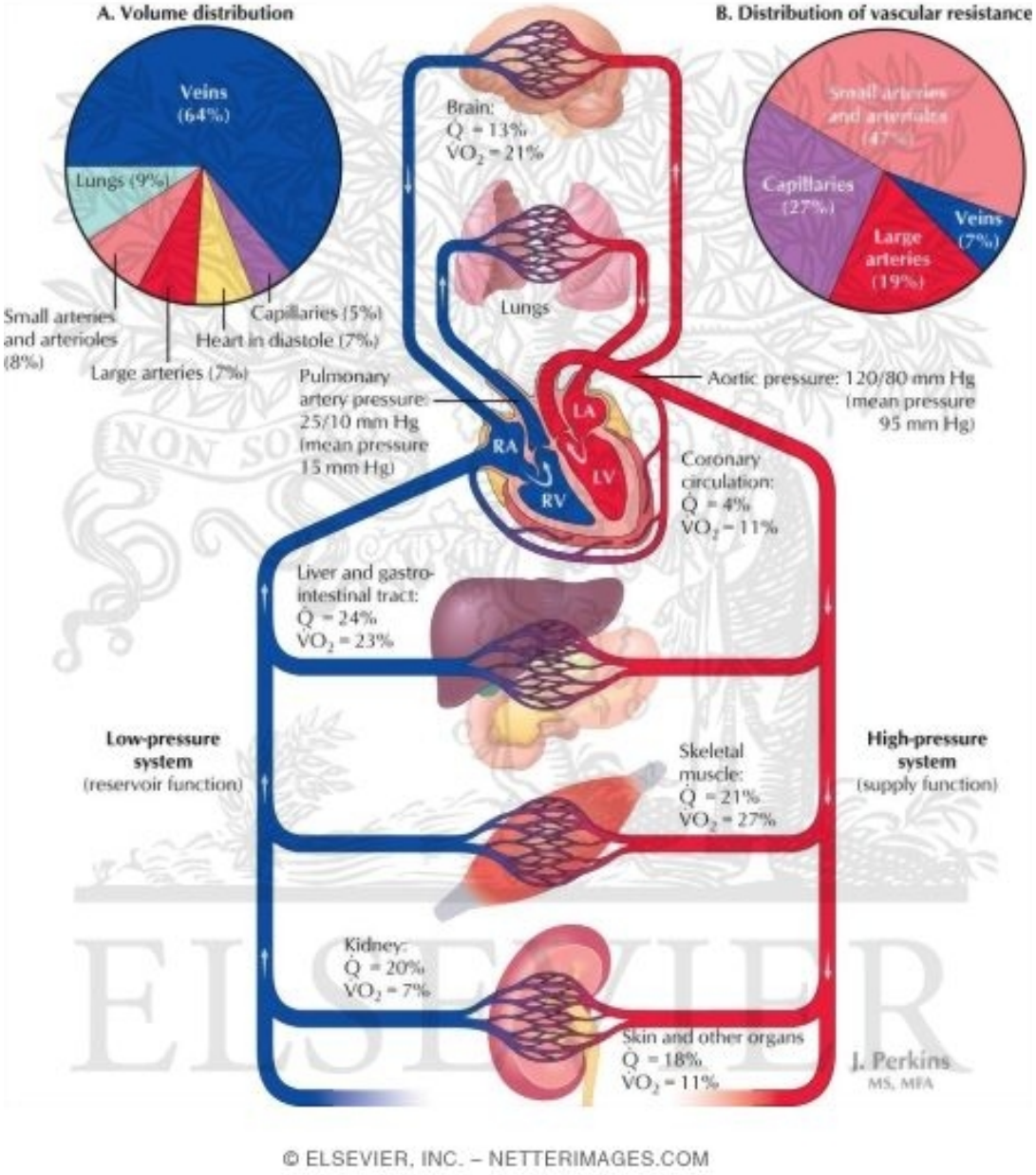




SMOOTH MUSCLE allows artery to ***contract or dilate***, changing vessel diameter

- **Vasoconstriction**: a decrease in lumen diameter
  - **Sympathetic innervation**
- **Vasodilation:** an increase in lumen diameter
  - **Parasympathetic** (ACh), NO, H+, lactic acid
- **Vasospasm:** constriction of an artery when it's damaged to reduce blood loss

Medium-Sized MUSCULAR ARTERIES



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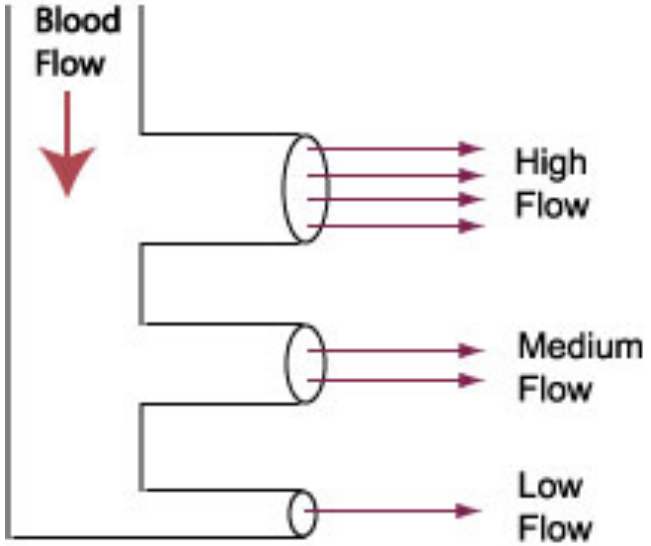
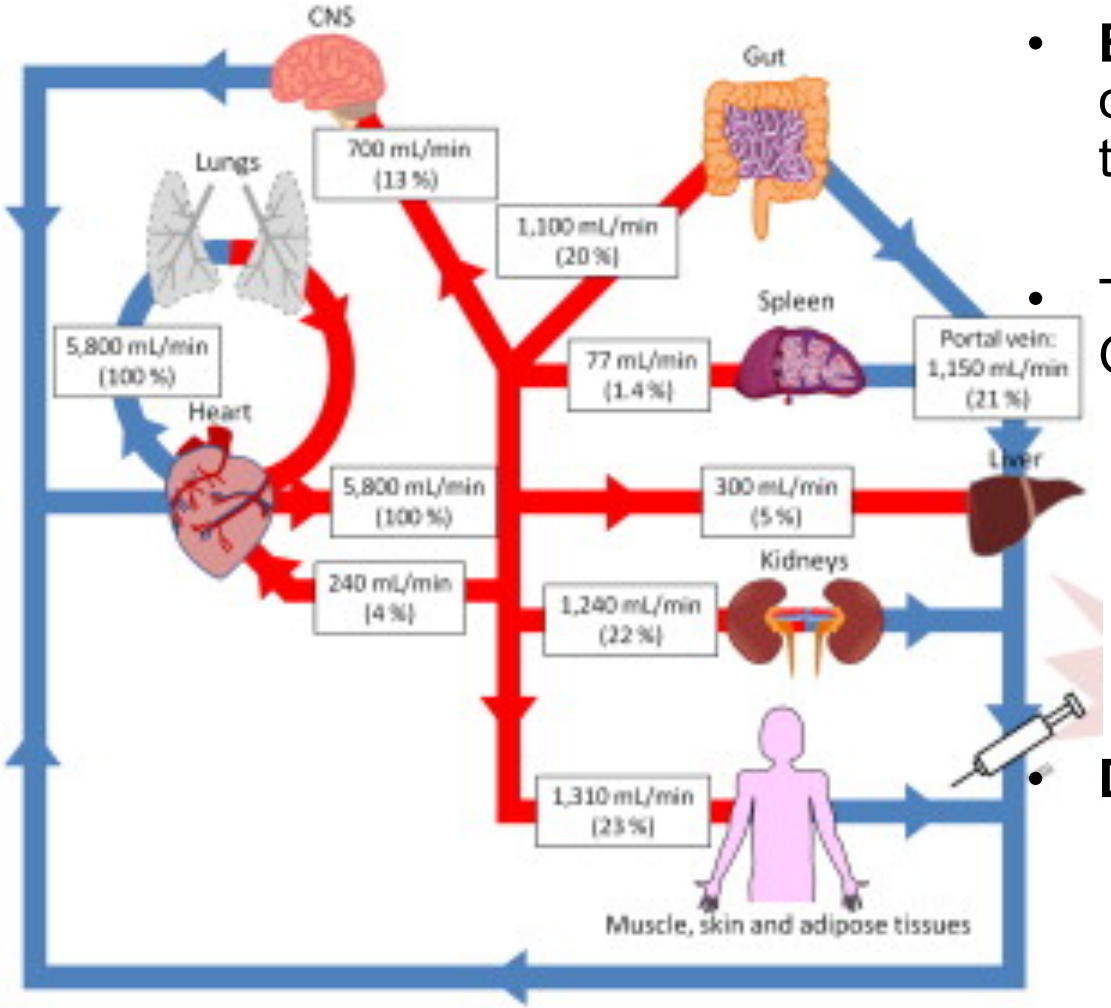
- The great vasoconstriction or vasodilation, determines the **<u>distribution, or % of blood that goes to the various parts of the body</u>**

- Muscular arteries are also called ***distributing arteries***



HEMODYNAMICS: factors affecting **Blood Flow**

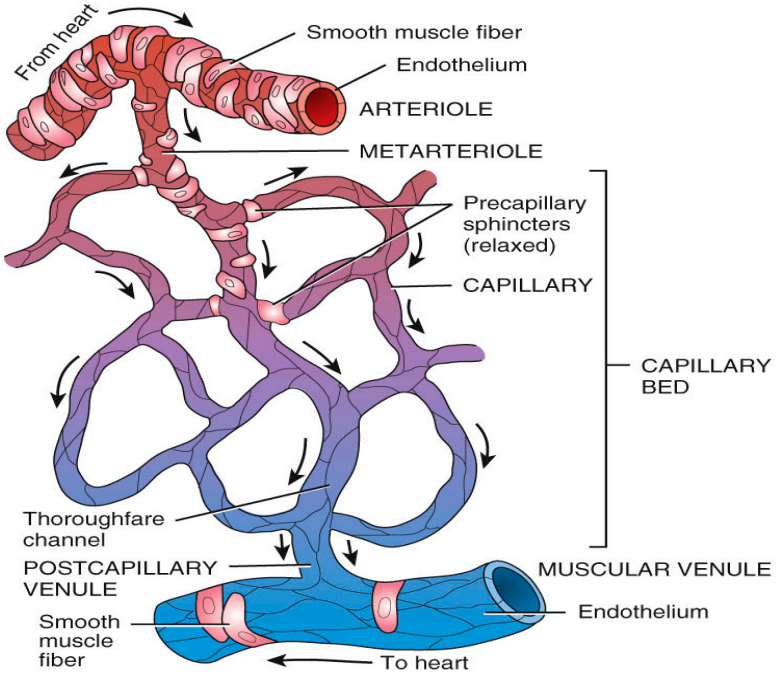


- **Blood Flow** (**mL/min**) = volume of blood flowing through any tissue in a given period of time

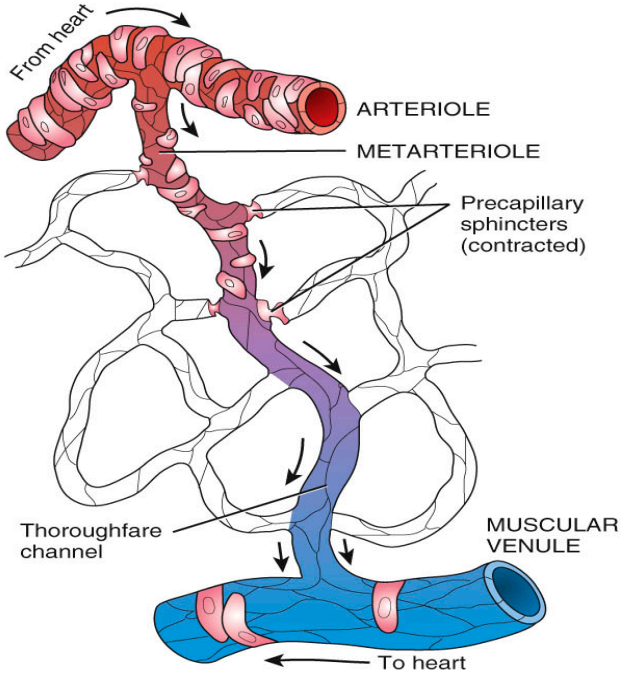
- Total Blood Flow = Cardiac Output (CO)
  - Volume of blood circulating through the systemic (or pulmonary) vessels *each minute*.
  - CO = heart rate (HR) x stroke volume (SV)

- **Distribution of CO** depends on:
  1. ***Pressure differences***
     - *blood flows from high to low pressure.* greater pressure difference= greater blood flow
  2. ***A Vessel's resistance*** to blood flow
     - The higher the resistance, the smaller the blood flow

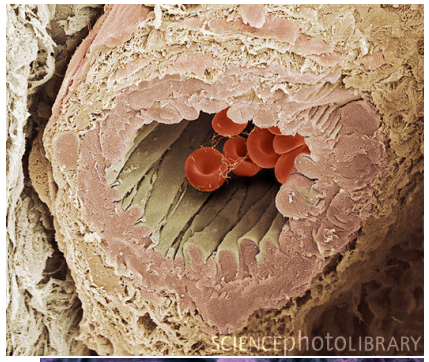
(RESISTANCE) ARTERIOLES: Friction



(a) Sphincters relaxed: blood flowing through capillaries



(b) Sphincters contracted: blood flowing through thoroughfare channel



1. Arterioles Regulate **RESISTANCE TO BLOOD FLOW**
   - Resistance is due to **friction** between blood & blood vessel wall
   - **Sympathetic nerves** in the tunica externa **constrict vessels**
   - More sympathetic constriction, more friction, more resistance to flow
2. Arterioles Regulate blood **flow into capillaries**
   - The terminal portion of an arteriole is called the "***metarteriole***"
   - Each metarteriole has various **precapillary sphincters** which control blood flow into capillaries

SUMMARY of ARTERY Types

1. Elastic or Conducting arteries
   - Pressure reservoir. Maintains diastolic /constant flow

2. Muscular or Distributing arteries
   - **Distribute** blood to organs (%)
   - Regulate rate of blood flow (mL/min)

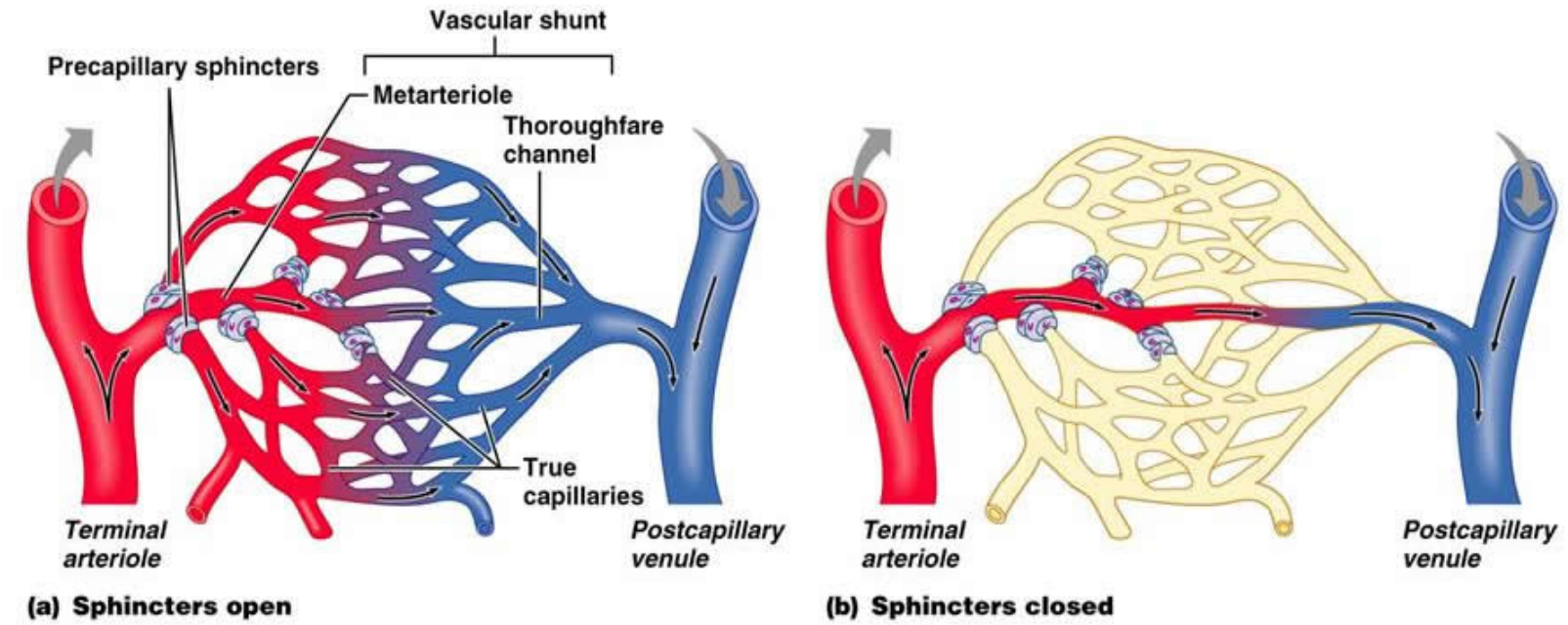
3. (Resistance) Arterioles
   - Regulate **resistance** to blood flow
   - Regulate flow of blood into capillaries

4. Arteriolar Capillaries
   - **Exchange** vessels

Section 2

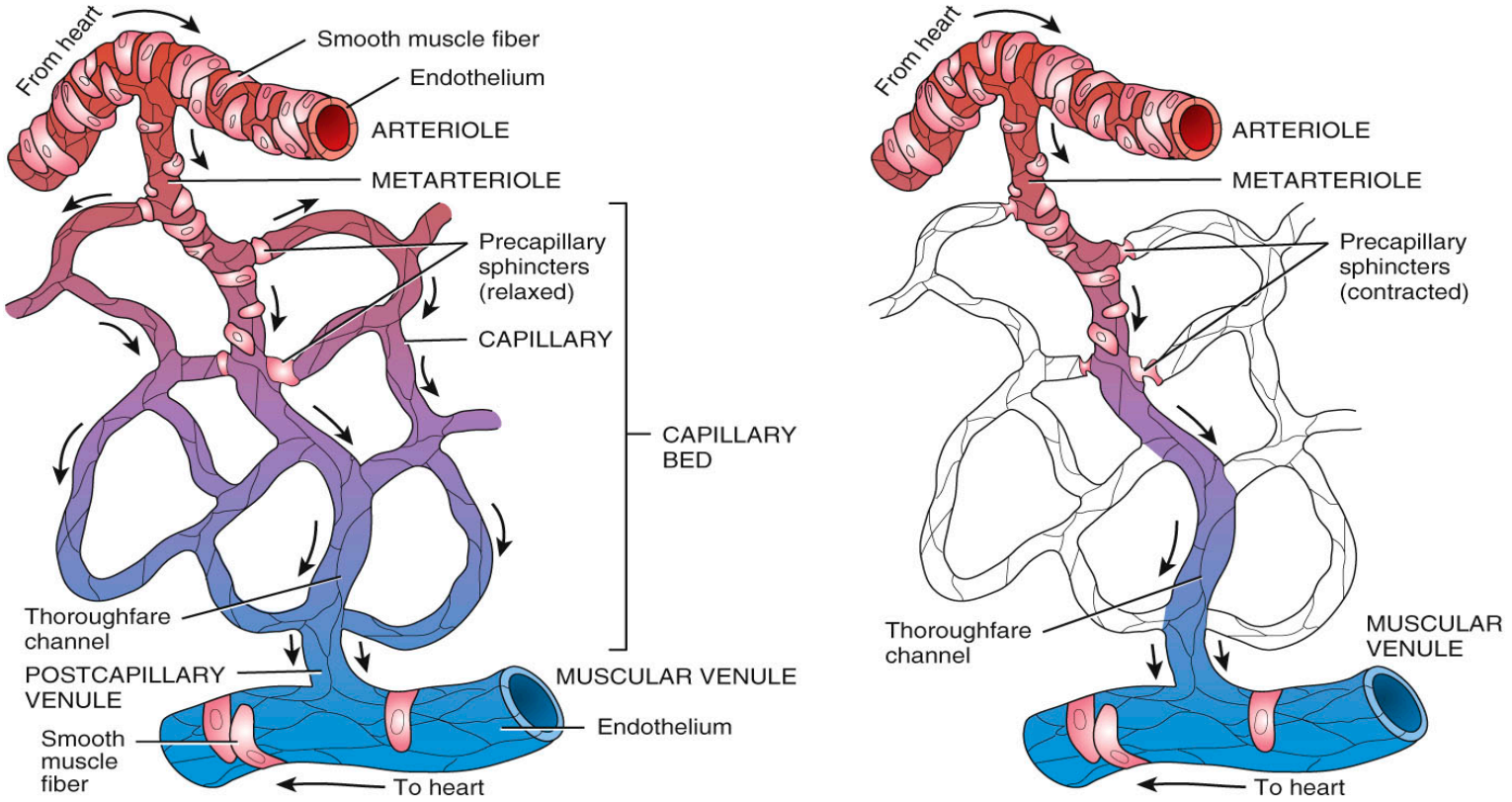
CAPILLARIES: EXCHANGE VESSELS

Capillary Beds & Metabolic Activity



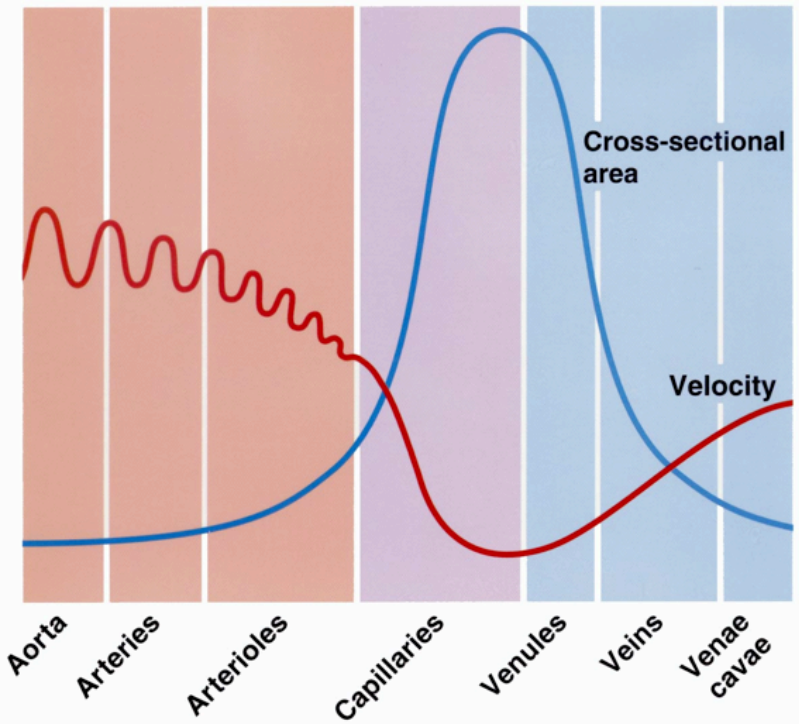
- **Capillary beds**: 10-100 capillaries arise from 1 metarteriole
- **Throughfare channel**: the distal end of a metarteriole can bypass a capillary bed
- Usually only a small part of a capillary network is full. but, when a tissue is active (i.e. contracting muscle), the entire network fills with blood
- Tissues with high metabolic activity eg muscles, liver, kidneys, nervous system have more capillaries
- Tissues with lower metabolic activity eg tendons, ligaments have less capillaries
- No capillaries in a few tissues, such as cornea, lens of the eyes, and cartilage

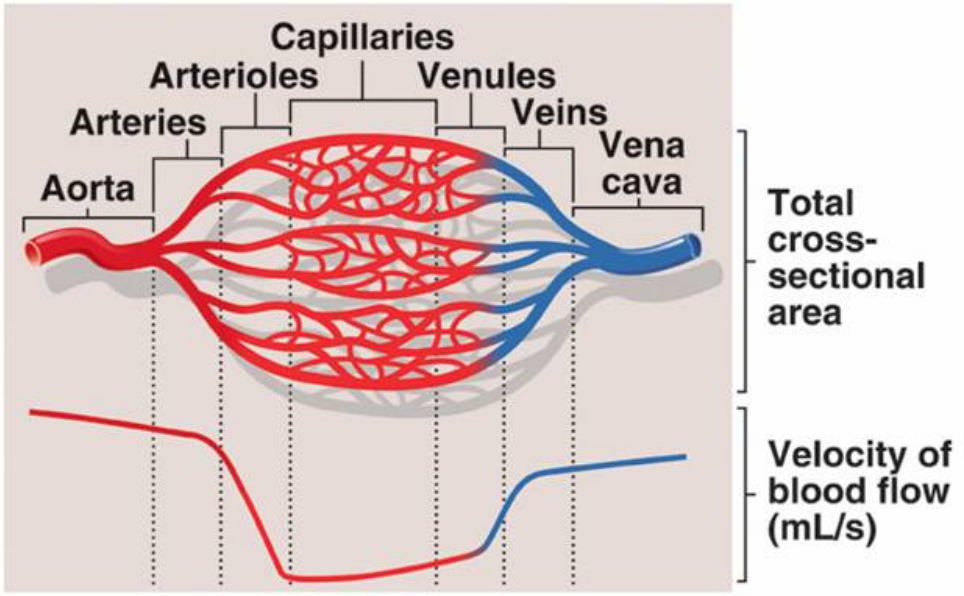
Microcirculation



- The "**Microcirculation** of the body" refers to blood flow through 1) metarterioles 2) capillaries and 3) postcapillary venules
- Capillaries connect arterioles to venules. Metarterioles contract and relax spontaneously.

VELOCITY of Blood Flow Slows at branched capillaries

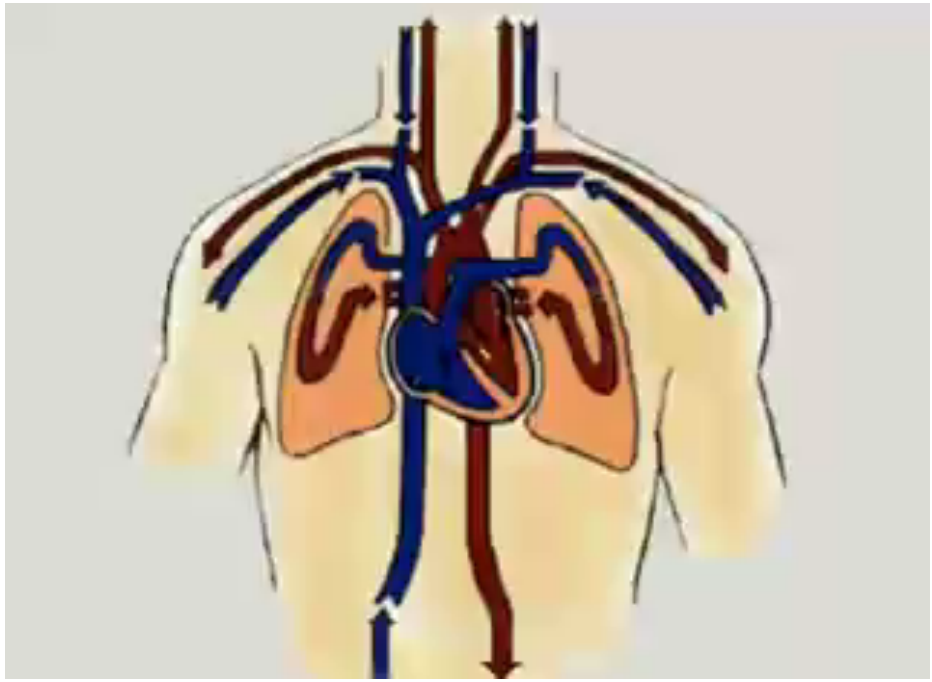




- Velocity (cm/sec) depends on branching:
  - When an artery branches, cross sectional area increases, so velocity of flow decreases
  - When venules merge to form a vein, cross sectional area decreases so velocity increases
  - Thus **blood flow is slowest at capillaries** which is good for exchange of materials

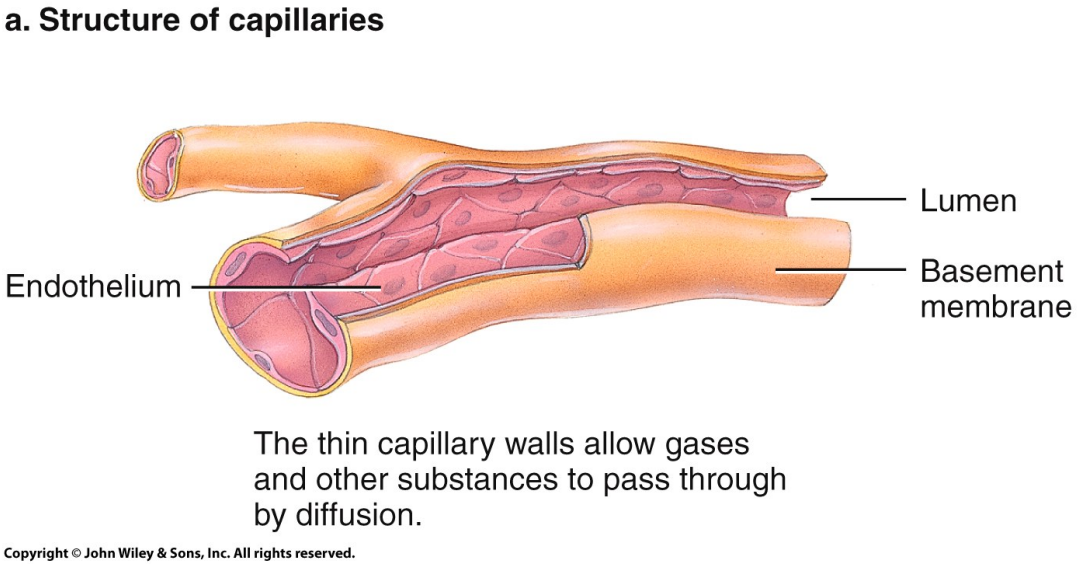
- **Circulation time**: time it takes 1 drop of blood to go from R atrium, to pulmonary & systemic circulation and back to R atrium - Normally 1 min at rest

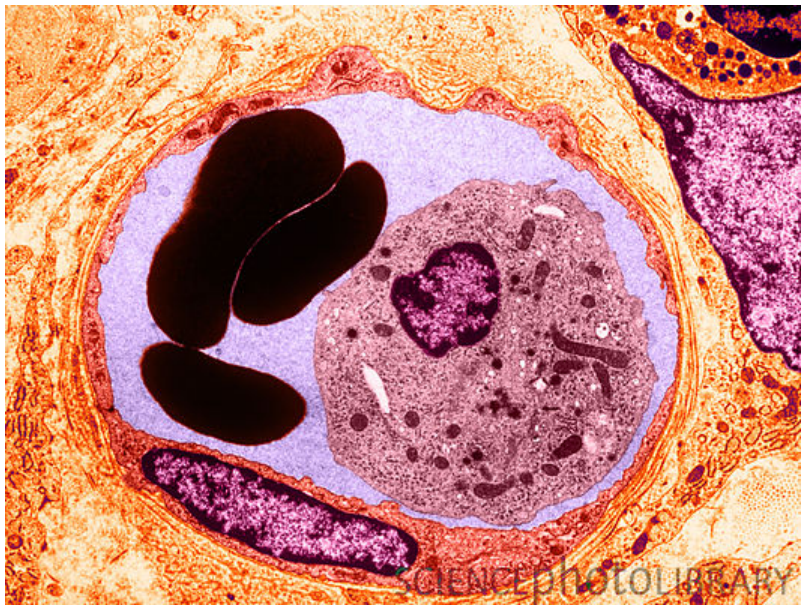
Vasomotion



- **Vasomotion**: the spontaneous, intermittent contraction & relaxation of metarterioles creates **intermittent blood flow through capillaries**

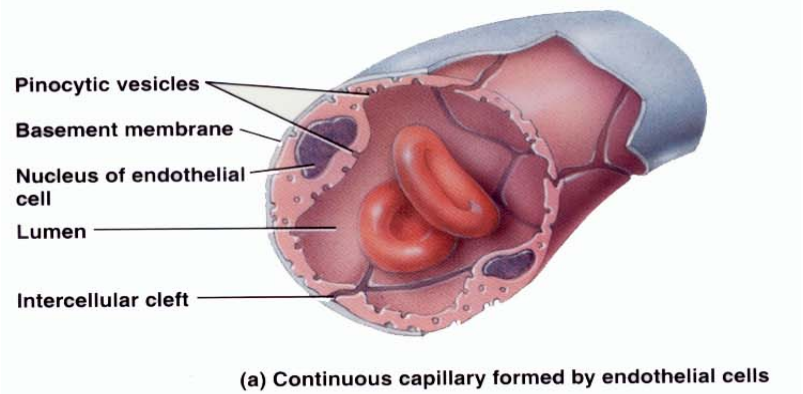
CAPILLARIES: Exchange Vessels



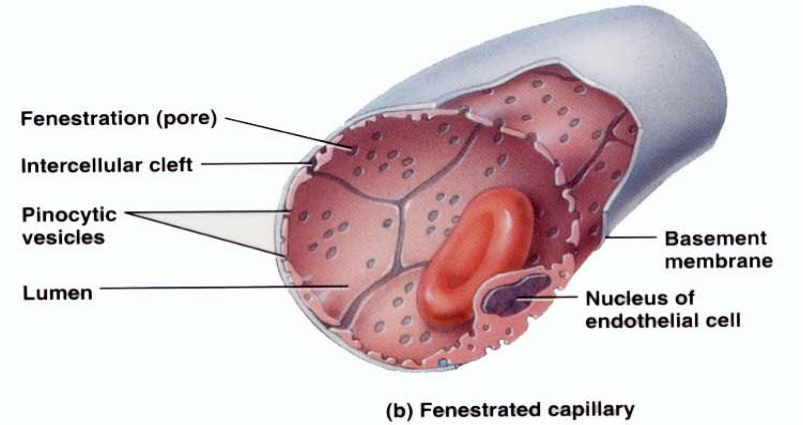


- Have no tunica media, no tunica externa, no innervation - just endothelial cells & a basement membrane

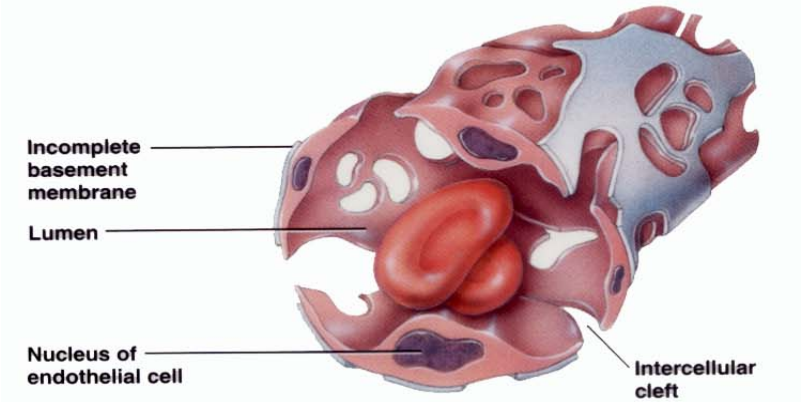
- ***Exchange*** vessels: Their primary function is to **exchange** substances between **blood** and **interstitial fluid**



(a) Continuous capillary formed by endothelial cells



(b) Fenestrated capillary



(c) Sinusoid

TYPES OF CAPILLARIES:

1. CONTINUOUS

- Endothelial cells form a **continuous tube** except for **intercellular clefts**
  - Found in brain, lungs, skeletal & smooth muscle

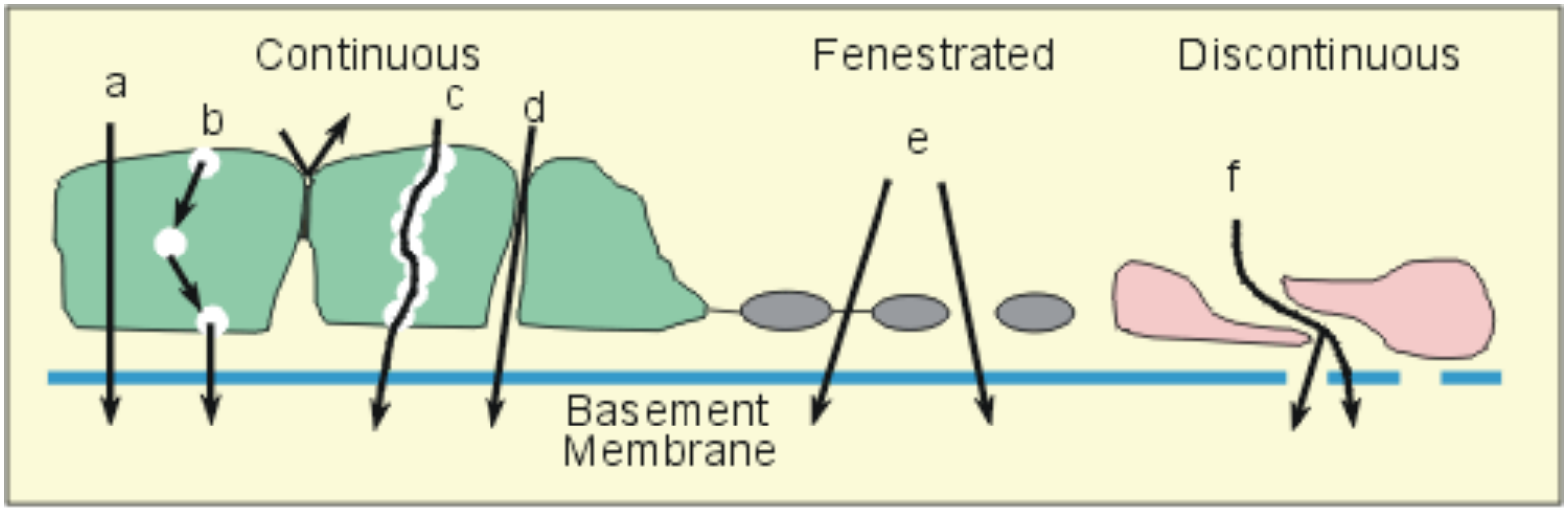
2. FENESTRATED (‘*windowed*’)

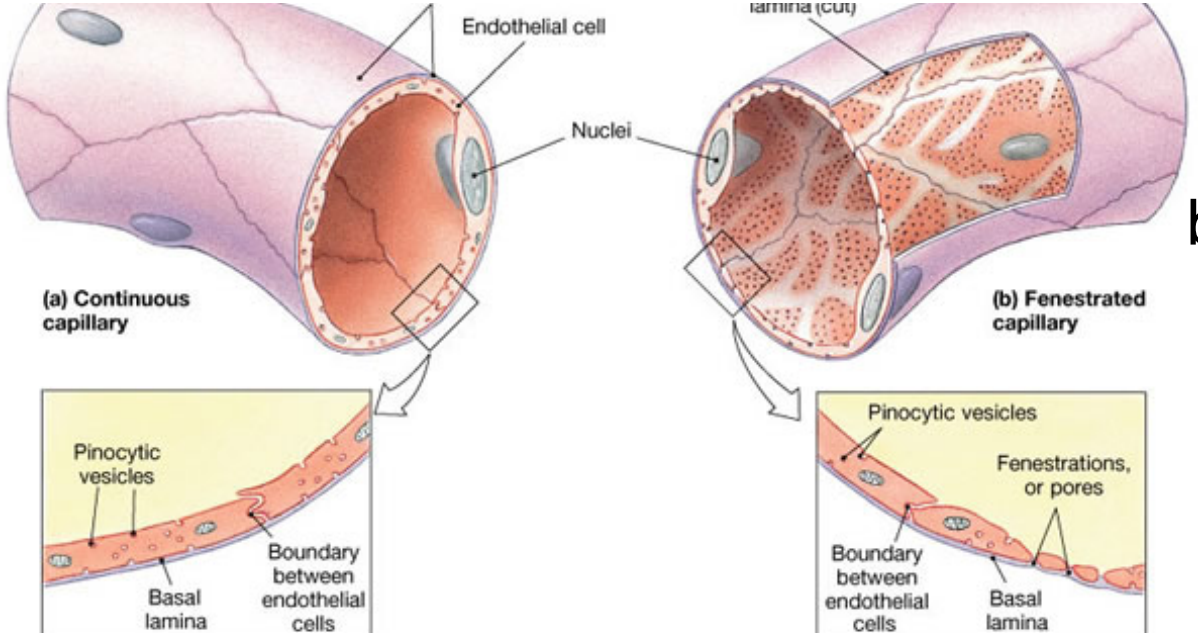
- The plasma membrane has **fenestrations or pores**
  - Found in kidneys, villi of small intestine, choroid plexus in brain, endocrine glands

3. SINUSOID

- Wider, more winding
- **Large fenestrations** and an incomplete basement membrane
- **Protein & RBCs can pass**
  - Found in red bone marrow, liver, spleen, anterior pituitary

Capillary Exchange

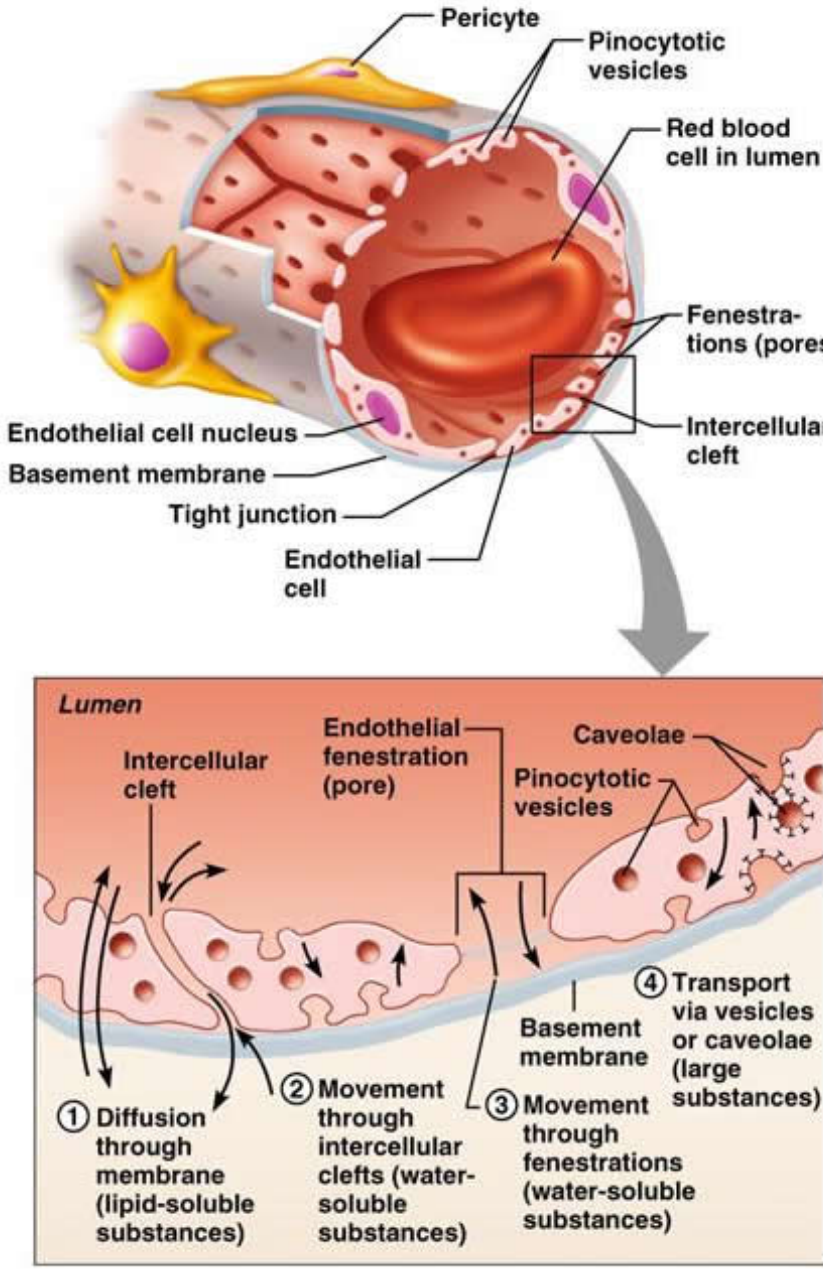




There are 3 ways to exchange substances between the blood & the interstitial fluid:

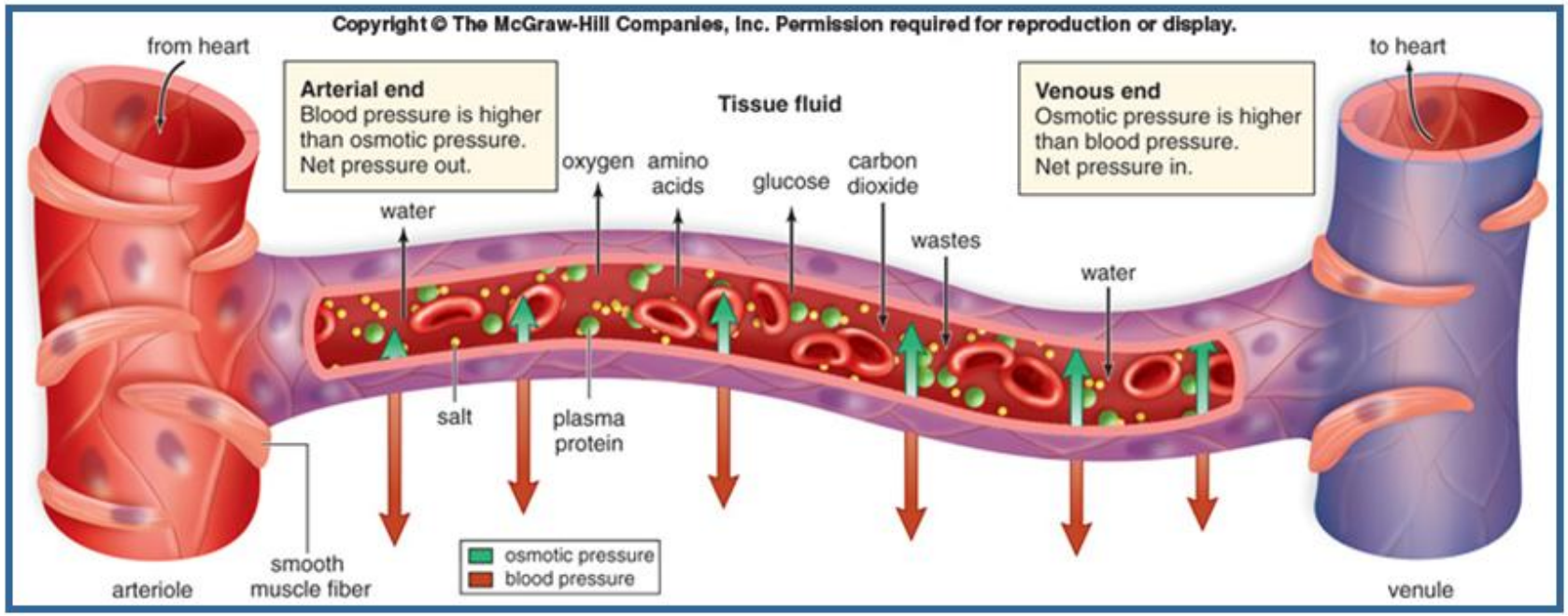
1. **Diffusion (a)**
2. **Transcytosis (b)**
3. **Bulk flow (d,e f,c)**

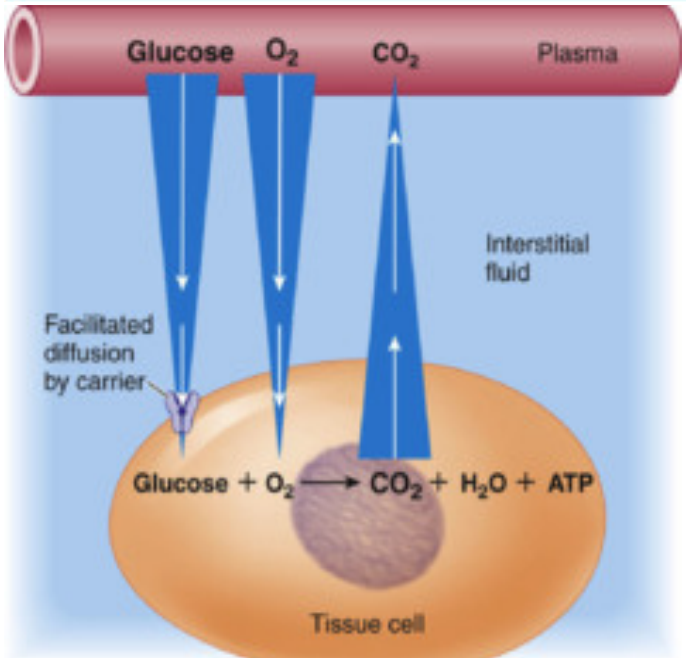
Capillary Exchange



- Solutes can diffuse from high concentration to low concentration, crossing capillary walls through the:
  1. Lipid bilayer of Endothelial cell
  2. Intercellular clefts
  3. Fenestrations
- **Plasma Proteins normally cannot cross capillary walls**
- However, in **sinusoid capillaries,** proteins & even RBCs can cross. Eg, in the:
  - Liver: plasma proteins cross - fibrinogen & albumin
  - Red marrow: RBCs cross
- Blood-brain barrier has tight junctions that limit diffusion

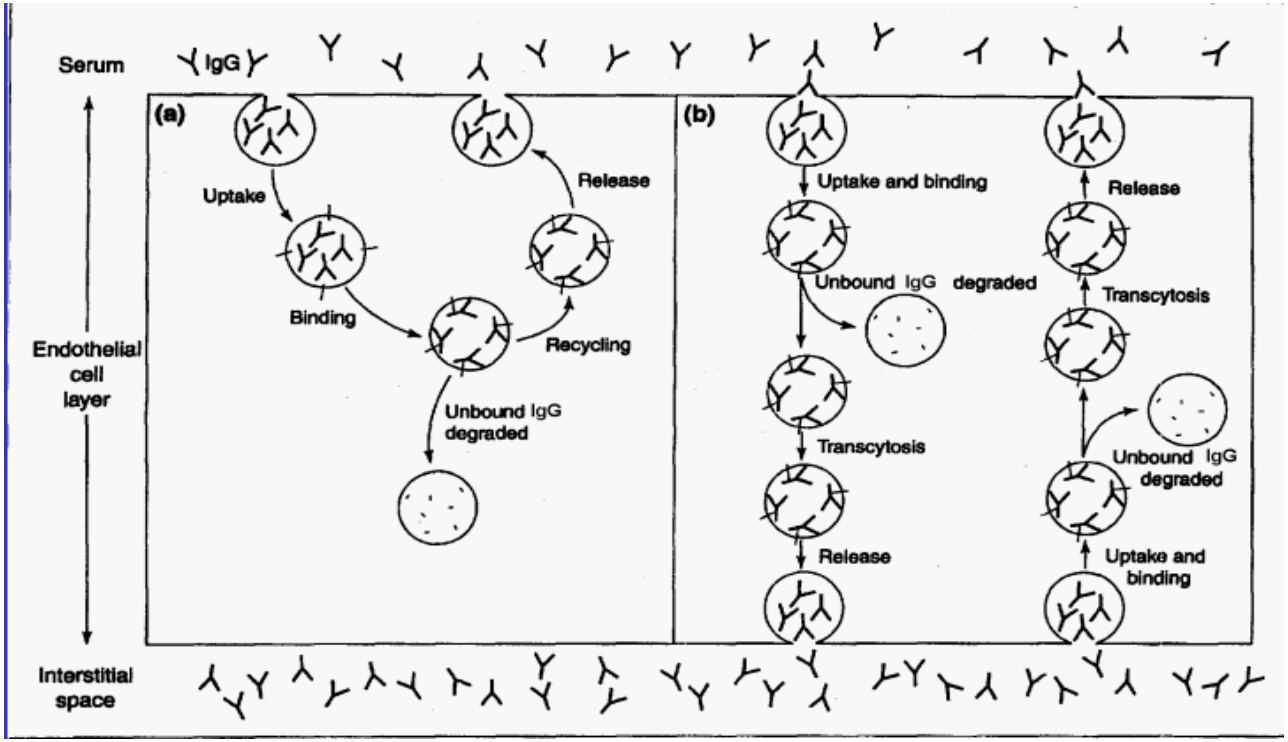
Direction of movement of some substances





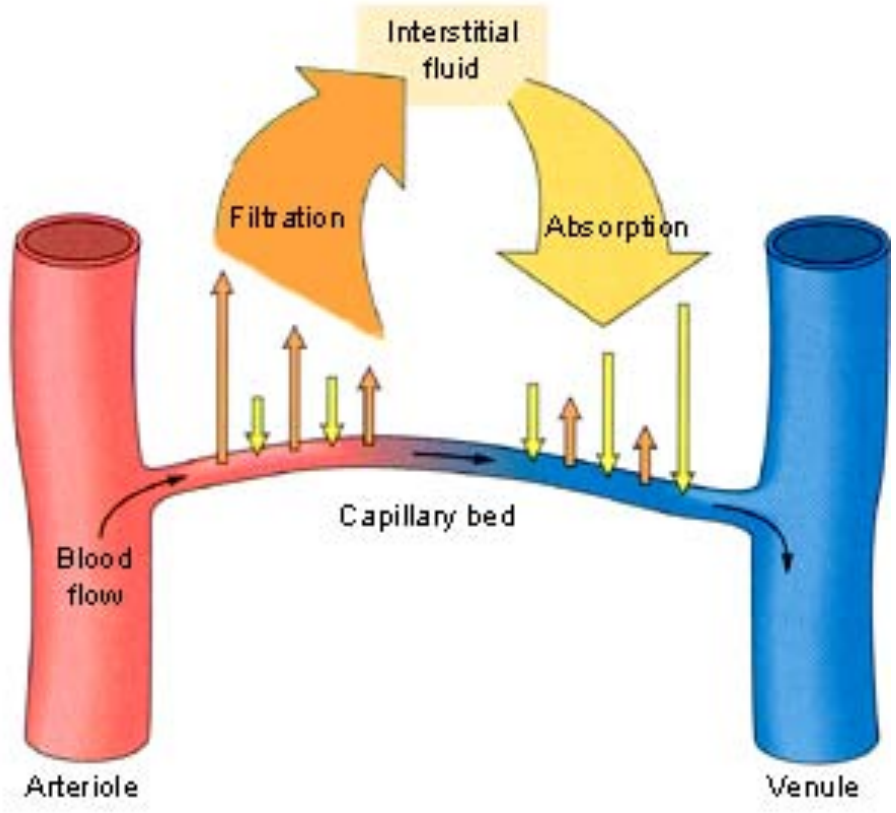
- From Blood to ECF to Cells:
  - O_2
  - Glucose
  - Amino acids
  - Hormones
- From Cells to ECF to Blood:
  - CO_2
  - Wastes

2.Capillary TRANSCYTOSIS



- Used to transport **large, lipid-insoluble molecules** that cannot cross the capillary walls in any other way
  - Eg **insulin, antibodies**
- Substances from the blood plasma enter capillary endothelial cells by endocytosis and exit the other side, into the interstitial space, by exocytosis

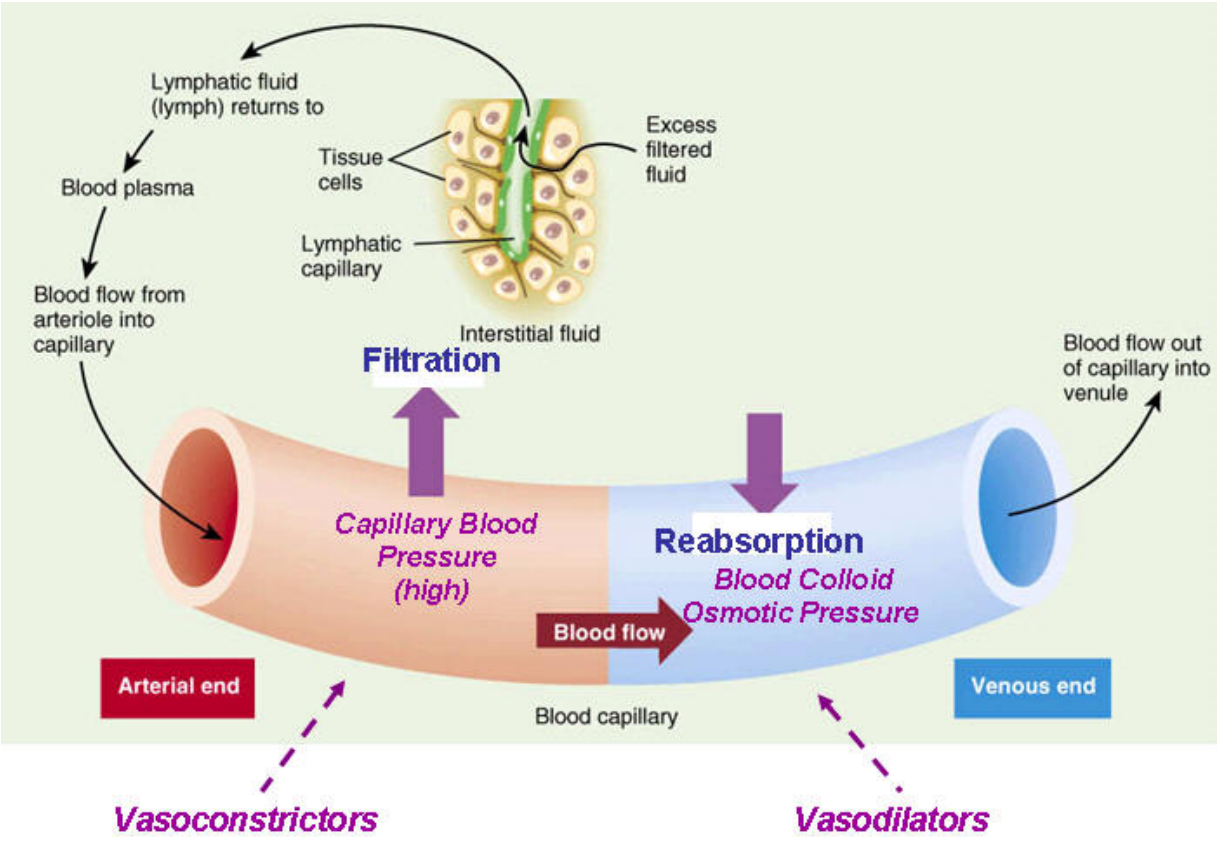
3. BULK FLOW: Filtration / Reabsorption



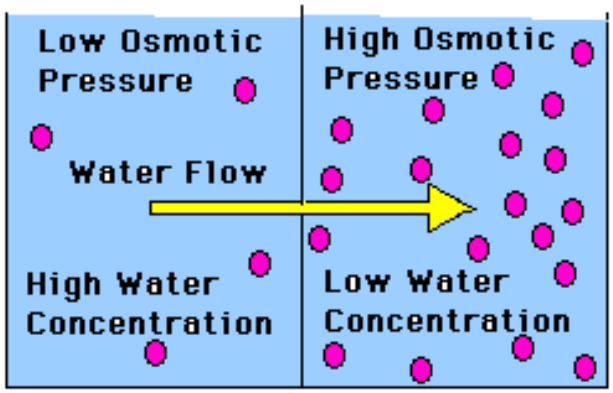
- **Due to <u>pressure</u> <u>differences,</u> FLUID** with *large numbers* of ions, molecules, & particles dissolved in it, will cross the capillary.
  - **Movement occurs from high pressure to low pressure**
  - faster rate than diffusion

- Diffusion is about specific solute & depends on concentration gradient
- Bulk flow depends on pressure & is more about fluid with solutes in it.
- **Regulates relative volumes** of **blood and interstitial fluid**

- **Filtration**: flow from capillaries into interstitial fluid
- **Reabsorption**: flow from interstitial fluid into capillaries



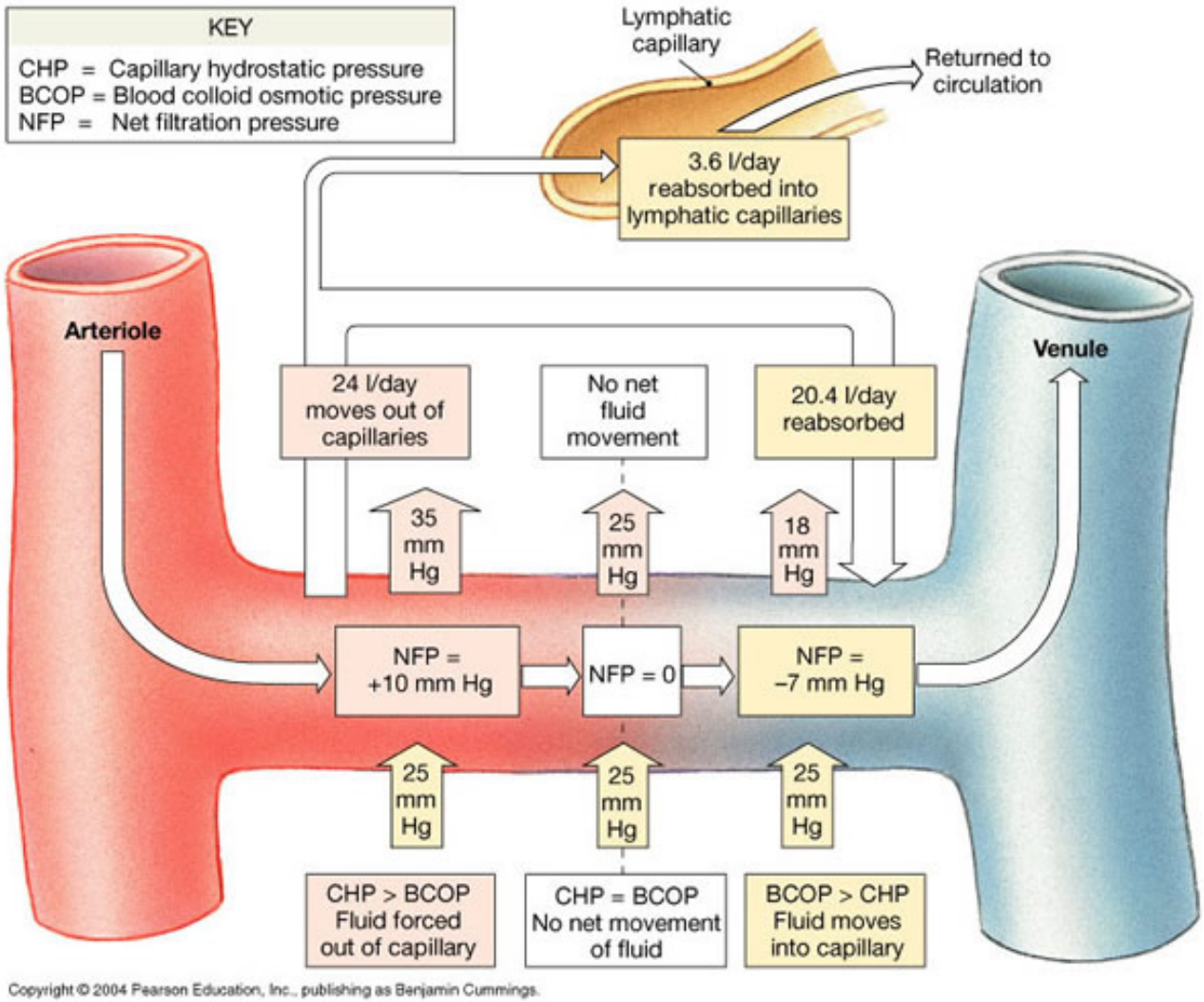
BULK FLOW: Osmotic & Hydrostatic Pressure



- **FILTRATION:** FLUID is PUSHED **OUT OF CAPILLARY** by
  1. **Blood hydrostatic pressure (BHP)** – pressure generated by pumping action of the heart
  2. Interstitial fluid osmotic pressure (IFOP) ≈ 1

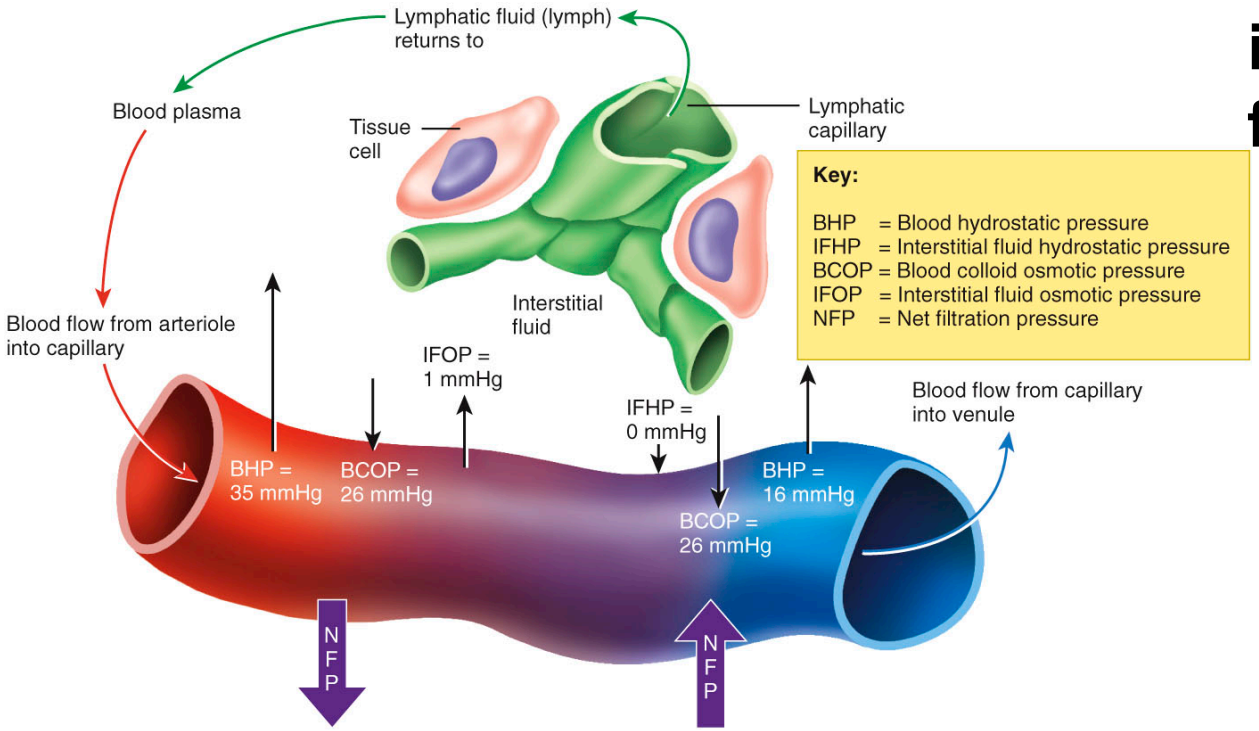
- **REABSORPTION:** FLUID is PULLED **INTO CAPILLARY** by
  1. **Blood colloid osmotic pressure (BCOP)** - created by concentration of plasma proteins in suspension
  2. Interstitial fluid hydrostatic pressure (IFHP) ≈ 0

Net Filtration Pressure (NFP)



- **Indicates final direction of fluid movement**
- **Net Filtration Pressure (NFP)** = (pressures that promote filtration) **-** (pressures that promote reabsorption)
  - Arterial end: net pressure out: 10mmHg so fluids tend to leave
    Venous end: net pressure in: -7mm Hg so fluids tend to be absorbed

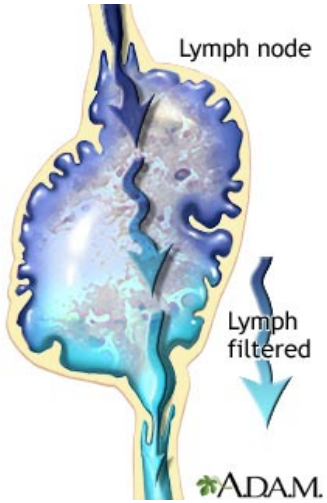
Starling's Law Of The Capillaries

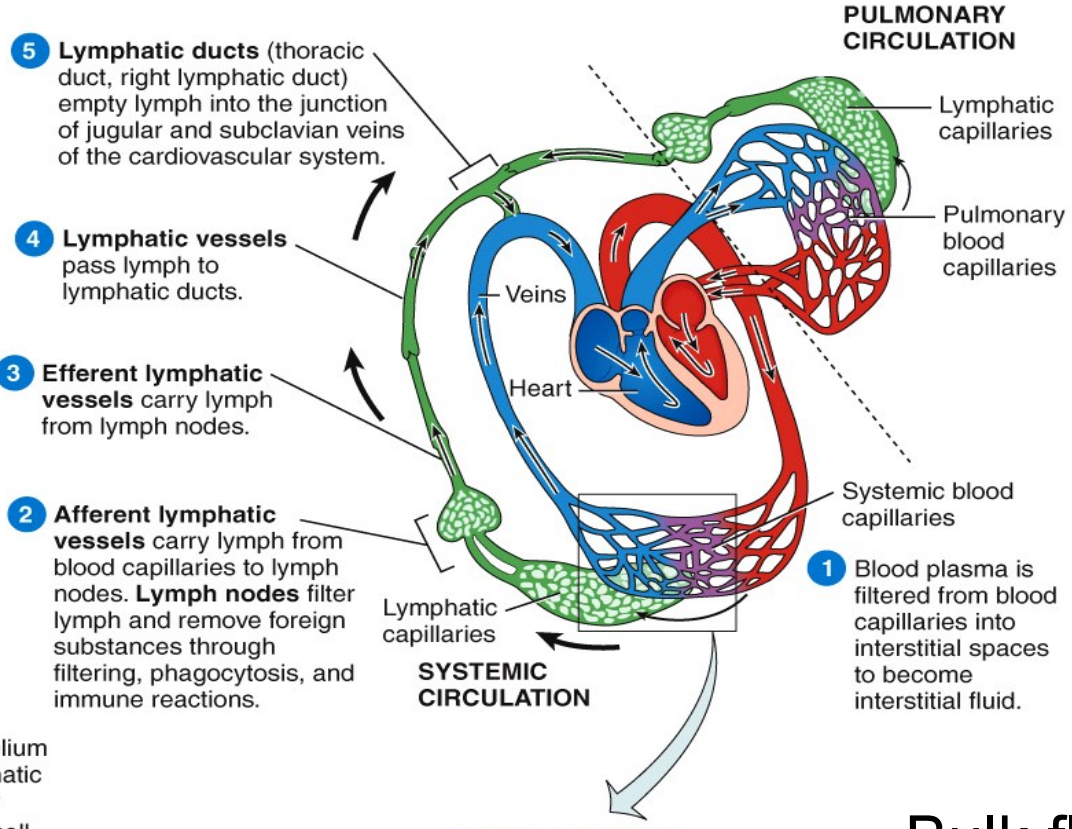


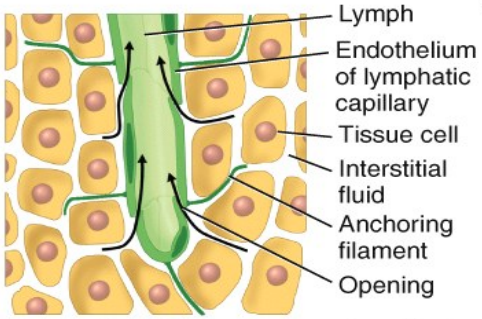
	Net filtration art arterial end of capillaries (20 liters per day)		Net reabsorption at venous end of capillaries (17 liters per day)
Net filtration pressure (NFP)	= (BHP + IFOP)	–	(BCOP + IFHP)
	Pressures promoting filtration		Pressure promoting reabsorption
	Arterial end		**Venous end**
	NFP = (35 + 1) – (26 + 0) = 10 mmHg		NFP = (16 + 1) – (26 + 0) = – 9 mmHg
Result	Net filtration		Net reabsorption

- **Nearly as much fluid is reabsorbed as was filtered**
  - 85% of the fluid that was filtered is then reabsorbed
  - Not 100% fluid returns because a few plasma proteins leave vessels into interstitial space
  - Remainder of fluid & proteins enter lymphatic capillaries (3L/ day) & is eventually returned to blood

Bulk flow to Lymphatic circulation

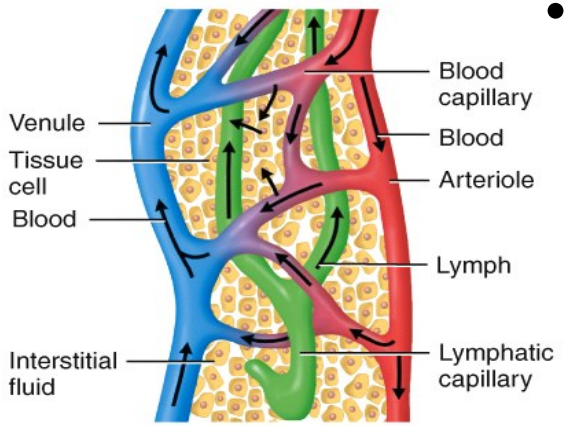






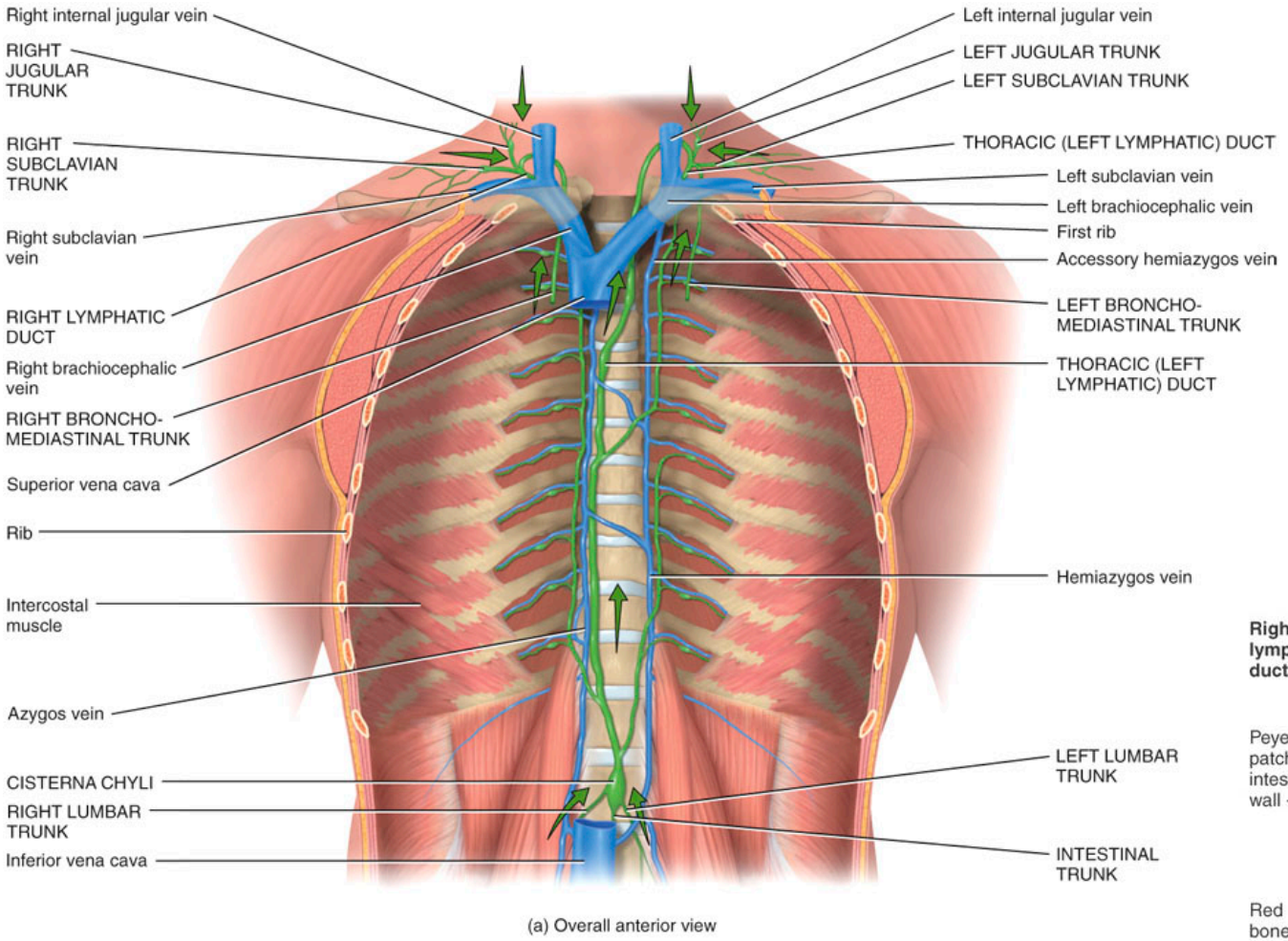
Endothelial cells that make up **lymphatic capillaries** overlap like roof shingles.

- When interstitial fluid pressure exceeds lymph pressure inside, the cells separate slightly, and fluid enters the capillary like floodwater pushing open a door.
- When the lymph pressure exceeds the interstitial fluid pressure, the cells close tightly, and lymph cannot escape back.

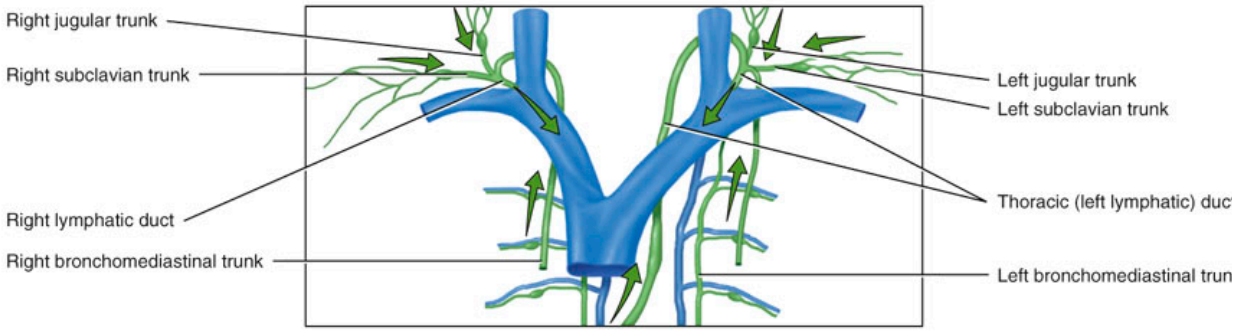


- Bulk flow creates interstitial fluid which then flows into the lymph and finally returns to the blood vessels

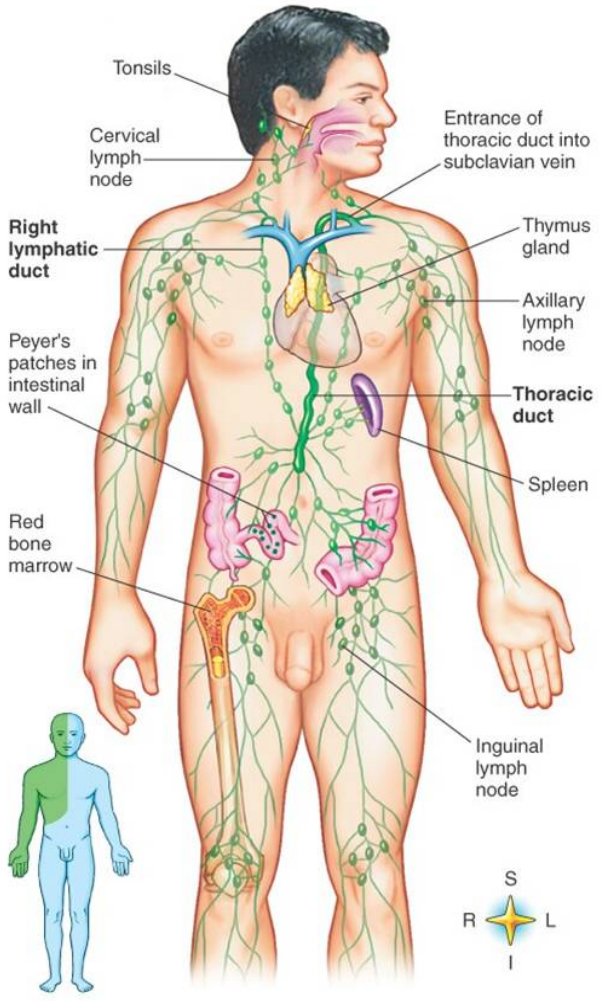
Lymphatic circulation



(a) Overall anterior view



(b) Detailed anterior view



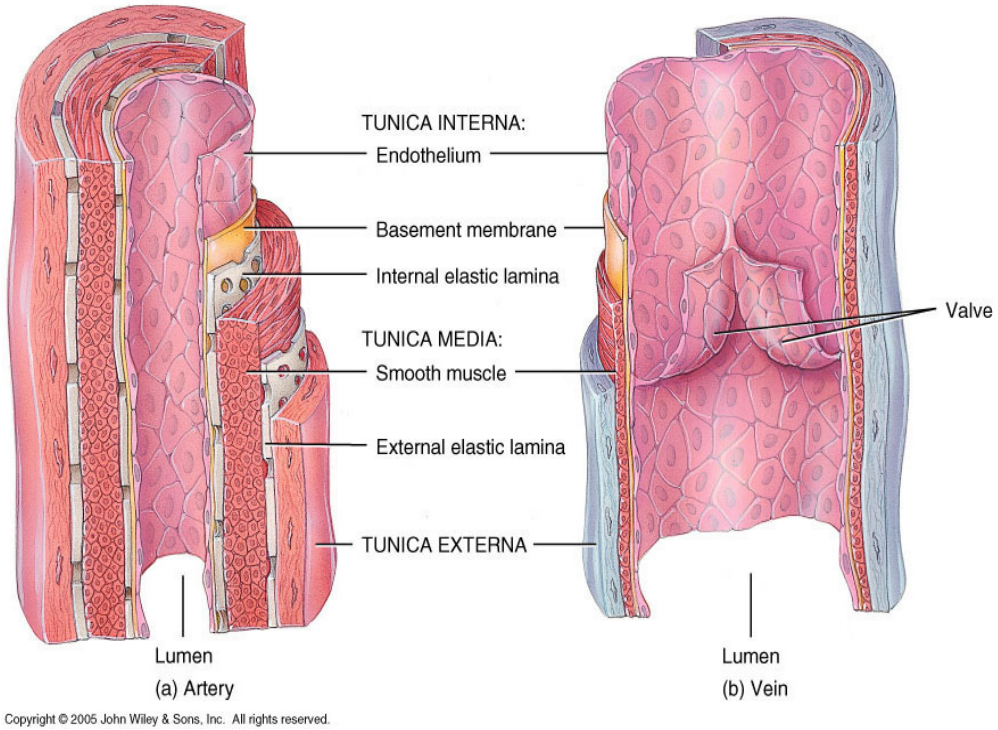
EDEMA: Increased interstitial fluid

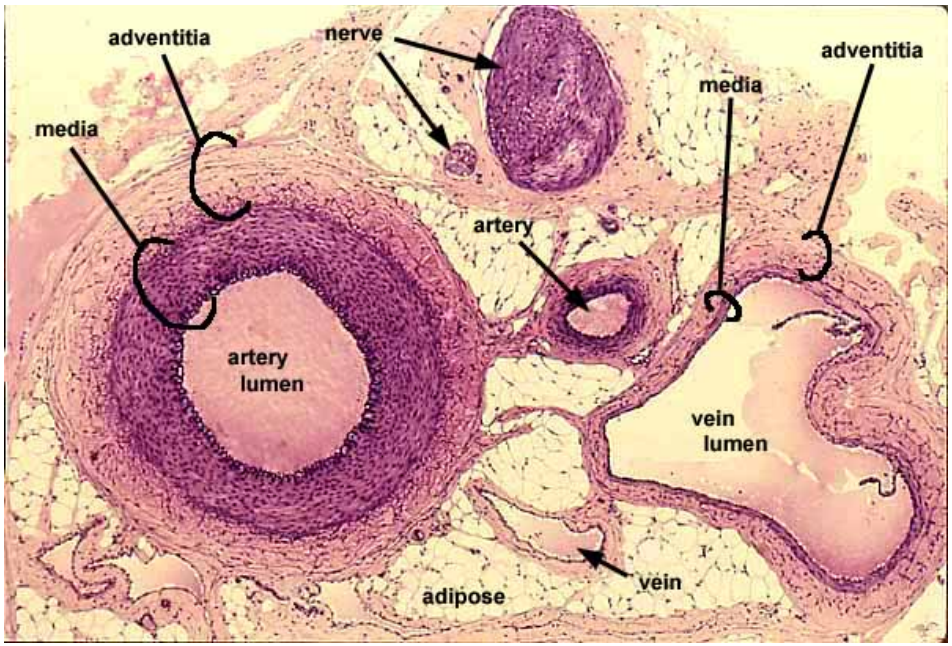
- An abnormal increase in **interstitial fluid** volume occurs if there is:
  - **Increased filtration** of fluid & solutes out of capillary due to:
    - Increased capillary permeability to plasma proteins
    - increased blood pressure
  - Or, **decreased reabsorption** of fluid & solutes from ECF due to:
    - Decreased # of plasma proteins in capillaries from liver disease, burns, malnutrition, kidney disease

Section 3

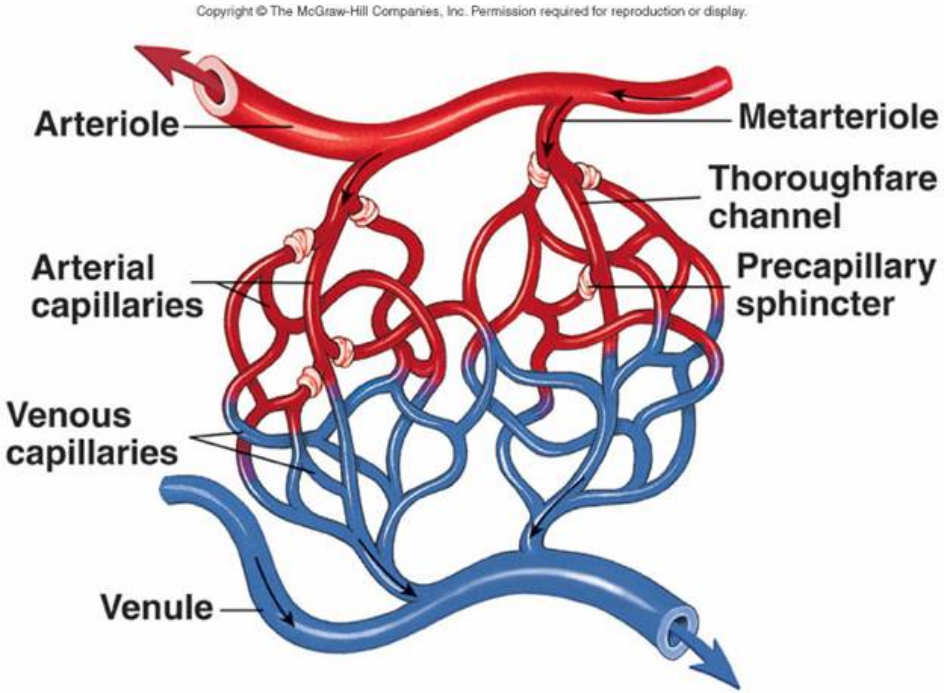
VEINS

Veins





- Same three tunics as arteries: interna, media, externa
  - Tunica externa is thickest layer
- **Thinner walls** - so the lumen of vein is larger than the lumen of a comparable artery
- **Not designed to withstand high pressure**
- Many veins contain **valves**
  - Valves are thin folds of the tunica interna
  - Cusps point towards the heart
  - **Prevent backflow of blood**

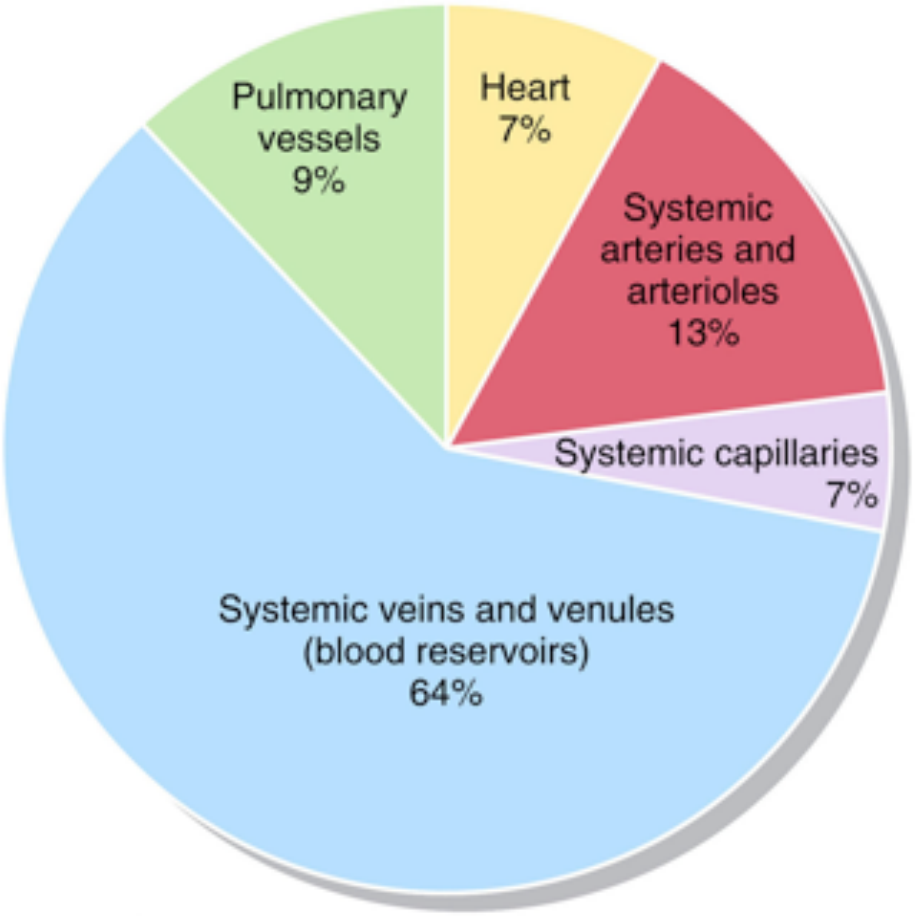


2 kinds of VENULES:

1. **Postcapillary Venules** are the smallest venules. They form when several capillaries unite
   - Walls are **very porous** serve as the site for **white blood cell emigration**

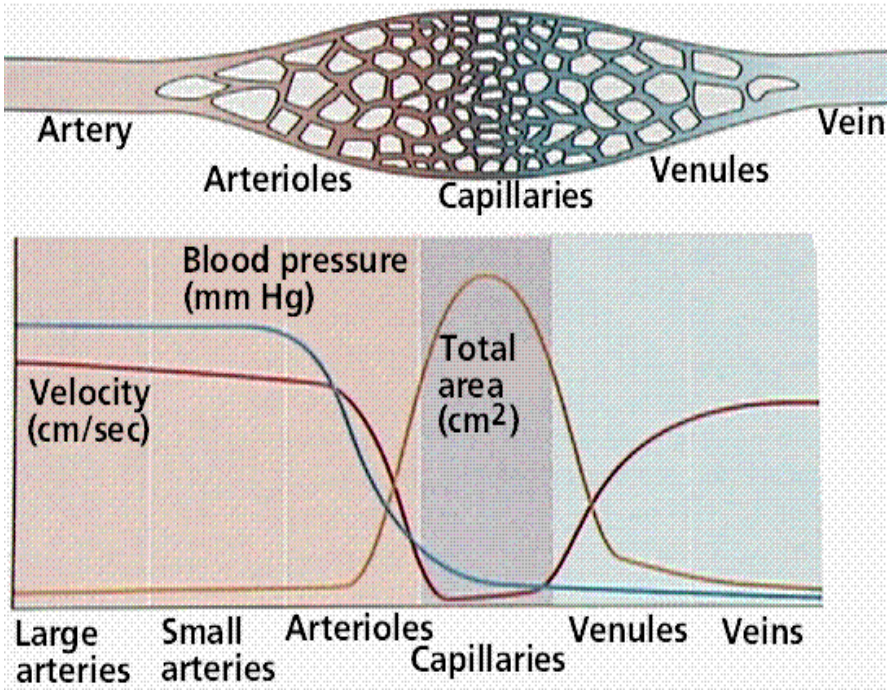
2. **Muscular Venules** have 1-2 layers of smooth muscle
   - **No more exchange** with interstitial fluid

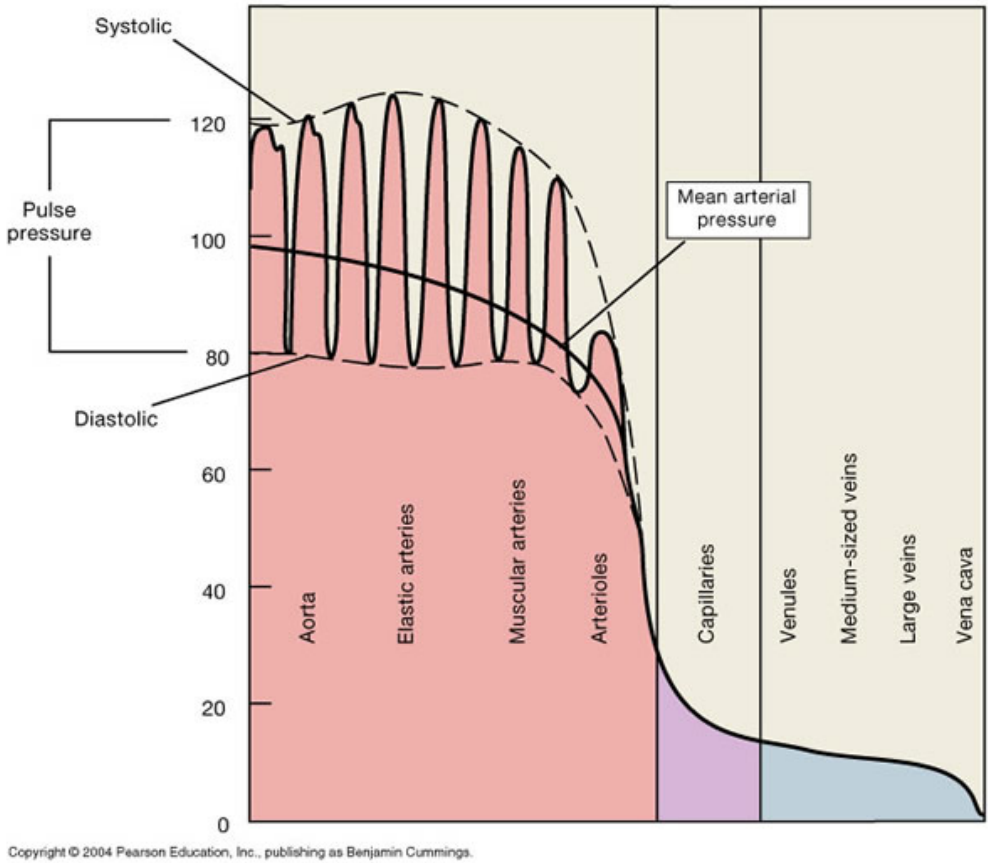
Veins Provide a Blood Reservoir



- **Blood reservoir:** at rest, the majority (64%) of blood is in the veins and venules
  - Especially veins of the liver & spleen
- if the need arises, blood can be diverted quickly to where it is needed through **venoconstriction**
  - constriction of veins, reduces the volume of blood in the reservoirs
  - eg sympathetic impulses during exercise constrict veins to increase Cardiac Output

Venous Blood Flow





- As the cross sectional area decreases, velocity of venous blood flow increases.
- Venous blood pressure is about 16mmHg which moves it toward the heart

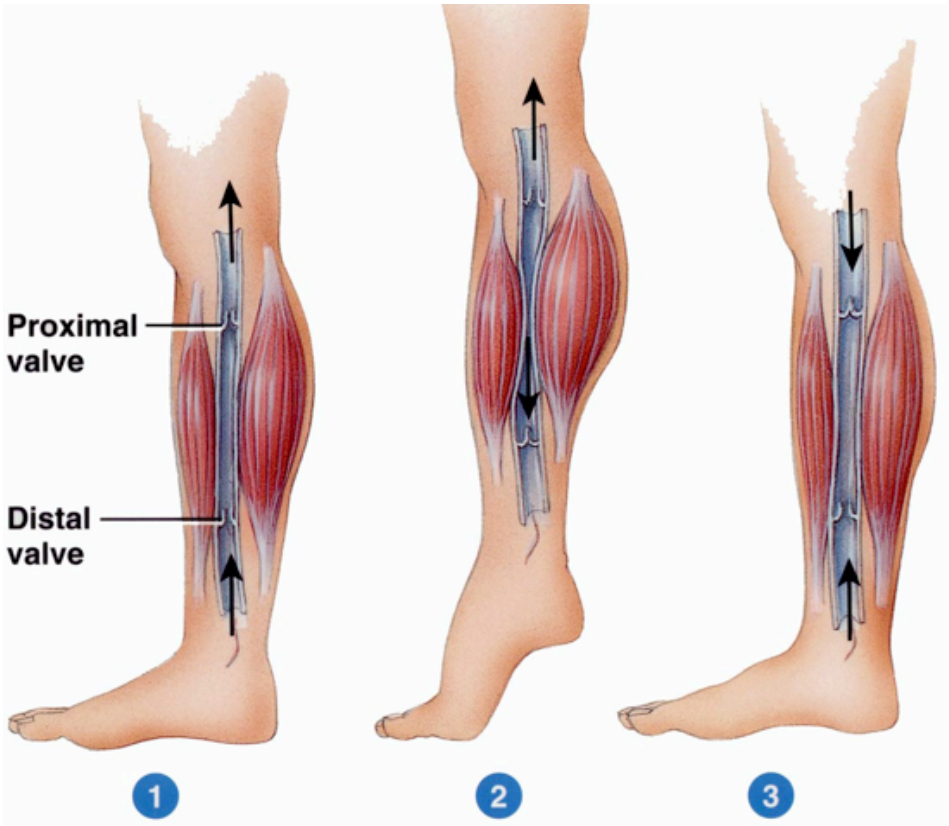
Venous Return (to the Heart)

- Venous Return refers to the volume of blood flowing back from the systemic veins to the right side of the heart

Venous return depends on:

1. **Contraction of LEFT ventricle**
   - only 16 mmHg of pressure left when blood arrives at venules is still enough to move it to the heart
   - Increased pressure in R atrium or R ventricle will **decrease** venous return
2. **Skeletal muscle pump** - more contractions increase VR
3. **Respiratory pump** - deeper breaths increase VR
4. Total blood volume

Skeletal Muscle Pump (Venous Return)

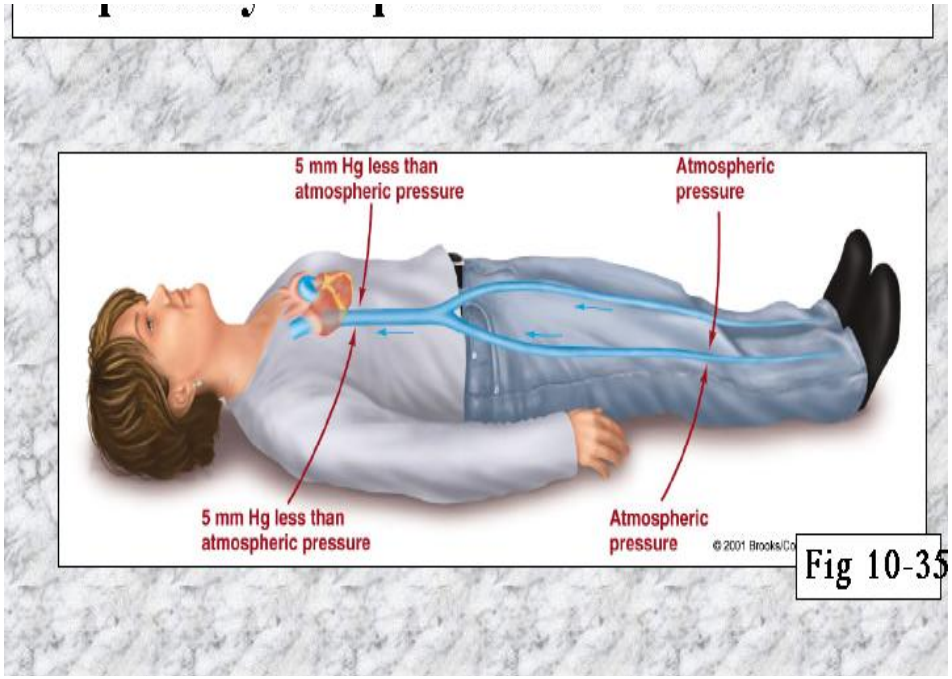


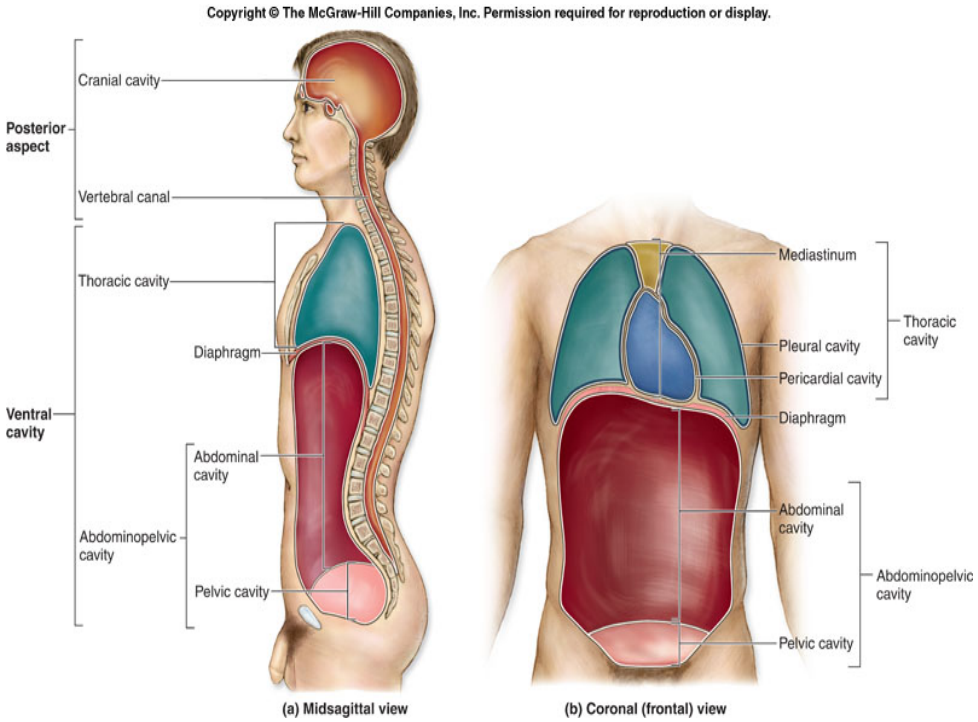
1. **At rest:** both proximal & distal valves are open, blood is flowing due to 16mm Hg blood pressure of veins

2. A muscle **Contraction** pushes blood through top valve '**milking**' it towards heart. Because bottom valve blocks blood flow downwards.

3. upon **Relaxation** recently milked blood cannot flow back down because top valve closes to block it. **Middle section is 'empty'**, thus BP is higher in foot. **Blood from foot opens bottom valve** and fills vein.

Respiratory Pump (Venous Return)



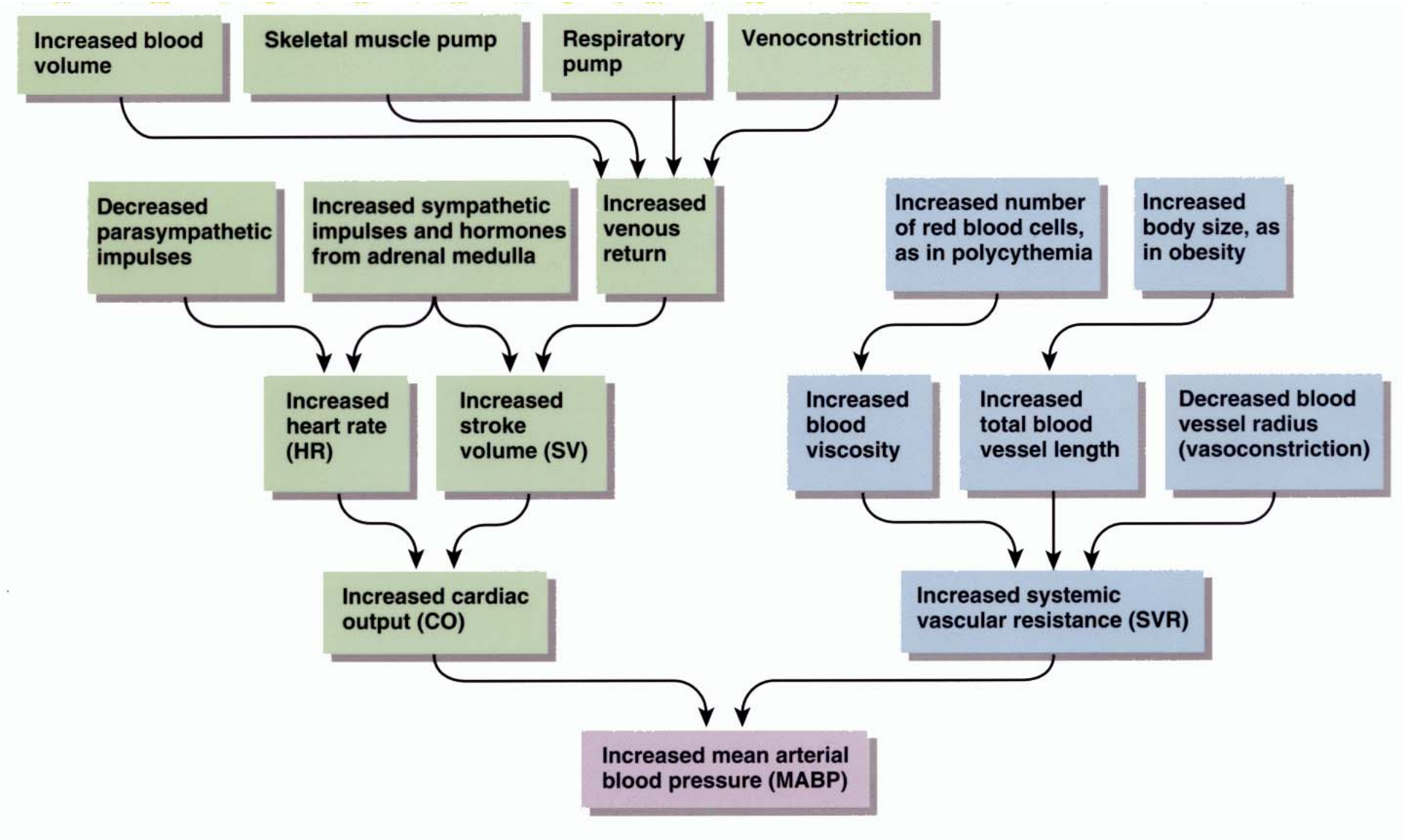


- **Inhalation** moves diaphragm down, increasing the size of the thoracic cavity
- pressure decreases in thoracic cavity while increasing pressure in the abdominal cavity.
- Blood moves from higher pressure abdomen to lower pressure thorax.

Section 4

BLOOD PRESSURE

Factors affecting Blood Pressure



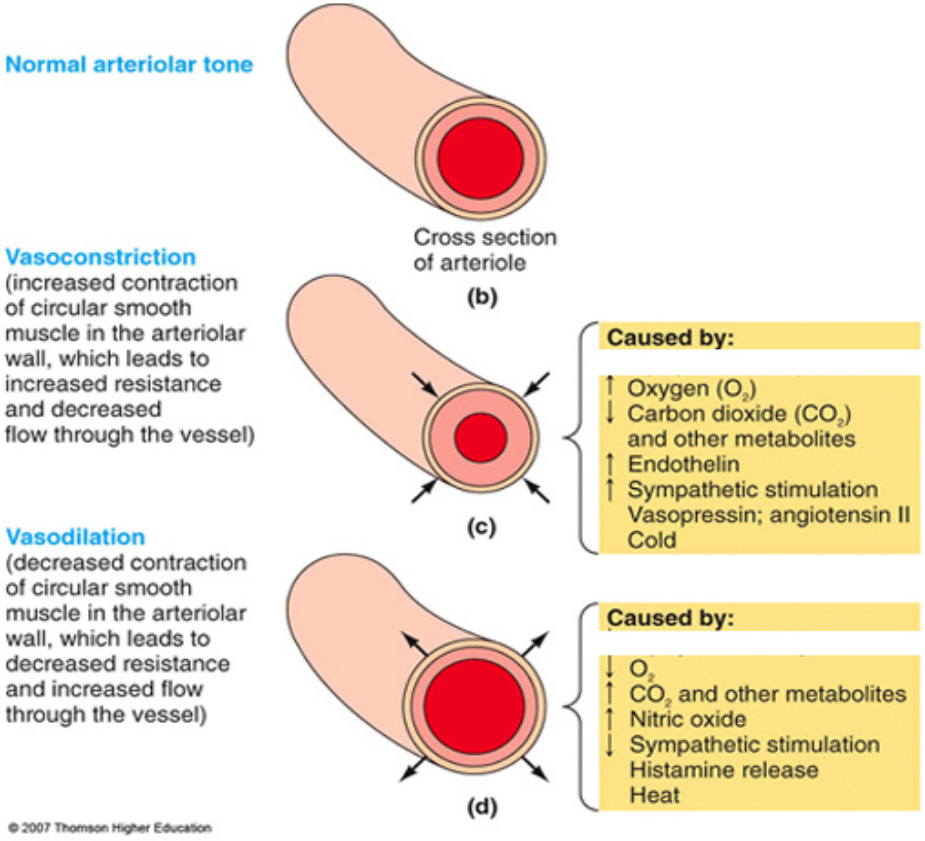
Anything that increases cardiac output will increase blood pressure

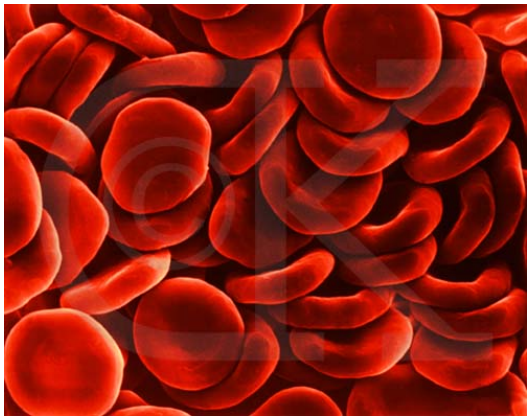
$$CO = SV \times HR$$

- Stroke Volume depends on
  1. Preload (=**Venous Return**)
  2. Contractility
  3. Afterload

VASCULAR RESISTANCE

Vascular Resistance

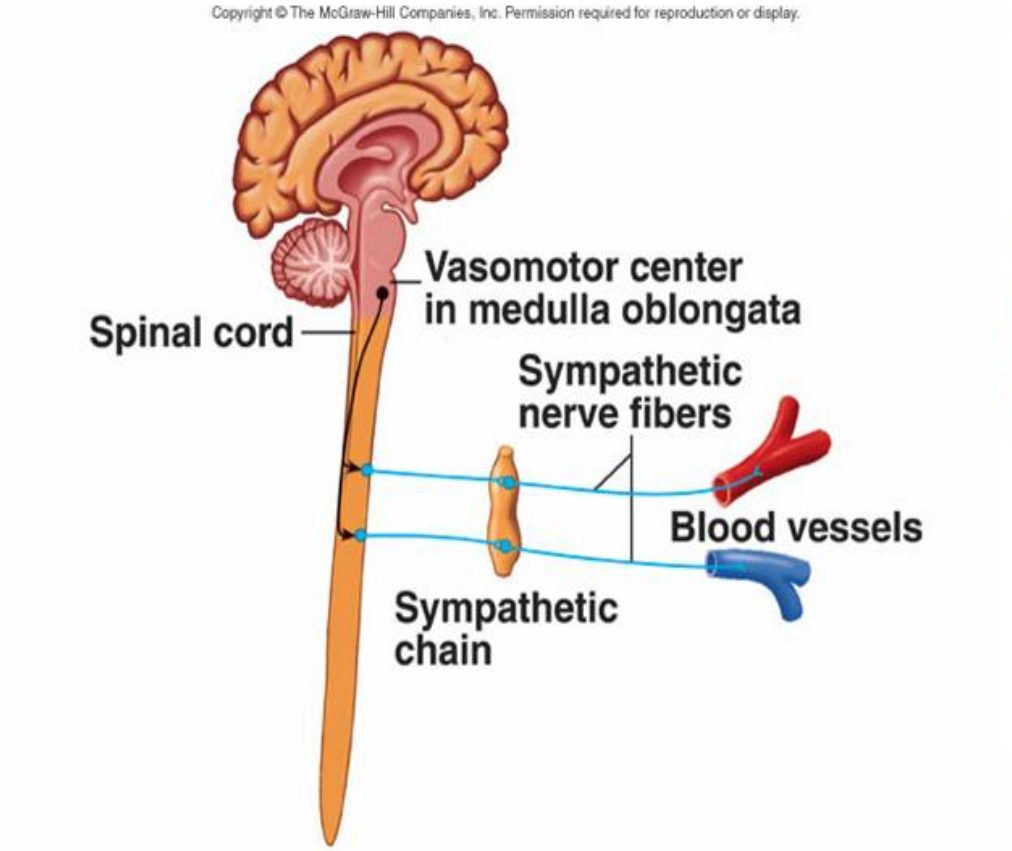


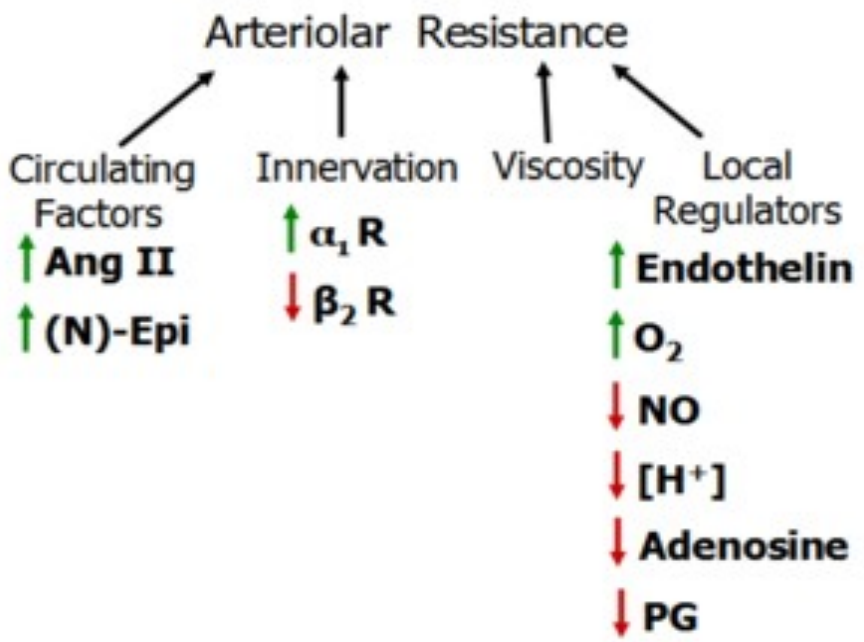


- **Vascular Resistance,** which opposes blood flow, is caused by **FRICTION between blood & blood vessel walls**

- Vascular resistance depends upon:
  1. **Size of vessel lumen:** smaller lumen has more friction / resistance to flow
  2. **Blood viscosity:** ratio of RBCs & proteins : plasma. A greater blood viscosity increases resistance to flow
  3. **Total blood vessel length**: longer vessels, increase friction & resistance (add 400 miles of additional blood vessels for each 2.2lb. of fat)

Vascular resistance & vasomotor center



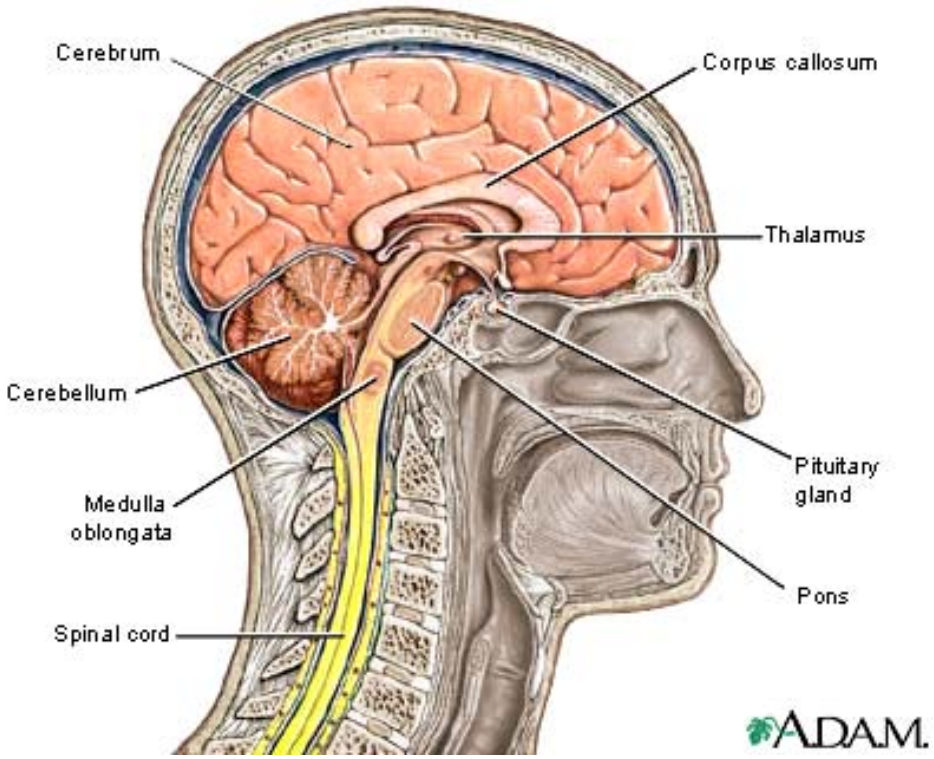


- The **Vasomotor center** in the brainstem regulates **Systemic Vascular Resistance** (SVR) or *Total Peripheral Resistance* by causing arterioles to constrict (α1) or dilate (β2).

- **The **major role of <u>ARTERIOLES</u>** is to constrict or dilate to control the resistance to blood flow in the body as a whole.

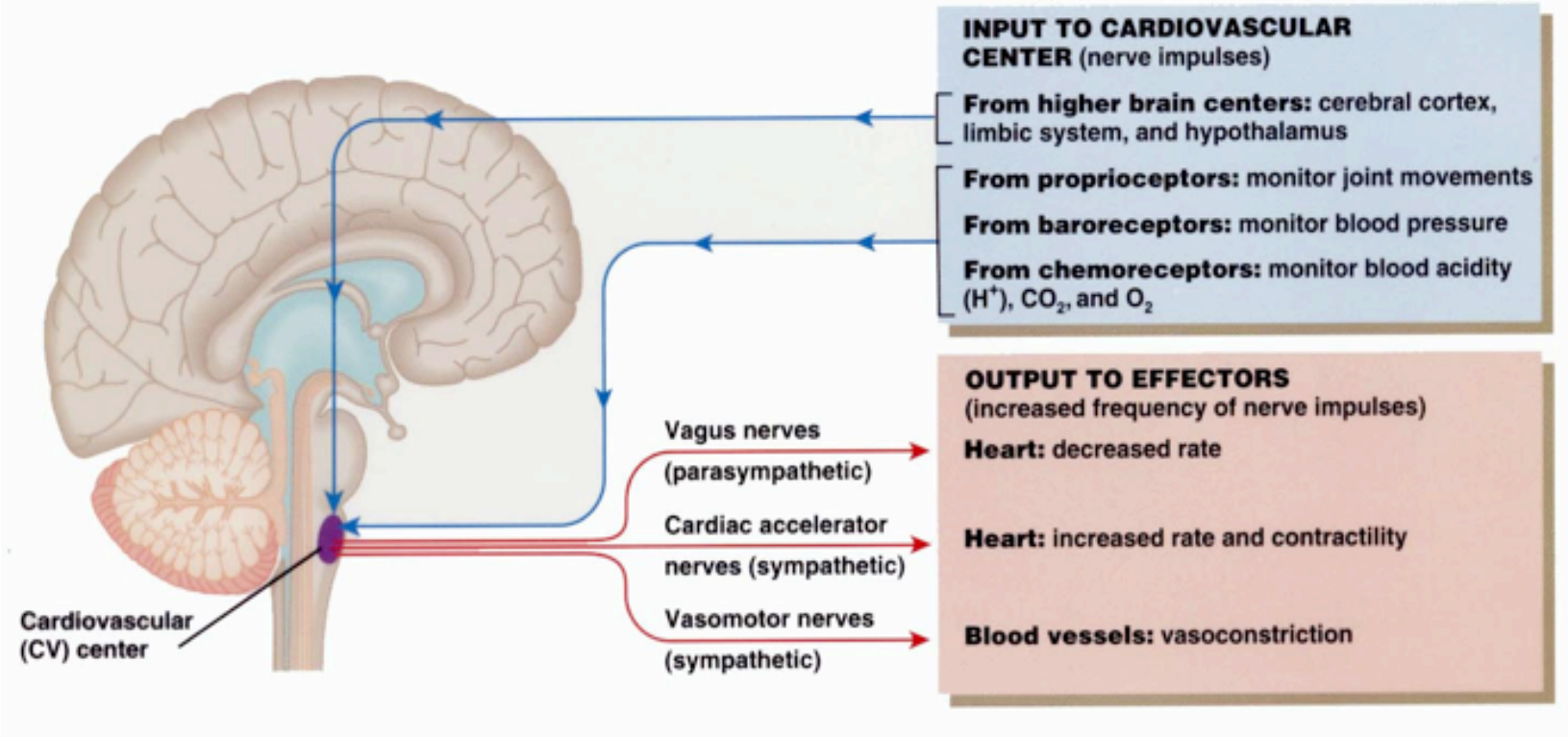
NEURAL CONTROL OF BLOOD PRESSURE

The Cardiovascular Center



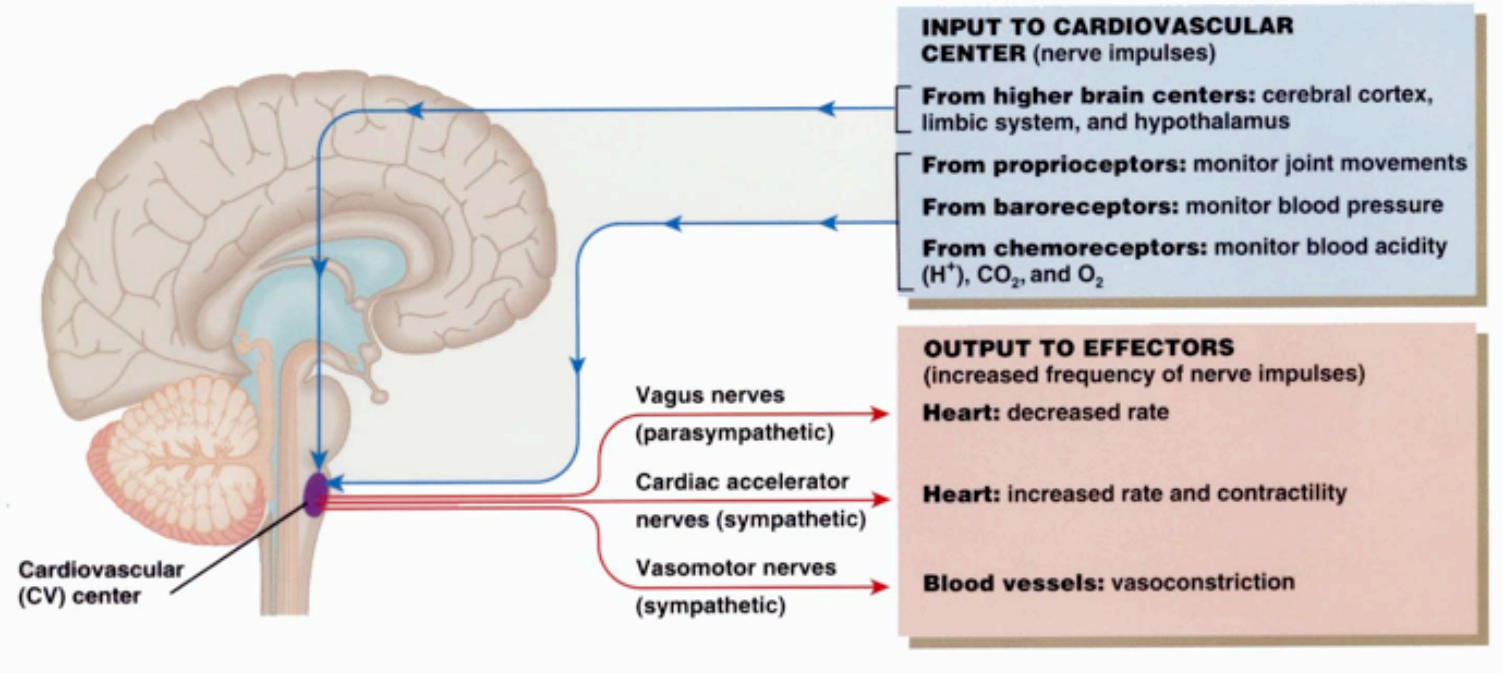
- The **Cardiovascular Center** affects heart rate, contractility, and vasoconstriction
  - Inputs:
    - Higher brain, Baroreceptors, Chemoreceptors, Proprioceptors
  - Outputs:
    - Cardioaccelerator nerves, Vasomotor nerves, Vagus nerve

Cardiovascular Center in Medulla



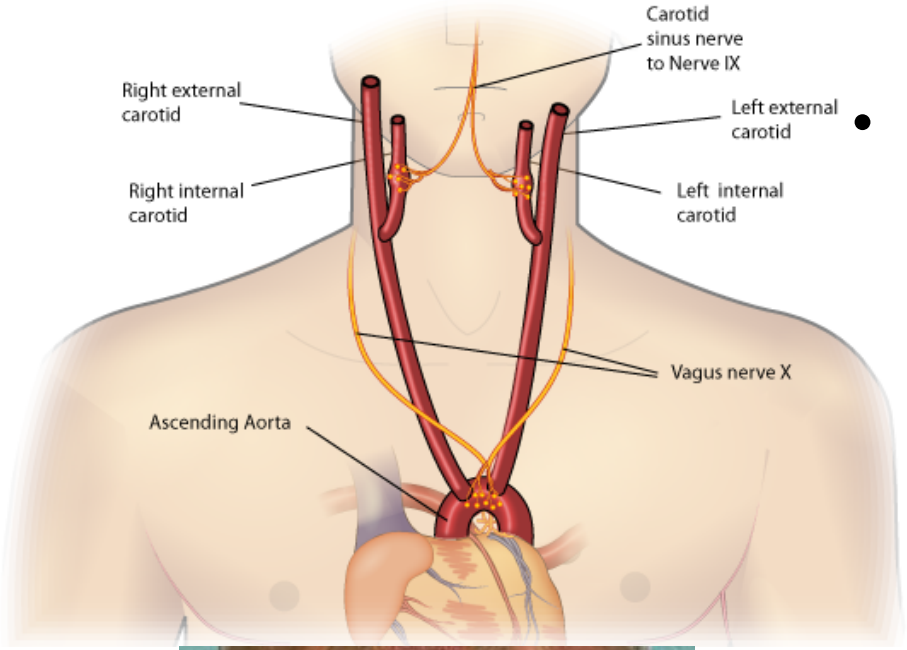
- CV center is in medulla oblongata
- Controls 1. **Heart rate** 2. **Contractility** 3. **Blood vessel diameter**
- Therefore affects: stroke volume, blood pressure, blood flow to specific tissues…
- Continuous impulse from **vasomotor nerves** creates **constant mild contraction of arterioles**, "**vasomotor tone":** resting level of **systemic vascular resistance**

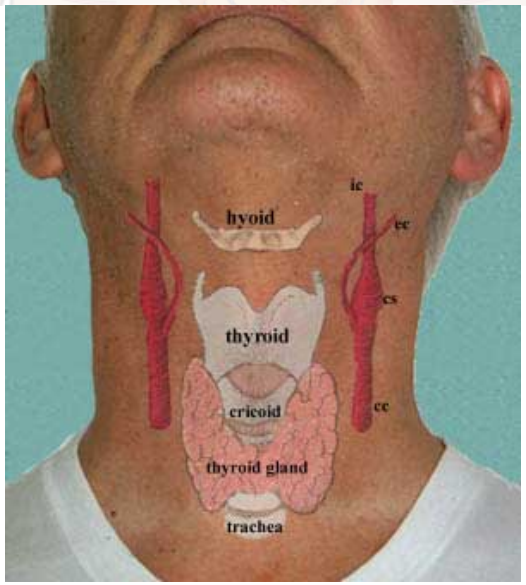
Neural **INPUT** to CV Center



1. **Higher Brain:** cortex, limbic system, hypothalamus
2. **Sensory receptors**:
   a) **Proprioceptors**: detect **motions / position in space** of joints and muscles
   b) **Baroreceptors:** detect **pressure changes** & **stretch** in blood vessel walls
   c) **Chemoreceptors:** monitor concentration of various **chemicals** in the blood eg O2 & CO2

b) **Baroreceptors:** Pressure & Stretch





- **Baroreceptors** are pressure-sensitive receptors:
  1. **Aortic arch** receptors (Aorta)
  2. **Carotid Sinus** receptors
     - **Carotid sinuses:** small widenings on R & L Internal Carotid arteries
  3. Other large arteries in neck / chest

- **Aortic Reflex**: regulates **systemic** blood pressure. signals reach CV center via vagus nerve (CN X)

- **Carotid Sinus reflex:** helps regulate blood pressure **in brain.** Signals sent to CV center via glossopharyngeal nerve (CN IX)

FYI Baroreceptors:

Carotid Sinus Massage & Carotid Sinus Syncope

1. **Carotid sinus massage:** massaging neck over carotid sinus, increases input to CV which **reflexively slows heart rate.** Use in a person with paroxysmal superventricular tachycardia

2. **Carotid sinus syncope:** fainting due to excessive pressure on, or hypersensitivity of the carotid sinus. Can be due to hyperextension of head or tight collars

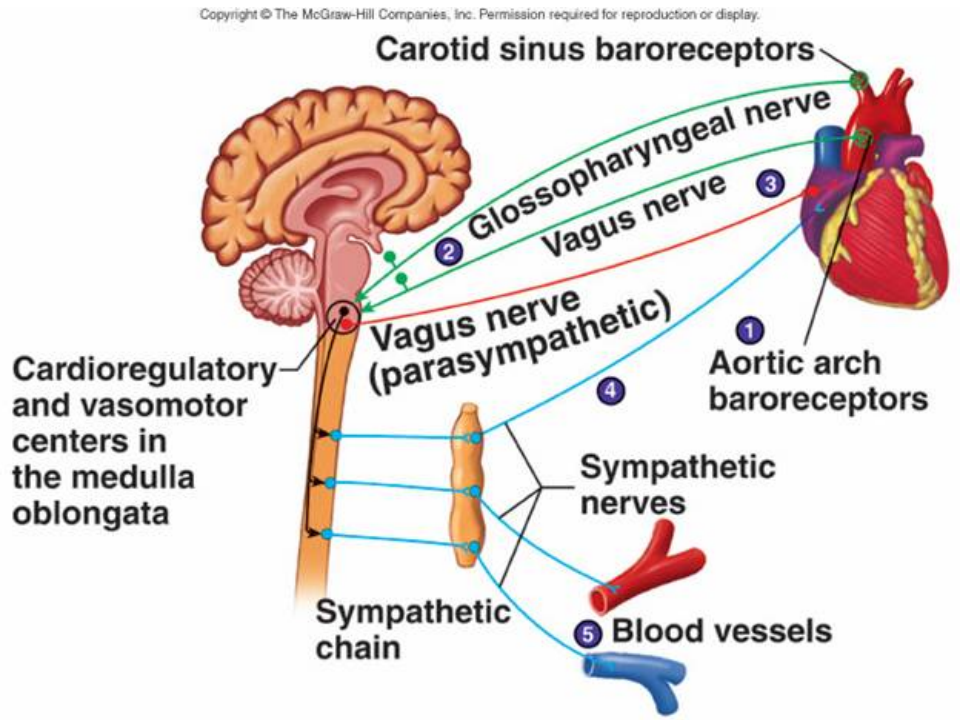
Syncope (Fainting)

- A sudden **loss of consciousness** not due to head trauma with spontaneous recovery
- From **insufficient blood flow** to brain, or, cerebral **ischemia**

Causes:

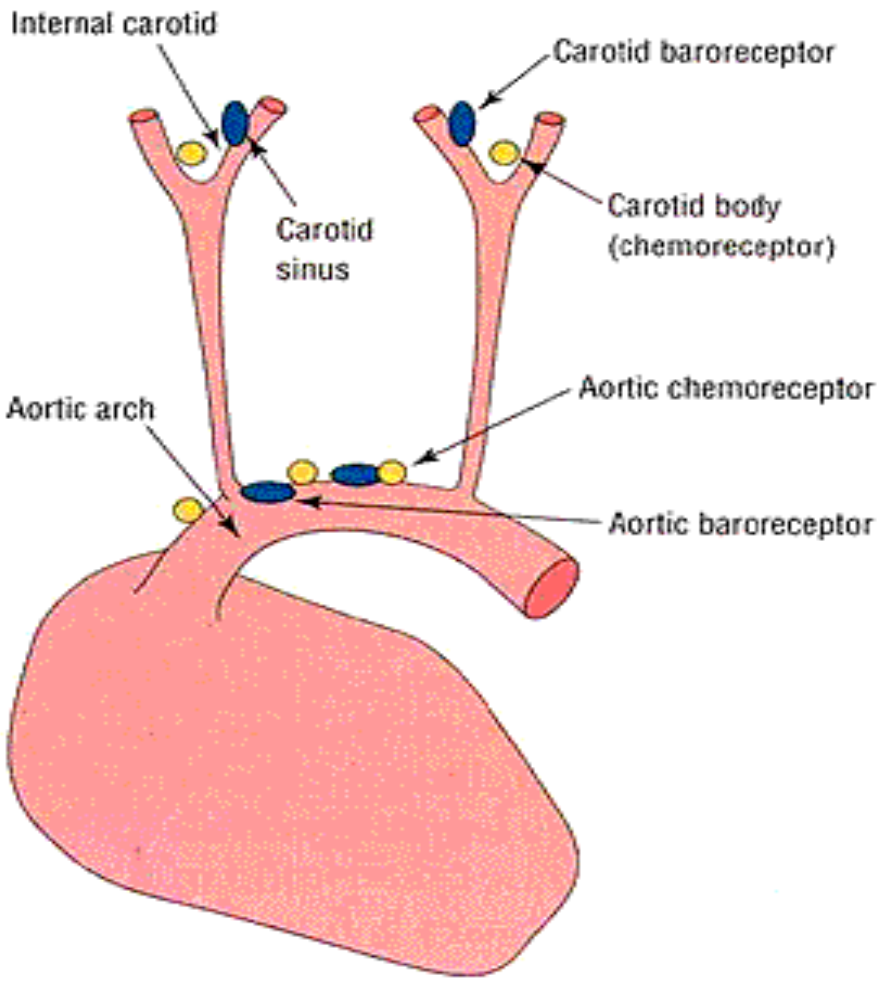
- Vasodepressor syncope – sudden **emotional** stress
- Situational syncope – **pressure** stress associated with urination, defecation, or severe coughing.
- Drug-induced syncope – antihypertensives, diuretics, vasodilators, & tranquilizers
- Orthostatic HYPOtension – an **excessive decrease** in **blood pressure** that occurs **upon standing up**

Baroreceptor Reflexes: when BP falls or rises…



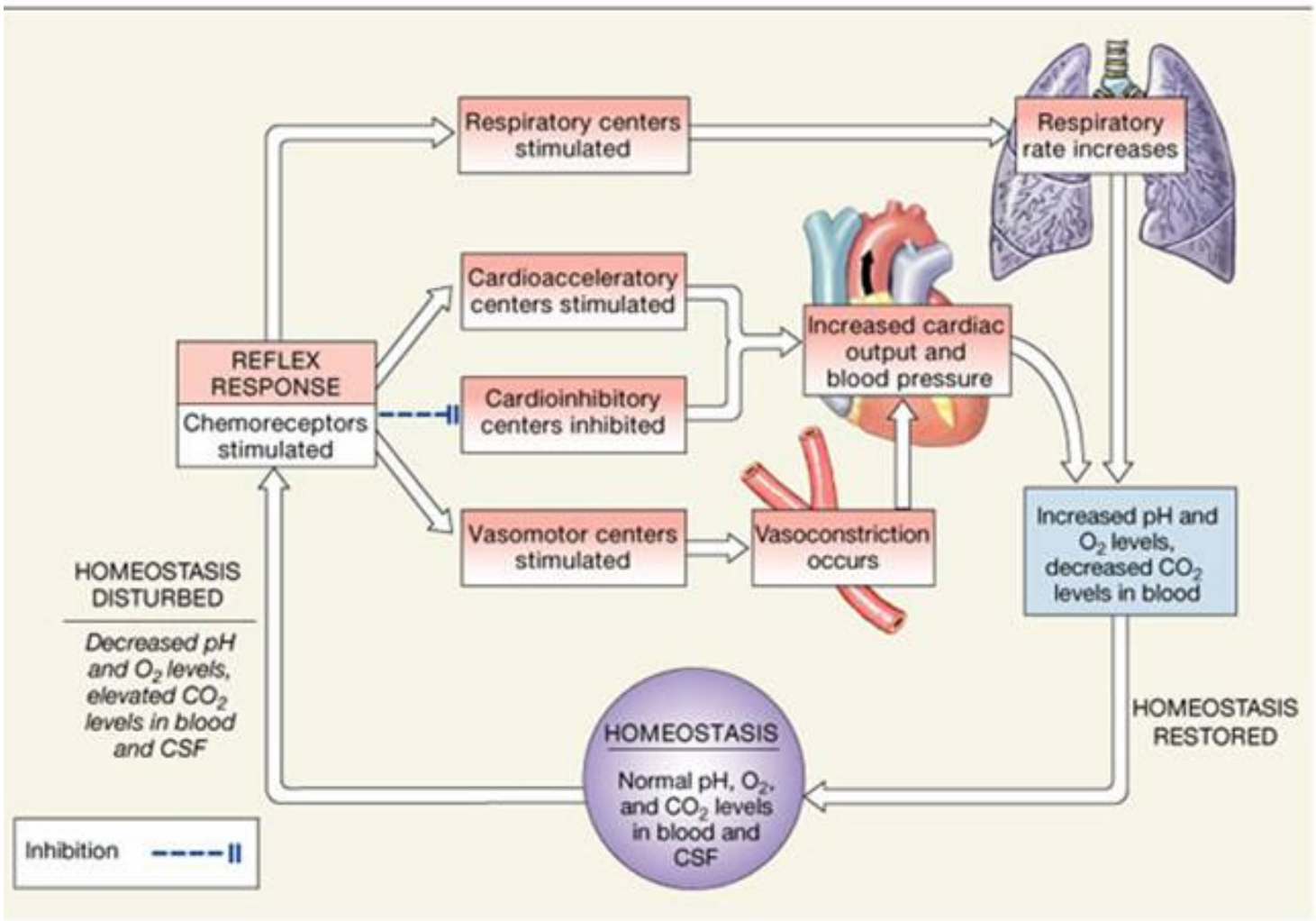
If BP falls baroreceptors stretch less = ↓rate of impulses to CV	**1. CV ↓ parasympathetic stimulation** **2. CV ↑ sympathetic stimulation** to: **a) <u>Heart</u>** via **Cardiac Accelerator Nerves** **b) <u>Blood vessel walls</u>** via **Vasomotor Nerves** 3. Adrenal medulla releases: Epi, NE	**Results: Heart:** ↑HR & contractility (thus ↑CO) **Vessels:** ↑SVR/ vasoconstriction Thus **BP increases**
If BP rises baro-receptors stretch more = ↑rate of impulses to CV	1. CV increases **parasympathetic vagus** nerve stimulation 2. CV decreases sympathetic stimulation	**Result: H:** ↓HR & contractility. **V:** ↓SVR/ Vasodilation. **Thus BP lowers**

c) Chemoreceptors detect high CO_2, H+



- Chemoreceptors, are located next to the baroreceptors in:
  - **Carotid Bodies**
  - **Aortic Bodies**
- Chemoreceptors send signals to the Cardiovascular center in the medulla when there is:
  - **Low O_2 Hypoxia** or
  - High CO_2 Hypercapnia
  - High H^+ Acidosis

Chemo-receptors



- CV center response to chemoreceptor stimulation:
  - Increases sympathetic vasoconstriction of **arterioles & veins**, increasing BP & O2 delivery
  - Sends info along to respiratory center to **adjust breathing rate**

AUTOREGULATION OF BLOOD PRESSURE

Autoregulation Of Blood Pressure

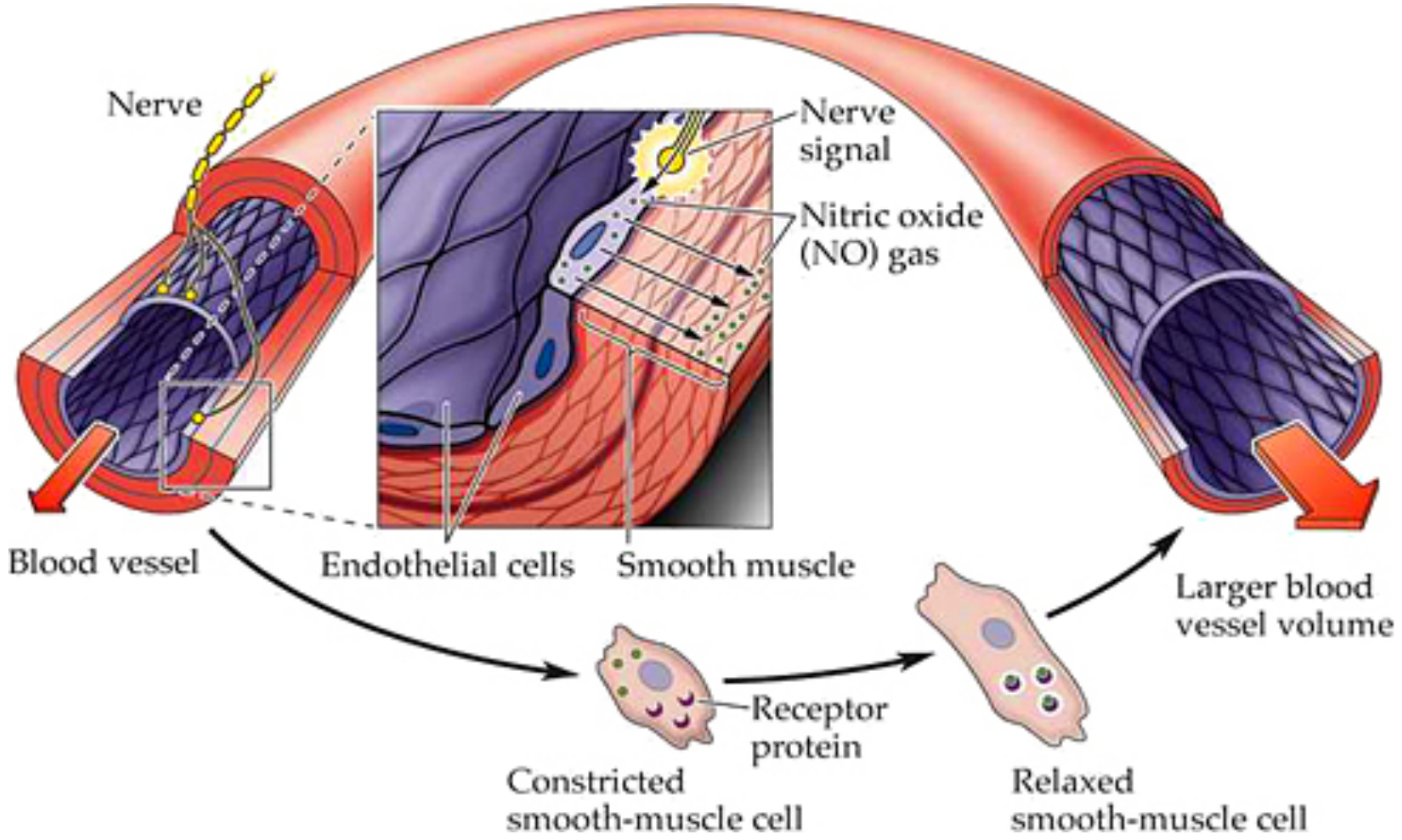
- *AUTOREGULATION: ability of a tissue to automatically adjust its own **blood flow** to match its metabolic demands*
  - At arteriole/capillary/organ level
    - Eg blood flow increases to ear when listening
  - Stimuli that cause autoregulatory changes in blood flow are either:
    1. physical or
    2. chemical

Autoregulation Of Blood Pressure

- Physical changes
  - **Warming** promotes vasodilation
  - **Cooling** causes vasoconstriction
  - **Arteriolar Myogenic response** – smooth muscle contracts more forcefully when it is stretched

- Vasodilating & Vasoconstricting chemicals
  - **Vasodilating** chemicals: K+, H+, lactic acid, ATP, and nitric oxide (NO). Kinins and histamine, released from tissue trauma
  - **Vasoconstricting** chemicals: thromboxane A2, superoxide radicals, serotonin (from platelets), and endothelins

FYI - nitric oxide dilates an artery

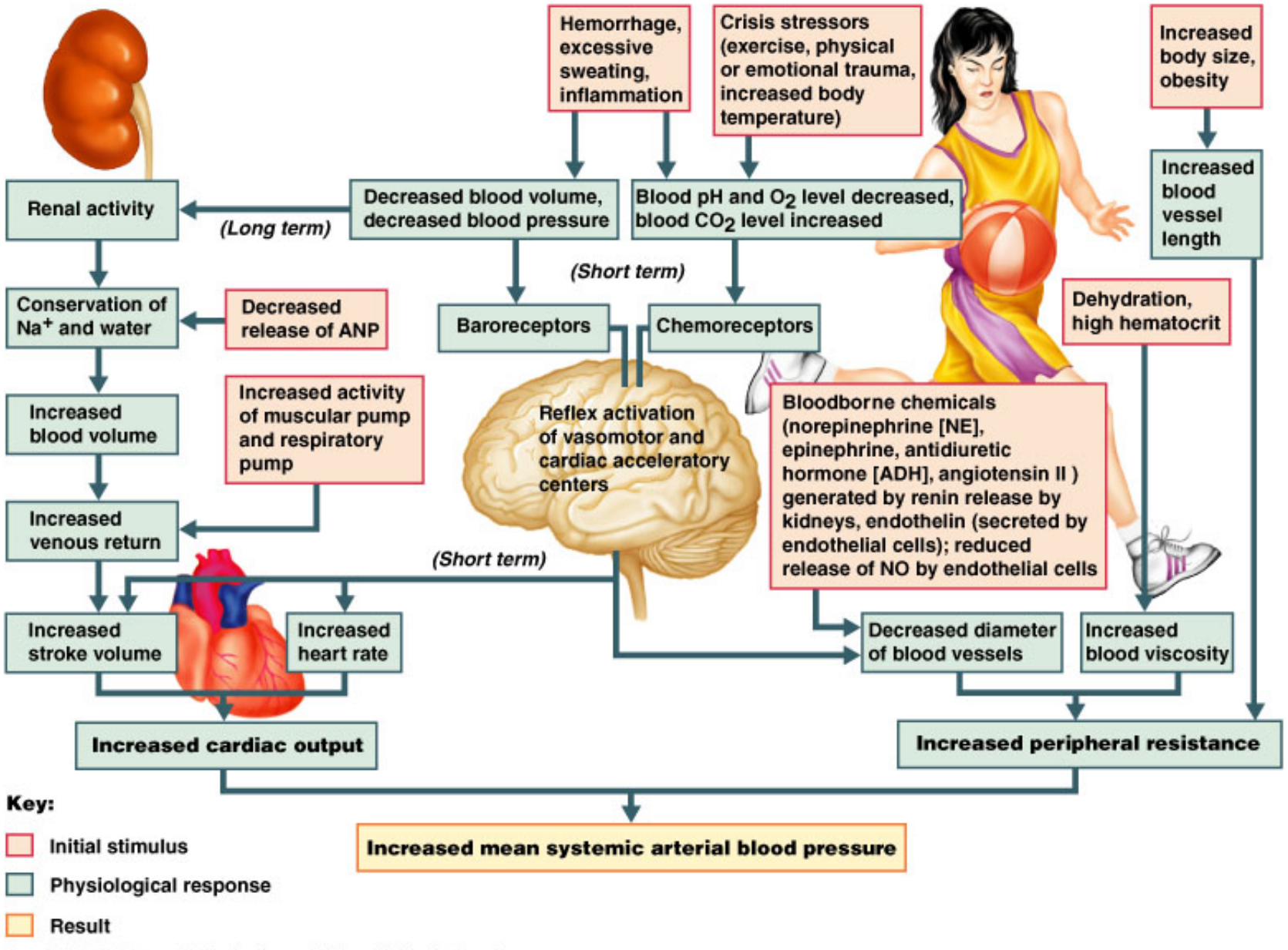


- Artery endothelial cells can produce Nitric Oxide to relax it's own smooth muscle & dilate

Systemic vs Pulmonary Autoregulation of BP

- pulmonary and systemic circulation have opposite autoregulatory responses to low O_2:
  - **Systemic** blood vessels **DILATE in response to low O_2** to increase O_2 delivery
  - **Pulmonary** blood vessels **CONSTRICT under low O_2** to ensure blood flows to better ventilated areas of lung

Factors affecting blood pressure



SHOCK

SHOCK: **Inadequate blood flow** to body tissues

4 kinds of shock:

1. **Hypovolemic:** Venous return & CO declines
   - Sudden hemorrhage
     - Trauma
     - Aneurysm rupture
   - Diarrhea, vomit
   - Excess sweat, urine

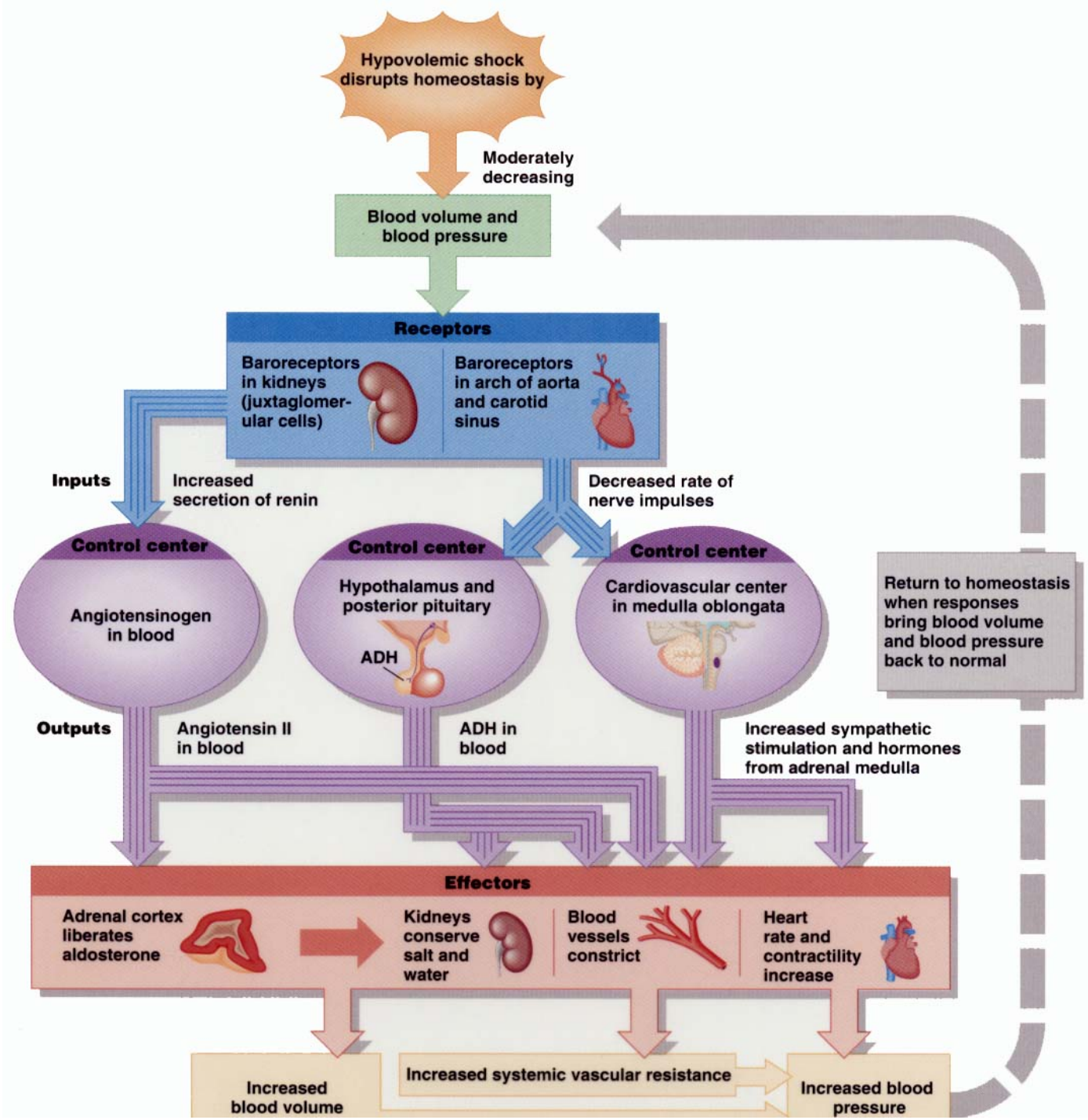
2. **Cardiogenic:** heart doesn't pump well
   - Myocardial infarction
   - Arrhythmias
   - Valve problems
   - Ischemia

3. **Vascular:** (vasodilation) Decrease in systemic vascular resistance
   - Anaphylactic shock
     - histamine causes vasodilation
   - Septic shock
     - Bacterial toxins produce vasodilation

4. **Obstructive:** circulation is blocked
   - Pulmonary embolism

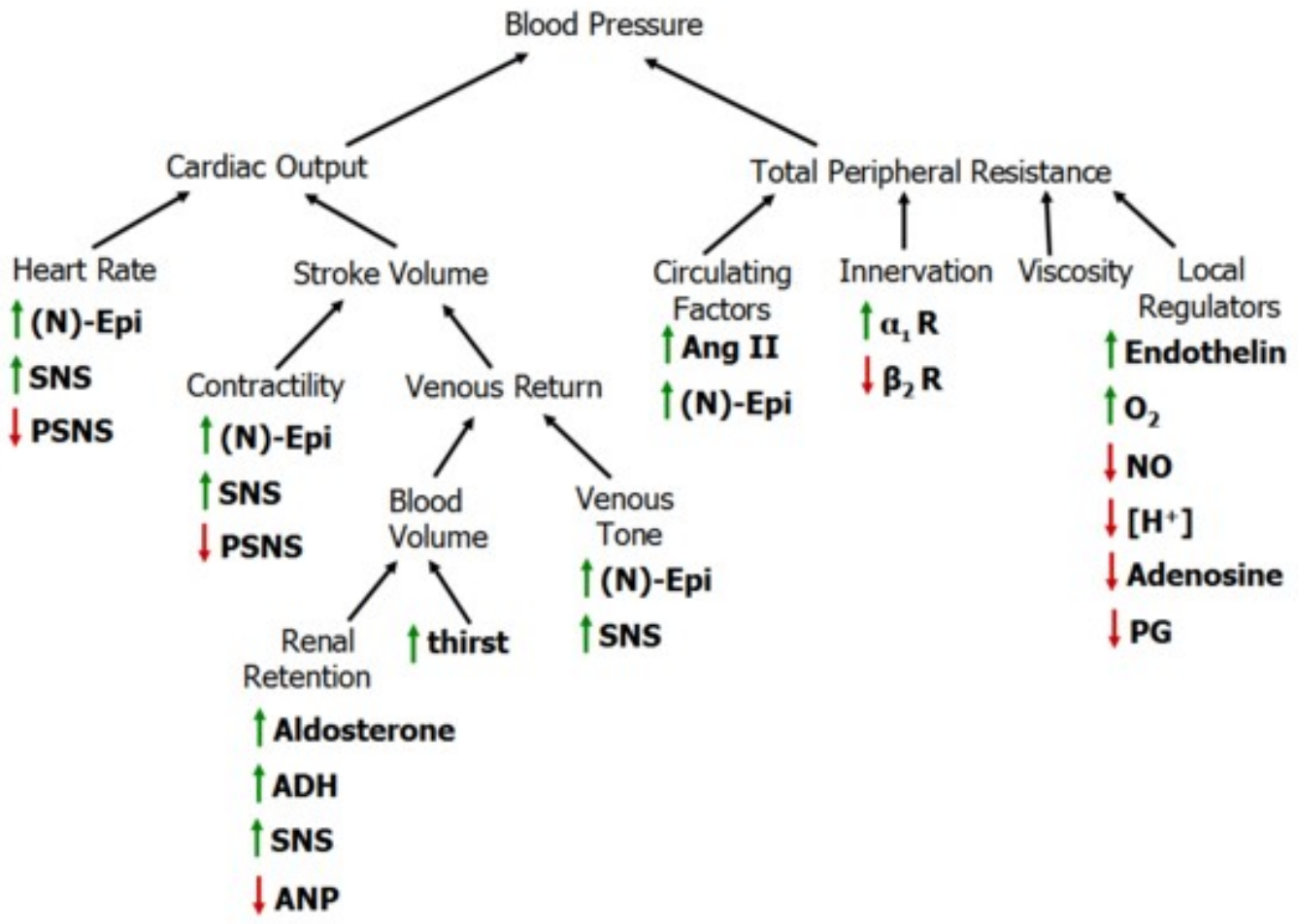
Signs and symptoms of shock

1. Low Systolic BP < 90 mmHg
2. Rapid HR:
   - sympathetic stimulation, Epi, NE
3. Weak & rapid pulse:
   - Reduced CO
   - Fast HR
4. Cool, pale, clammy skin:
   - Sympathetic constriction
   - Sympathetic sweat stim
5. Altered mental state:
   - Reduced Oxygen to brain
6. Reduced urine formation
   - Increased ADH, Aldosterone
7. Thirsty
   - From loss of ECF
8. Blood pH low (acidic)
   - Lactic acid buildup- anaerobic respiration
9. Nausea
   - Impaired blood flow to GI


Hypovolemic shock disrupts homeostasis by
Moderately decreasing
Blood volume and blood pressure
Receptors
Baroreceptors in kidneys (juxtaglomer-ular cells)
Baroreceptors in arch of aorta and carotid sinus
Inputs
Increased secretion of renin
Decreased rate of nerve impulses
Control center
Angiotensinogen in blood
Control center
Hypothalamus and posterior pituitary
ADH
Control center
Cardiovascular center in medulla oblongata
Return to homeostasis when responses bring blood volume and blood pressure back to normal
Outputs
Angiotensin II in blood
ADH in blood
Increased sympathetic stimulation and hormones from adrenal medulla
Effectors
Adrenal cortex liberates aldosterone
Kidneys conserve salt and water
Blood vessels constrict
Heart rate and contractility increase
Increased blood volume
Increased systemic vascular resistance
Increased blood pressure

HORMONAL CONTROL OF BP

HORMONAL & NEURAL CONTROL OF BP



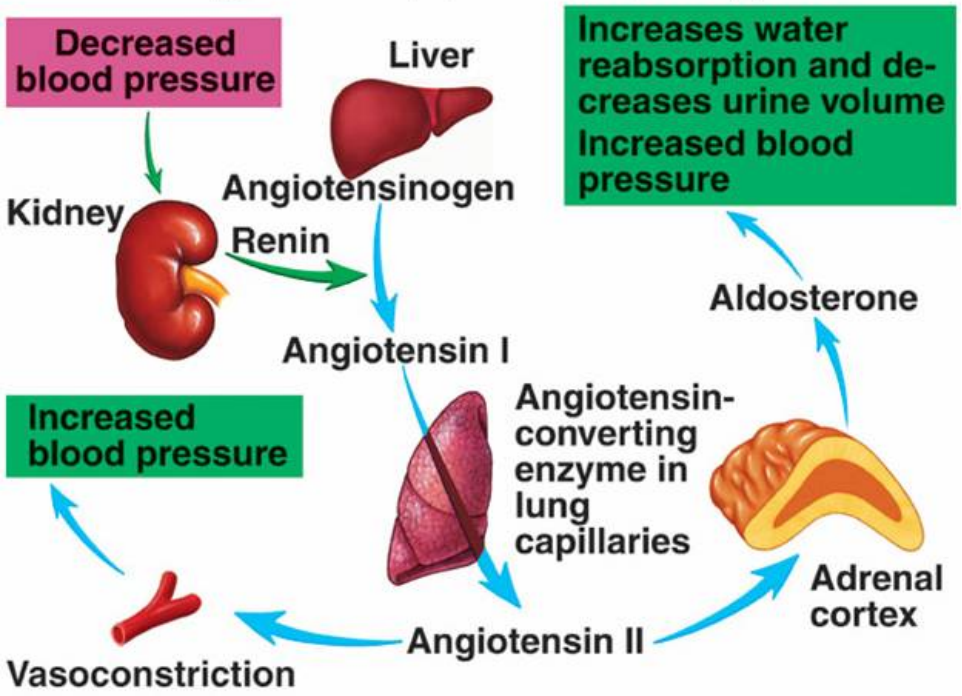
1. **<u>Nerves</u>: Sympathetic & Parasympathetic N.**
2. **<u>Hormones</u>:** NE, Epi, Angio II, ADH, ANP, NO, Aldosterone

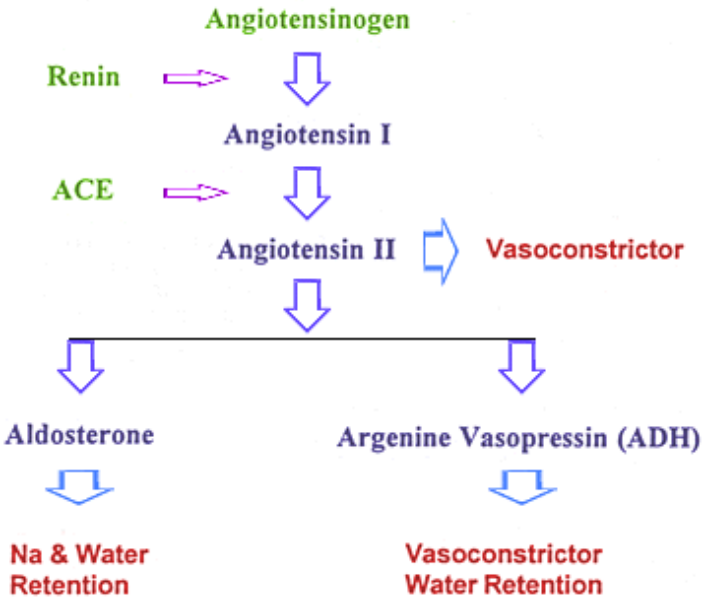
Hormonal Control of Blood Volume / Venous Return

- Hormones that raise blood volume or increase vasoconstriction thus increase blood pressure
  - (RAA) Renin- Angiotensin- Aldosterone
    - From Liver, Kidney, Lung, Adrenal
  - (ADH) Antidiuretic Hormone
    - From Posterior Pituitary
  - (E & NE) Epinephrine & Norepinephrine
    - From Adrenal Medulla

- Hormone that lowers blood volume or vasodilate to decrease blood pressure
  - (ANP) Atrial Natriuretic Peptide
    - From the atria of the heart

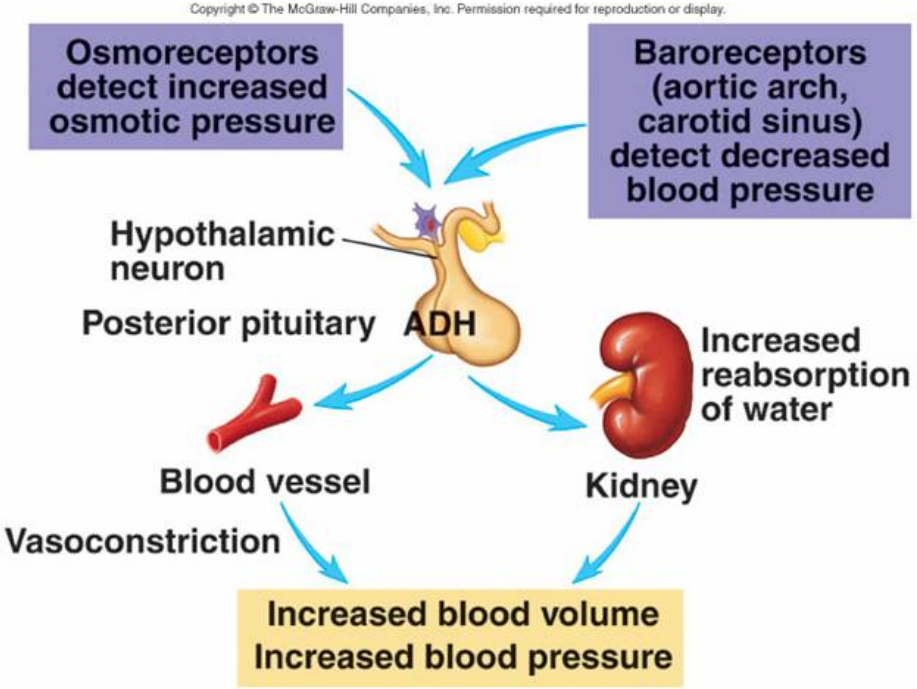
Hormones that Increase BP

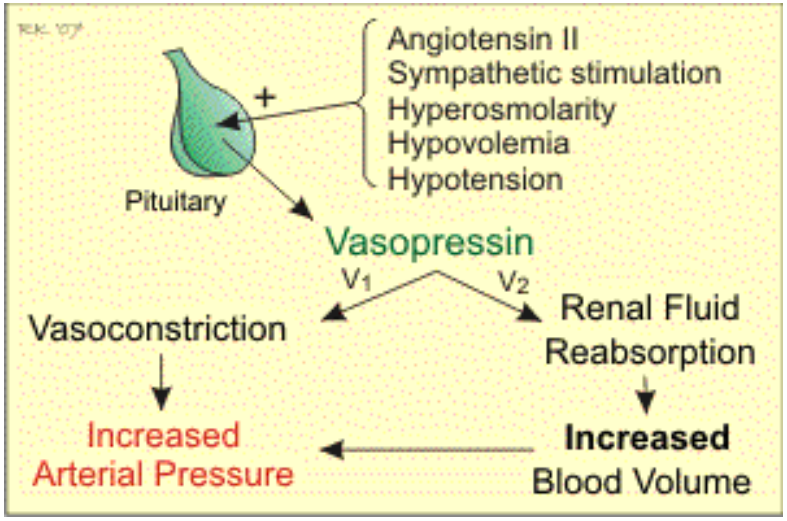




1. **Renin-Angiotensin-Aldosterone (RAA) system**
   - If Blood volume falls or blood flow to the kidney decreases
   - Kidney releases Renin into blood
   - Lung releases *Angiotensin Converting Enzyme* (ACE) into blood.
   - Angiotensinogen (from liver) is changed to active hormone **Angiotensin II which:**
     - **Vasoconstricts,** raising BP
     - Causes **Aldosterone** secretion from adrenal cortex to reabsorb more water in kidneys, **raising blood volume**

Hormones that Increase BP: ADH

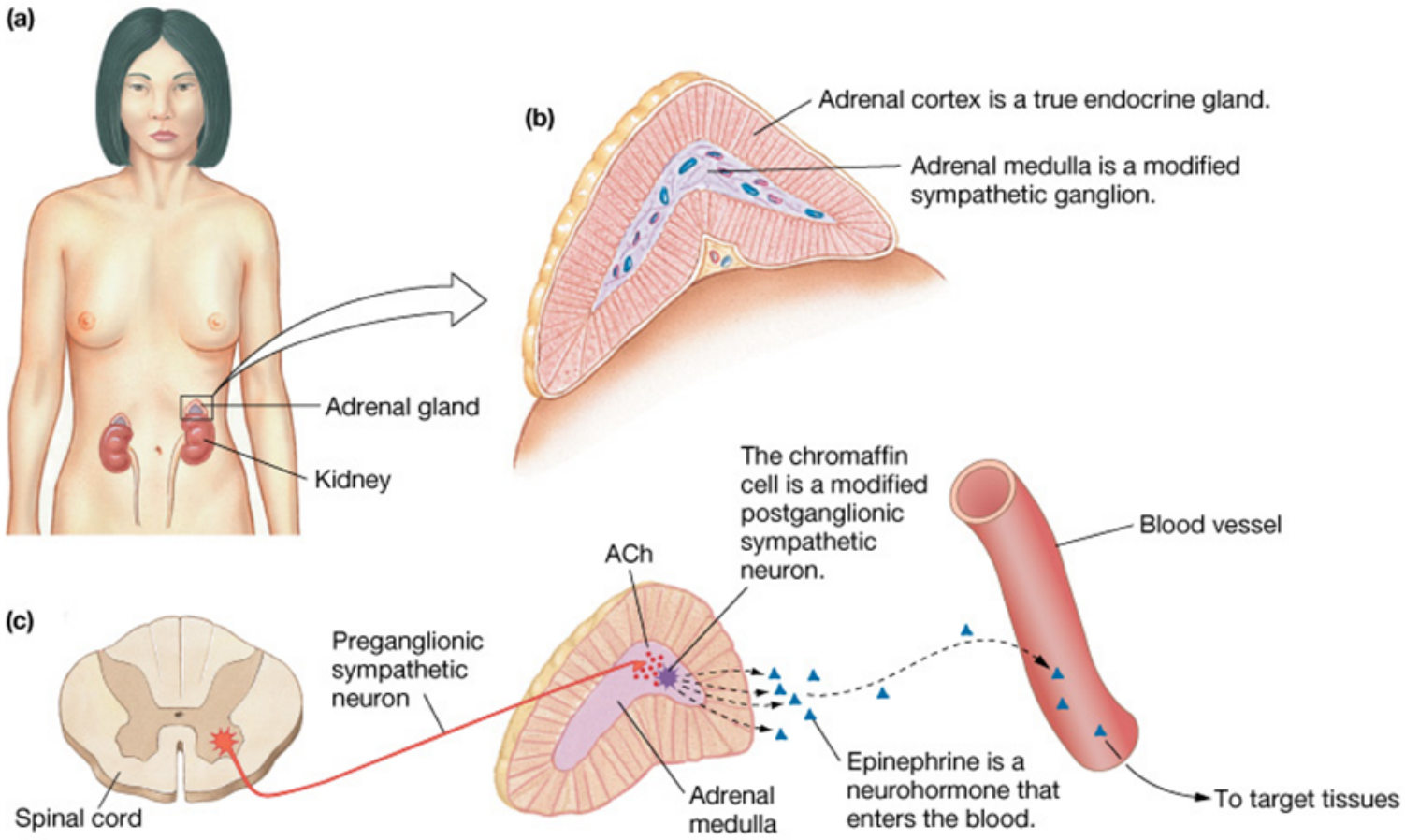




2. **Antidiuretic hormone (ADH)** or Vasopressin

   - Is produced in the hypothalamus, but Released from the **posterior pituitary**
   - Response to dehydration/ decreased blood volume
   - Increases
     - **Vasoconstriction**
     - Water reabsorption by kidneys & therefore **Blood volume**

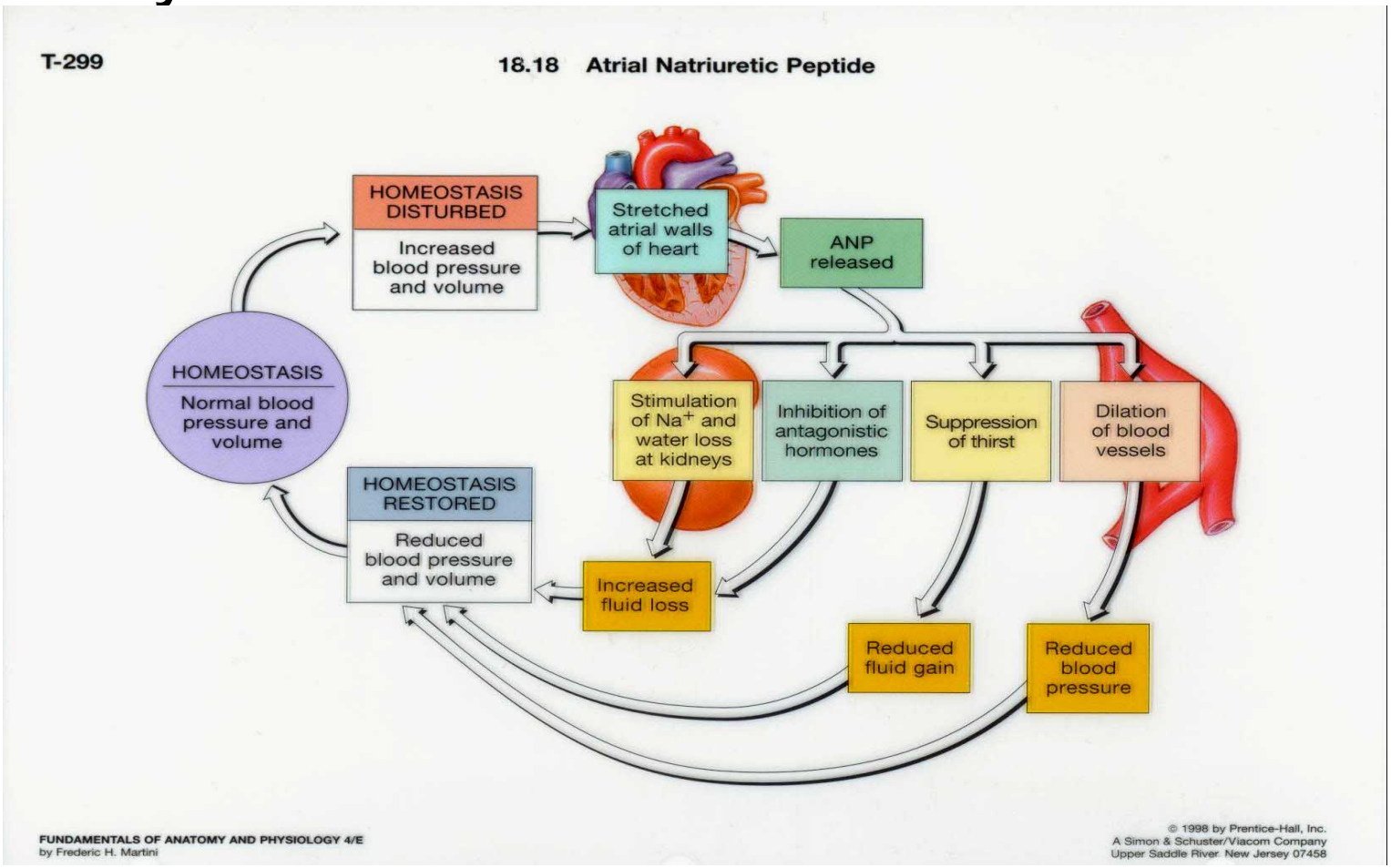
Hormones that Increase BP: NE & Epi



3. **Epinephrine** and **Norepinephrine**

- Released by **Adrenal medulla** w/ sympathetic stimulation
- Increases: **heart rate, force of contraction,** Peripheral **vasoconstriction,** & Coronary vasodilation

Only one Hormone LOWERS BP: **ANP**



<u>ATRIAL</u> NATRIURETIC PEPTIDE: ANP

- Released by cells of **atria**
- Lowers blood pressure by:
  - **vasodilation**
  - reducing blood volume - promotes **loss of <u>salt</u> and water** in urine

TABLE 21.2

Blood Pressure Regulation by Hormones

FACTOR INFLUENCING BLOOD PRESSURE	HORMONE	EFFECT ON BLOOD PRESSURE
CARDIAC OUTPUT		
Increased heart rate and contractility	Norepinephrine Epinephrine	Increase
SYSTEMIC VASCULAR RESISTANCE		
Vasoconstriction	Angiotensin II	Increase
	Antidiuretic hormone (vasopressin)	
	Norepinephrine*	
	Epinephrine†	
Vasodilation	Atrial natriuretic peptide	Decrease
	Epinephrine†	
	Nitric oxide	
BLOOD VOLUME		
Blood volume increase	Aldosterone Antidiuretic hormone	Increase
Blood volume decrease	Atrial natriuretic peptide	Decrease

*Acts at α_1 receptors in arterioles of abdomen and skin.

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

Table 21.02 Tortora - PAP 12/e