Chapter 20 (2)

Blood Pressure and Blood Flow

Lecture Objectives

- **Explain how to measure blood pressure**
- **Define systolic and diastolic pressures**

Blood Pressure

- Blood pressure (BP) is the force blood exerts against a vessel wall
- The blood's high pressure and low pressure are measured in mmHg (i.e. milliter of mercury): e.g. 120/80
- measured at brachial artery // measurement should be at level of the heart
  - systolic pressure: peak arterial BP taken during ventricular contraction (ventricular systole)
  - diastolic pressure: minimum arterial BP taken during ventricular relaxation (diastole - between heart beats)

Pulse Pressure

Normal blood pressure value for young adult: 120/80 mm Hg (benchmark used for exam!)

Pulse pressure – difference between systolic and diastolic pressure (40 mmHg)

Important measurement of stress exerted on small arteries by pressure surges generated by the heart

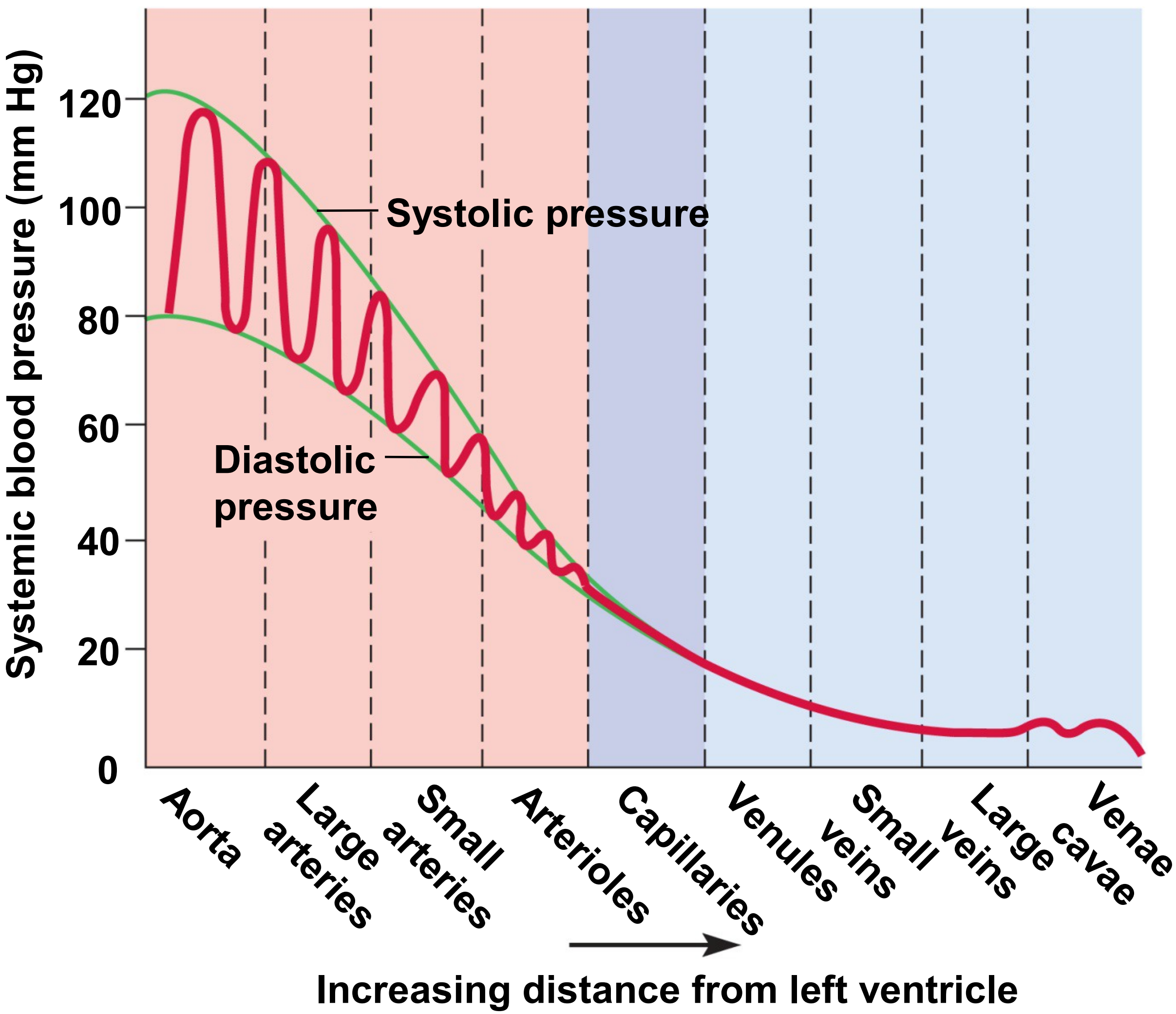
High blood pressure damages tissue // called the silent killer!

Do you know if you have high blood pressure?

Why is high blood pressure called the silent killer?

Blood Vessel Pressure

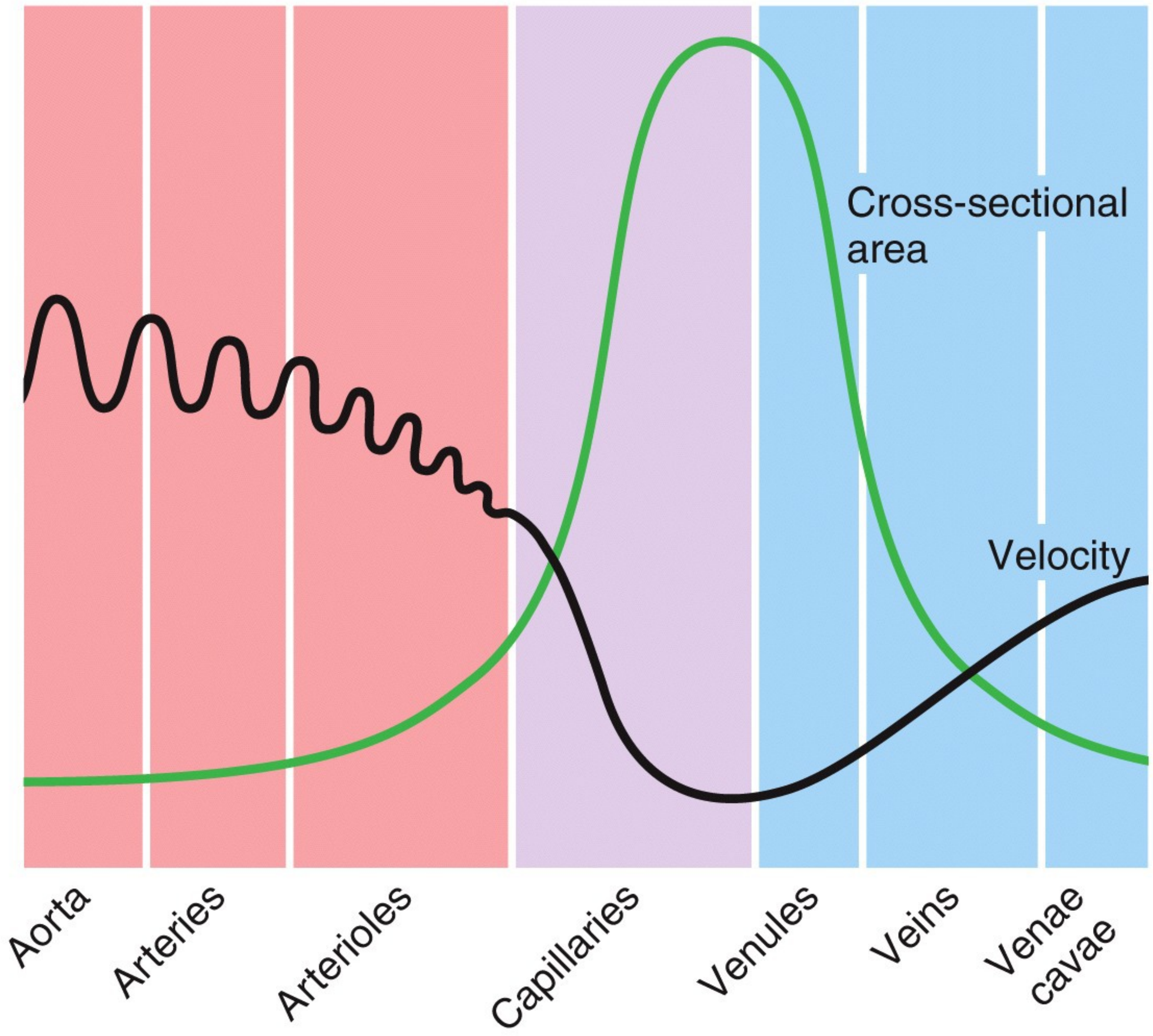
(Changes With Distance From Heart)



> What is pulse pressure?

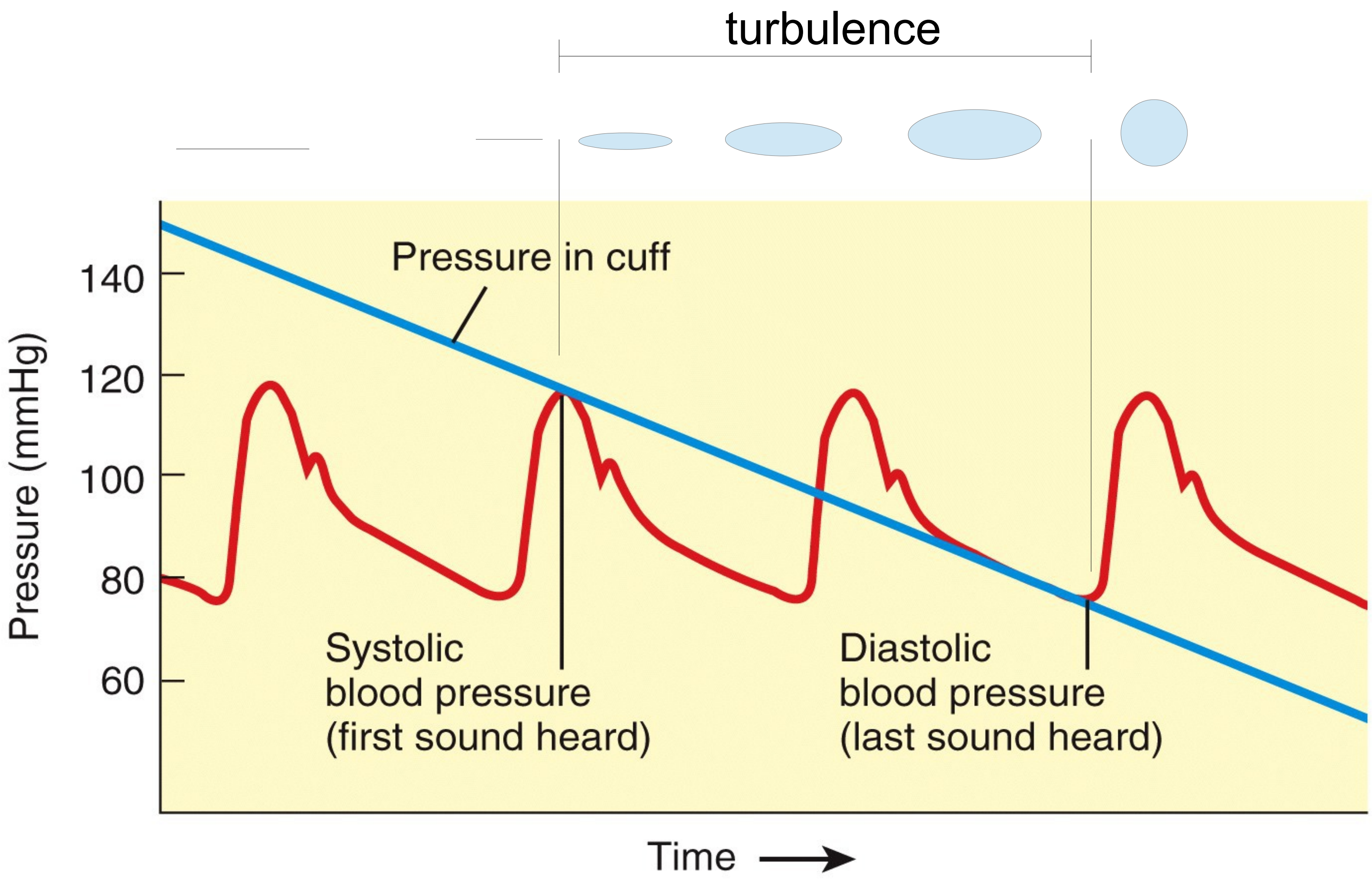
> Why do you want a large pulse pressure at the aorta?

> Why do you want no pulse pressure in a capillary?



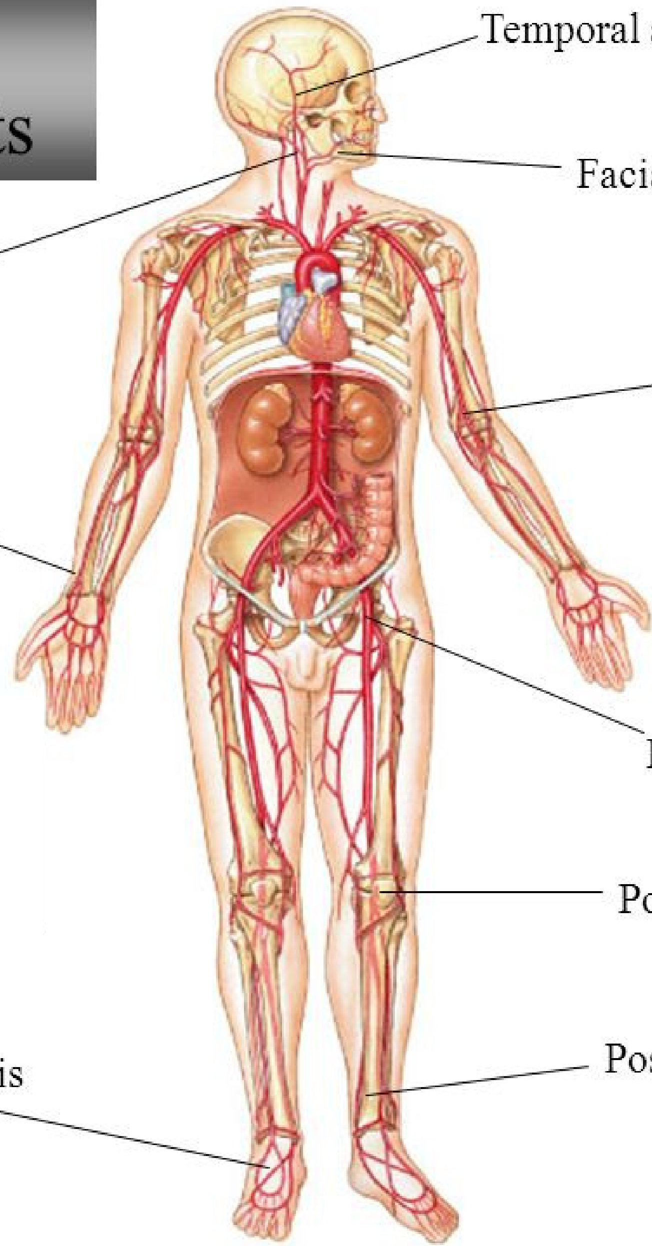
> What is the significance of this chart?
> Why does this make sense?

Blood pressure can be measured at the brachial artery with a sphygmomanometer /// *This is a lab requirement // (See posted video)*



NOTE – Sound is turbulence!!!

Location of Pressure Points



Locations where you can check pulse.

Table 10.2 The correlation between palpable pulses and systolic blood pressure

Palpable pulse site	Systolic blood pressure
Radial	>80 mmHg
Femoral	>70 mmHg
Carotid	>60 mmHg

Source: Greaves et al. (2001). Reproduced by permission of Edward Arnold (Publishers) Limited.

Abnormal Blood Pressures

- **Hypertension** – high blood pressure
  - chronic is resting BP > 140/90
  - consequences // can weaken small arteries and may cause aneurysms
  - may cause enlarged heart with less cardiac output
- **Hypotension** – chronic low resting BP
  - caused by blood loss
  - dehydration, anemia

Hypertension

- hypertension – most common cardiovascular disease affecting about 30% of Americans over 50
- primary hypertension caused by obesity, sedentary behavior, diet, and nicotine
- secondary to other disease /// e.g. kidney disease, hyperthyroidism
- “the silent killer” // major cause of heart failure, stroke, and kidney failure
  - damages heart by increasing afterload /// myocardium enlarges until overstretched and inefficient
  - renal arterioles thicken in response to stress /// drop in renal BP leads to salt retention (aldosterone) and worsens the overall hypertension

Do you know your blood pressure? Most young people do not!

Factors That Increase Blood Pressure

BP is a function of:

cardiac output

total blood volume

increase venous return

peripheral resistance

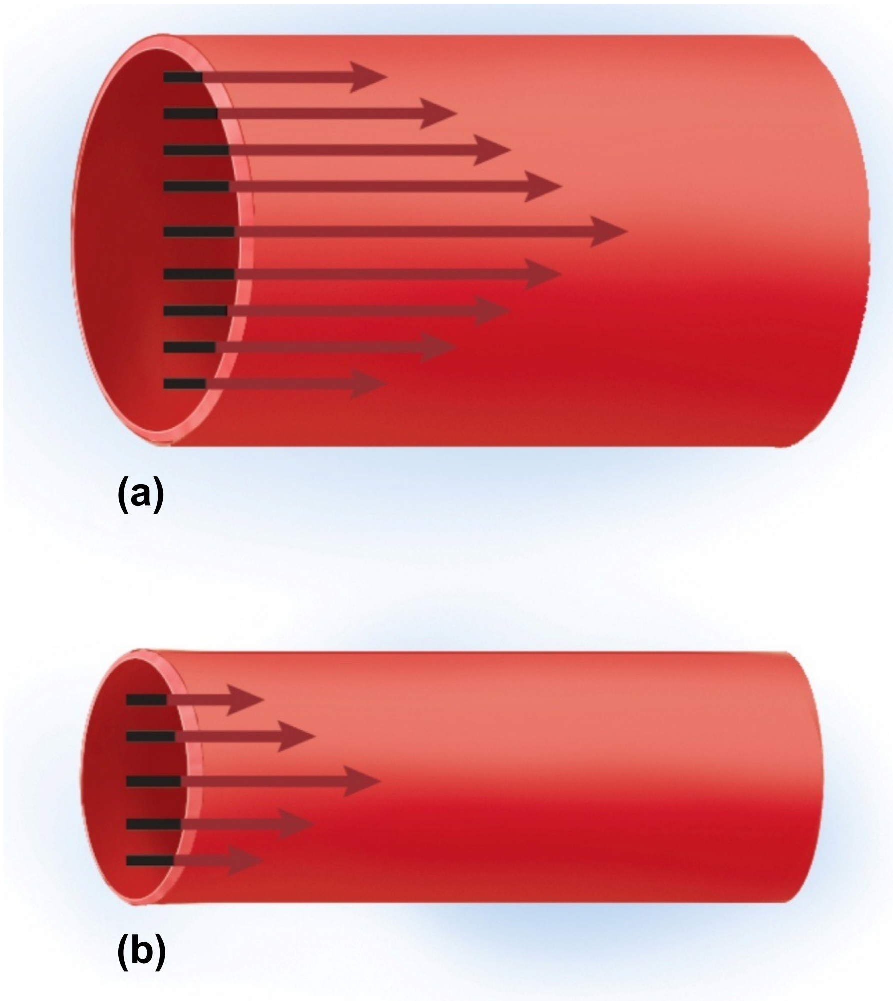
Know This !!!!!!

Peripheral resistance is a function of:

blood viscosity
vessel length
vessel radius (but most important) // vasomotor regulated!

This too is important !!!!!!

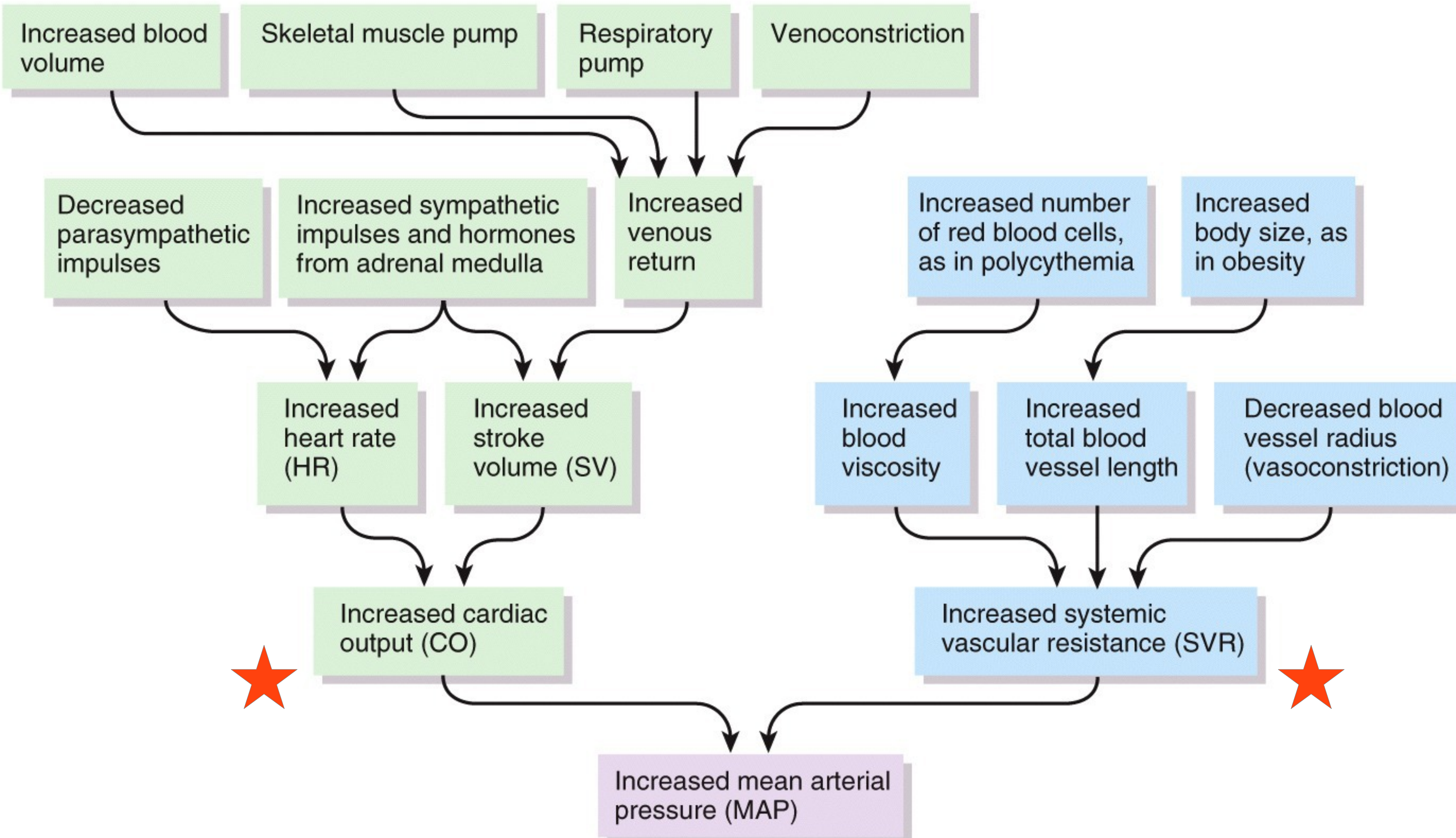
Laminar Flow and Vessel Radius



Peripheral Resistance Control by Arterioles

- Arterioles are the most significant point of control over peripheral resistance and blood flow
  - on proximal side of capillary beds and best positioned to regulate flow into the capillaries
  - outnumber any other type of artery, providing the most numerous control points
  - more muscular in proportion to their diameter
    - highly capable of vasomotion
- <u>Arterioles responsible for half of the total peripheral resistance</u>

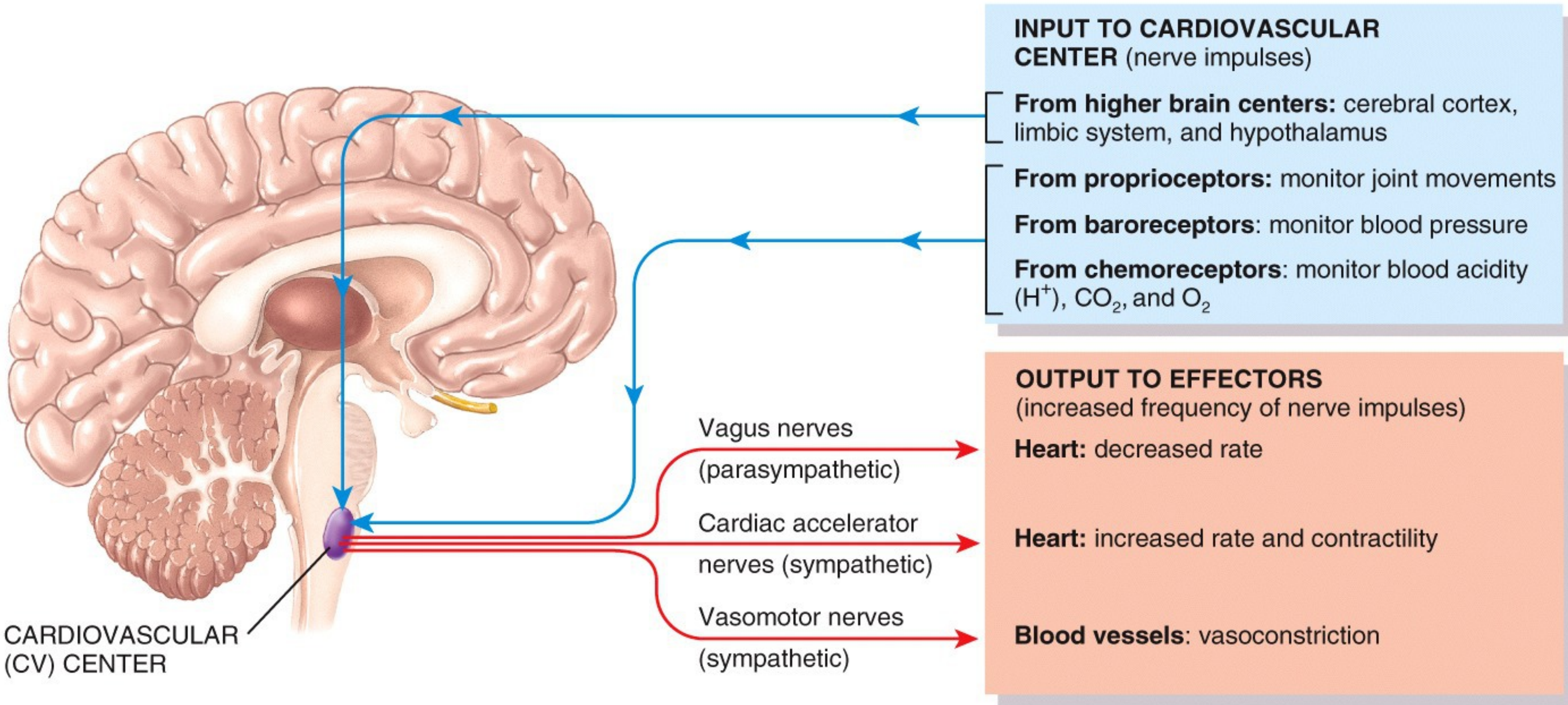
Summary of Factors That Increase Blood Pressure



Other Conditions Affecting Local Blood Flow

- Reactive hyperemia
  - If blood supply is first cut off so carbon dioxide builds up in tissue so when blood flow is restored then high carbon dioxide concentration results in above normal blood flow through tissue. Think about your rosy cheeks when you come into the house after a winter walk.
- Angiogenesis (examples) = growth of new blood vessels /// controlled by growth factors
  - occurs as you repair a bruised area
  - occurs in re-growth of uterine lining
  - around a coronary artery obstructions
  - in exercised muscle
  - In malignant tumors

Cardiovascular Center in Medulla Oblongata Related to Blood Pressure



What are the two functions of the vasomotor center?

- 1 = Method to raise or lower BP throughout the whole body
  - increasing BP requires medullary vasomotor center
  - or widespread circulation of a hormone like epinephrine
  - important in supporting cerebral perfusion during a hemorrhage or dehydration

Second Function of the Vasomoter Center

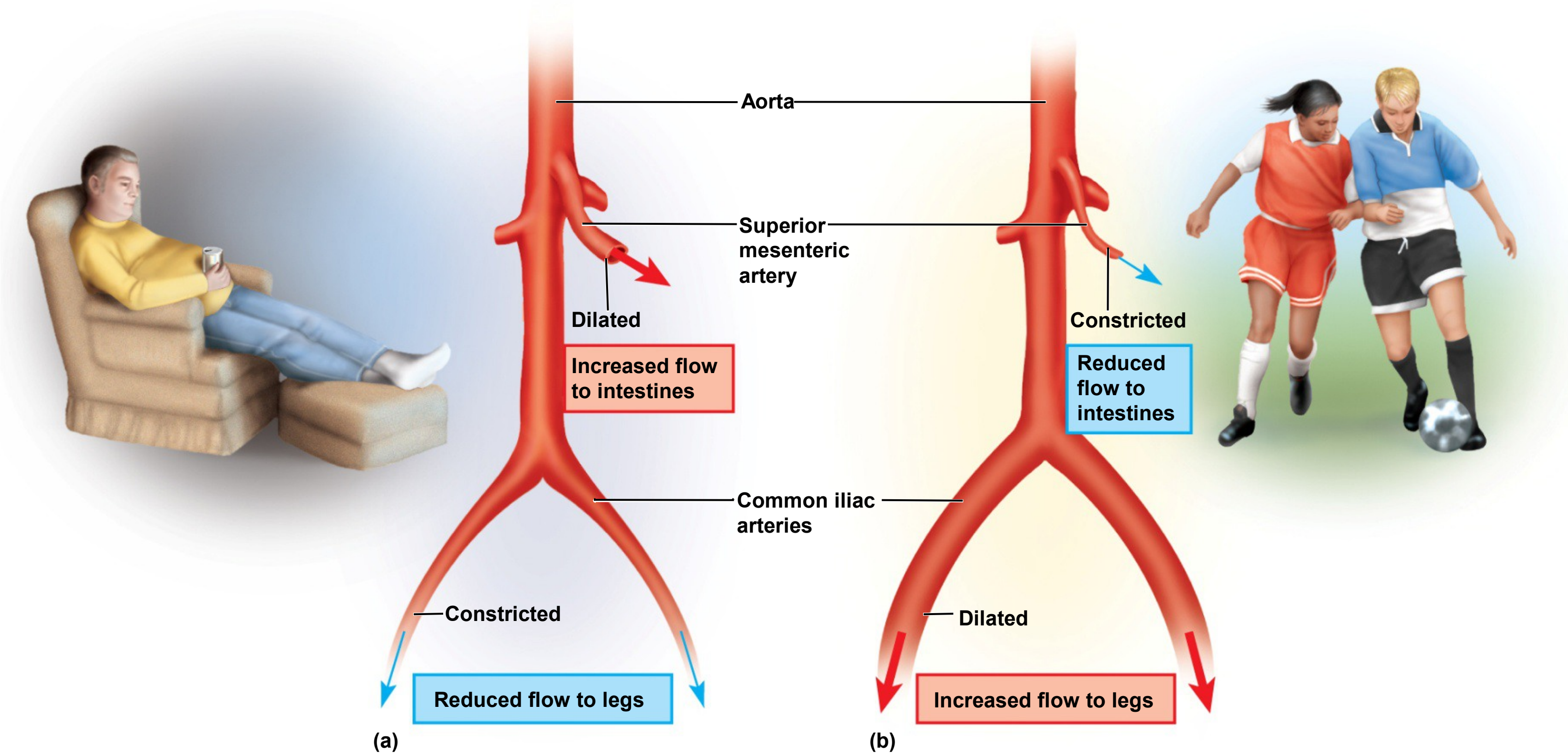
2 = Method to re-route blood from one region to another region in order to meet metabolic need of individual organs

either may be centrally or locally controlled

during exercise, sympathetic system reduces blood flow to kidneys and digestive tract and increases blood flow to skeletal muscles

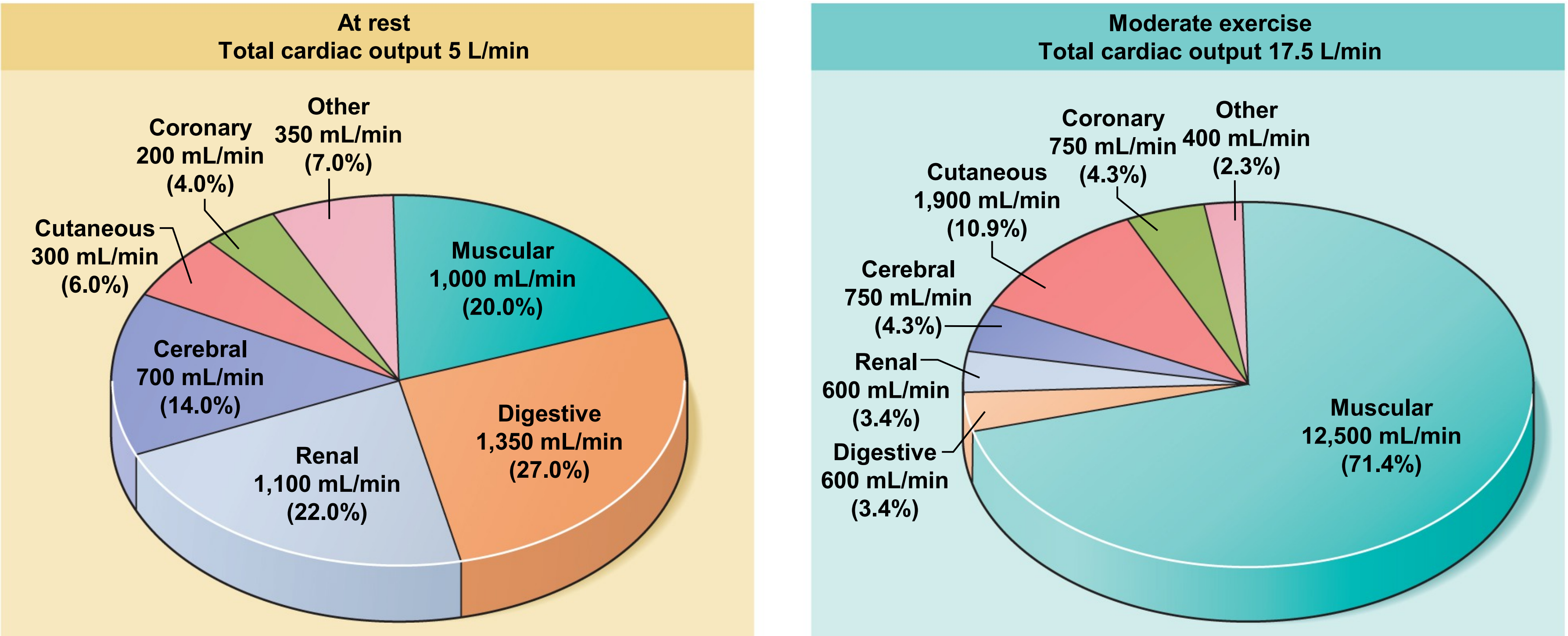
metabolite accumulation in a tissue affects local circulation without affecting circulation elsewhere in the body

Blood Flow in Response to Needs



arterioles shift blood flow with changing priorities

Blood Flow Comparison



during exercise

increased perfusion of lungs, myocardium, and skeletal muscles

decreased perfusion of kidneys and digestive tract

Importance of Peripheral Resistance

- The opposition to flow of blood in vessels away from the heart /// occurs in arterioles (small vessels right before the capillary beds)

- Peripheral resistance depends on three variables

  - 1. blood viscosity // "thickness of blood"

    - RBC count and albumin concentration elevate viscosity the most

    - decreased viscosity with anemia and hypoproteinemia speed flow

    - increased viscosity with polycythemia and dehydration slow flow

Peripheral Resistance (cont.)

- **2. vessel length**
  - the farther liquid travels through a tube, the more cumulative friction it encounters
  - pressure and flow decline with distance
- **3. vessel radius** *///* *<u>most powerful influence over flow</u>*
  - only significant way of controlling peripheral resistance.
  - ***<u>vasomotion</u>*** - change in vessel radius
    - **vasoconstriction** - by muscular effort that results in smooth muscle contraction
    - **vasodilation** - by relaxation of the smooth muscle

Peripheral Resistance (cont.)

- (vessel radius continued)
- vessel radius markedly affects **blood velocity**
- **laminar flow** - flows in layers, faster in center
- blood flow (F) proportional to the fourth power of radius (r), $F \propto r^4$
  - arterioles can constrict to 1/3 of fully relaxed radius
    - if r = 3 mm, F = (3^4) = 81 mm/sec; if r = 1 mm, F = 1mm/sec
    - an increase of three times the radius of a vessel results in eighty one times the flow

Mean Arterial Blood Pressure

Mean arterial pressure (MAP) – the mean arterial pressure is an estimate of what would be the "average pressure" throughout the cardiac cycle

MAP = diastolic pressure + (1/3 of pulse pressure)

MAP = 80 + (1/3) 40 = 93.2

Best indicator for edema risk levels, fainting (syncope), atherosclerosis, kidney failure, and aneurysm

Preventing Excess Blood Pressure in Blood Vessels

- The body's chief <u>mechanisms in preventing excessive blood pressure</u> is the **stretch and recoil of arteries** during the cardiac cycle

- <u>The importance of arterial elasticity</u>

  - expansion and recoil maintains steady flow of blood throughout cardiac cycle

  - smoothes out pressure fluctuations

  - decreases stress on small arteries

- Note /// BP rises with age // caused by change in amount of elastic connective tissue fibers /// arteries less distendable and absorb less systolic force

Blood Flow Between Different Points

- From aorta to capillaries, blood velocity (speed) decreases for three reasons:
  - greater distance, more friction to reduce speed
  - smaller radius of arterioles and capillaries offers more resistance
  - farther from heart, the number of vessels and their total cross-sectional area becomes greater and greater
- From capillaries to vena cava, flow increases again
  - decreased resistance going from capillaries to veins
  - large amount of blood forced into smaller channels
  - however /// never regains velocity of large arteries

Regulation Blood Flow in Capillary Bed

Neural Control – Hormonal Control - Autoregulation

- Vasomotion is a quick and powerful way to change blood flow into the capillary bed. Two mechanisms are outside of the capillary bed and change blood flow by adjusting tension on the arterioles right before the capillary bed.

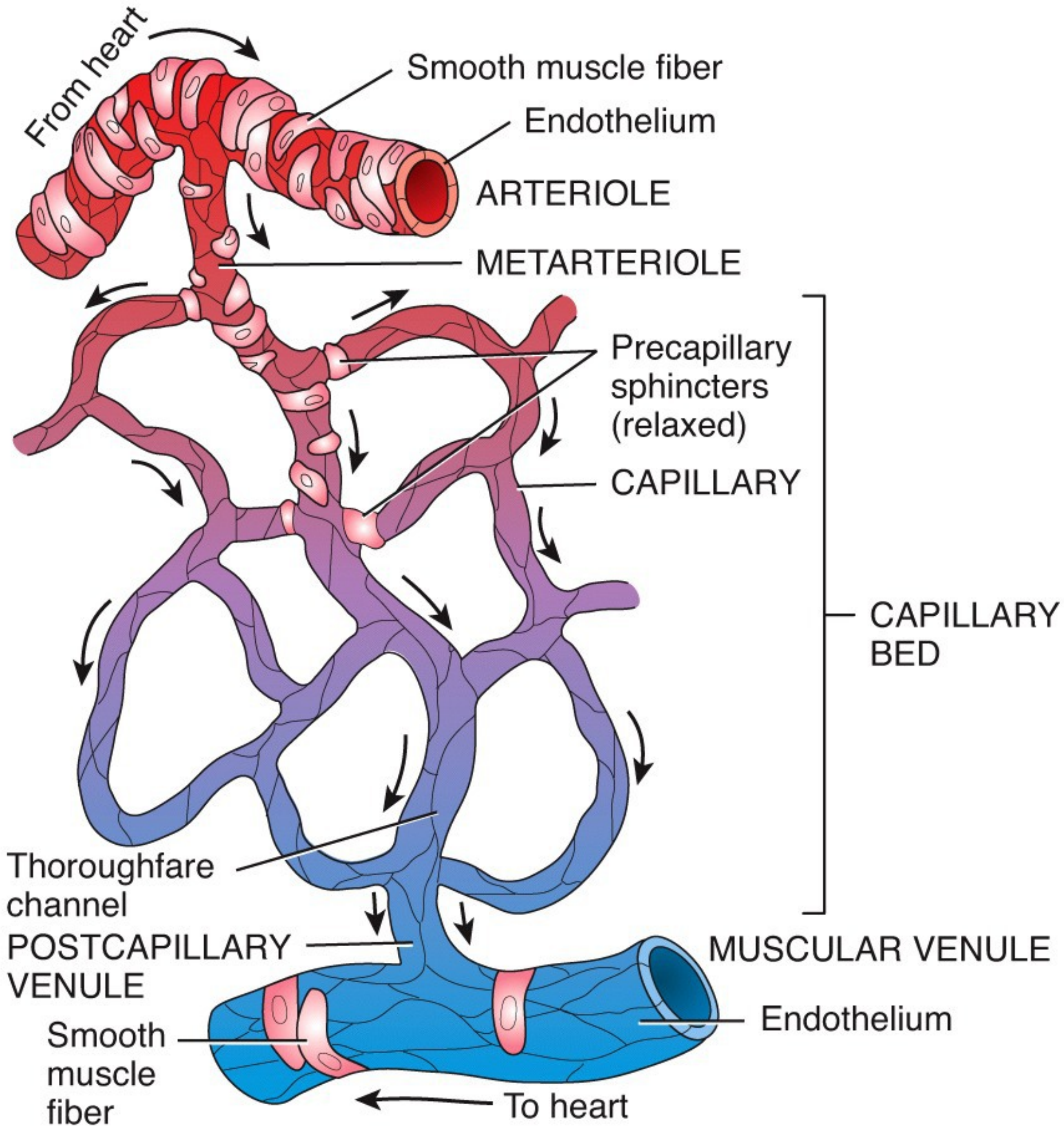
  1) neural control (vasomotor center in medulla oblongata)

  2) hormonal control (secretions from adrenal gland - catacholamines)

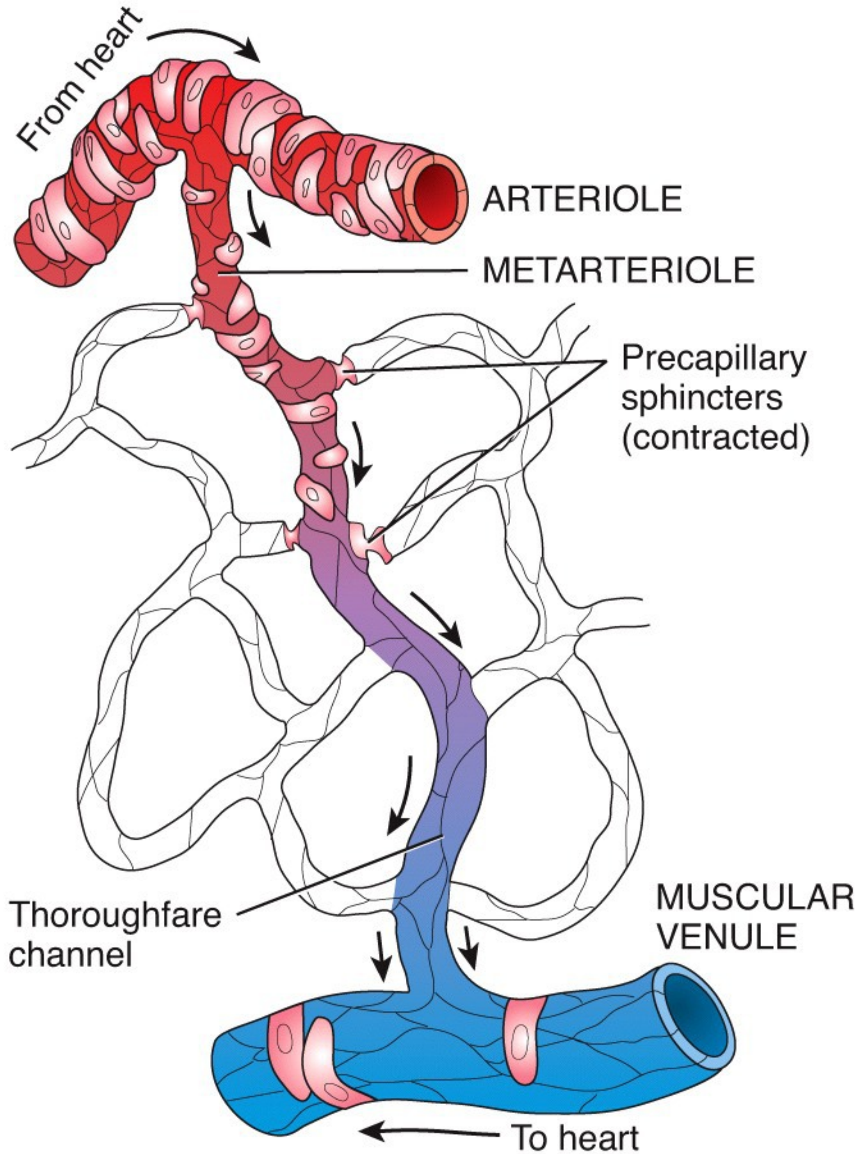
- The third mechanism regulates capillary blood flow from within the capillary bed by adjusting tension on the smooth muscles of the per-capillary sphincters. This mechanism is called Autogregulation
  - the blood flow through capillary bed is regulated by a local control mechanisms
  - increasing carbon dioxide within the capillary bed relaxes the smooth muscle
  - this allows more blood to flow into the capillary bed
  - metabolic theory of autoreglation)

Autoregulation

- Autoregulation = Local Control = the ability of the tissues to regulate its own blood supply
  - Metabolic Theory of Auto-Regulation
    - This principle applies to the capillry beds
    - If tissue is not adequately perfused with blood then *carbon dioxide accumulate* and stimulates vasodilation which increases perfusion
    - Bloodstream delivers oxygen and removes carbon dioxide
    - When carbon dioxide levels drop then smooth muscle constricts
    - Why does this make sense? Explain.



(a) Sphincters relaxed: blood flowing through capillaries



(b) Sphincters contracted: blood flowing through thoroughfare channel

Other Local Control Mechanisms

- Vasoactive chemicals /// substances secreted by platelets, endothelial cells, and perivascular tissue may also stimulate vasomotion /// Eg. vasodilation caused by histamine

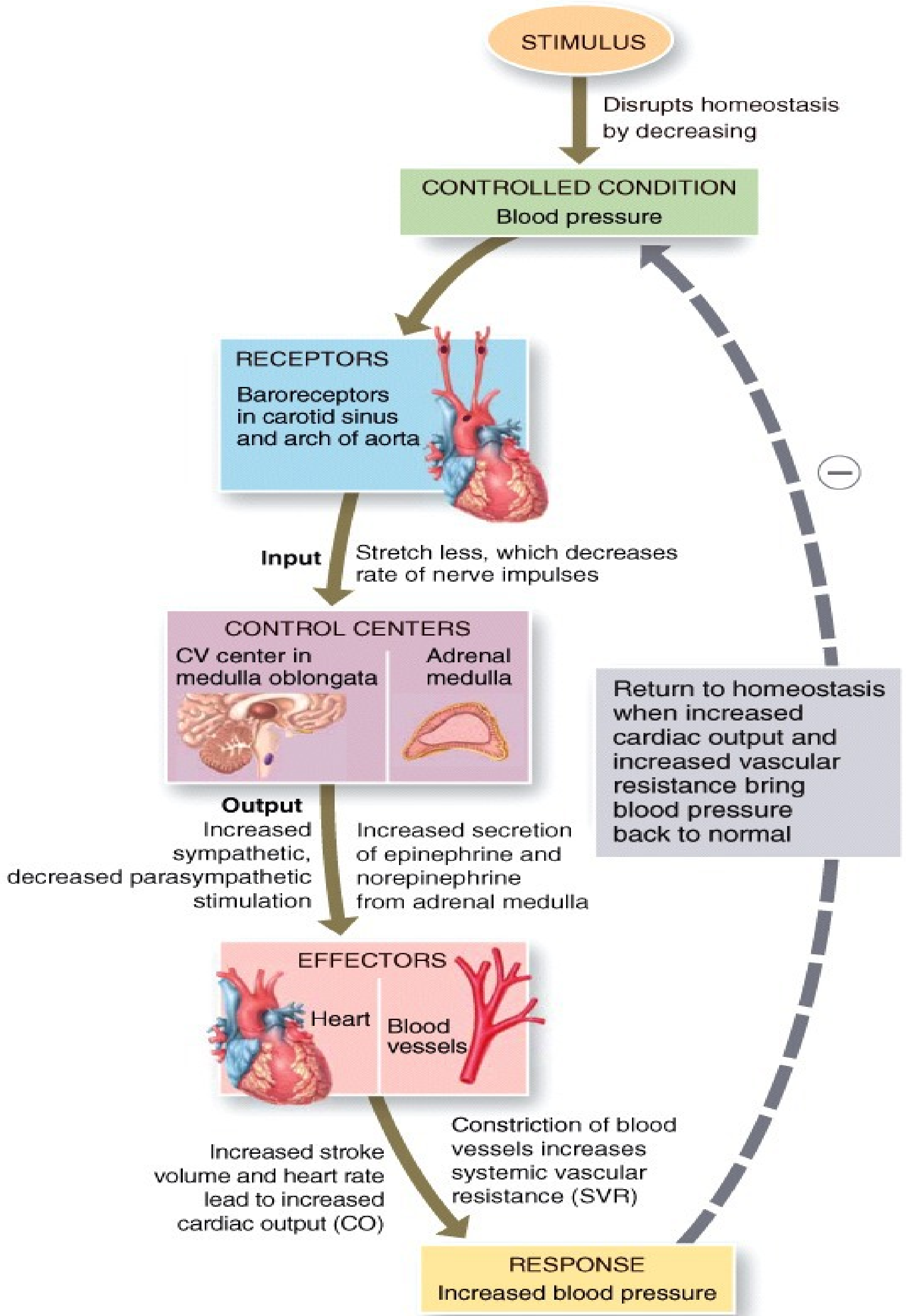
- Endothelial cells secrete
  - Prostacyclin (makes inside surface of blood vessels “slippery” // less likely for platelets to stick to lining of blood vessels and release chemicals which would cause vasoconstrition
  - nitric oxide (vasodilators)
  - endothelins (vasoconstrictor)

Vasomotor Control of BP & Flow

- Smooth muscle of arterioles regulated by the sympathetic division of the autonomic nervous systems
- Vasomotor center located in medulla oblongata
  - causes some arterioles in the body to constrict
  - but dilates vessels in skeletal and cardiac muscle to dilate to meet demands of exercise
    - *Note: precapillary sphincters respond only to local and hormonal control due to lack of innervation*
  - vasomotor center is the integrating center for three autonomic reflexes:
    - <u>baroreflexes</u>
    - <u>chemoreflexes</u>
    - <u>medullary ischemic reflex</u>

Baroreflex Control of Blood Pressure

- An ANS, negative feedback response to changes in blood pressure
  - Mechanism:
    - 1) An increases in BP detected by **carotid sinuses**
    - 2) signals sent to brainstem by way of **glossopharyngeal nerve**
    - 3) inhibit the sympathetic cardiac and vasomotor neurons reducing sympathetic tone → blood pressure drops
      - excite vagal fibers (parasympathetic)
        - » slow heart rate
        - » reduce cardiac output
        - » reduceg BP
    - 4) Note: decrease in BP will have opposite effects


STIMULUS
Disrupts homeostasis by decreasing
CONTROLLED CONDITION
Blood pressure
RECEPTORS
Baroreceptors in carotid sinus and arch of aorta
Input
Stretch less, which decreases rate of nerve impulses
CONTROL CENTERS
CV center in medulla oblongata
Adrenal medulla
Output
Increased sympathetic, decreased parasympathetic stimulation
Increased secretion of epinephrine and norepinephrine from adrenal medulla
EFFECTORS
Heart
Blood vessels
Increased stroke volume and heart rate lead to increased cardiac output (CO)
Constriction of blood vessels increases systemic vascular resistance (SVR)
RESPONSE
Increased blood pressure
Return to homeostasis when increased cardiac output and increased vascular resistance bring blood pressure back to normal

Baroreflex

- Baroreflexes important in **short-term regulation** of BP
  - e.g. adjustments for rapid changes in posture / like when you “hop” out of bed!
- This reflex is unable to correct for chronic hypertension

Chemoreflex

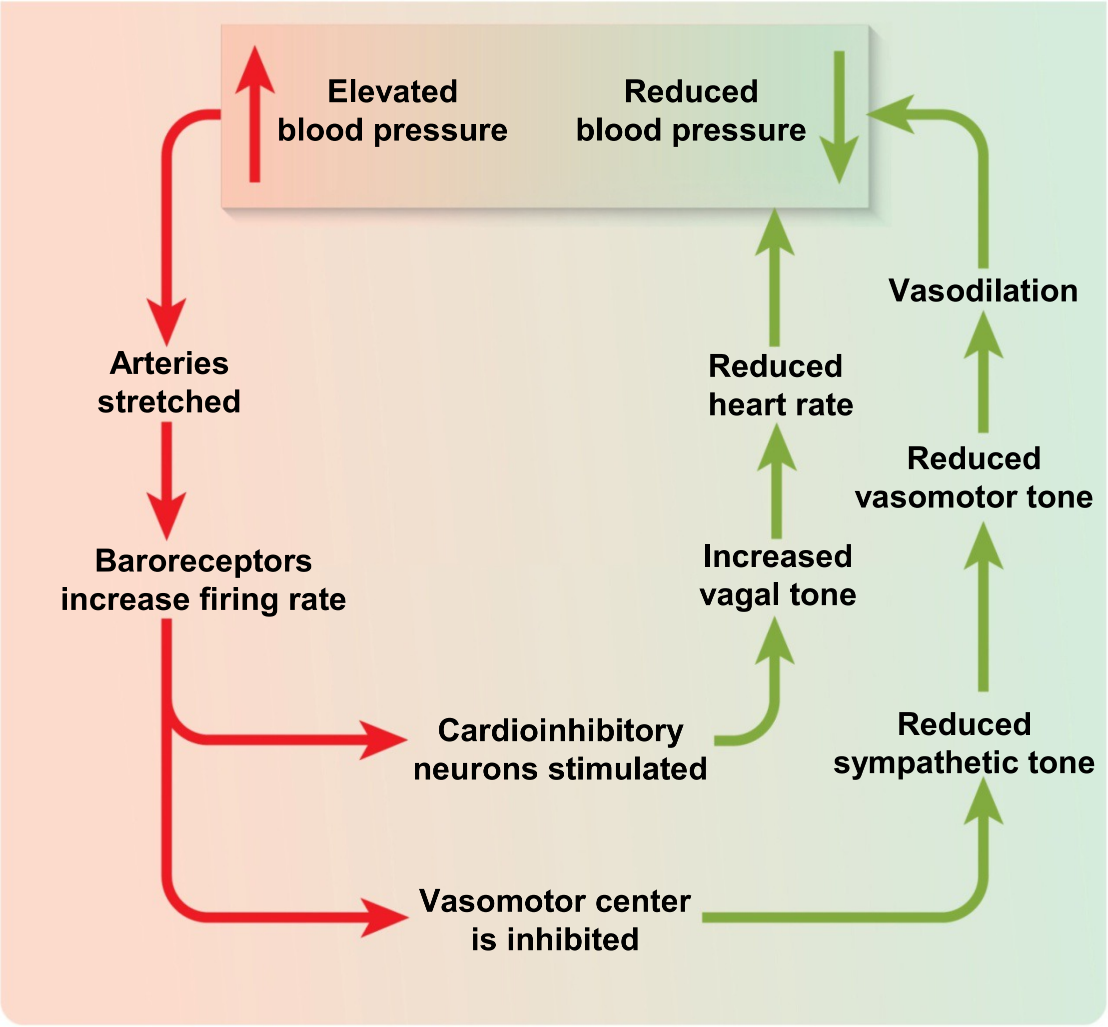
- An automatic response to changes in blood chemistry
  - especially pH, and concentrations of O_2 and CO_2

- Chemoreceptors called aortic bodies and carotid bodies /// located in aortic arch, subclavian arteries, external carotid arteries

- Primary role /// adjust respiration to changes in blood chemistry

- Secondary role /// vasomotion
  - hypoxemia, hypercapnia, and acidosis stimulate chemoreceptors
  - acting through vasomotor center to cause widespread vasoconstriction
  - increasing BP, increasing lung perfusion and gas exchange

Response to Elevated Blood Pressure
Negative Feedback Control



Medullary Ischemic Reflex

- Automatic response to a reduced blood perfusion in the brain
  - medulla oblongata monitors its own blood supply
  - *activates corrective reflexes when it senses ischemia (insufficient perfusion of the brain)*
    - cardiac and vasomotor centers send sympathetic signals to heart and blood vessels
      - increases heart rate and contraction force
      - causes widespread vasoconstriction in the systemic regions below the neck
      - goal is to raises overall BP and restores normal perfusion to the brain
- Other areas of the brain can also have an affect on vasomotor center /// stress, anger, and arousal can influence medulla oblongata to increase BP (Think about the Triune Brain Theory!)

Hormonal Control

- **Hormones may also influence blood pressure.......**
  - **1 - by their their vasoactive effects (i.e. smooth muscle contraction at arterioles)**
  - **2 - by regulating water balance // change blood volume through the renin-angiotensinogen-aldosterone pathway**

- **The Renin–Angiotensinogen-Aldosterone Pathway**
  - Renin is released into blood by kidney in response to low blood pressure
  - Renin converts the blood protein angiotensinogen into angiotensin-1
  - Angiotensin-1 circulates through lungs where angiotensin converting enzyme changes angiotensin-1 into angiotensin-2
  - Angiotensin-2 will cause the adrenal gland to release aldosterone /// aldosterone is a salt retention hormone – it promotes Na^+ and water retention by kidneys // angiotensin-2 is also a vasopresser and will increase peripheral resistance in the arterioles which increases blood pressure
  - This mechanism increases blood pressure by increasing both blood volume and peripheral resistance.

More Hormonal Control

- **Atrial natriuretic peptide**
  - increases urinary sodium excretion
  - reduces blood volume and promotes vasodilation
  - lowers blood pressure
- **Antidiuretic hormone**
  - promotes water retention and raises BP
  - pathologically high concentrations - vasoconstrictor
- **Epinephrine and norepinephrine**
  - effectsmost blood vessels /// binds to α-adrenergic receptors – **vasoconstriction**
  - skeletal and cardiac muscle blood vessels /// binds to β-adrenergic receptors - **vasodilation**

What are the two funcitons of the vasomotor center?

- 1 = Method to raise or lower BP throughout the whole body
  - increasing BP requires medullary vasomotor center
  - or widespread circulation of a hormone like epinephrine
  - important in supporting cerebral perfusion during a hemorrhage or dehydration

Second Function of the Vasomoter Center

- 2 = Method to re-route blood from one region to another region in order to meet metabolic need of individual organs
  - either may be centrally or locally controlled
  - during exercise, sympathetic system reduces blood flow to kidneys and digestive tract and increases blood flow to skeletal muscles
  - metabolite accumulation in a tissue affects local circulation without affecting circulation elsewhere in the body

Variations in Capillary Activity

- Capillaries usually reabsorb 85% of the fluid they filter – key exception:
  - kidney capillaries in glomeruli do not reabsorb
  - alveolar capillaries in lung absorb completely to keep fluid out of air spaces
- Capillary activity varies from moment to moment
  - collapsed in resting tissue, reabsorption predominates since BP is low
  - metabolically active tissue has increase in capillary flow and BP /// <u>increase in muscular bulk by 25% due to accumulation of fluid</u>

Edema

- the accumulation of excess fluid in a tissue
- occurs when fluid filters into a tissue faster than it is absorbed
- three primary causes
  - increased capillary filtration /// kidney failure, histamine release, old age, poor venous return
  - reduced capillary absorption /// hypoproteinemia, liver disease, dietary protein deficiency
  - obstructed lymphatic drainage /// surgical removal of lymph nodes

Consequences of Edema

- tissue necrosis /// oxygen delivery and waste removal impaired
- pulmonary edema /// suffocation threat
- cerebral edema /// headaches, nausea, seizures, and coma
- severe edema or circulatory shock /// excess fluid in tissue spaces causes low blood volume and low blood pressure

Circulatory Shock

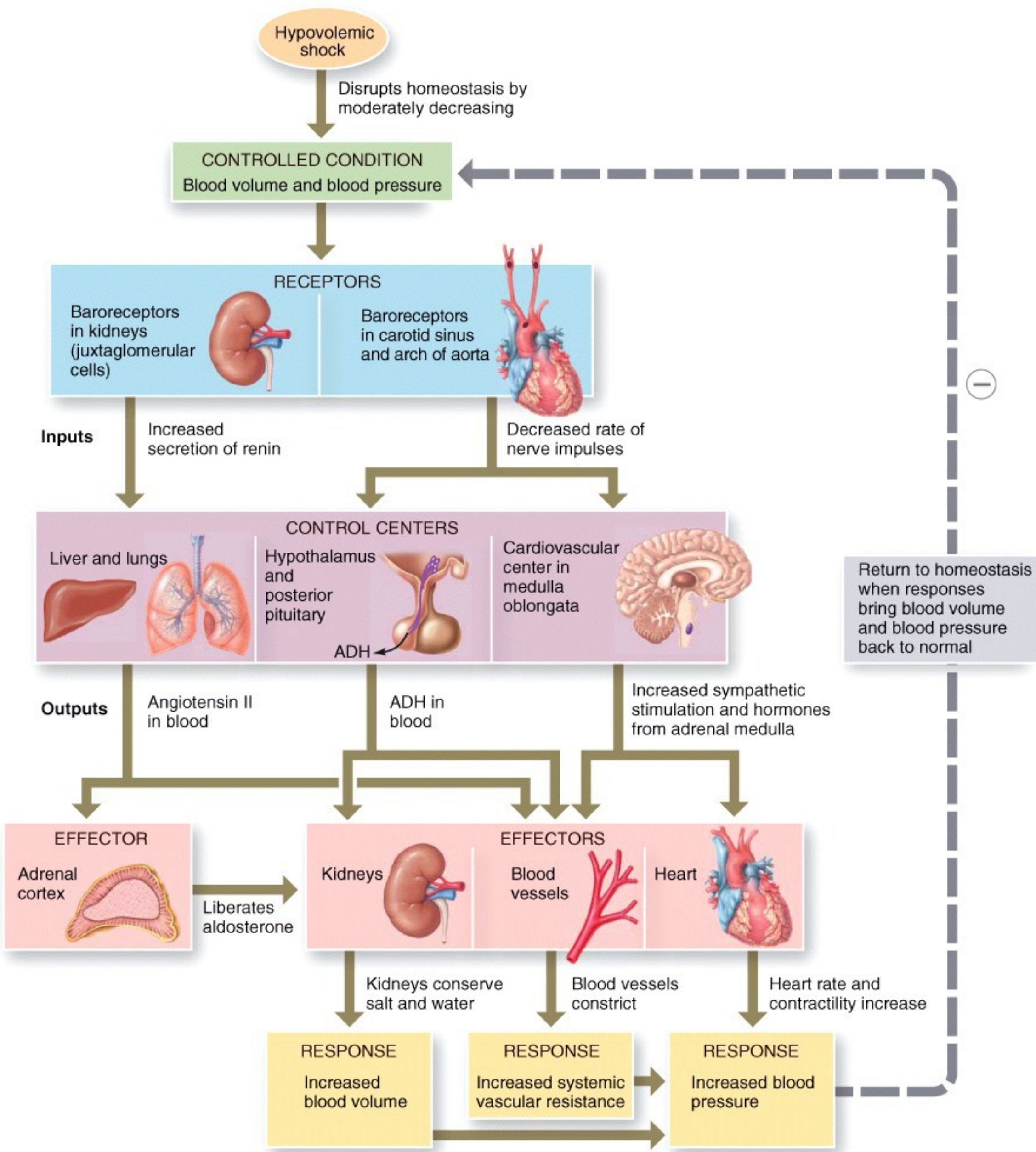
- <u>Any state in which cardiac output is insufficient to meet the body's metabolic needs</u>
  - Cardiogenic shock - inadequate pumping of heart (MI)
  - Low venous return (LVR) – cardiac output is low because too little blood is returning to the heart
    - Three common forms of low venous shock
      1. **hypovolemic shock** - most common /// loss of blood volume /// trauma, burns, dehydration
      2. **obstructed venous return shock ///** tumor or aneurysm compresses a vein
      3. **venous pooling (vascular) shock**

         long periods of standing, sitting or widespread vasodilation

         neurogenic shock - loss of vasomotor tone, vasodilation

         causes from emotional shock to brainstem injury

How do we restore normal blood pressure during hypovolemic shock?



Other Causes of Circulatory Shock

- **Septic shock**
  - bacterial toxins trigger vasodilation and increased capillary permeability
- **Anaphylactic shock**
  - severe immune reaction to antigen, histamine release, generalized vasodilation, increased capillary permeability

Responses to Circulatory Shock

Compensated Shock VS Decompensated Shock

Compensated Shock

- several homeostatic mechanisms bring about spontaneous recovery

- decreased BP triggers the following ……..

  - baroreflex
  - production of angiotensin II
  - both counteract shock by stimulating vasoconstriction

- if person faints (syncope) and then falls into horizontal position, gravity has helped to restore blood flow to brain

  - quicker if feet are raised

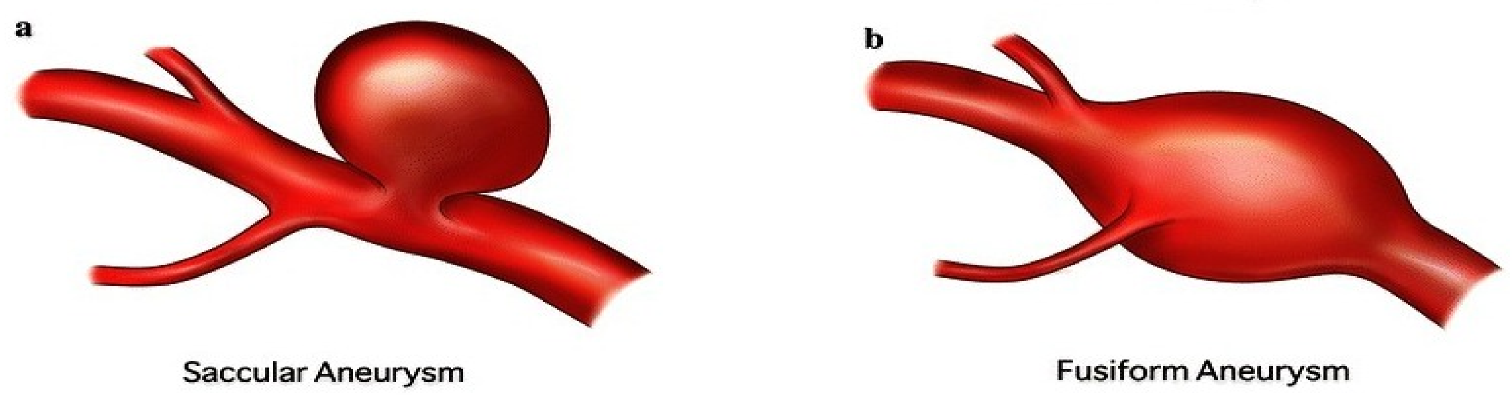
Decompensated Shock

- *If shock compensation mechanisms are inadequate*, several life-threatening positive feedback loops occur
  - poor cardiac output results in myocardial ischemia (ischemia is reduced blood flow) which can result in an infarction (necrosis due to lack of blood flow) /// this further weakens the heart and reduces output
  - slow circulation can lead to disseminated intra-vascular coagulation
    - vessels become congested with clotted blood
    - venous return grows worse
  - ischemia and acidosis in brainstem depresses vasomotor and cardiac centers
    - loss of vasomotor tone, further dilation in systemic curcuit, which results in further drop in BP and less cardiac output
  - resulting damage to cardiac and brain tissue may be too great to survive – death occurs

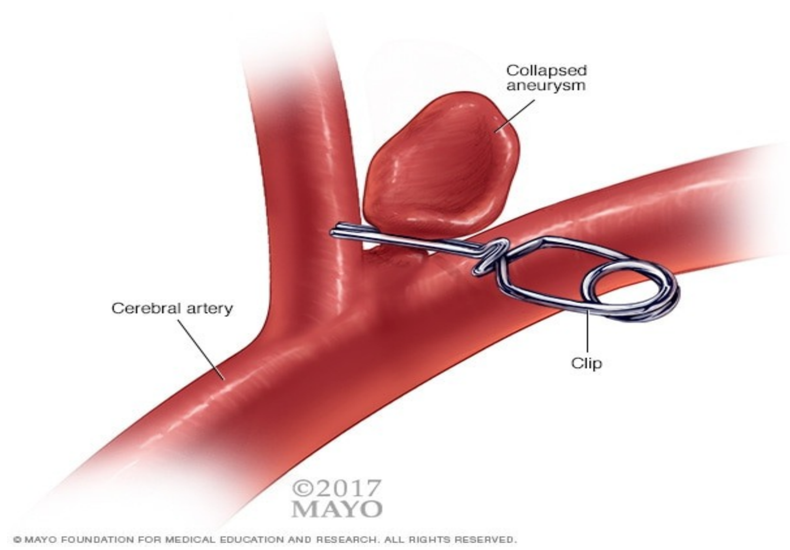
Aneurysm

- Weak point in an artery or the heart wall
  - forms a thin-walled, bulging sac that pulsates with each heartbeat and may rupture at any time
  - **dissecting aneurysm -** blood accumulates between the tunics of the artery and separates them, usually because of degeneration of the tunica media
  - **most common sites** *//* abdominal aorta, renal arteries, and arterial circle at the base of the brain
  - can cause pain by putting pressure on other structures
  - can rupture causing hemorrhage
  - result from congenital weakness of the blood vessels or result of trauma or bacterial infections such as syphilis
    - most common cause is atherosclerosis and hypertension

Aneurysm



a
b
Saccular Aneurysm
Fusiform Aneurysm



Collapsed aneurysm
Cerebral artery
Clip
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Varicose Veins

- blood pools in the lower legs in people who stand for long periods stretching the veins
  - cusps of the valves pull apart in enlarged superficial veins further weakening vessels
  - blood backflows and further distends the vessels, their walls grow weak and develop into varicose veins
- hereditary weakness, obesity, and pregnancy also promote problems
- hemorrhoids are varicose veins of the anal canal

Normal and Varicose Veins