PHYSIOLOGY

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LECTURE 9-PARTS (1) & (2) : STRUCTURE AND FUNCTION OF BLOOD VESSELS AS WELL AS FACTORS AFFECTING BLOOD FLOW AND BLOOD PRESSURE

Objectives

1. Discuss **structure and function of blood vessels.**

2. Describe **capillary exchange**.

3. Explore **hemodynamics: factors affecting blood flow.**

(Pages 730- 743 of the reference)

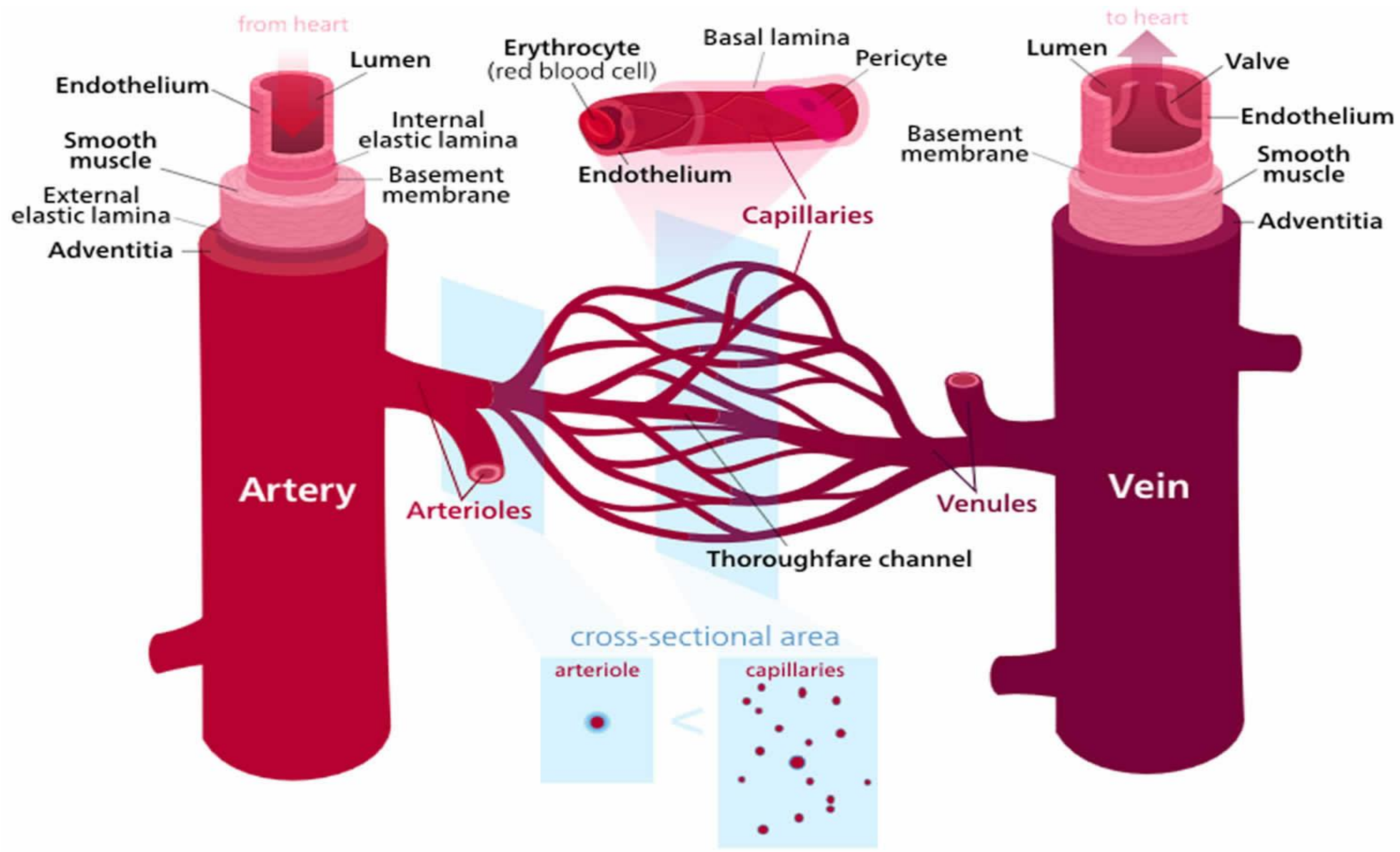
Objectives

4. Discuss **control of blood pressure and blood flow.**

5. Describe **checking circulation**.

6. Explore **shock and homeostasis.**

(Pages 744- 753 of the reference)



from heart
Lumen
Endothelium
Internal elastic lamina
Smooth muscle
Basement membrane
External elastic lamina
Adventitia
Erythrocyte (red blood cell)
Basal lamina
Pericyte
Endothelium
Capillaries
to heart
Lumen
Valve
Endothelium
Basement membrane
Smooth muscle
Adventitia
Artery
Arterioles
Thoroughfare channel
Venules
Vein
cross-sectional area
arteriole
<
capillaries

STRUCTURE AND FUNCTION OF BLOOD VESSELS

- The five main types of blood vessels are **arteries, arterioles, capillaries, venules, and veins**.

- **Arteries carry blood away from the heart to other organs**. Large, elastic arteries leave the heart and divide into medium-sized, muscular arteries that branch out into the various regions of the body. Medium-sized arteries then divide into small arteries, which in turn divide into still smaller arteries called **arterioles.**

- As the **arterioles enter a tissue**, they **branch into numerous tiny vessels called capillaries**. The thin walls of capillaries allow the exchange of substances between the blood and body tissues. **Groups of capillaries within a tissue reunite to form small veins called venules. These in turn merge to form progressively larger blood vessels called veins. Veins are the blood vessels that convey blood from the tissues back to the heart.**

BASIC STRUCTURE OF A BLOOD VESSEL

The three structural layers of a generalized blood vessel **from innermost to outermost** are the tunica interna (intima), tunica media, and tunica externa (adventitia).

TUNICA INTERNA (INTIMA)

- **The tunica interna (intima)** forms the inner lining of a blood vessel and is in direct contact with the blood as it flows through the lumen, or interior opening, of the vessel. Although this layer has multiple parts, these tissue components contribute minimally to the thickness of the vessel wall.

- Its **innermost layer is called endothelium**, is a thin layer of flattened cells that lines the inner surface of the entire cardiovascular system (heart and blood vessels). The **endothelial cells are active participants in a variety of vessel-related activities**, including physical influences on blood flow, secretion of locally acting chemical mediators that influence the contractile state of the vessel's overlying smooth muscle, and assistance with capillary permeability. In addition, their smooth luminal surface facilitates efficient blood flow by reducing surface friction.

TUNICA INTERNA (INTIMA)

- The **second component** of the tunica interna is a **basement membrane** deep to the endothelium. It provides a physical support base for the epithelial layer. It appears to play an important role in guiding cell movements during tissue repair of blood vessel walls.

- The **outermost part of the tunica interna**, which forms the boundary between the tunica interna and tunica media, is the **internal elastic lamina,** is a thin sheet of elastic fibers with a variable number of windowlike openings that facilitate diffusion of materials through the tunica interna to the thicker tunica media.

TUNICA MEDIA

- ✓ Is the tissue layer that displays the **greatest variation among the different vessel types**. In most vessels, **it is a relatively thick layer comprising mainly smooth muscle cells and substantial amounts of elastic fibers.**
- ✓ An **increase in sympathetic stimulation** typically stimulates the **smooth muscle to contract**, squeezing the vessel wall and narrowing the lumen. Such a **decrease in the diameter of the lumen of a blood vessel** is called **vasoconstriction.**
- ✓ In contrast, when **sympathetic stimulation decreases**, **smooth muscle fibers relax**. The resulting **increase in lumen diameter** is called **vasodilation.**

TUNICA EXTERNA

The outer covering of a blood vessel, the tunica externa, consists of **elastic and collagen fibers**.

In addition to the important role of supplying the vessel wall with nerves and self-vessels, the tunica externa helps anchor the vessels to surrounding tissues.

ARTERIES

Their walls stretch easily or expand without tearing in response to a small increase in pressure (due to their plentiful elastic fibers).

The wall of an artery has the three layers of a typical blood vessel.

ELASTIC ARTERIES

- **The largest arteries in the body.**
- **TUNICA INTERNA:** Well-defined internal elastic lamina.
- **TUNICA MEDIA:** Thick and dominated by elastic fibers; well-defined external elastic lamina.
- **TUNICA EXTERNA:** Thinner than tunica media.
- **Function: Conduct blood from heart to muscular arteries**.

MUSCULAR ARTERIES

- **The Medium-sized arteries.**
- **TUNICA INTERNA:** Well-defined internal elastic lamina.
- **TUNICA MEDIA:** Thick and dominated by smooth muscle; thin external elastic lamina.
- **TUNICA EXTERNA:** Thicker than tunica media.
- **Function: Distribute blood to arterioles**.

ARTERIOLES

- **Microscopic (15–300 micrometer in diameter).**
- **TUNICA INTERNA:** Thin with a fenestrated internal elastic lamina that disappears distally.
- **TUNICA MEDIA:** One or two layers of circularly oriented smooth muscle; distalmost smooth muscle cell forms a precapillary sphincter.
- **TUNICA EXTERNA:** Loose collagenous connective tissue and sympathetic nerves.
- **Function: Deliver blood to capillaries and help regulate blood flow from arteries to capillaries.**

CAPILLARIES

- **Microscopic; smallest blood vessels (5–10 micrometer in diameter).**
- **TUNICA INTERNA:** Endothelium and basement membrane.
- **TUNICA MEDIA:** None.
- **TUNICA EXTERNA:** None.
- **Function: Permit exchange of nutrients and wastes between blood and interstitial fluid; distribute blood to postcapillary venules.**

POSTCAPILLARY VENULES

- **Microscopic (10–50 micrometer in diameter).**
- **TUNICA INTERNA:** Endothelium and basement membrane.
- **TUNICA MEDIA:** None.
- **TUNICA EXTERNA:** Sparse.
- **Function: Pass blood into muscular venules; permit exchange of nutrients and wastes between blood and interstitial fluid and function in white blood cell emigration.**

MUSCULAR VENULES

- **Microscopic (50–200 micrometer in diameter).**
- **TUNICA INTERNA:** Endothelium and basement membrane.
- **TUNICA MEDIA:** One or two layers of circularly oriented smooth muscle.
- **TUNICA EXTERNA:** Sparse.
- **Function: Pass blood into vein**; **act as reservoirs for accumulating large volumes of blood (along with postcapillary venules).**

VEINS

- **Range from 0.5 mm to 3 cm in diameter.**
- **TUNICA INTERNA:** Endothelium and basement membrane; no internal elastic lamina; contain valves; lumen much larger than in accompanying artery.
- **TUNICA MEDIA:** Much thinner than in arteries; no external elastic lamina.
- **TUNICA EXTERNA:** Thickest of the three layers.
- **Function:** **Return blood to heart**, facilitated by valves in limb veins.

CAPILLARY EXCHANGE

- **Is the movement of substances between blood and interstitial fluid.**
- Substances enter and leave capillaries by **three basic mechanisms**: **diffusion**, **transcytosis, and bulk flow.**

DIFFUSION

- **The most important method of capillary exchange is simple diffusion.**

- Because O_2 and nutrients normally are present in higher concentrations in blood, they diffuse down their concentration gradients into interstitial fluid and then into body cells. CO_2 and other wastes released by body cells are present in higher concentrations in interstitial fluid, so they diffuse into blood.

TRANSCYTOSIS

- **A small quantity of material crosses capillary walls by transcytosis.**

- In this process, **substances in blood plasma** become **enclosed within tiny pinocytic vesicles** that **first enter endothelial cells by endocytosis**, then **move across the cell and exit on the other side by exocytosis**.

BULK FLOW: FILTRATION AND REABSORPTION

- **Bulk flow is a passive process in which large numbers of ions, molecules, or particles in a fluid move together in the same direction.**
- **Bulk flow occurs from an area of higher pressure to an area of lower pressure, and it continues as long as a pressure difference exists.**
- **Diffusion is more important for solute exchange between blood and interstitial fluid, but bulk flow is more important for regulation of the relative volumes of blood and interstitial fluid.**
- Pressure-driven movement of fluid and solutes from blood capillaries into interstitial fluid is called **filtration**. Pressure-driven movement from interstitial fluid into blood capillaries is called **reabsorption**.

HEMODYNAMICS: FACTORS AFFECTING BLOOD FLOW

- **Blood flow** is the volume of blood that flows through any tissue in a given time period (in mL/min). **Total blood flow is cardiac output (CO), the volume of blood that circulates through systemic (or pulmonary) blood vessels each minute.**
- How the cardiac output becomes distributed into circulatory routes that serve various body tissues depends on **two more factors**:
- **(1) the pressure difference that drives the blood flow through a tissue.**
- **(2) the resistance to blood flow in specific blood vessels.**

- Blood flows from regions of higher pressure to regions of lower pressure; **the greater the pressure difference, the greater the blood flow. But the higher the resistance, the smaller the blood flow.**

BLOOD PRESSURE

- **Contraction of the ventricles generates blood pressure (BP), the hydrostatic pressure exerted by blood on the walls of a blood vessel.**
- **BP is determined by cardiac output, blood volume, and vascular resistance.**
- BP is highest in the aorta and large systemic arteries; in a resting, young adult, **BP rises to about 110 mmHg during systole (ventricular contraction) and drops to about 70 mmHg during diastole (ventricular relaxation).**
- **Mean arterial pressure (MAP),** the average blood pressure in arteries, is **roughly one-third of the way between the diastolic and systolic pressures. It can be estimated as follows:**

MAP= diastolic BP +1/3 (systolic BP - diastolic BP)

BLOOD PRESSURE

- **We have already seen that cardiac output equals heart rate multiplied by stroke volume.** Another way to calculate cardiac output is to divide mean arterial pressure (MAP) by **resistance (R): CO = MAP/R.** By rearranging the terms of this equation, you can see that **MAP = CO * R.**
- Blood pressure also depends on the total volume of blood in the cardiovascular system. **The normal volume of blood in an adult is about 5 liters. Any decrease in this volume,** as from **hemorrhage, decreases the amount of blood that is circulated through the arteries each minute.**
- **A modest decrease can be compensated for by homeostatic mechanisms that help maintain blood pressure**, **but if the decrease in blood volume is greater than 10% of the total, blood pressure drops**. **Conversely, anything that increases blood volume, such as water retention in the body, tends to increase blood pressure**.

VASCULAR RESISTANCE

- **Vascular resistance is the opposition to blood flow due to friction between blood and the walls of blood vessels.**
- Vascular resistance depends on **(1) size of the blood vessel lumen, (2) blood viscosity, and (3) total blood vessel length.**

SIZE OF THE LUMEN

- **The smaller the lumen of a blood vessel, the greater its resistance to blood flow.**
- **Resistance is inversely proportional to the fourth power of the diameter (d) of the blood vessel's lumen.**

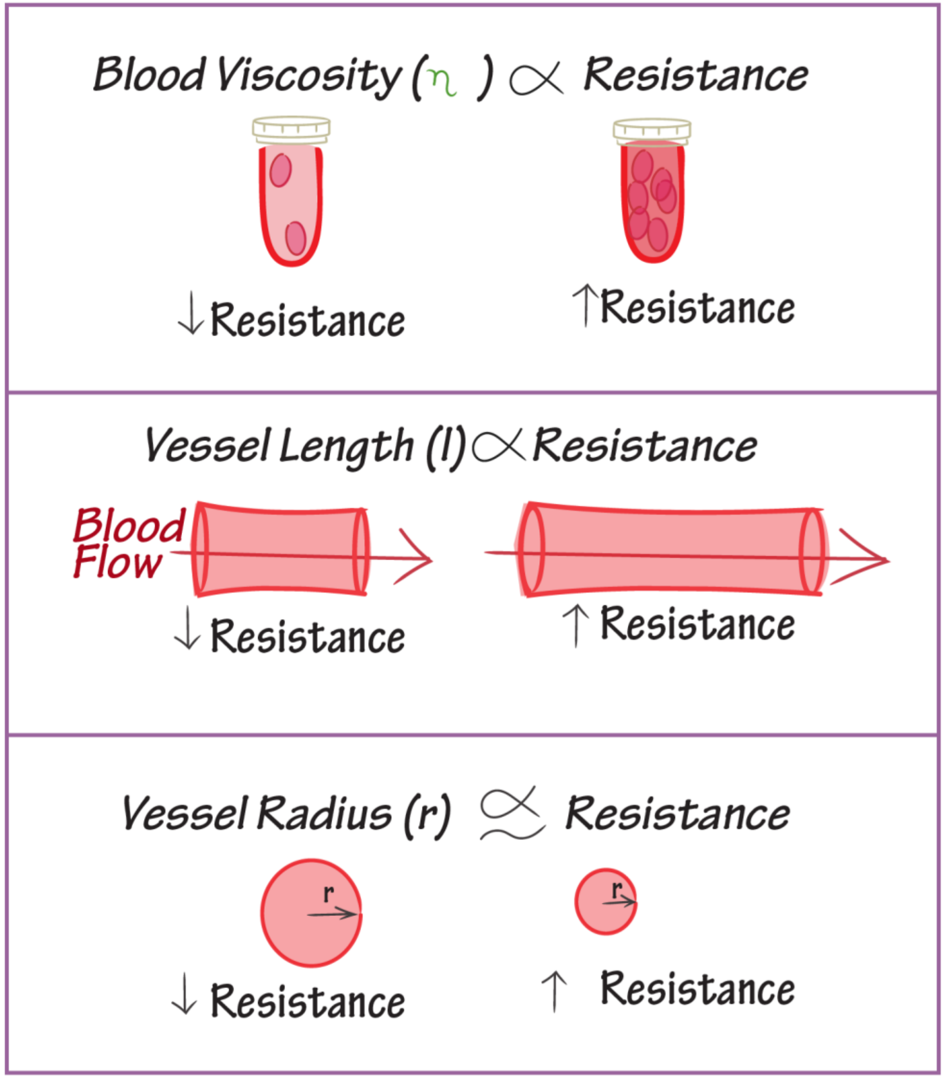
BLOOD VISCOSITY

- **The viscosity of blood depends mostly on the ratio of red blood cells to plasma (fluid) volume, and to a smaller extent on the concentration of proteins in plasma.**
- **The higher the blood's viscosity, the higher the resistance.**
- **Any condition that increases the viscosity of blood, such as dehydration or polycythemia (an unusually high number of red blood cells), thus increases blood pressure.**
- **A depletion of plasma proteins or red blood cells, due to anemia or hemorrhage, decreases viscosity and thus decreases blood pressure.**

SYSTEMIC VASCULAR RESISTANCE (SVR)

- **Resistance to blood flow through a vessel is directly proportional to the length of the blood vessel.**
- **The longer a blood vessel, the greater the resistance.**
- **Systemic vascular resistance (SVR),** also known as **total peripheral resistance (TPR)**, refers to all of the vascular resistances offered by systemic blood vessels.
- **The diameters of arteries and veins are large, so their resistance is very small** because most of the blood does not come into physical contact with the walls of the blood vessel. **The smallest vessels—arterioles, capillaries, and venules—contribute the most resistance.**

Determinants of Resistance:

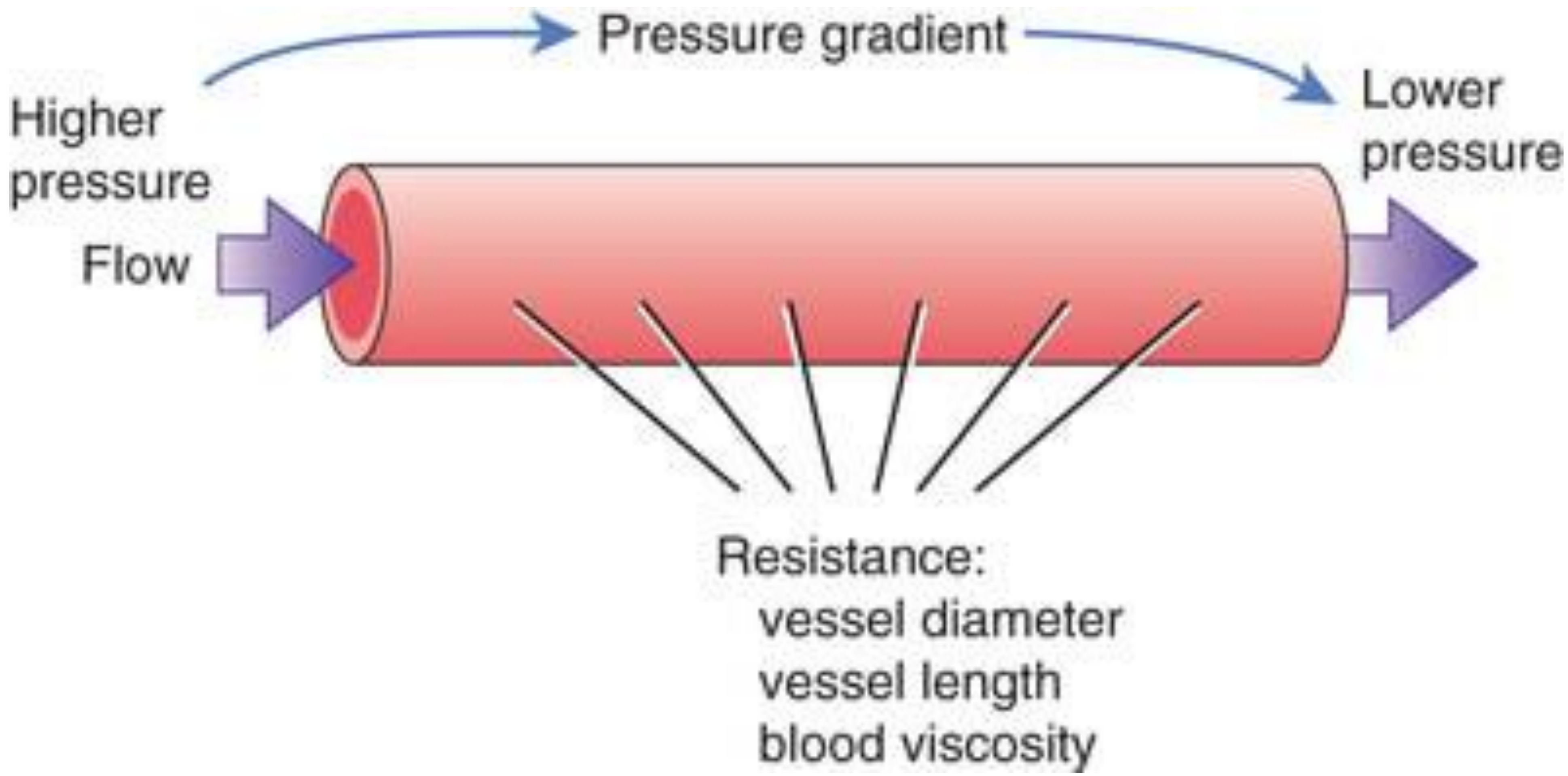


Factors Affecting Blood Flow

Pressure and resistance both affect blood flow to tissues, but they have opposing effects.

Blood flow and pressure are directly related: when pressure increases, flow increases.

Blood flow and resistance are inversely related: when resistance increases, flow decreases.

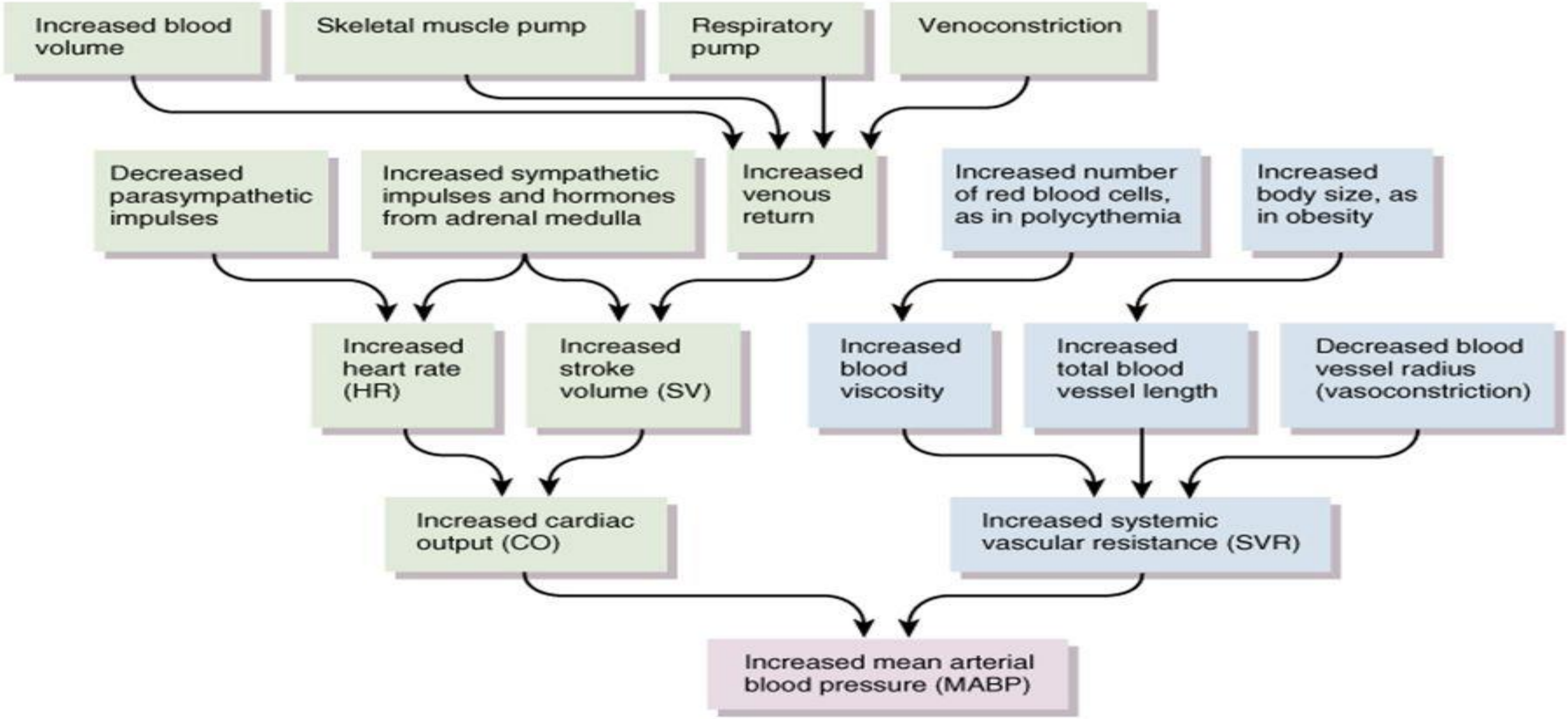


Pressure gradient
Higher pressure
Lower pressure
Flow
Resistance:
vessel diameter
vessel length
blood viscosity

VELOCITY OF BLOOD FLOW

- Earlier we saw that blood flow is the volume of blood that flows through any tissue in a given time period (in mL/min).
- **The speed or velocity of blood flow (in cm/sec) is inversely related to the cross-sectional area.**
- **Velocity is slowest where the total cross-sectional area is greatest.**
- Each time an artery branches, the total cross-sectional area of all of its branches is greater than the cross-sectional area of the original vessel, **so blood flow becomes slower and slower as blood moves further away from the heart, and is slowest in the capillaries.**

Factors that Increase Blood Pressure



Physiological factors affecting blood pressure

Factor	Effect on blood pressure
The pumping action of the heart	The greater the cardiac output, the higher the arterial pressure
The blood volume	The greater the blood volume, the higher the arterial pressure
The viscosity of the blood	The more viscous the blood, the higher the arterial pressure
The condition of the blood vessels (resistance)	The greater the resistance, the higher the arterial pressure

CONTROL OF BLOOD PRESSURE AND BLOOD FLOW

- **Several interconnected negative feedback systems control blood pressure** by adjusting heart rate, stroke volume, systemic vascular resistance, and blood volume.

- **Some systems allow rapid adjustments** to cope with sudden changes, such as the drop in blood pressure in the brain that occurs when you get out of bed; **others act more slowly** to provide long-term regulation of blood pressure.

CONTROL OF BLOOD PRESSURE AND BLOOD FLOW

- **Role of the Cardiovascular Center in the medulla oblongata:**

- 1- helps regulate heart rate and stroke volume.
- 2- controls neural, hormonal, and local negative feedback systems that regulate blood pressure and blood flow to specific tissues.

- **Groups of neurons scattered within the CV center:**
- Some neurons stimulate the heart (cardiostimulatory center); others inhibit the heart (cardioinhibitory center).
- Still others control blood vessel diameter by causing constriction (vasoconstrictor center) or dilation (vasodilator center).

1. ROLE OF THE CARDIOVASCULAR CENTER

- The **cardiovascular center** receives input both **from higher brain regions and from sensory receptors**. Nerve impulses descend from **the cerebral cortex, limbic system, and hypothalamus** to affect the cardiovascular center.

- The three main types of sensory receptors that provide input to the cardiovascular center **are proprioceptors, baroreceptors, and chemoreceptors.**

- **Proprioceptors monitor movements of joints and muscles and provide input to the cardiovascular center during physical activity.**
- **Baroreceptors monitor changes in pressure and stretch in the walls of blood vessels.**
- **Chemoreceptors monitor the concentration of various chemicals in the blood.**

CV Center

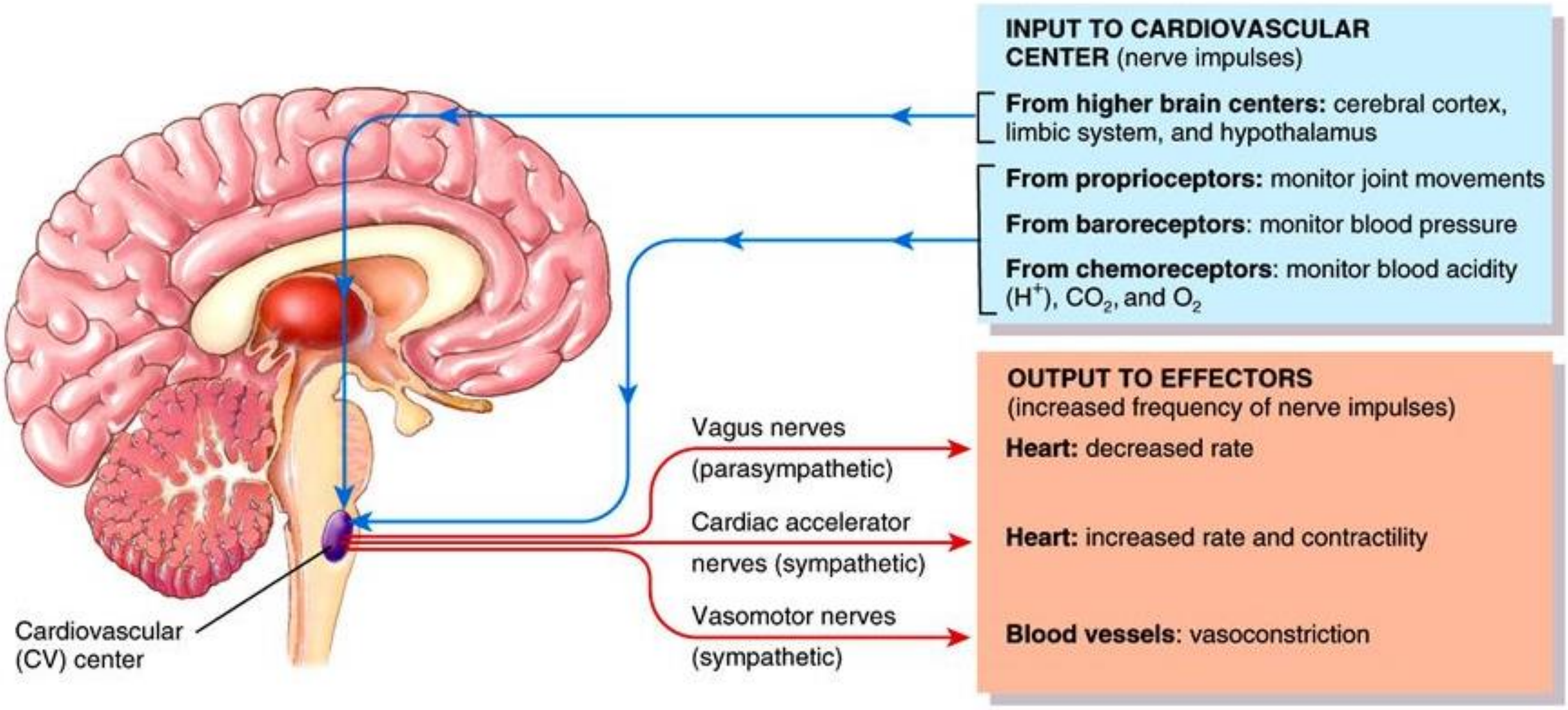


Figure 21.12 Tortora - PAP 12/e

ROLE OF THE CARDIOVASCULAR CENTER

- ❖ **Output from the cardiovascular center flows along <u>sympathetic and parasympathetic neurons of the ANS</u>.**

- ✓ **Sympathetic impulses reach the heart via the cardiac accelerator nerves. An increase in sympathetic stimulation increases heart rate and contractility.**

- ✓ **Parasympathetic stimulation, conveyed along the vagus (X) nerves, decreases heart rate.**

ROLE OF THE CARDIOVASCULAR CENTER

- ❖ **The cardiovascular center also continually sends impulses to smooth muscle in blood vessel walls via <u>vasomotor nerves</u>.**

- ✓ **Impulses propagate along sympathetic neurons that innervate blood vessels in viscera and peripheral areas.**

- ✓ **The result is a moderate state of tonic contraction or vasoconstriction, called vasomotor tone, that sets the resting level of systemic vascular resistance. Sympathetic stimulation of most veins causes constriction that moves blood out of venous blood reservoirs and increases blood pressure.**

2. NEURAL REGULATION OF BLOOD PRESSURE

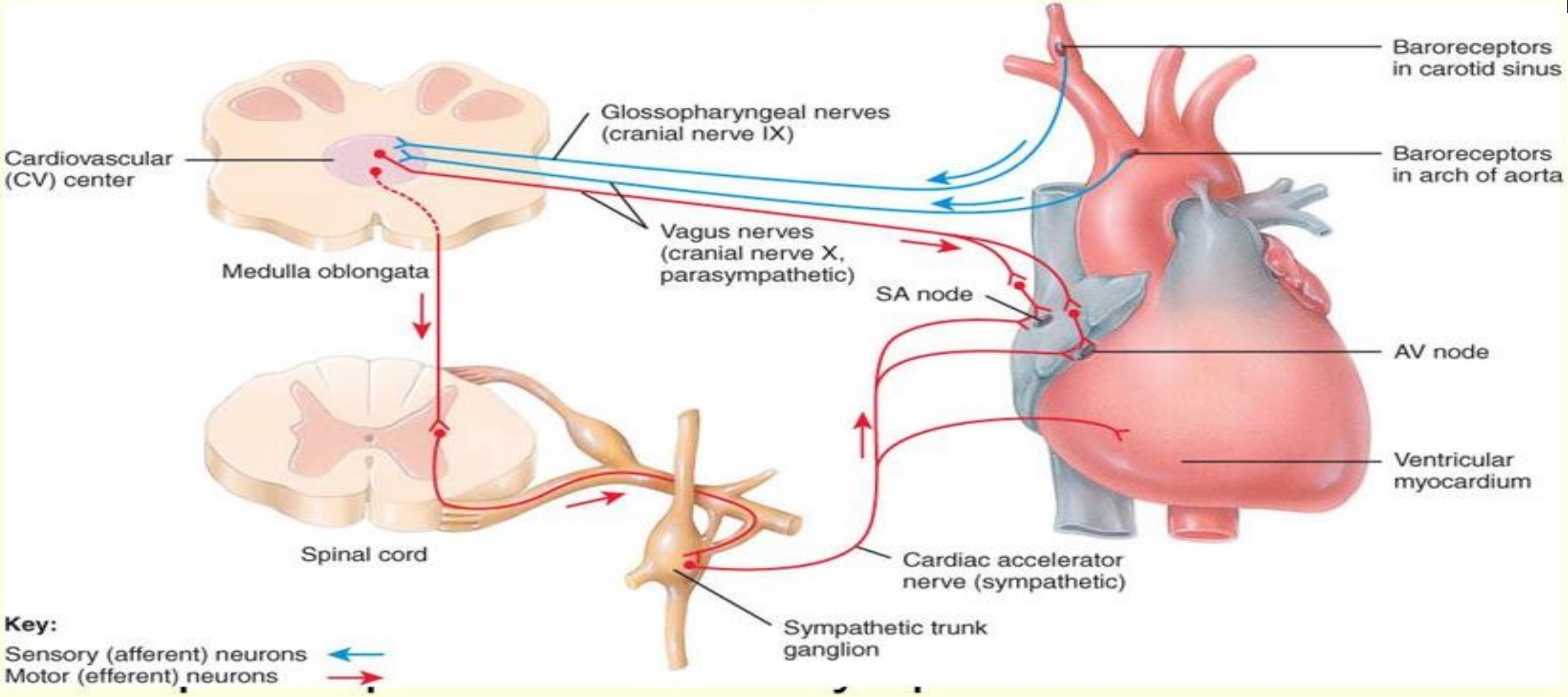
The nervous system regulates blood pressure via negative feedback loops that occur as two types of reflexes: **baroreceptor reflexes and chemoreceptor reflexes.**

BARORECEPTOR REFLEXES

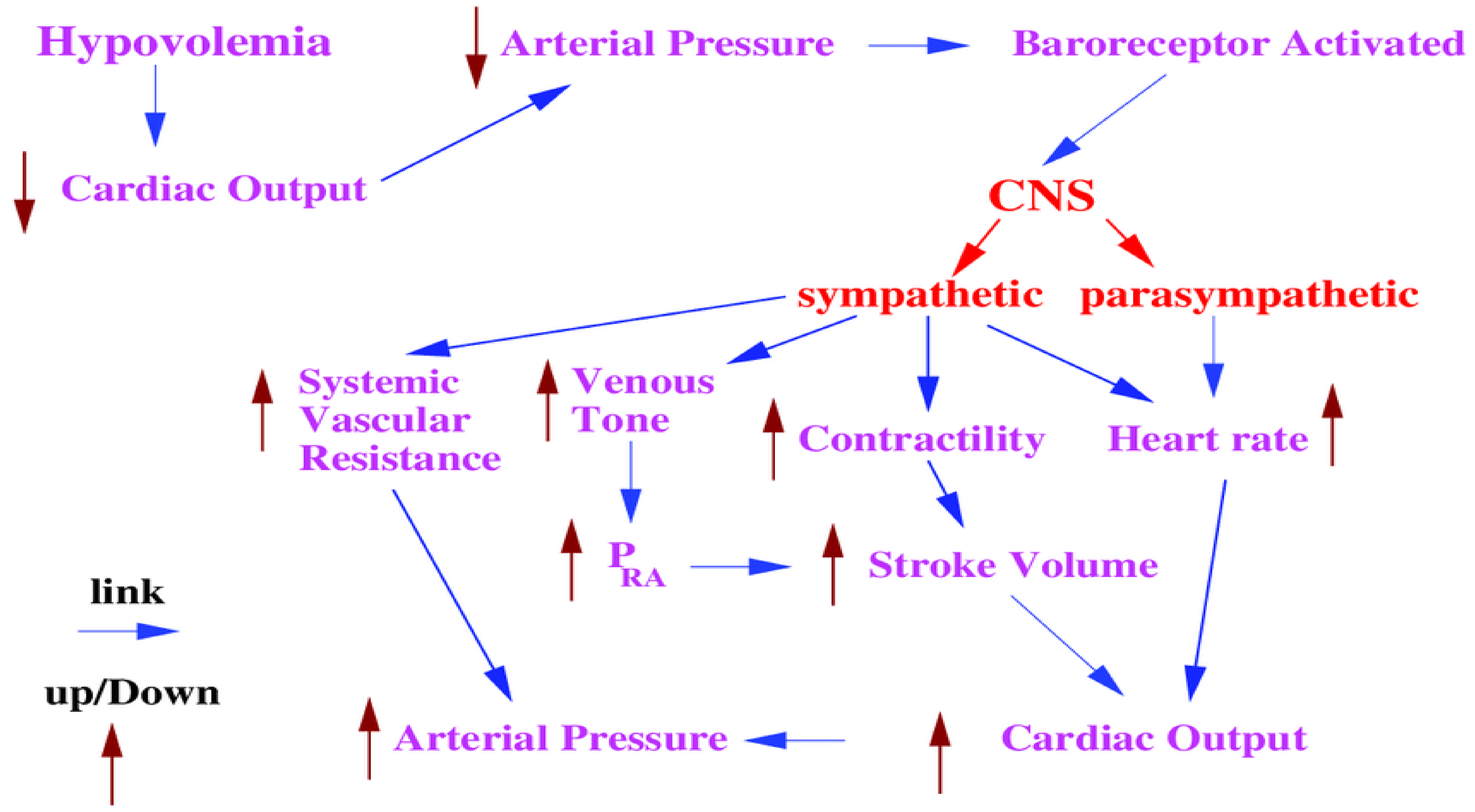
Baroreceptors are **pressure-sensitive sensory receptors**. They **are located in the aorta, internal carotid arteries** (arteries in the neck that supply blood to the brain), and other large arteries in the neck and chest.

They **send impulses to the cardiovascular center to help regulate blood pressure**.

Innervation of the Heart

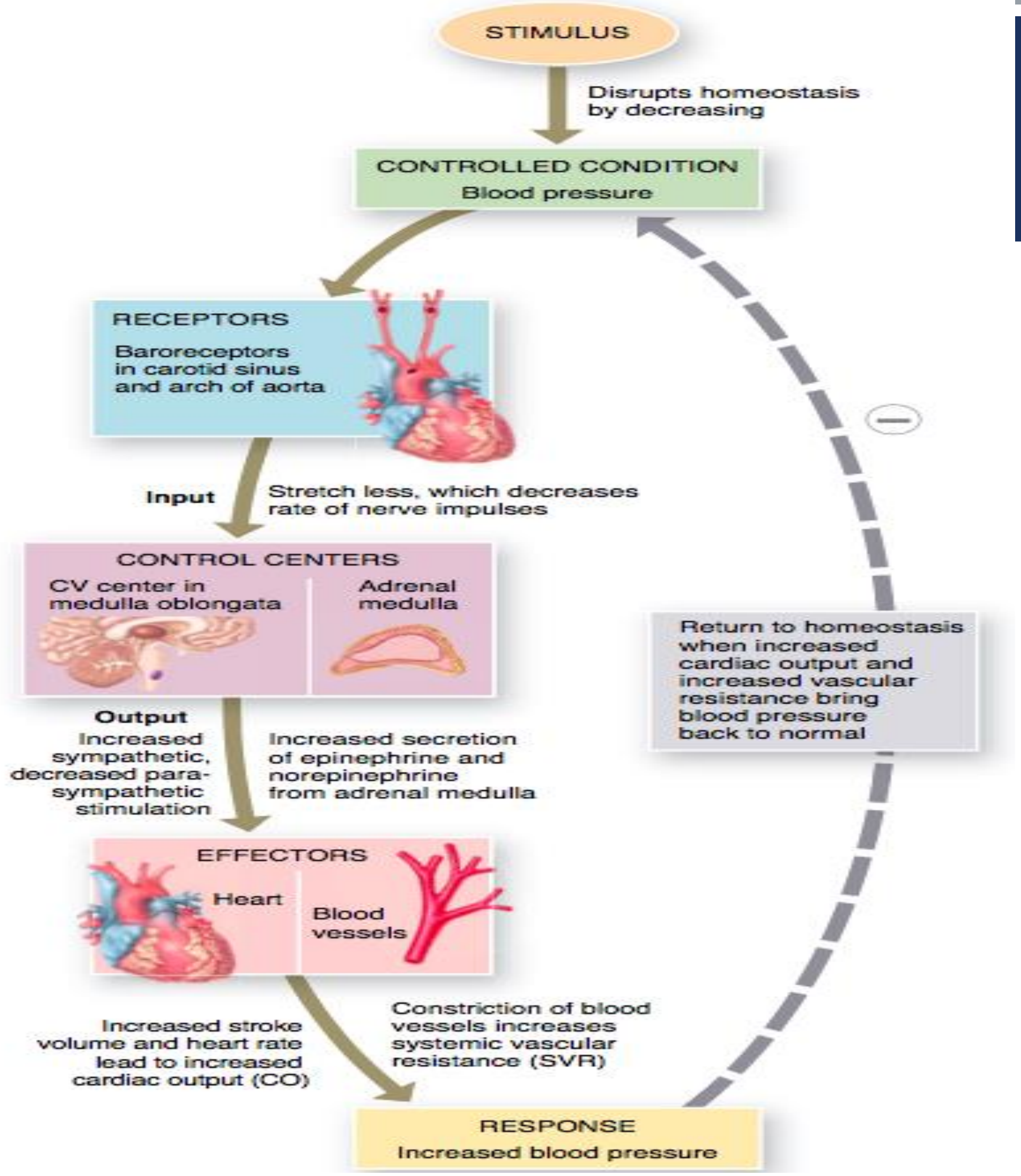


- Slow it down with parasympathetic stimulation (X)
- Sensory information from baroreceptors (IX)

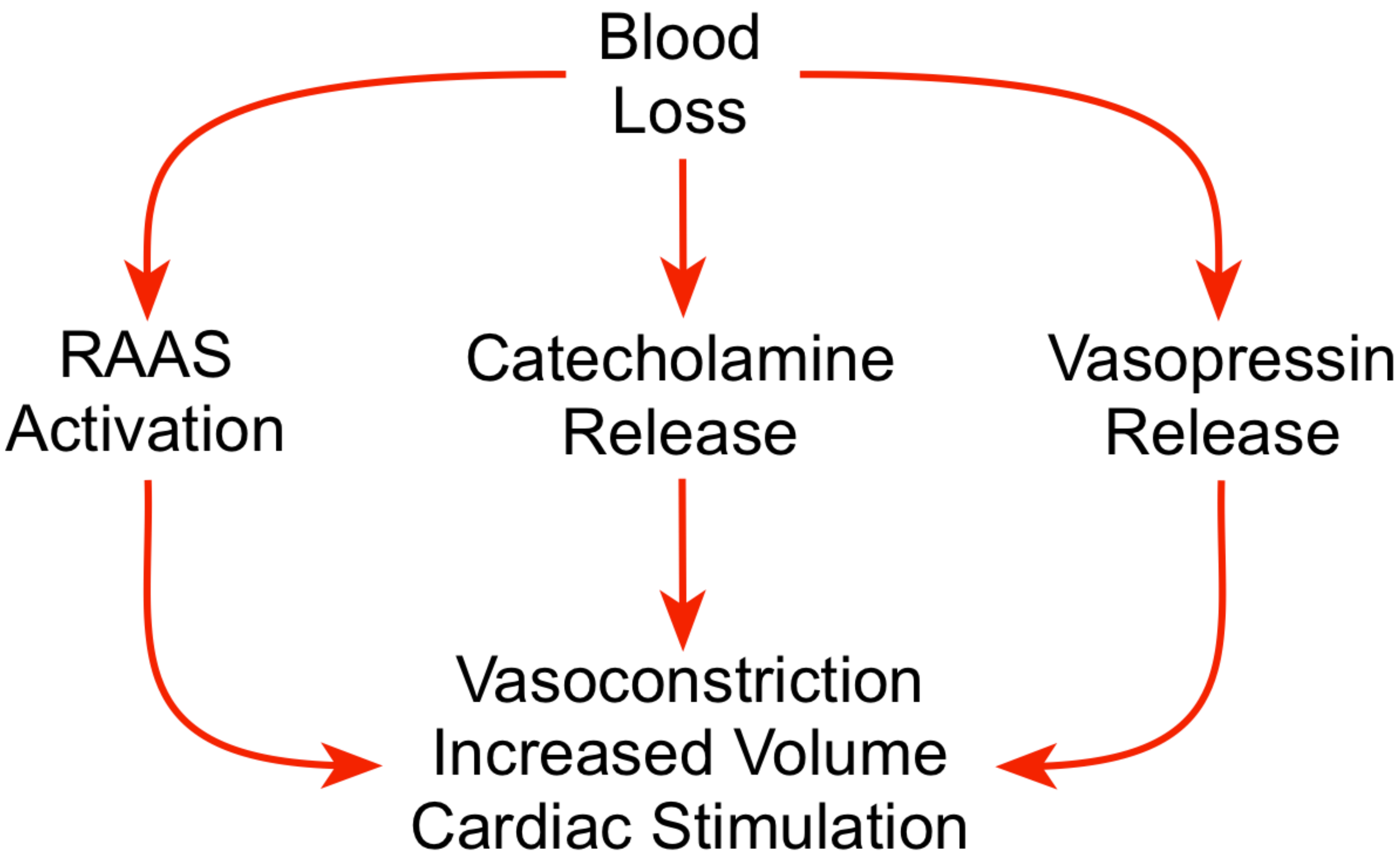

Hypovolemia
Arterial Pressure
Baroreceptor Activated
Cardiac Output
CNS
sympathetic
parasympathetic
Systemic Vascular Resistance
Venous Tone
Contractility
Heart rate
P_{RA}
Stroke Volume
link
up/Down
Arterial Pressure
Cardiac Output

BARORECEPTOR REFLEXES

- **Baroreceptors are pressure-sensitive neurons that monitor stretching.**
- **When blood pressure falls, the baroreceptors are stretched less, and they send nerve impulses** at a slower rate to the cardiovascular center. In response, the CV **center decreases parasympathetic stimulation** of the heart by way of motor axons of the vagus nerves and increases sympathetic stimulation of the heart via cardiac accelerator nerves.
- **Moving from a prone (lying down) to an erect position decreases blood pressure and blood flow** in the head and upper part of the body. The **baroreceptor reflexes, however, quickly counteract the drop in pressure.** Sometimes these reflexes operate more slowly than normal, especially in the elderly.



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 para-sympathetic 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


Blood Loss
RAAS Activation
Catecholamine Release
Vasopressin Release
Vasoconstriction
Increased Volume
Cardiac Stimulation

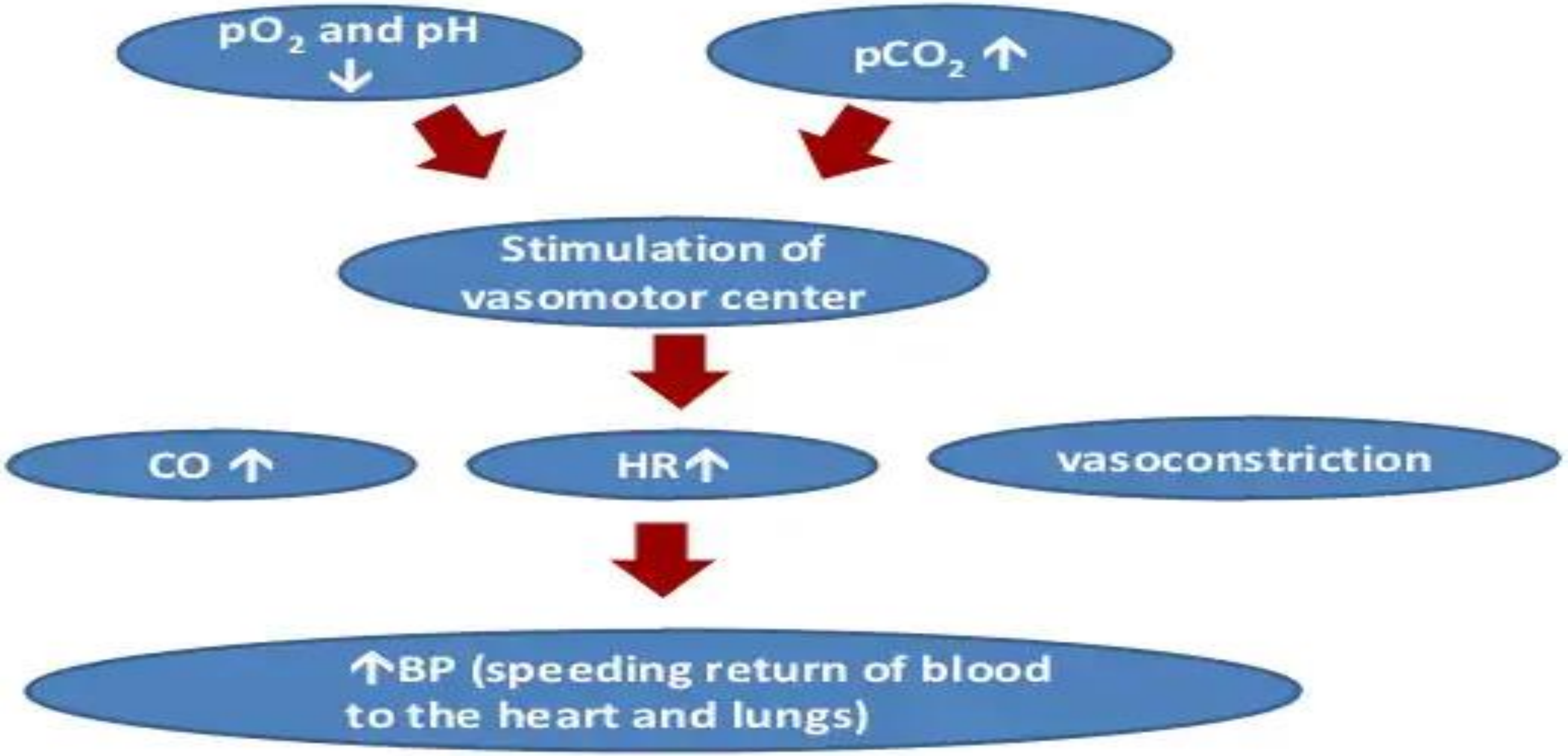
CHEMORECEPTOR REFLEXES

- **Chemoreceptors,** sensory receptors that **monitor the chemical composition of blood**, are **located close to the baroreceptors** of the carotid sinus and arch of the aorta in small structures called **carotid bodies and aortic bodies**, respectively.

- These chemoreceptors **detect changes in blood level of O_2, CO_2, and H+.** Hypoxia (lowered O_2 availability), acidosis (an increase in H+ concentration), or hypercapnia (excess CO_2) stimulates the chemoreceptors to send impulses to the cardiovascular center. In response, the CV center increases sympathetic stimulation to arterioles and veins, producing vasoconstriction and an increase in blood pressure. These chemoreceptors also provide input to the respiratory center in the brain stem to adjust the rate of breathing.

Chemoreceptor

- Chemosensitive cells that respond to changes in pCO_2 and pO_2 and pH levels (Hydrogen ion).



3- HORMONAL REGULATION OF BLOOD PRESSURE

1- Renin–angiotensin–aldosterone (RAA) system:

- When blood volume falls or blood flow to the kidneys decreases, **juxtaglomerular cells in the kidneys secrete renin into the bloodstream**.
- In sequence, renin and angiotensin-converting enzyme (ACE) act on their substrates to produce the active hormone angiotensin II, which **raises blood pressure in two ways.**
- **First,** angiotensin II is a potent vasoconstrictor; it raises blood pressure by increasing systemic vascular resistance.
- **Second,** it stimulates secretion of aldosterone, which increases reabsorption of sodium ions and water by the kidneys. The water reabsorption increases total blood volume, which increases blood pressure.

3- HORMONAL REGULATION OF BLOOD PRESSURE

2- Epinephrine and norepinephrine:

- In response to sympathetic stimulation, the adrenal medulla releases epinephrine and norepinephrine.
- These hormones **increase cardiac output by increasing the rate and force of heart contractions.**

3- Antidiuretic hormone (ADH):

- It is produced by the hypothalamus and released from the posterior pituitary in response to dehydration or decreased blood volume.
- It causes in an **increase in blood volume and a decrease in urine output**.

3- HORMONAL REGULATION OF BLOOD PRESSURE

4- Atrial natriuretic peptide (ANP):

- Released by cells in the atria of the heart, atrial natriuretic peptide (ANP) **lowers blood pressure by causing vasodilation and by promoting the loss of salt and water in the urine, which reduces blood volume.**

4- AUTOREGULATION OF BLOOD FLOW

- In each capillary bed, local changes can regulate vasomotion.
- When **vasodilators** produce local dilation of arterioles and relaxation of precapillary sphincters, blood flow into capillary networks is increased, which increases O_2 level.
- Vasoconstrictors have the opposite effect.
- **The ability of a tissue to automatically adjust its blood flow to match its metabolic demands is called autoregulation.**

4- AUTOREGULATION OF BLOOD FLOW

- **Autoregulation also controls regional blood flow in the brain; blood distribution to various parts of the brain changes dramatically for different mental and physical activities**.

- During a conversation, for example, blood flow increases to your motor speech areas when you are talking and increases to the auditory areas when you are listening.

4- AUTOREGULATION OF BLOOD FLOW

- Two general types of stimuli cause autoregulatory changes in blood flow:

1. **Physical changes.** Warming promotes vasodilation, and cooling causes vasoconstriction. In addition, smooth muscle in arteriole walls exhibits a myogenic response— it contracts more forcefully when it is stretched and relaxes when stretching lessens.
2. **Vasodilating and vasoconstricting chemicals.** Several types of cells—including white blood cells, platelets, smooth muscle fibers, macrophages, and endothelial cells—release a wide variety of chemicals that alter blood-vessel diameter.

4- AUTOREGULATION OF BLOOD FLOW

- An important difference between the pulmonary and systemic circulations is their autoregulatory response to changes in O_2 level.

- The walls of blood vessels in the systemic circulation dilate in response to low O_2. With vasodilation, O_2 delivery increases, which restores the normal O_2 level.

- By contrast, the walls of blood vessels in the pulmonary circulation constrict in response to low levels of O_2. This response ensures that blood mostly bypasses those alveoli (air sacs) in the lungs that are poorly ventilated by fresh air. Thus, most blood flows to better-ventilated areas of the lung.

CHECKING CIRCULATION

1. **Pulse:**

- The alternate expansion and recoil of elastic arteries after each systole of the left ventricle creates a traveling pressure wave that is called the pulse.

- The pulse is strongest in the arteries closest to the heart, becomes weaker in the arterioles, and disappears altogether in the capillaries.

- The pulse rate normally is the same as the heart rate, about 70 to 80 beats per minute at rest. **Tachycardia** is a rapid resting heart or pulse rate over 100 beats/ min. **Bradycardia** is a slow resting heart or pulse rate under 50 beats/min.

CHECKING CIRCULATION

2. Measuring Blood Pressure:

- **The term blood pressure** usually refers to the pressure in arteries generated by the left ventricle during systole and the pressure remaining in the arteries when the ventricle is in diastole. Blood pressure is usually measured in the brachial artery in the left arm.

- The device used to measure blood pressure is a **sphygmomanometer.**
- **The normal blood pressure of an adult male is less than 120 mmHg systolic and less than 80 mmHg diastolic.** For example, "110 over 70" (written as 110/70) is a normal blood pressure.

CHECKING CIRCULATION

2. Measuring Blood Pressure:

- The difference between systolic and diastolic pressure is called **pulse pressure**. This pressure, normally about 40 mmHg, provides information about the condition of the cardiovascular system. **For example**, conditions such as atherosclerosis greatly increase pulse pressure. **The normal ratio of systolic pressure to diastolic pressure to pulse pressure is about 3:2:1**.

SHOCK AND HOMEOSTASIS

- **Shock** is a failure of the cardiovascular system to deliver enough O_2 and nutrients to meet cellular metabolic needs.

- **The causes of shock are many and varied**, but all are characterized by **inadequate blood flow to body tissues**. With inadequate oxygen delivery, cells switch from aerobic to anaerobic production of ATP, and lactic acid accumulates in body fluids. If shock persists, cells and organs become damaged, and **cells may die unless proper treatment begins quickly**.

TYPES OF SHOCK

- Shock can be of four different types:

- (1) Hypovolemic shock due to decreased blood volume
- (2) Cardiogenic shock due to poor heart function.
- (3) Vascular shock due to inappropriate vasodilation.
- (4) Obstructive shock due to obstruction of blood flow.

TYPES OF SHOCK

Cause	Pathophysiology*	Patterns of abnormalities		
		Filling status	Cardiac function	Systemic resistance
Hypovolemic	**Loss of volume**	low	low	high
Vasogenic	**Vasodilation**	low	high	low
Cardiogenic	**Pump failure**	high	low	high
Obstructive	**Obstruction to flow**	Variable**	low	high

*primary problem mentioned in BOLD ; **depending on site of obstruction

HYPOVOLEMIC SHOCK

- **It is due to decreased blood volume (i.e. blood loss as acute (sudden) hemorrhage and loss of body fluids i.e. through excessive sweating).**

- **Whatever the cause, <u>when the volume of body fluids falls</u>, <u>venous return to the heart declines</u>, <u>filling of the heart lessens</u>, <u>stroke volume decreases</u>, and <u>cardiac output decreases</u>. Replacing fluid volume as quickly as possible is essential in managing hypovolemic shock.**

CARDIOGENIC SHOCK

- ✓ **The heart fails to pump adequately, most often because of a myocardial infarction (heart attack).**

- ✓ Other causes of cardiogenic shock include poor perfusion of the heart (ischemia), heart valve problems, excessive preload or afterload, impaired contractility of heart muscle fibers, and arrhythmias.

VASCULAR SHOCK

- ✓ A variety of conditions can cause inappropriate dilation of arterioles or venules.

- ✓ In **anaphylactic shock**, a severe allergic reaction—for example, to a bee sting—releases histamine and other mediators that cause vasodilation.
- ✓ In **neurogenic shock**, vasodilation may occur following trauma to the head that causes malfunction of the cardiovascular center in the medulla.
- ✓ Shock stemming from certain bacterial toxins that produce vasodilation is termed **septic shock**.

OBSTRUCTIVE SHOCK

- ✓ **It occurs when blood flow through a portion of the circulation is blocked.**
- ✓ The most common cause is **pulmonary embolism**, a blood clot lodged in a blood vessel of the lungs.

HOMEOSTATIC RESPONSES TO SHOCK

- **The major mechanisms of compensation in shock are negative feedback systems that work to return cardiac output and arterial blood pressure to normal.**

- **Activation of the renin–angiotensin–aldosterone system:** angiotensin II causes vasoconstriction and stimulates the adrenal cortex to secrete aldosterone, a hormone that increases reabsorption of sodium ions and water by the kidneys.
- **Secretion of antidiuretic hormone:** the posterior pituitary releases more antidiuretic hormone (ADH). ADH enhances water reabsorption by the kidneys, which conserves remaining blood volume.

HOMEOSTATIC RESPONSES TO SHOCK

- **Activation of the sympathetic division of the ANS:** aortic and carotid baroreceptors initiate powerful sympathetic responses throughout the body. One result is marked vasoconstriction of arterioles and veins of the skin, kidneys, and other abdominal viscera. (Vasoconstriction does not occur in the brain or heart.) Constriction of arterioles increases systemic vascular resistance, and constriction of veins increases venous return.

- **Release of local vasodilators:** In response to hypoxia, cells liberate vasodilators—including potassium ions, hydrogen ions, lactic acid, adenosine, and nitric oxide—that dilate arterioles and relax precapillary sphincters. Such vasodilation increases local blood flow and may restore O_2 level to normal in part of the body.

HOMEOSTATIC RESPONSES TO SHOCK

- ❖ If blood volume drops more than 10–20%, or if the heart cannot bring blood pressure up sufficiently, compensatory mechanisms may fail to maintain adequate blood flow to tissues. At this point, shock becomes life-threatening as damaged cells start to die.

SIGNS AND SYMPTOMS OF SHOCK

- **Systolic blood** pressure is lower than 90 mmHg.
- **Resting heart rate is rapid** due to sympathetic stimulation and increased blood levels of epinephrine and norepinephrine.
- **Pulse is weak and rapid** due to reduced cardiac output and fast heart rate.
- **Skin is cool, pale, and clammy** due to sympathetic constriction of skin blood vessels and sympathetic stimulation of sweating.
- **Mental state is altered** due to reduced oxygen supply to the brain.
- **Urine formation is reduced** due to increased levels of aldosterone and antidiuretic hormone (ADH).
- **The person is thirsty** due to loss of extracellular fluid.
- **The pH of blood is low** (acidosis) due to buildup of lactic acid.
- **The person may have nausea** because of impaired blood flow to the digestive organs from sympathetic vasoconstriction.

THANK YOU

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