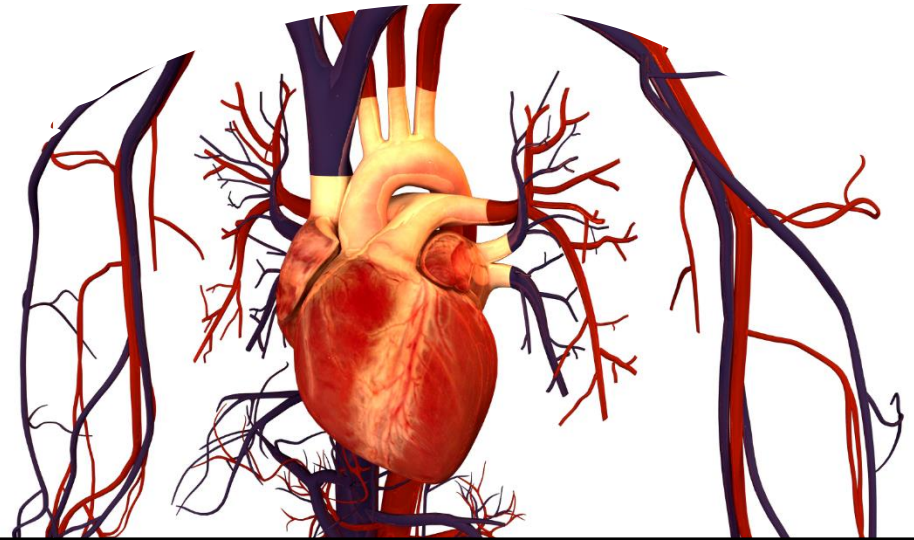
Regulations of Arterial Blood Pressure



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Regulations of Arterial Blood Pressure

Lecture Outcomes

- To recognize different regulatory mechanisms of arterial blood pressure.
- To understand baroreceptors' reflex regulatory mechanism of arterial blood pressure.
- To understand chemoreceptors' reflex regulatory mechanism of arterial blood pressure.
- To understand hormonal regulatory mechanisms of arterial blood pressure.

Regulation of Arterial Blood Pressure

- Maintaining BP is important to ensure a steady blood flow (perfusion) to the tissues.
- Inability to regulate blood pressure can contribute to diseases.

Regulation of Arterial Blood Pressure

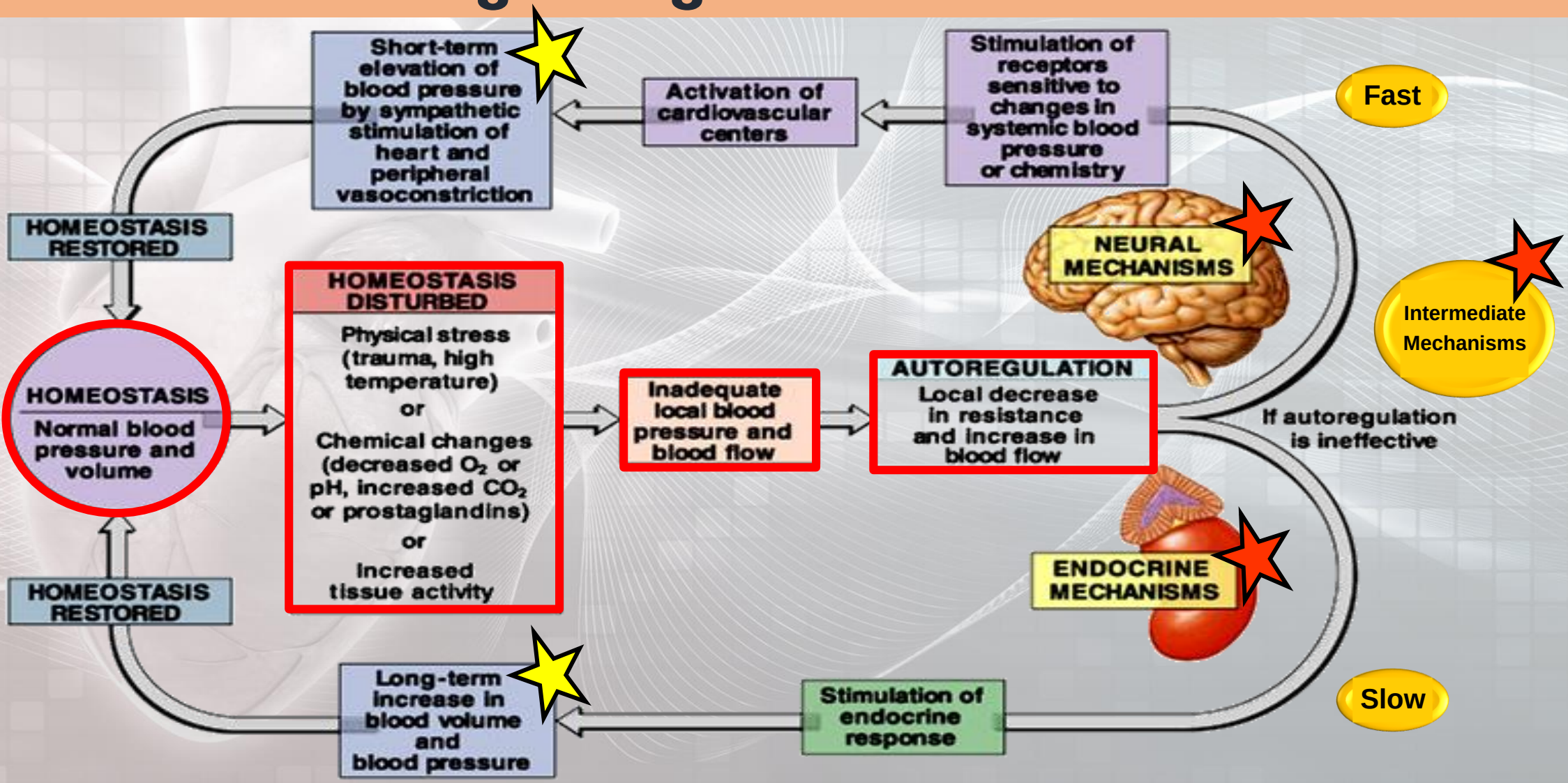
In order to regulate the blood pressure, determining factors should be regulated:

- Cardiac output (Flow.)
- Peripheral Resistance.
- Blood volume.

Blood Pressure = Cardiac Output X Peripheral Resistance

MAP CO PR

Mechanisms Regulating Mean Arterial Pressure



Neurally- Mediated Regulation of ABP

Fast Response
(Short- Term)

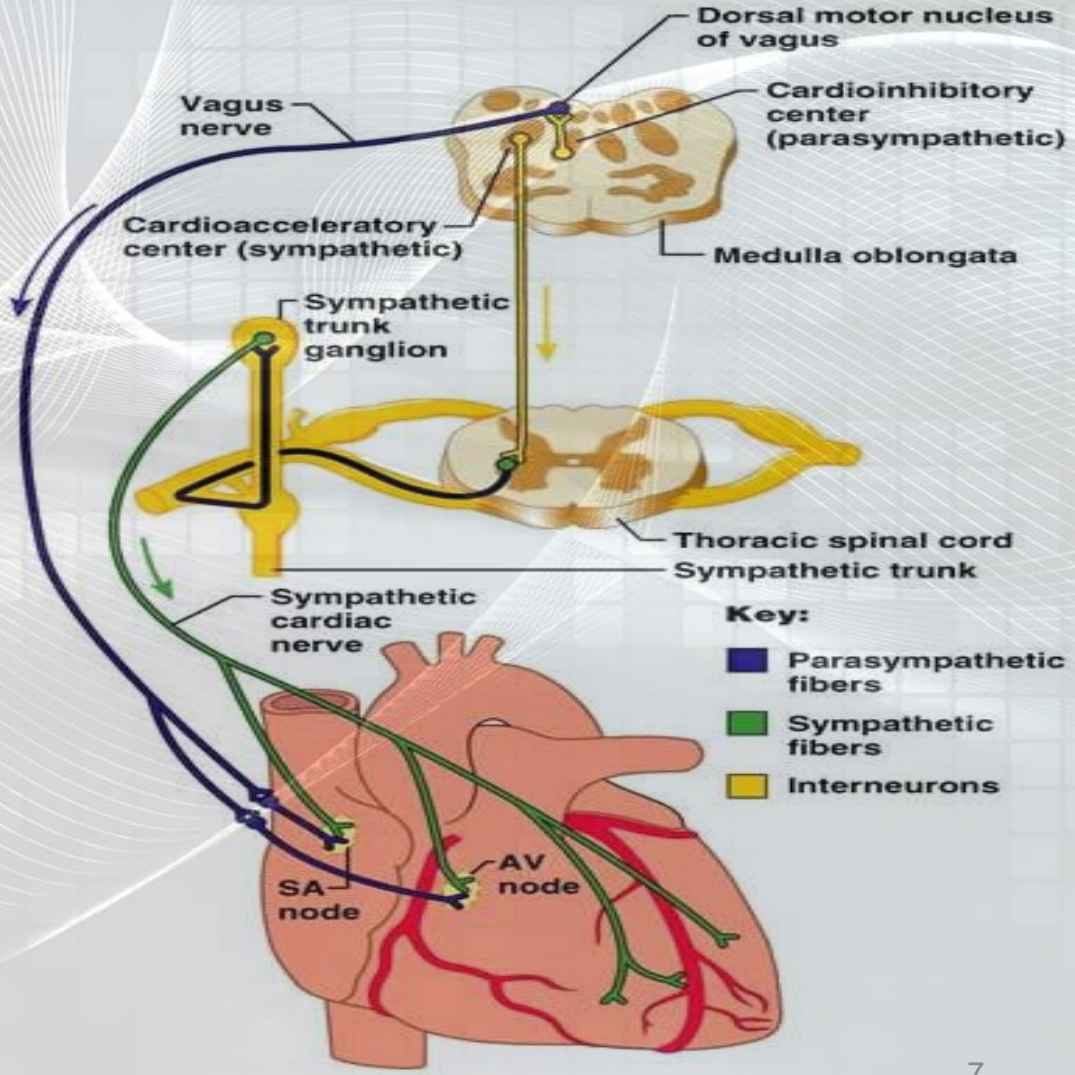
Concerned in regulating the
Cardiac Output (CO) & Peripheral Resistance (PR)

Rapidly Acting Control Mechanisms

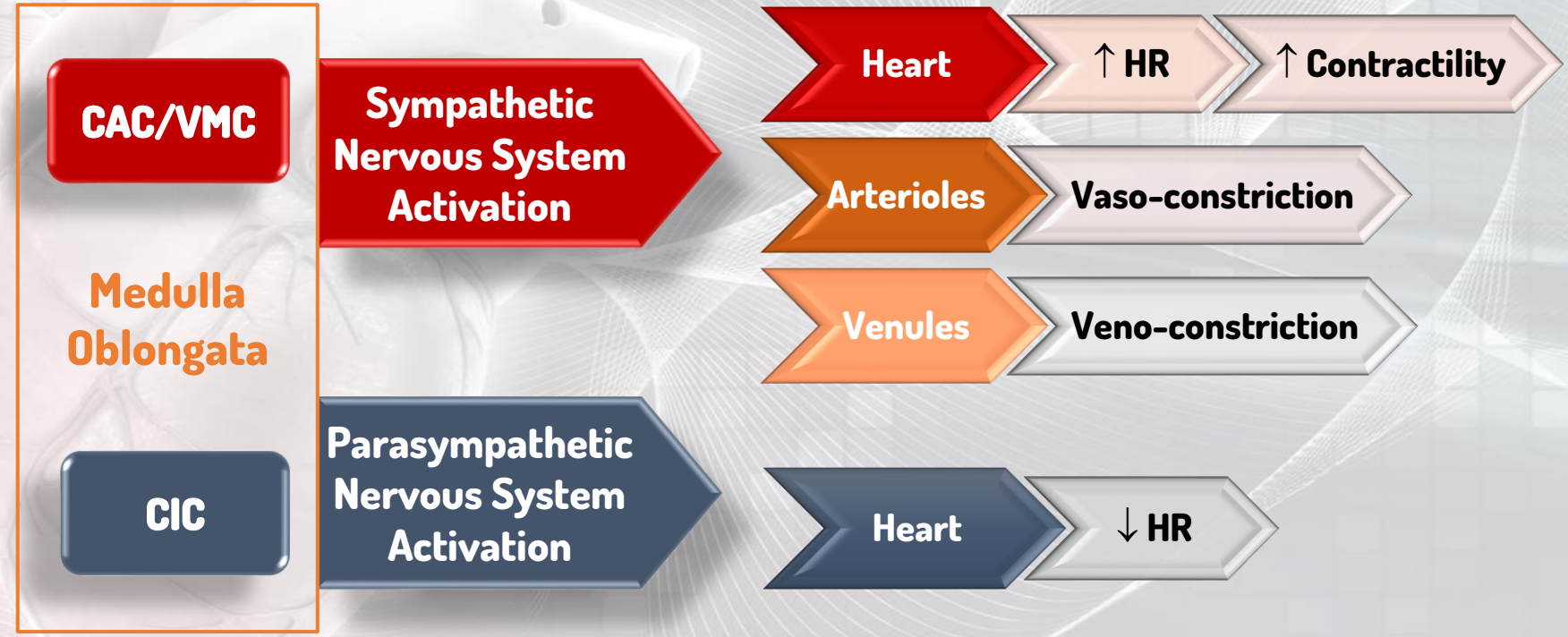
- **Acts** within sec/min.
- Concerned in **regulating** the Cardiac Output (**CO**) & the Peripheral Resistance (**PR**).
- **Reflex** mechanisms act **through** the **autonomic nervous system:**

Centers in Medulla Oblongata:

- **Cardio-Acceleratory (CAC) or Vasomotor Center (VMC)** → Sympathetic nervous system.
- **Cardio-Inhibitory Center (CIC)** → Parasympathetic nervous system.

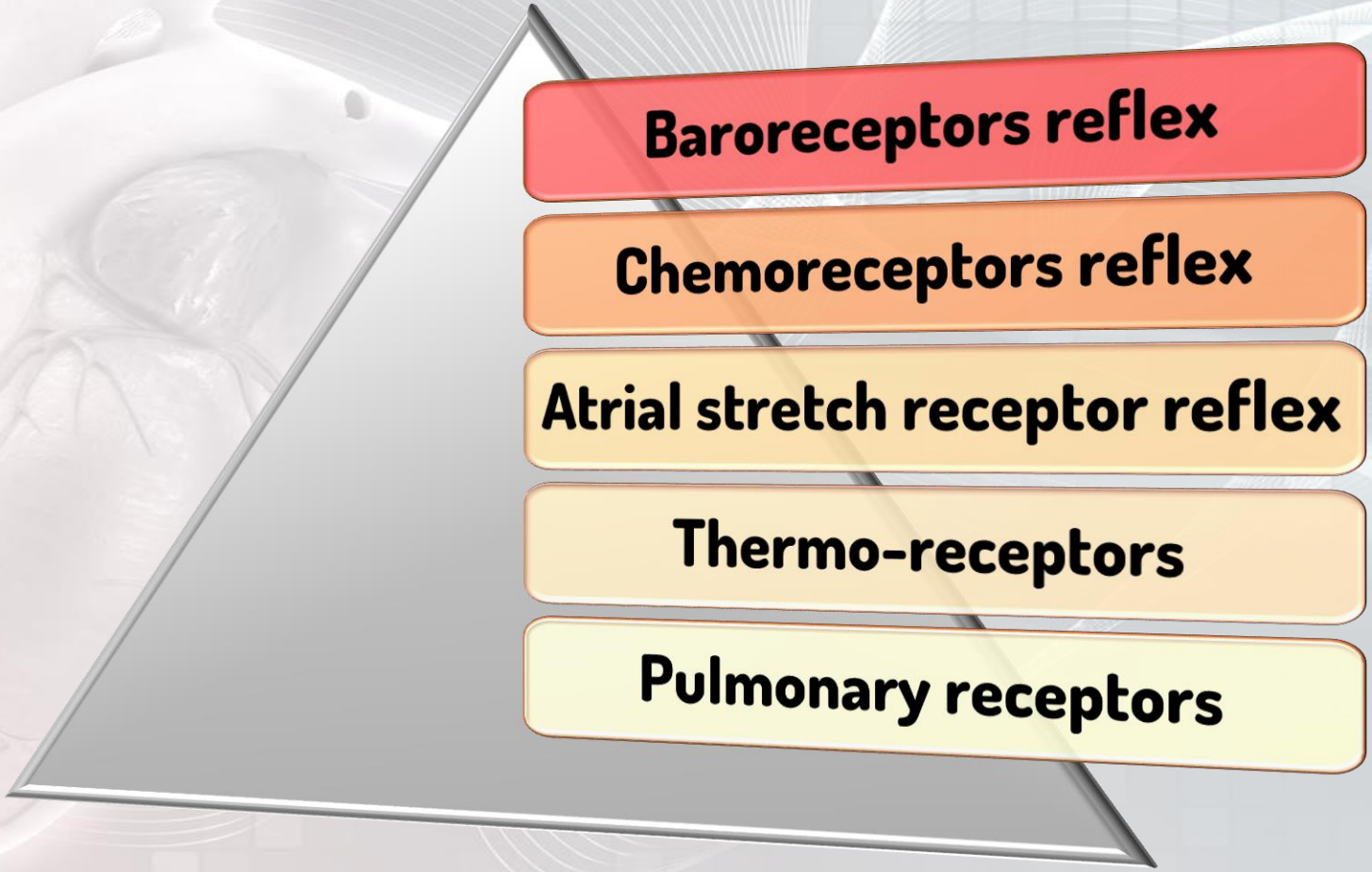


Autonomic Nervous System Stimulation



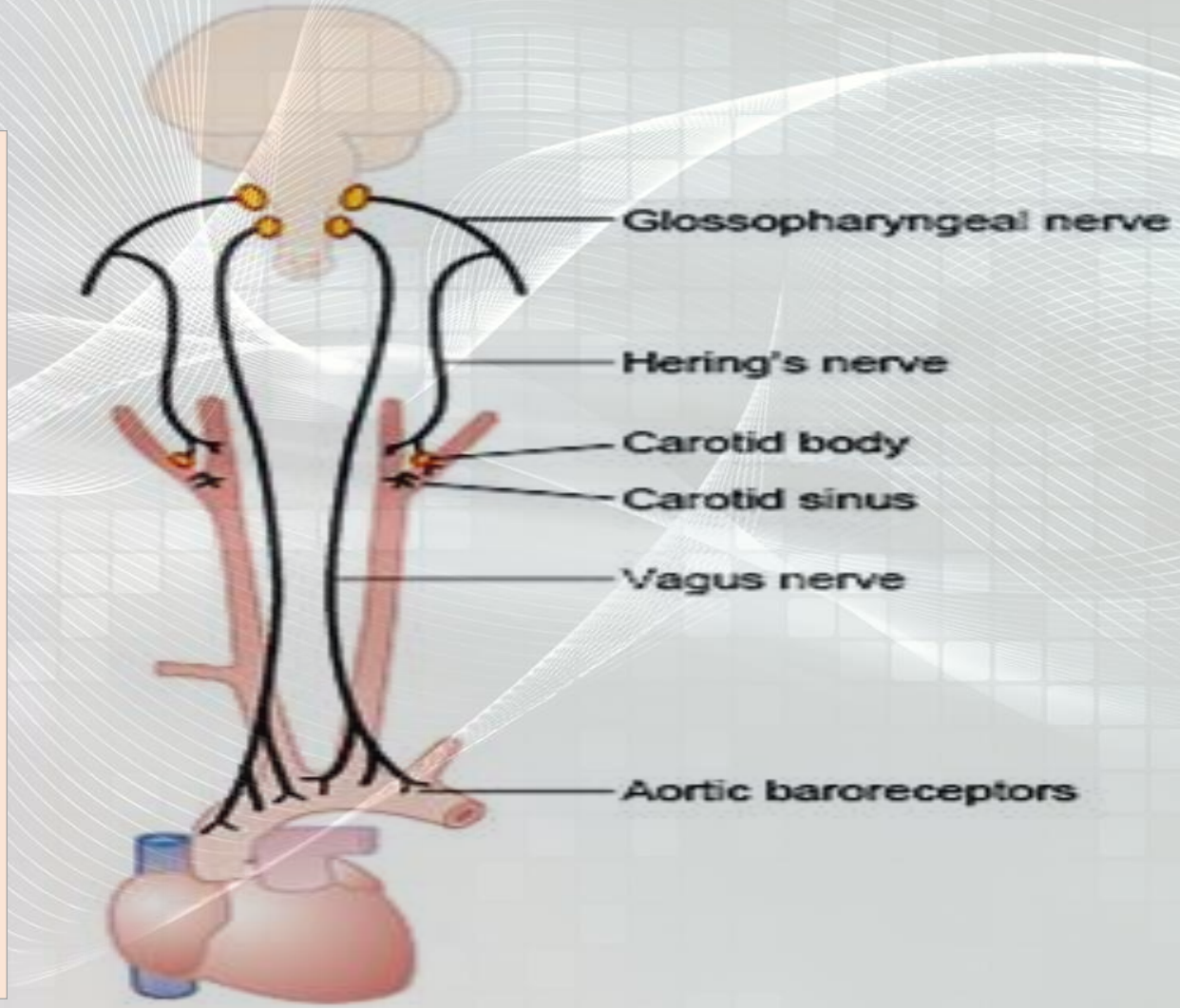
CAC= Cardioacceleratory center; VMC= Vasomotor center; CIC= Cardiac inhibitory center; HR= Heart rate.

Short Term Regulatory Reflex Mechanisms of ABP

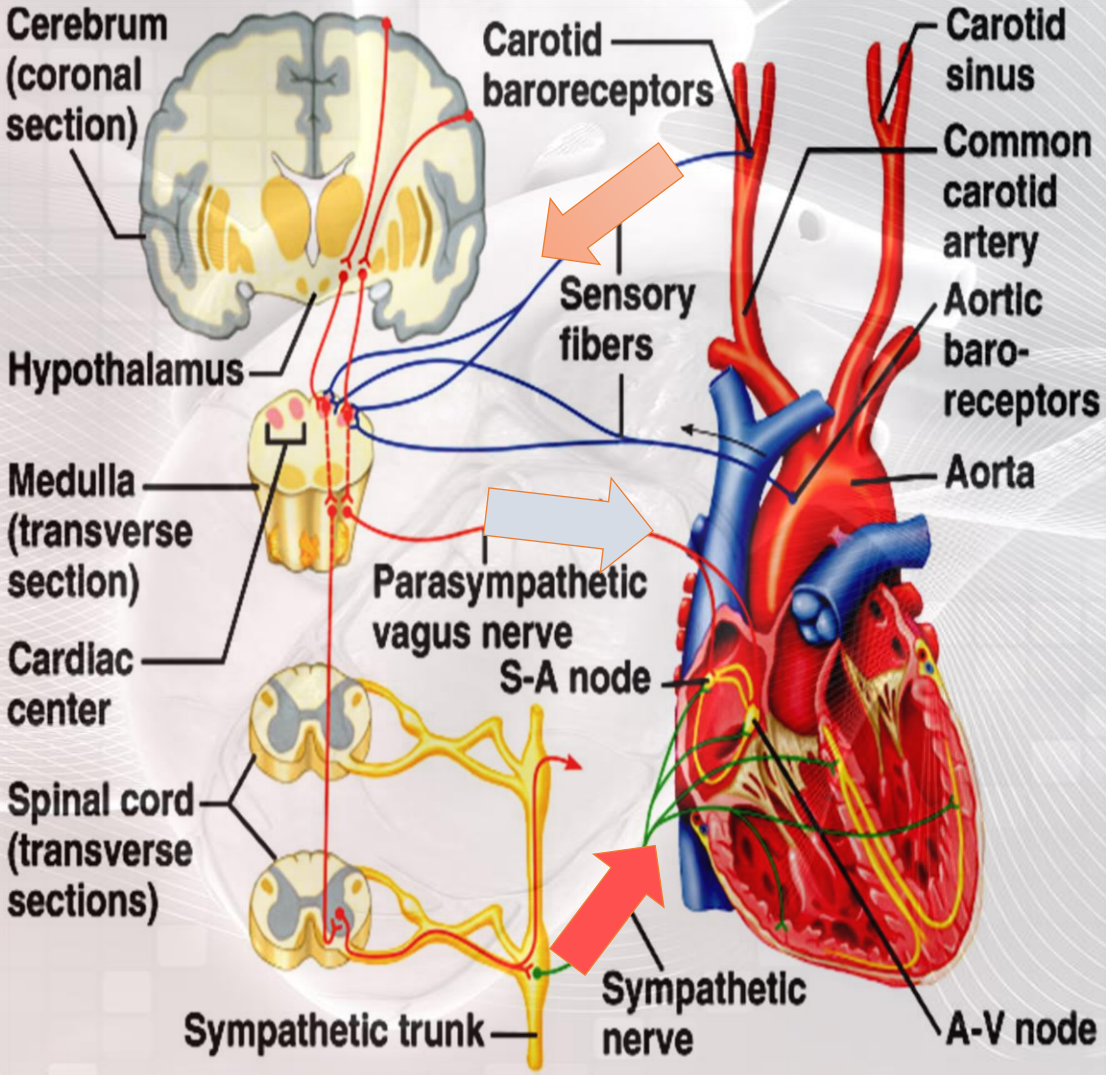


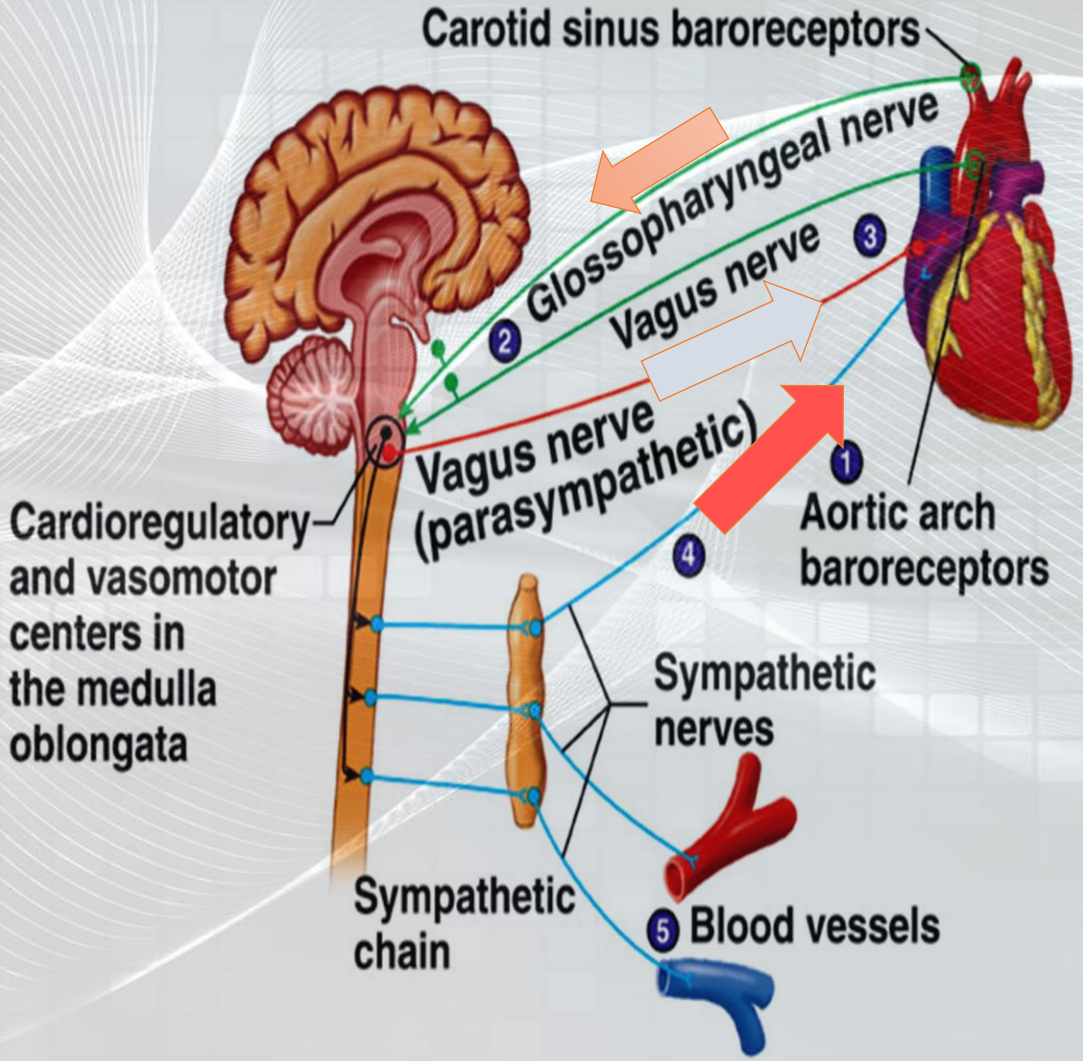
Baroreceptor Reflex

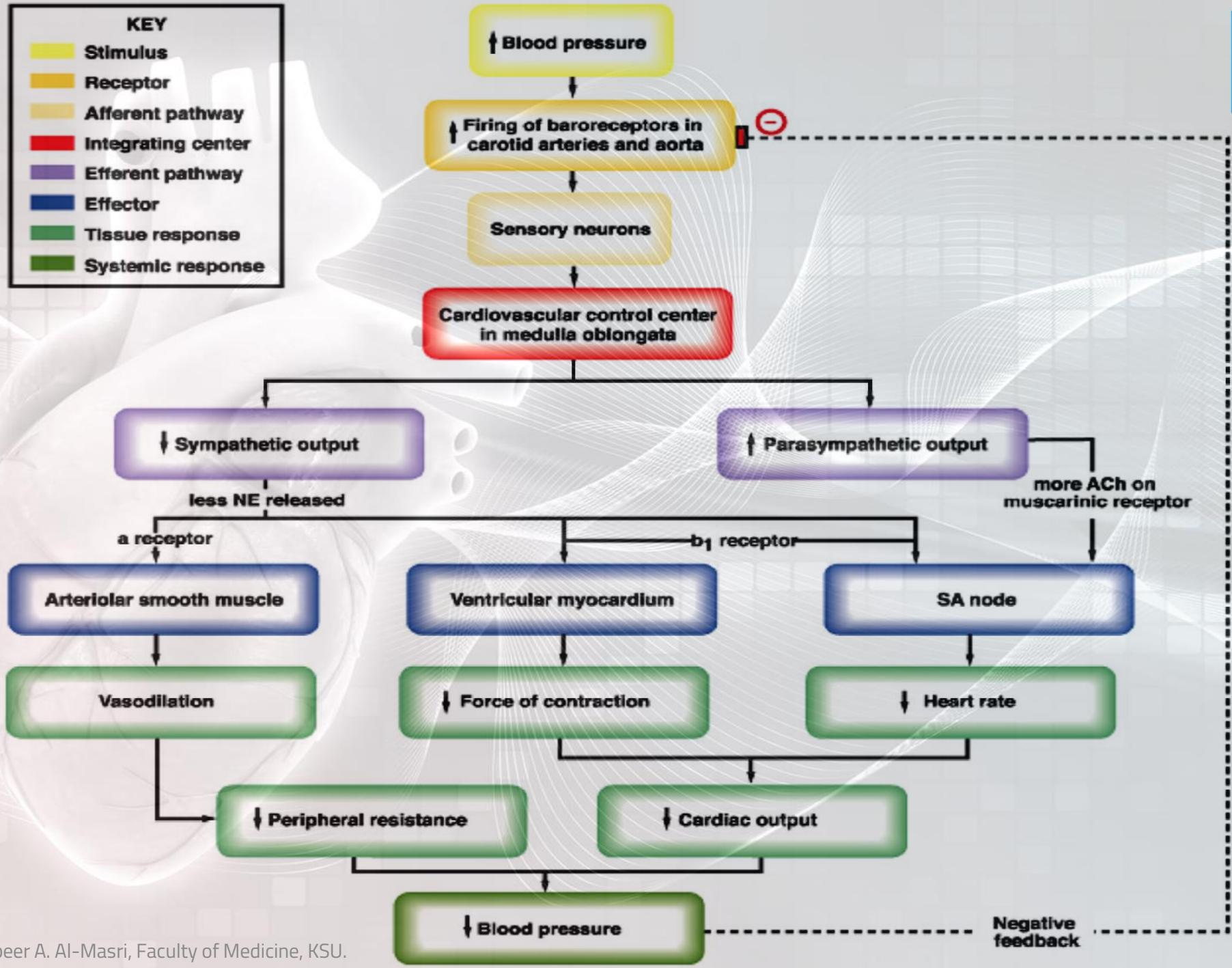
- **Baroreceptors are Mechano-stretch receptors.**
- Located in the wall of carotid sinus & aortic arch.
- **Stimulated in response to blood pressure changes.**
- **Fast** & **Neurally mediated**.
- Stimulation of Baroreceptors will send sensory signals through the Glossopharyngeal sensory nerve fibers to the required centers in Medulla Oblongata.
- **Provide powerful moment-to-moment control of arterial blood pressure.**

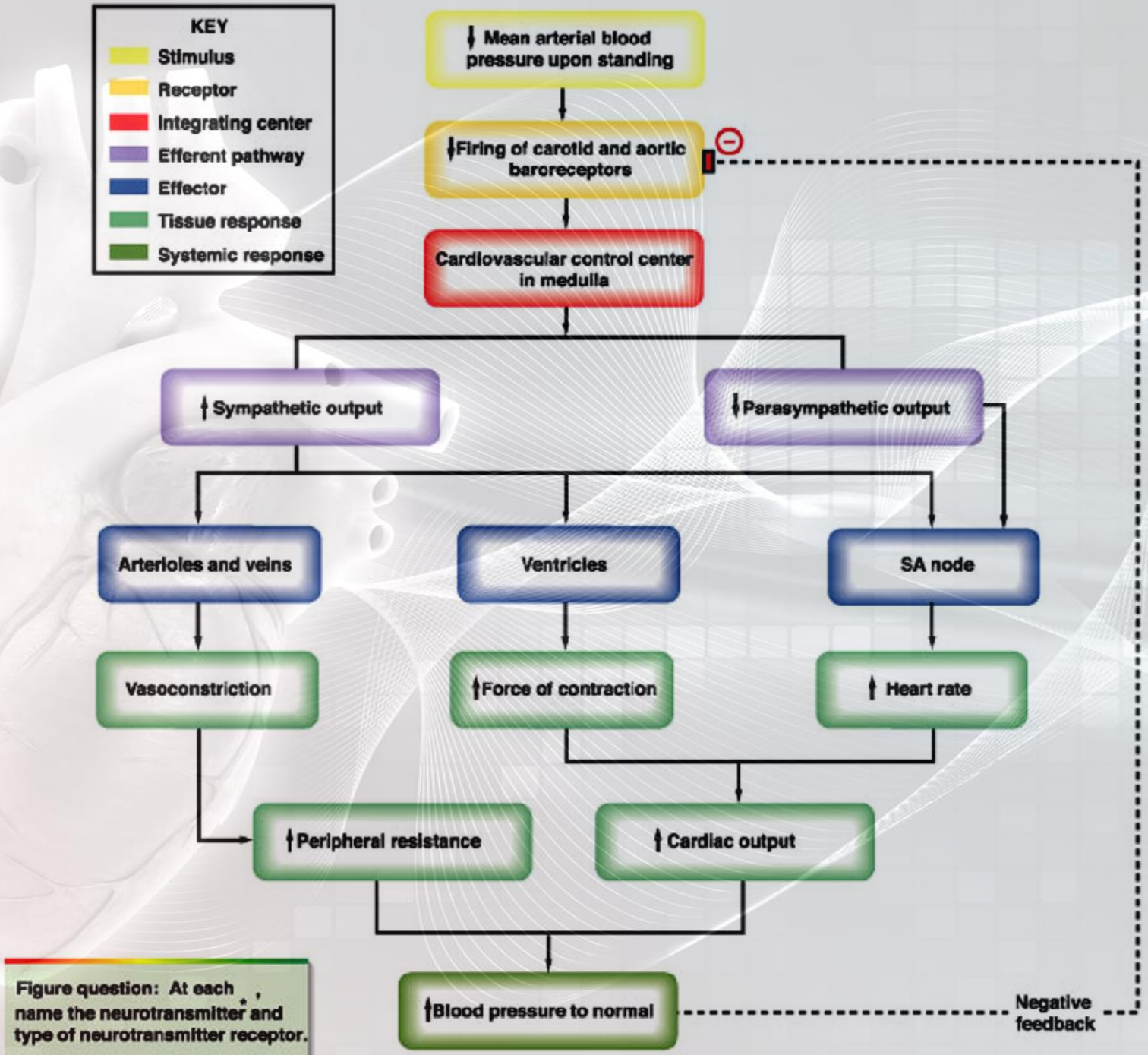


Baroreceptor Reflex






KEY
Stimulus
Receptor
Afferent pathway
Integrating center
Efferent pathway
Effector
Tissue response
Systemic response
Blood pressure
Firing of baroreceptors in carotid arteries and aorta
Sensory neurons
Cardiovascular control center in medulla oblongata
Sympathetic output
Parasympathetic output
less NE released
more ACh on muscarinic receptor
a receptor
b1 receptor
Arteriolar smooth muscle
Ventricular myocardium
SA node
Vasodilation
Force of contraction
Heart rate
Peripheral resistance
Cardiac output
Blood pressure
Negative feedback


KEY
Stimulus
Receptor
Integrating center
Efferent pathway
Effector
Tissue response
Systemic response
Mean arterial blood pressure upon standing
Firing of carotid and aortic baroreceptors
Cardiovascular control center in medulla
Sympathetic output
Parasympathetic output
Arterioles and veins
Ventricles
SA node
Vasoconstriction
Force of contraction
Heart rate
Peripheral resistance
Cardiac output
Blood pressure to normal
Negative feedback
Figure question: At each , name the neurotransmitter and type of neurotransmitter receptor.

Baroreceptor Reflex Mechanism During Changes in Body Posture

- **On immediate standing**, Arterial Pressure in the head & upper parts of the body tends to fall, which may cause loss of consciousness.
- Falling pressure will elicit an **immediate reflex** at the **Baroreceptors**, resulting in **strong sympathetic discharge** throughout the body.
- This immediate reflex mechanism minimizes the drop in the arterial pressure that occured in the head & upper parts of the body.

Chemoreceptor Reflex

- **Chemoreceptors** are closely associated with the Baroreceptors' control pressure system.
- **Chemoreceptor reflex** operates in much same way as the Baroreceptor reflex, **EXCEPT** that chemoreceptors are ***chemo-sensitive cells*** instead of stretch receptors.
- Reduced blood flow (due to reduced Mean Arterial Pressure- **MAP**) will stimulate the **chemoreceptors** through,
  - **Oxygen lack** ($\downarrow[O_2]$), Increased **Hydrogen ions** ($\uparrow[H^+]$), &/or Increased Carbon dioxide ($\uparrow[CO_2]$).
- Their response is **excitatory**, NOT inhibitory; mainly through activation of sympathetic nervous system.
- There are **two types** of chemoreceptors.

Chemoreceptor Reflexes:
Two Types

Peripheal

Peripheral chemoreceptors:

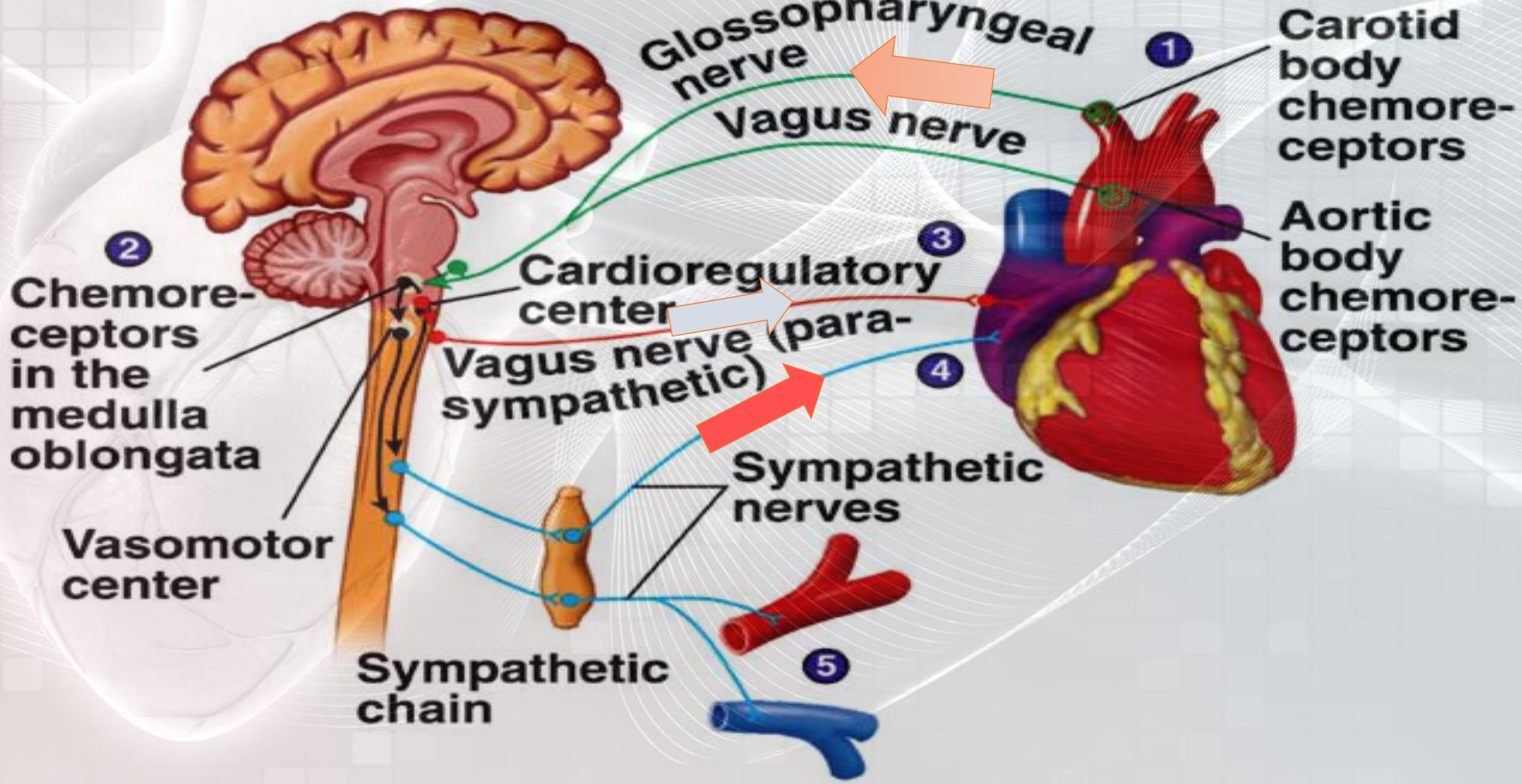
- Sensory receptors located in carotid & aortic bodies.
- Sensitive to **O_2** lack (↓), **CO_2** changes (↑ or ↓), & **pH** changes (↓ or ↑.)
- Their stimulation will excite the sensory nerve fibers, along with the Baroreceptor excitatory fibers.
- They are stimulated when the **MAP** is **lower than 60 mmHg**.

Central

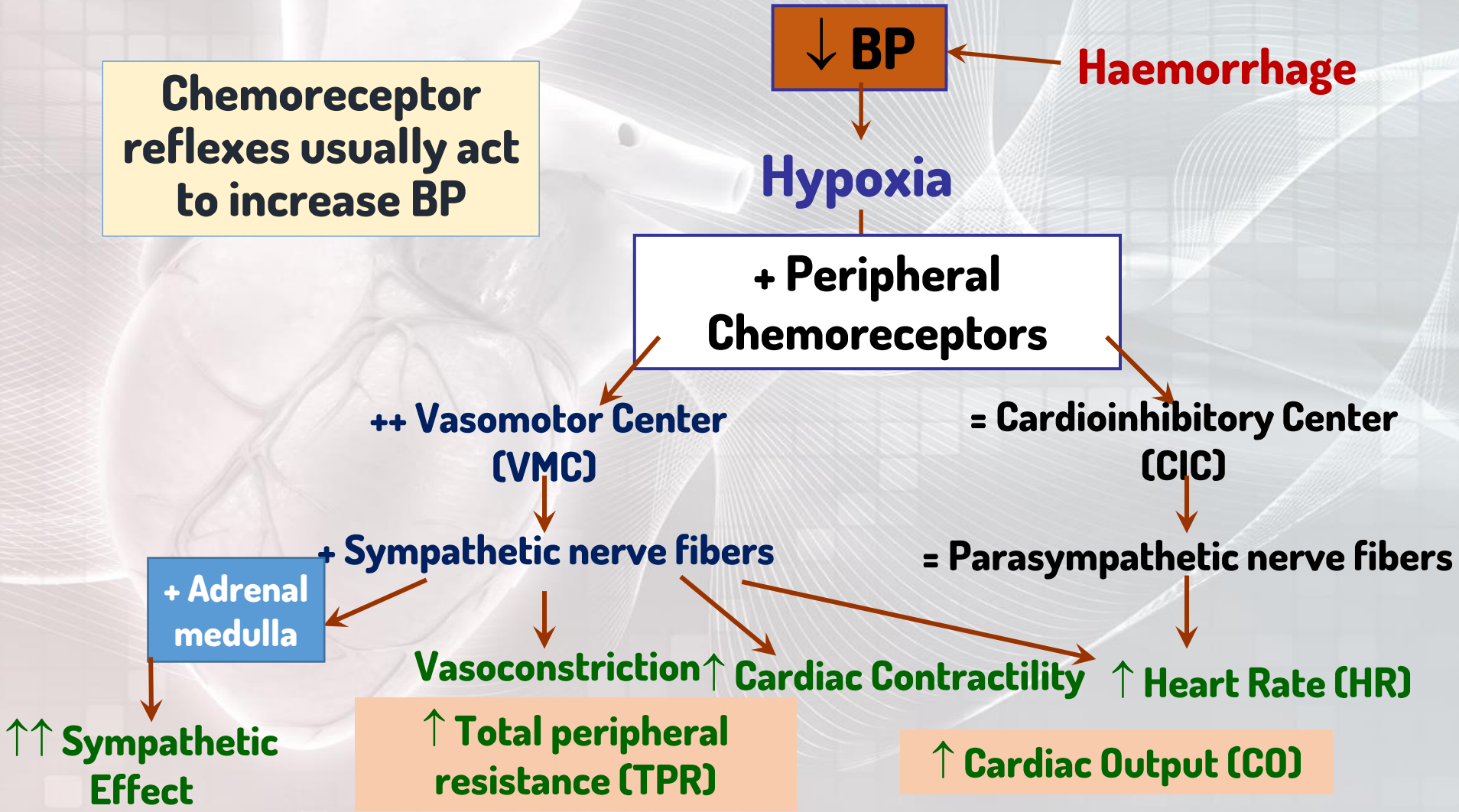
Central Chemoreceptors:

- Sensory receptors located in the medulla itself.
- Very sensitive to **CO_2** excess (↑) & drop (↓) in **pH** in the medulla.
- They are stimulated when the **MAP** is **lower than 20 mmHg** with high accumulation of local CO_2 & lactic acid.

Peripheral Chemoreceptor Reflex

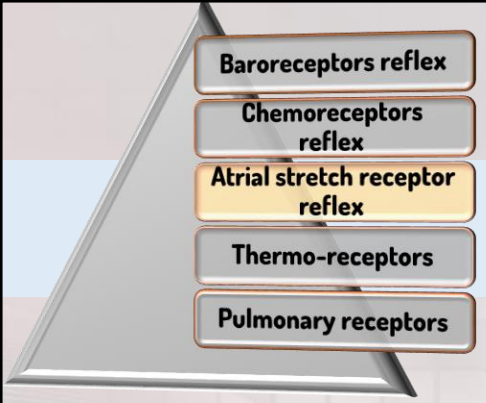


Peripheral Chemoreceptor Reflexes



CNS Ischemic Response:
"Last ditch stand" pressure control mechanism

- It is not one of the normal regulatory mechanisms of ABP. It operates principally as an **Emergency Pressure Control** system to prevent further decrease in arterial blood pressure.
- It's one of the most powerful activators of the sympathetic vasomotor (vasoconstrictor system) nervous control areas in medulla oblongata.
- It acts **rapidly** & **very powerfully**.
- It acts whenever blood flow to the brain ↓ dangerously close to the lethal level (Mean arterial pressure (**MAP**) **< 20 mmHg** with high accumulation of local **CO_2** & **lactic acid**), in order to prevent further drop in the MAP.



Other Vasomotor Reflexes

1. Atrial stretch receptor reflex:

- **Receptors in large veins close to heart, walls of the atria (response of blood volume).**

Increase Venous Return (due to ↑ blood volume) ⇒ ++ stretch atria & activate atrial stretch receptors ⇒ sensory afferent nerves to medulla ⇒ **inhibiting sympathetic cardiovascular center** ⇒ **reflex vasodilation**

More Inhibition of Renin & Anti diuretic hormone (ADH) secretion, leads to **reflex increase urine excretion** to decrease blood volume towards normal & ↓ ABP through:

(a) ↓ **Sympathetic drive to kidney: Reflex vasodilatation**

- → Dilate afferent arterioles → ↑ Glomerular capillary hydrostatic pressure →↑ glomerular filtration rate (GFR) → ↓ blood volume (towards normal).
- ↓ Renin secretion (Renin activates Angiotensinogen in blood) → Inhibition of RAAS → inhibit Aldosterone production → ↓ Na+ & water retention & ↓ Blood volume (towards normal).

(b) ↓ **ADH secretion** → ↓ water retention & ↓ Blood volume (towards normal).

(c) ↑ **Atrial Natriuretic Peptide (ANP)** causes loss of blood volume.

Other Vasomotor Reflexes

2. Thermo-receptors: (in skin / hypothalamus)

- Exposure to heat ⇒ vasodilatation.
- Exposure to cold ⇒ vasoconstriction.

3. Pulmonary receptors:

Lung inflation ⇒ vasoconstriction.

Hormonally- Mediated Regulation of ABP

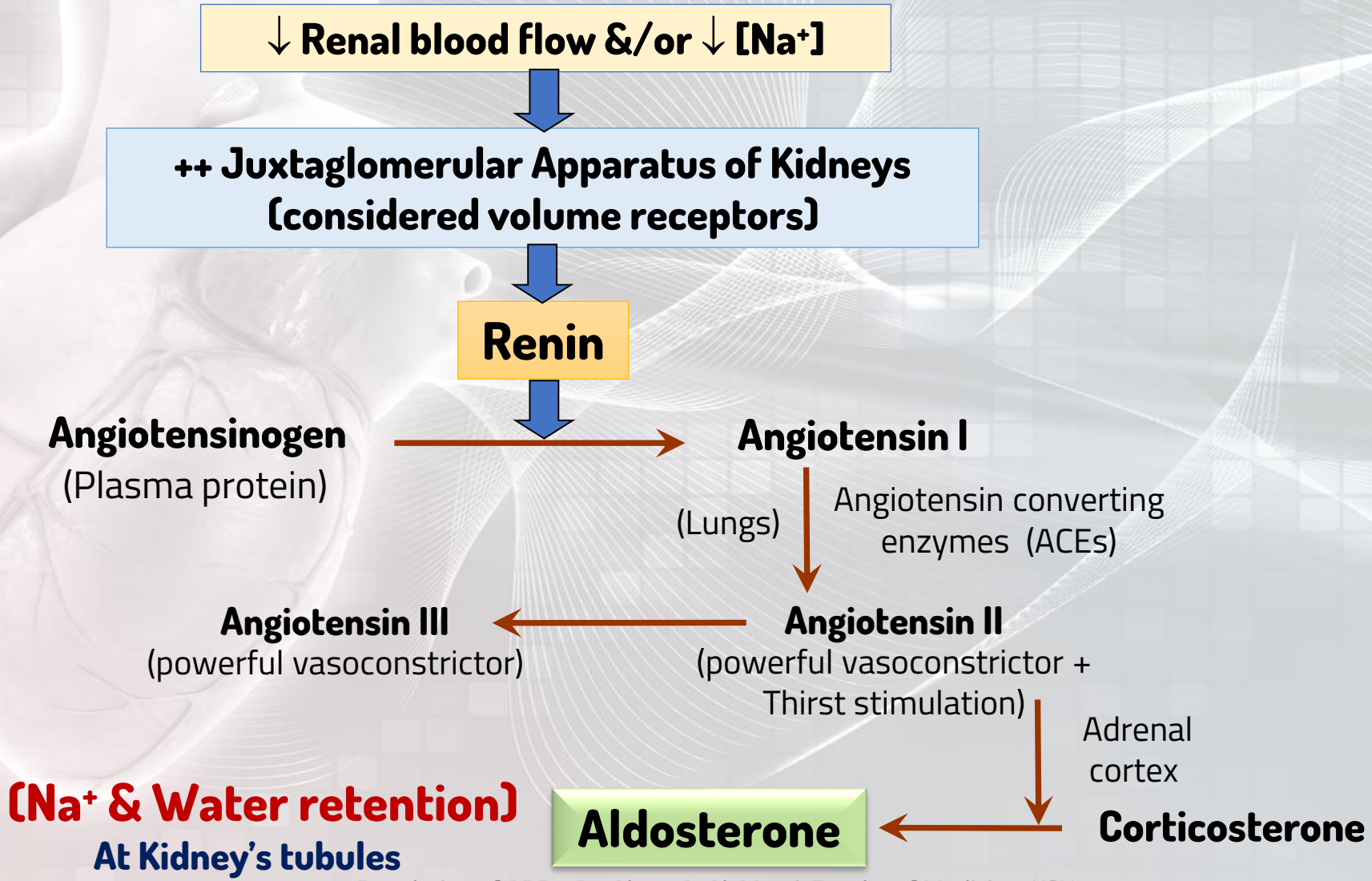
Slow Response
(Long- Term)

Concerned in regulating the Blood Volume

Long- Term Regulation of ABP

- **Hormonally mediated**.
- Takes **few hours** to begin showing significant response.
- **Mainly renal:** Acts if BP is too low.
  1. Renin-Angiotensin-Aldosterone System.
  2. Vasopressin [Anti-diuretic hormone (ADH)] Mechanism.
- **Others:**
  3. Atrial Natriuretic Peptide Mechanism (Low-pressure volume receptors.)
  4. Erythropoietin (EPO).

1. Renin – Angiotensin Aldosterone System



2. Anti-Diuretic Hormone (ADH), or Vasopressin

- Hypovolemia & dehydration stimulates Hypothalamic Osmoreceptors.
- **ADH** will be released from posterior Pituitary gland:
  - Promotes **Water reabsorption** at kidney tubules to ↑ blood volume.
  - Causes **Vasoconstriction**, in order to ↑ arterial blood pressure (ABP).
- Thirst stimulation.
- Usually, when secreted Aldosterone is secreted.

3. Low-pressure volume receptors:

- **Atrial Natriuretic Peptide (ANP) hormone:**
  - ANP is hormone released from the cardiac muscle cells (wall of Right Atrium) **as a response to an increase in ABP** in order to decrease the blood volume.
  - Simulates an ↑ in urinary production, causing a ↓ in blood volume & blood pressure.

4. Erythropoietin (EPO)

- **EPO** is a hormone secreted by the **kidneys** when the **blood volume** is **too low**.
- Acts on the bone marrow & leads to formation of Red blood cells (**RBCs**) → to ↑ the blood volume.

Intermediate Mechanisms Regulating ABP

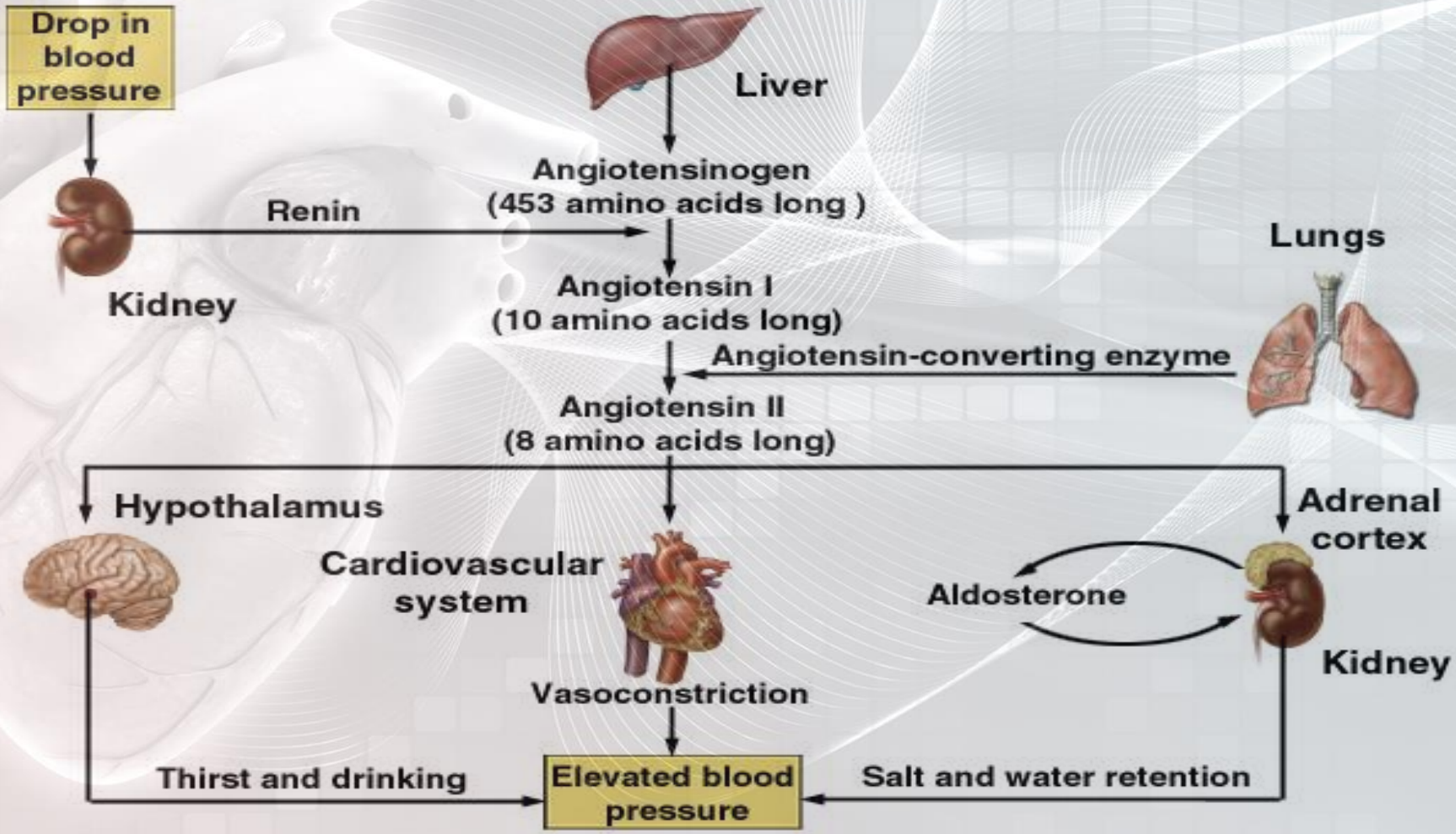
Intermediate Mechanisms:

Activated within 30 min to several hrs.

1. Angiotensin vasoconstriction mechanism.
2. ADH vasoconstriction mechanism.
3. Fluid-Shift mechanism.
4. Stress-relaxation of the vasculature.

- **During this time, the nervous mechanisms usually become less & less effective.**

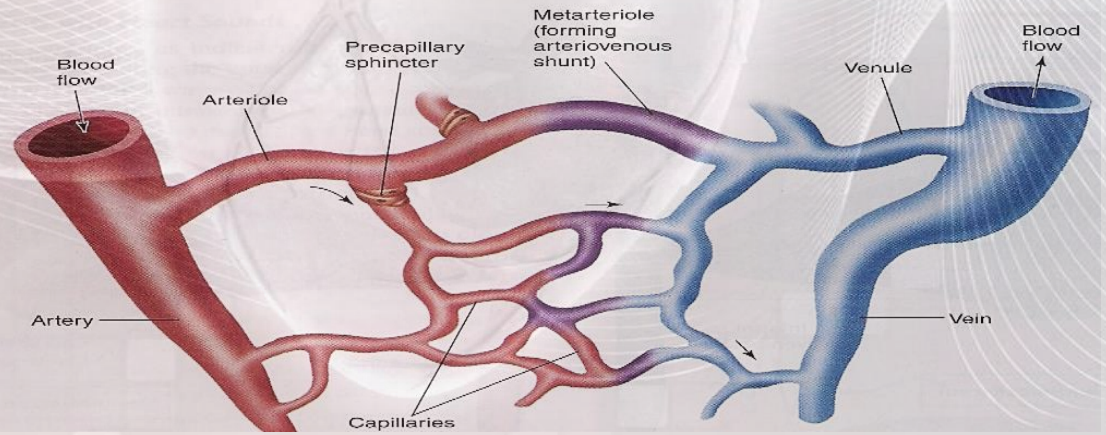
1. Angiotensin Vasoconstriction System

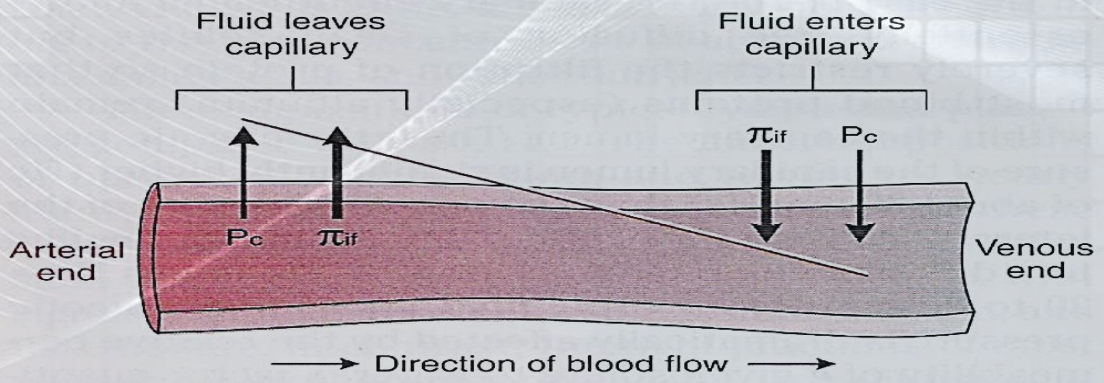


2. ADH Vasoconstriction System

3. Fluid Shift Mechanism

- Movement of fluid from interstitial spaces into **capillaries** in response to ↓ **BP** to maintain blood volume.
- Conversely, when **capillary pressure** ↑ **too high**, fluid is lost out of circulation into the tissues, reducing blood volume as well as all pressures throughout circulation.





4. Stress-Relaxation Mechanism

- **Adjustment of blood vessel smooth muscle to respond to changes in blood volume.**
- When pressure in blood vessels becomes **too high**, blood vessels become stretched & keep on stretching more & more for minutes or hours; resulting in fall of pressure in the vessels toward normal.
- This continuing stretch of the blood vessels can serve as an intermediate-term pressure "buffer."


Thank You