HOMEOSTASIS

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Hyman physiology lab

First Semester

Week 2

Date: 15/10/2025

Outline

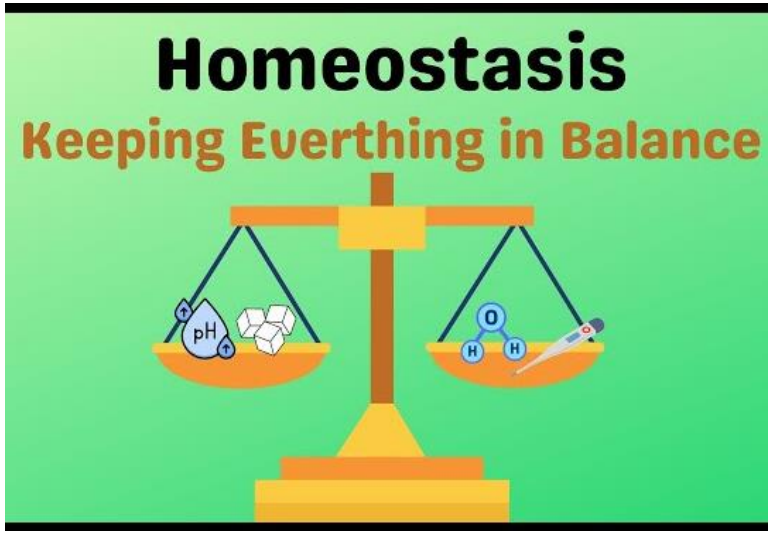
- Homeostasis
- pH homeostasis
- Blood pressure Homeostasis
- Practical od blood pressure and Heart rate Homeostasis

Objectives

- Familiarize students with terms of Homeostasis
- Understudying the roles of chemical buffers
- Understanding the roles of systematic buffers
- Understanding sympathetic and parasympathetic nerve control

Homeostasis

Homeostasis is a fundamental biological concept that refers to the ability of an organism or a system to maintain internal stability and balance in response to changes in the external environment. It involves a series of regulatory mechanisms and processes that work together to keep various physiological variables within a relatively narrow range, ensuring that the organism's internal conditions remain optimal for its functioning.



Homeostasis

Factors homeostatically regulated include

- Concentration of nutrient molecules
- Concentration of O_2 and CO_2
- Concentration of waste products
- pH
- Concentration of water, salt, and other electrolytes
- Volume and pressure
- Temperature

Blood pressure

Blood glucose

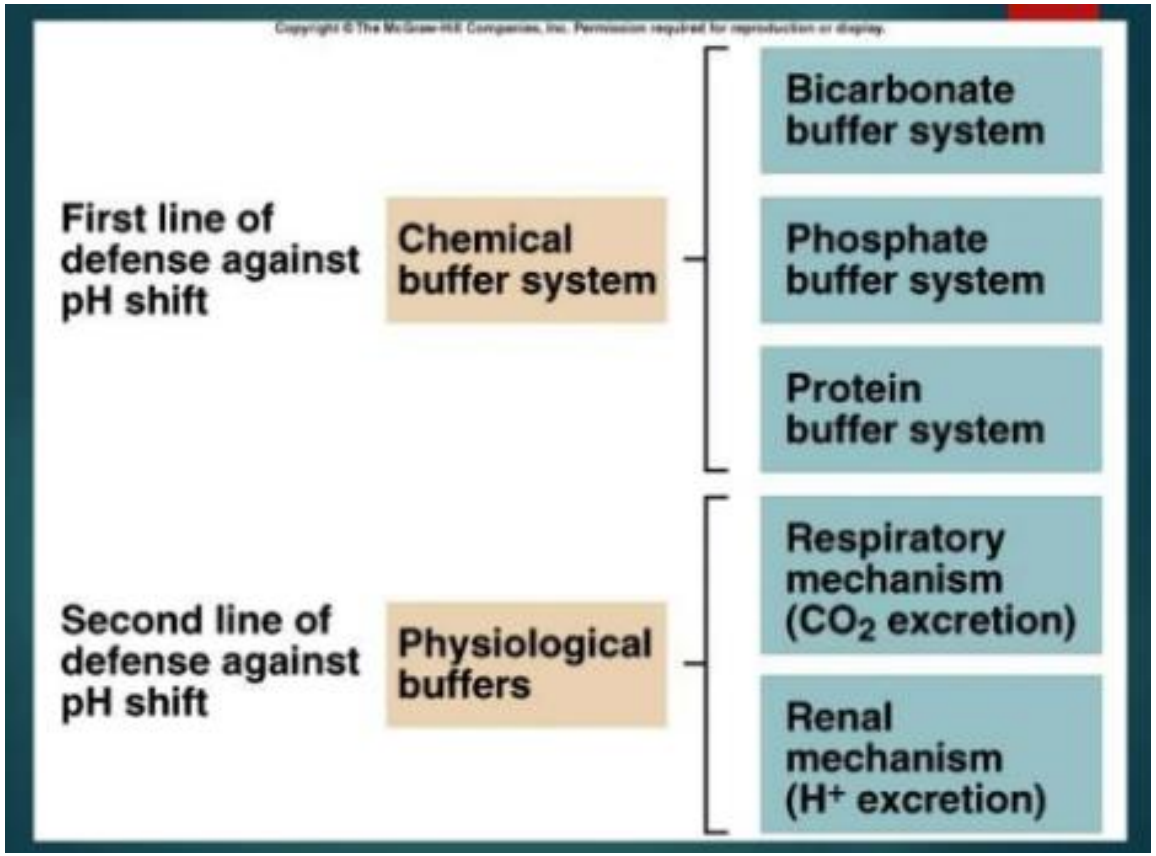
Heart rate

pH Homeostasis

- **Acid–base homeostasis (ABB)** is the **homeostatic** regulation of the **pH** of the body's extracellular fluid pH reflects the overall H^+ concentration in body fluids. Increasing the number of H^+ in the blood will lower pH (more acidic); while decreasing the number of H^+ will increase pH (more alkaline).

- The pH of the extracellular fluid, including the blood plasma, is normally tightly regulated between **7.35** and **7.45** by the **chemical buffers**, the **respiratory system**, and the **renal system**

- **To maintain ABB**, any excess acids or bases that are either consumed or produced by the body must be excreted by the lungs or kidneys or by chemical buffers. This keeps systemic pH stable & preserves the body's buffers



Physiological and chemical buffers of the body function together in maintaining acid–base balance.

1- A chemical buffer is a substance that binds H^+ and removes it from solution as its concentration begins to rise, or releases H^+ into solution as its concentration falls. Chemical buffers can restore normal pH within a fraction of a second.

- Buffers are the body's first line of defense against pH fluctuations. They act quickly to neutralize excess acids or bases, preventing significant changes in pH.

1. **The Bicarbonate Buffer System**
2. **The Phosphate Buffer System**
3. **The Protein Buffer System** Proteins (including hemoglobin in red blood cells and plasma proteins) contain amino acids that can accept or donate hydrogen ions.

The Bicarbonate Buffer System

- The bicarbonate buffer system is a solution of **carbonic acid** and **bicarbonate ions**.
- As we can see in the carbonic acid reaction, carbonic acid (H_2CO_3) forms by the reaction of carbon dioxide with water, then dissociates into bicarbonate (HCO_3–) and H^+:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+.$$

- **This is a reversible reaction.** When it proceeds to the right, carbonic acid acts as a weak acid by releasing H^+ and lowering pH.
- When the reaction proceeds to the left, bicarbonate acts as a weak base by binding H^+, removing the ions from solution, and raising pH.

The Phosphate Buffer System

$$H_2PO_4^- \leftrightharpoons H^+ + HPO_4^{2-}$$

- When the pH drops (acidic), HPO_4^{2-} binds excess H^+.

  When the pH rises (basic), $H_2PO_4^-$ releases H^+.

2- Physiological buffer system—namely**, the respiratory or urinary system**—that stabilizes pH by controlling the body's output of acids, bases, or CO_2.

- Of all buffer systems, **the urinary system** buffers the **greatest** quantity of acid or base, but it requires several hours to days to exert an effect. The respiratory system exerts an effect within a few minutes but cannot alter the pH as much as the urinary system can.

- **The respiratory mechanism**: The lungs regulate pH by controlling the concentration of CO_2 (acidic gas) in the blood: Chemoreceptors in the brain sense pH changes and **vary the rate and depth of respirations to regulate CO_2 levels**.
- Changes in ventilation serve to produce a change in PCO_2 within minutes.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+.$$

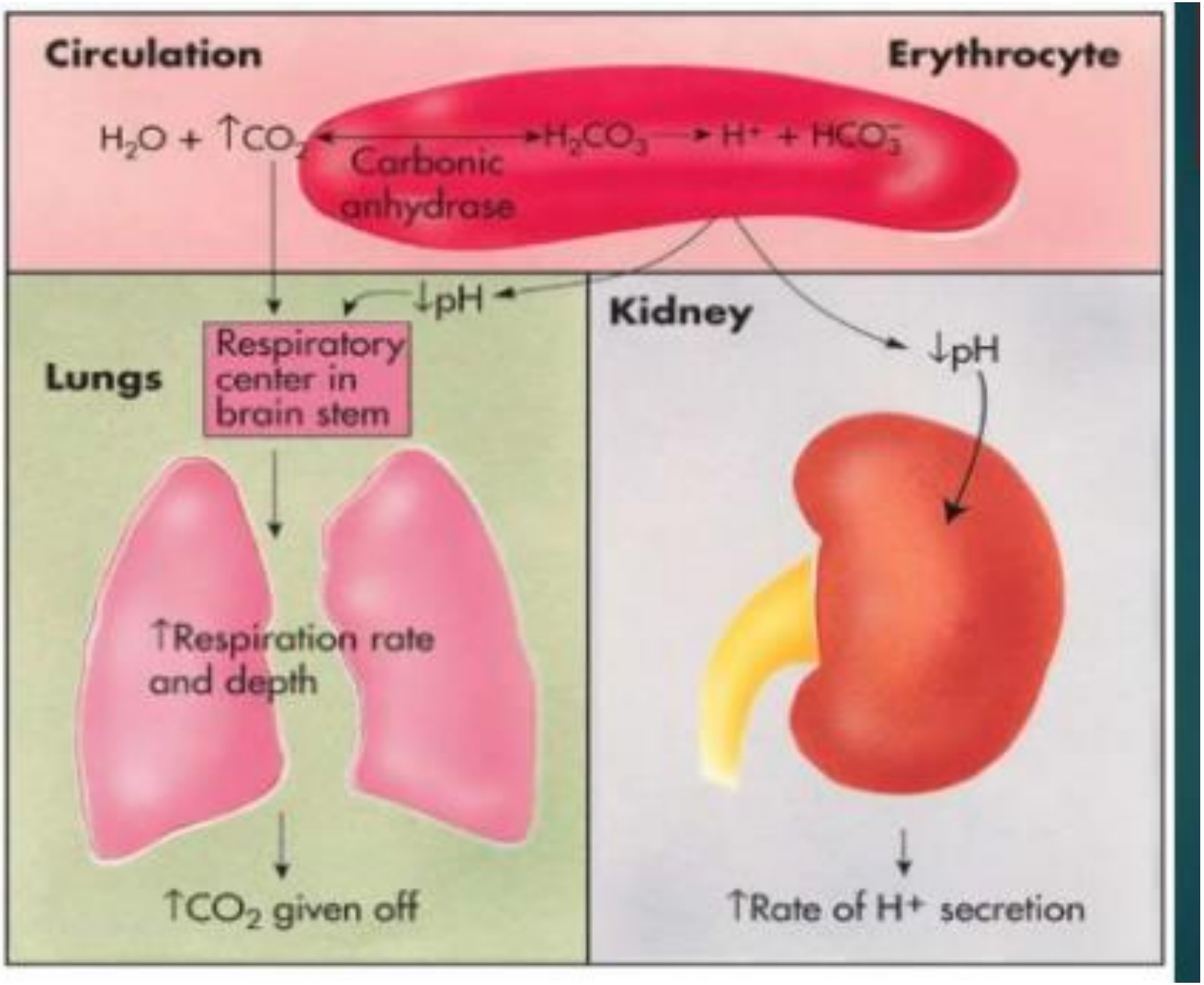
- Increased ventilation: Faster, deeper breathing eliminates
- Decreased ventilation: Slower, shallower breathing
- If pH drops (acidic) → the brain increases breathing → hyperventilation removes CO_2, less H_2CO_3 is formed→ pH rises back to normal.
- If pH rises (basic) → breathing slows slightly → hypoventilation retains CO_2 → pH drops back to normal.

The partial pressure of arterial CO_2 (PCO_2) reflects the level of CO_2 in the blood.

Breathing Type	Role in Homeostasis	If Prolonged → Disorder	Common Causes
Mild hypoventilation	Raises CO_2 to restore pH	Respiratory acidosis	- Airway obstruction (e.g., asthma, COPD)- - Lung disease - Drug overdose (depresses breathing center) - Chest muscle weakness
Mild hyperventilation	Lowers CO_2 to restore pH	Respiratory alkalosis	- Anxiety, fear (rapid breathing) - High altitude - Fever - Certain brainstem injuries

Renal (Kidney) Regulation of pH

- The kidneys are responsible for long-term regulation of pH through:
- **Excretion or retention of hydrogen ions (H^+):**
  - If the blood is too acidic, the kidneys excrete excess H^+ into the urine, while reabsorbing bicarbonate (HCO_3^-) back into the blood to neutralize the acid.
  - If the blood is too alkaline, the kidneys retain H^+ and excrete more bicarbonate.
- **Bicarbonate (HCO_3^-) management:**
  - The kidneys can produce new bicarbonate ions and release them into the blood to neutralize excess acid.
  - They can also excrete bicarbonate into the urine when the blood is too alkaline.
- The renal system works more slowly than the buffer systems and respiratory compensation, but it plays a crucial role in maintaining the body's long-term acid-base balance.


Circulation
Erythrocyte
$H_2O + \uparrow CO_2$
Carbonic anhydrase
H_2CO_3
$H^+ + HCO_3^-$
↓pH
Lungs
Respiratory center in brain stem
↑Respiration rate and depth
↑CO_2 given off
Kidney
↓pH
↑Rate of H^+ secretion

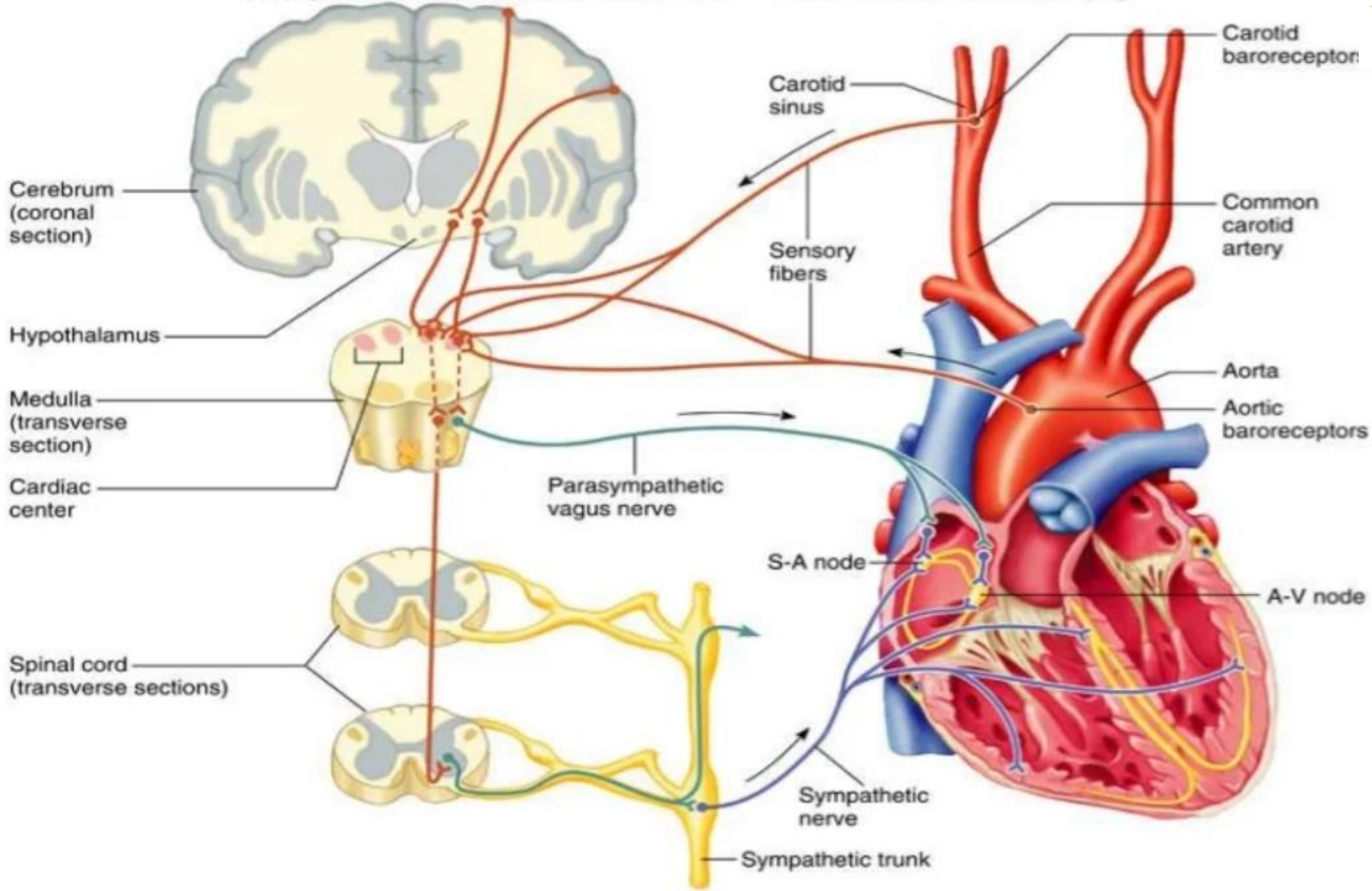
Heart Pulse Rate Homeostasis

- **Pulse rate is remained in steady state as part of Blood pressure Homeostasis**
- **Baroreceptors in Aortic arch and Carotid sinus determine change in Blood pressure**

  The cardiac rate (or pulse rate) is largely determined by the antagonistic effects of two different nerves.

- ***Sympathetic nerve*** stimulates an increase in cardiac rate.
- ***Parasympathetic*** *nerve* produces inhibitory effects that slow the cardiac rate.
- The resting pulse rate is not constant. but instead varies about a set-point value.
- https://www.youtube.com/watch?v=X3BCFOlk1oQ

Autonomic nerve impulses alter the activities of the S-A and A-V nodes



Homeostasis Experiment

- This experiment is about doing exercise in order to disrupt body homeostasis and then we will detect whether the body returns to initial condition or not.
- For this experiment we have 3 parameters

1. Temperature
2. Pulse Rate
3. Blood Pressure

Procedure

1. We will take the initial temperature, Pulse Rate and Blood Pressure.
2. We will ask the students to run for few minutes
3. After running, we immediately take the Temperature, Pulse Rate, Blood Pressure.
4. finally, we will let the student to rest for 20min and the take the Temperature, Pulse Rate, Blood Pressure again.

Note: We will need these devices to measure the parameters:

1- Temperature: Thermometer

2- Pulse Rate: Pulse Oximeter

3- Blood Pressure: Sphygmomanometer

Name	Gender	Temperature (C°)		Pulse Rate (bpm)			Blood Pressure(mmHg	
		Initial	After Exercise	Initial	After Exercise	Recovery Period After 20 min	Initial	After Exercise

References

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