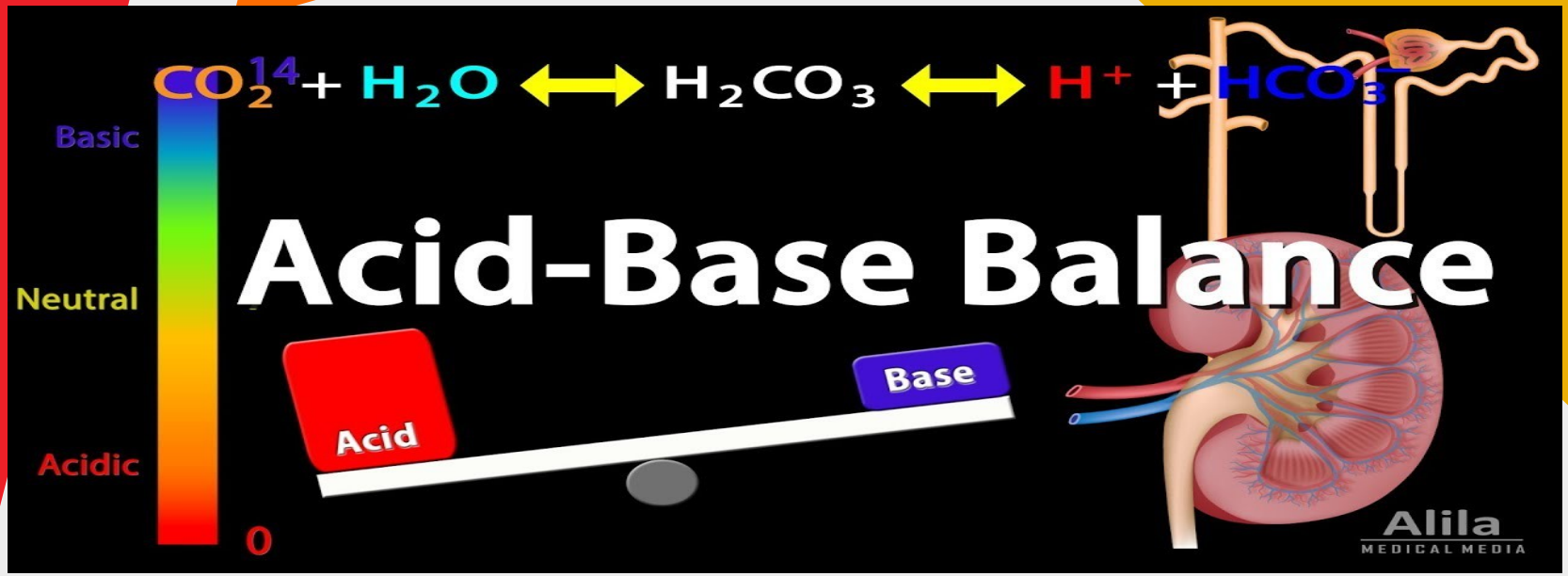


GHC 2013

FLUID, ELECTROLYTE AND ACID-BASE BALANCE (II)

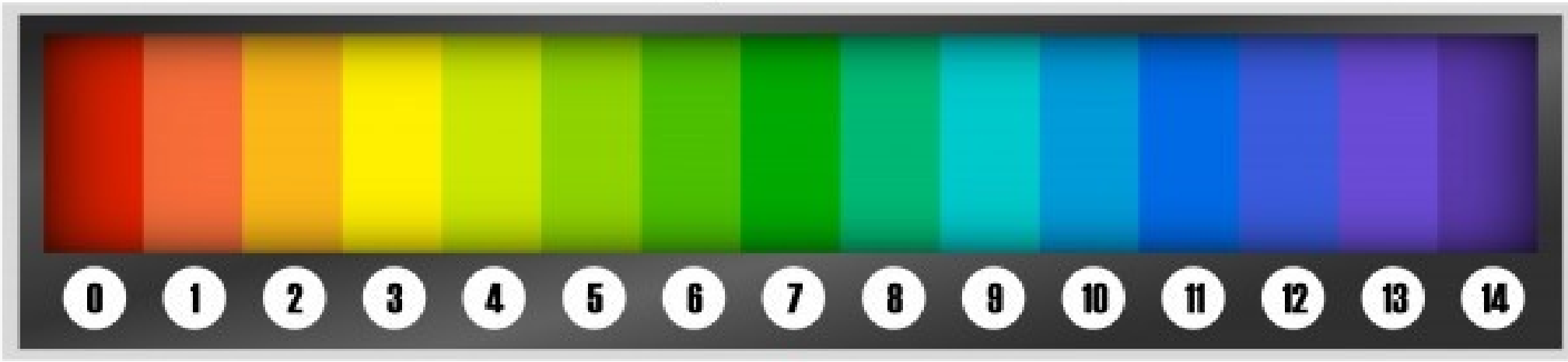
LEARNING OUTCOMES

- Explain acid-base balance.
- List the major sources of hydrogen ions in the body.
- Distinguish between strong and weak acids and bases.
- Explain how chemical buffer systems, the respiratory center, and the kidneys minimize changing pH values of the body fluids.

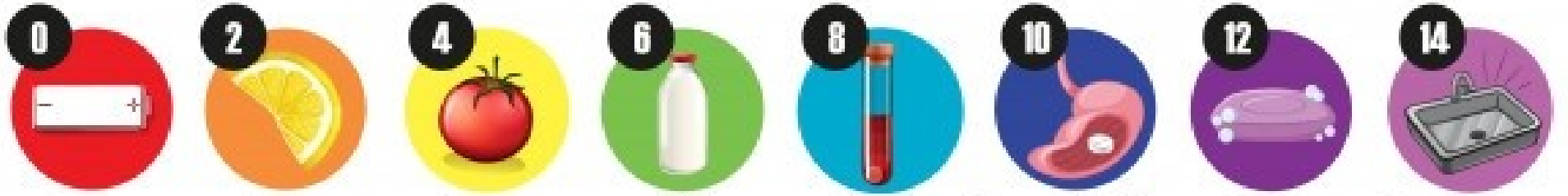
Acid-base balance

- Proper physiological functioning depends on a very tight balance between the **concentrations of acids and bases in the blood**.
- Acid-base balance is measured using the **pH scale**.
- A variety of buffering systems permits blood and other bodily fluids to maintain a narrow pH range, even in the face of perturbations.

The pH Scale

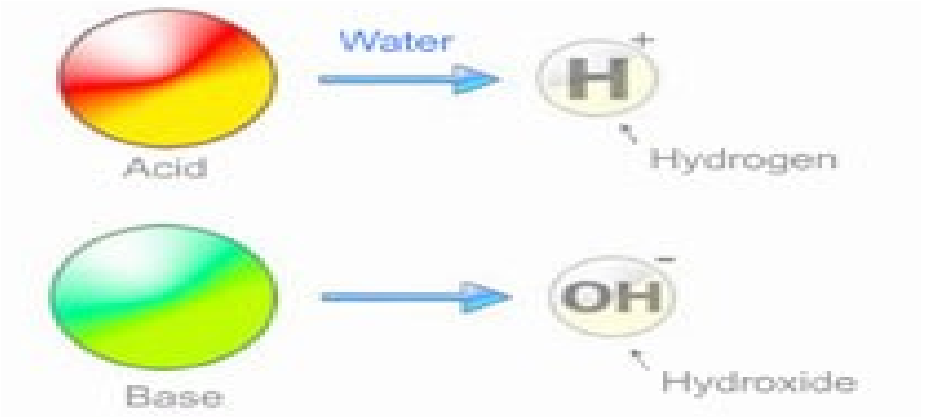


ACIDIC NEUTRAL ALKALINE



Strength of Acids and Bases

- Acids vary in which they ionize
  - Strong acids, such as hydrochloric acid, **ionize more completely**
  - Weak acids, such as carbonic acid, ionize **less completely**
- Bases also vary in strength
  - Strong bases, such as hydroxide ions, combine readily with hydrogen ions
  - Weak bases, such as bicarbonate ions, combine with hydrogen ions less readily



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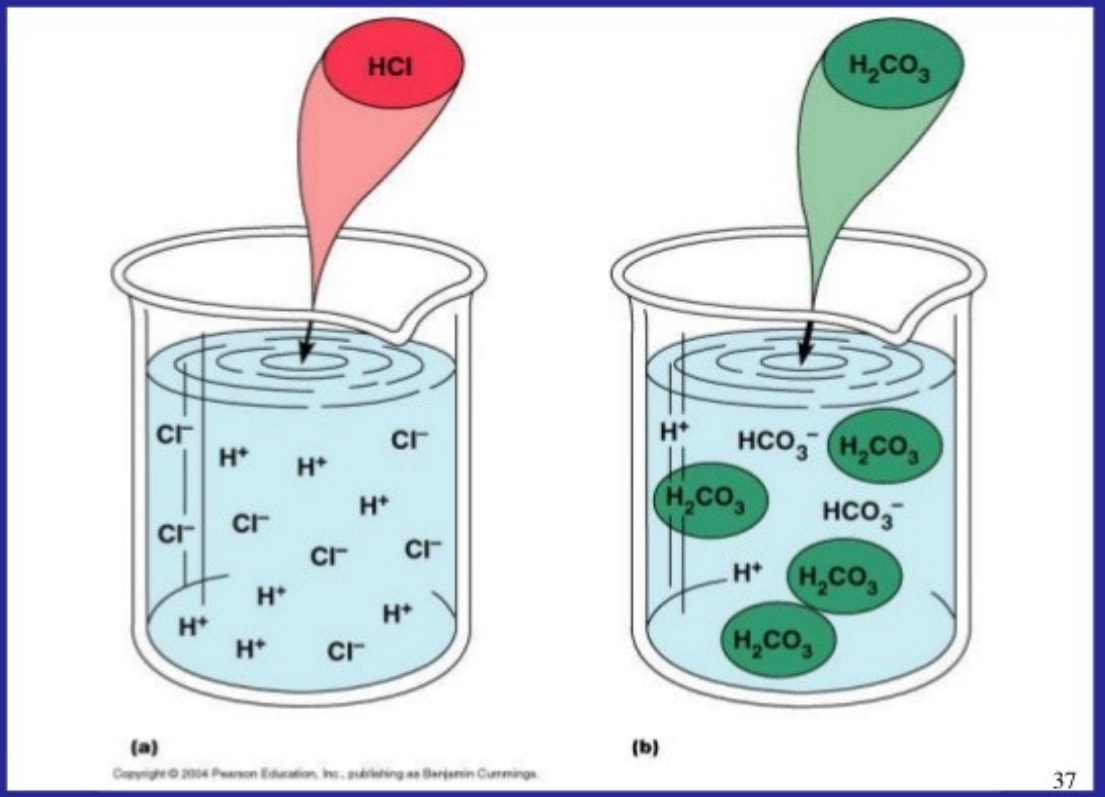

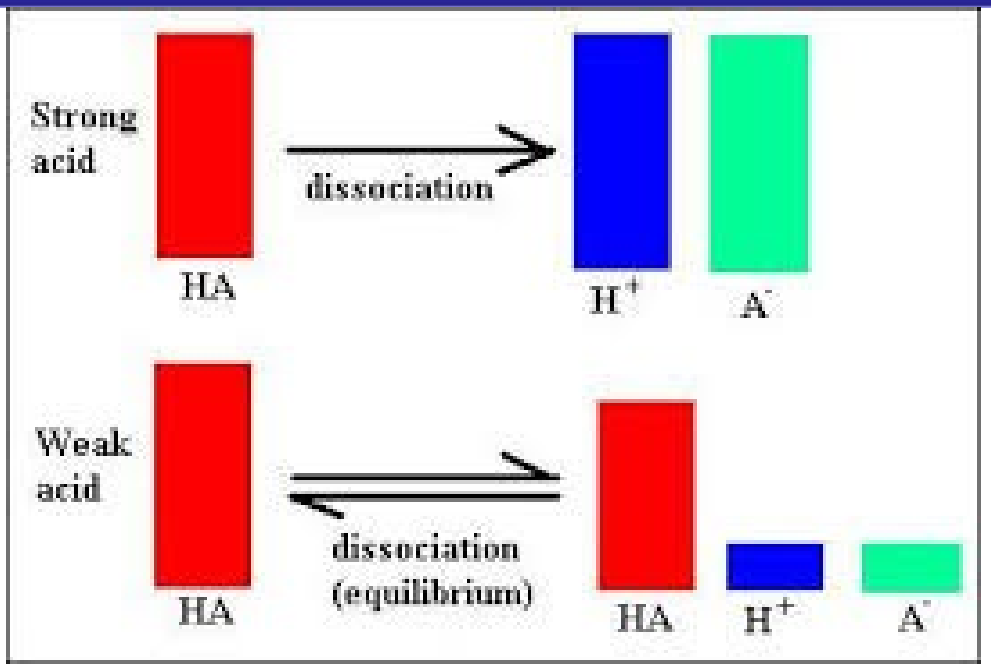

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Major sources of hydrogen ions

- Anaerobic respiration producing lactic acid
- Aerobic respiration of glucose
- Metabolism of fat producing ketones
- Production of carbon dioxide producing bicarbonate

IMPORTANCE OF ACID-BASE BALANCE

- Acid-base balance is very important for the homeostasis of the body and almost all the physiological activities depend upon the acid-base status of the body.
- Acids are constantly produced in the body.
- However, the acid production is balanced by the production of bases so that the acid-base status of the body is maintained.

Buffer system

- A variety of buffering systems exist in the body that helps maintain the pH of the blood and other fluids within a narrow range – between pH 7.35 and 7.45.
- A buffer is a substance that prevents a radical change in fluid pH by absorbing excess hydrogen or hydroxyl ions.
- Most commonly, the substance that absorbs the ion is either a weak acid, which takes up a hydroxyl ion (OH–), or a weak base, which takes up a hydrogen ion (H+).
- Several substances serve as buffers in the body, including cell and plasma proteins, hemoglobin, phosphates, bicarbonate ions, and carbonic acid.

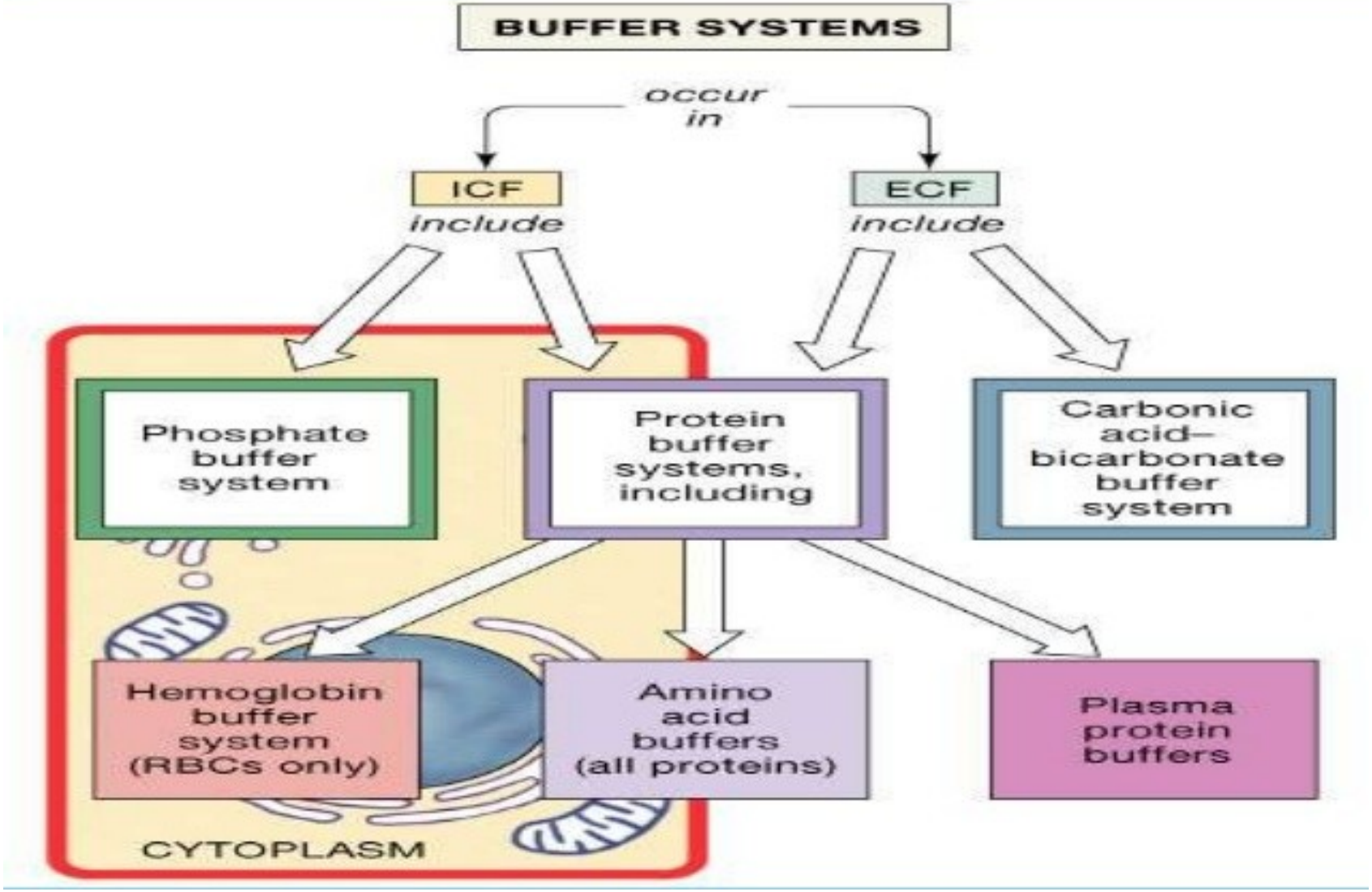
Buffer system

- The bicarbonate buffer is the primary buffering system of the interstitial fluid (IF) surrounding the cells in tissues throughout the body.
- The respiratory and renal systems also play major roles in acid-base homeostasis by removing CO_2 and hydrogen ions, respectively, from the body.

Regulation of hydrogen ion concentration

- **Acid-base buffer systems**
  - Buffer systems are composed of sets of two or more chemicals.
  - They convert strong acids into weaker acids or strong bases into weaker bases.
  - They include the **bicarbonate buffer system, phosphate buffer system, and protein buffer system.**
  - **Buffer systems minimise pH changes.**

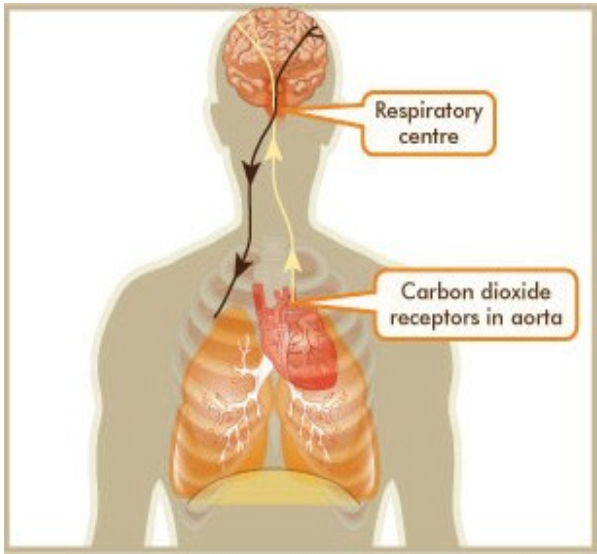
Buffer Systems in Body Fluids



Buffer System	Constituents	Actions
Bicarbonate system	Bicarbonate ion (HCO_3^-)	Converts a strong acid into a weak acid
	Carbonic acid (H_2CO_3)	Converts a strong base into a weak base
Phosphate system	Monohydrogen phosphate ion (HPO_4^{2-})	Converts a strong acid into a weak acid
	Dihydrogen phosphate ($H_2PO_4^-$)	Converts a strong base into a weak base
Protein system (and amino acids)	$-NH_3^+$ group of an amino acid or protein	Releases hydrogen ions in the presence of excess base
	$-COO^-$ group of an amino acid or protein	Accepts hydrogen ions in the presence of excess acid

Respiratory Excretion of Carbon Dioxide

- The respiratory center is located in the brainstem.
- It helps regulate pH by **controlling the rate and depth of breathing.**
- Increasing CO_2 and H^+ ion concentrations stimulates chemoreceptors associated with the respiratory center;
- Breathing rate and depth increase, and CO_2 concentration decreases.
- If the CO_2 and H^+ ion concentrations are low, the respiratory center inhibits breathing.



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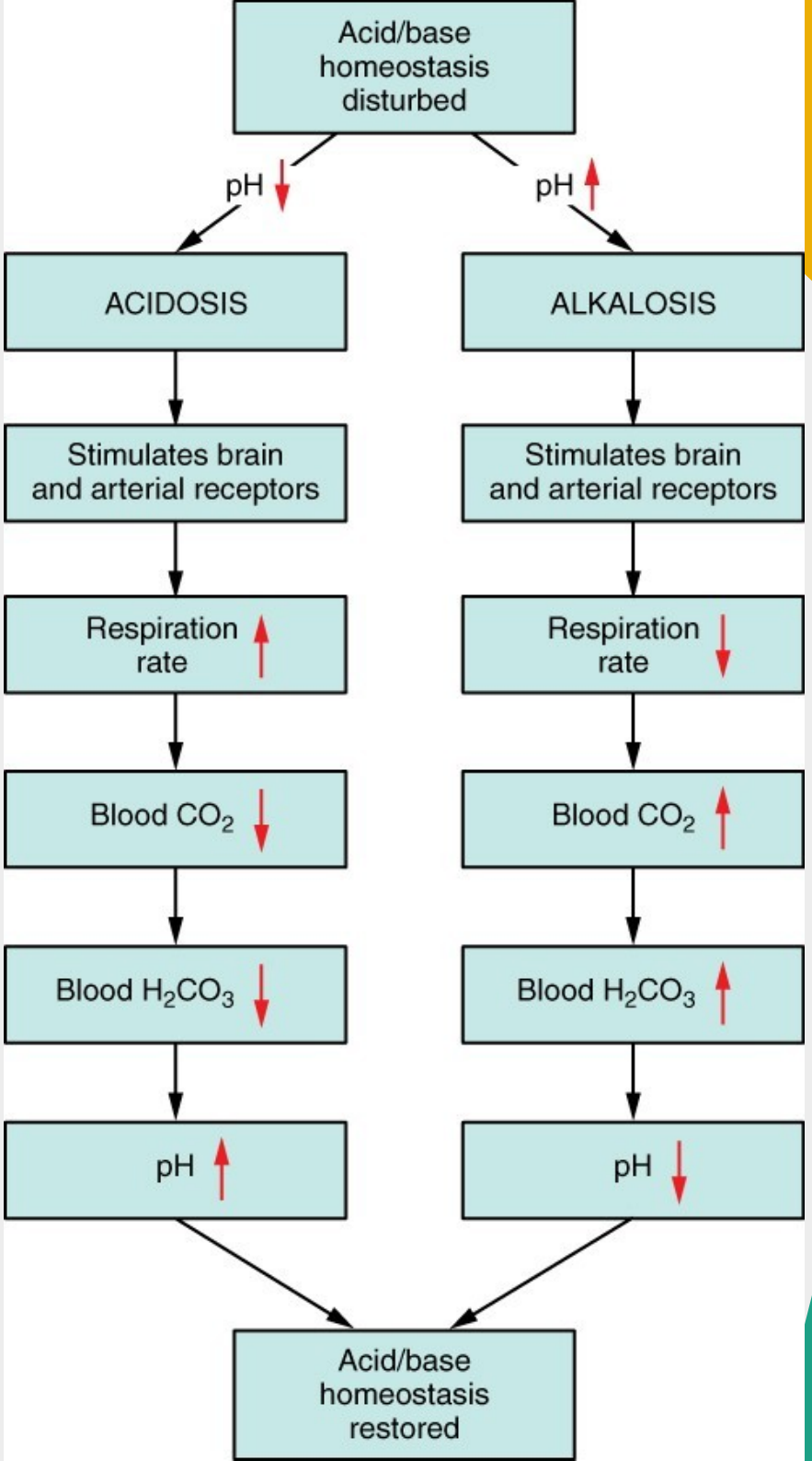
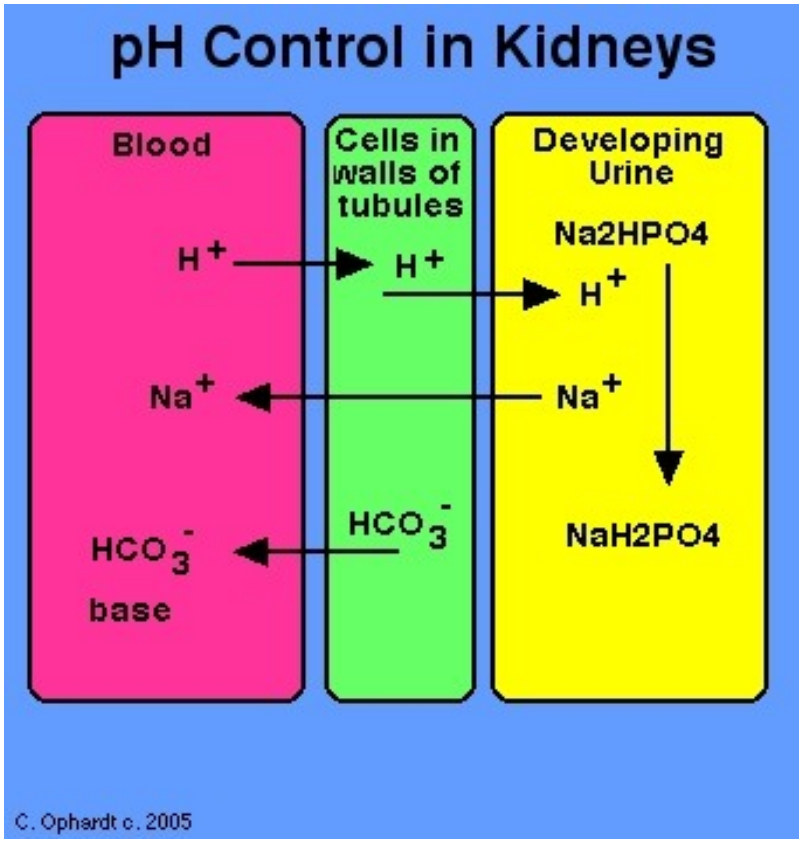
Regulation of acid-base through respiratory action



Renal Excretion of Hydrogen Ions

- Nephrons secrete H^+ ions to regulate pH.
- Phosphates buffer H^+ ions in urine.
- Ammonia produced by renal cells helps transport H^+ ions to the outside of the body.



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Compensation Mechanisms

Chemical buffers

On the scene in seconds

Already present in tissue and will handle minor changes in the acid-base balance.

Respiratory

Retention or elimination of CO_2

within **minutes**

Respiratory compensation can handle mild to moderate acid-base shifts.

Renal

Regulate bicarb (HCO_3) to combat hydrogen losses and gains

Starts in hours, but more permanent

When the other 2 mechanisms fail, the renal system slowly gets to work and requires up to 5 days to complete.

Imbalance of acid-base

- An increase in acidity causes pH levels to fall while increase in alkaline causes pH levels to rise.
- Levels of acid in blood are too high= acidosis, when the blood is too alkaline= alkalosis.
- Respiratory acidosis and alkalosis are due to a problem with the lungs.
- Metabolic acidosis and alkalosis are due to a problem with the kidneys.

Imbalance	pH	PCO_2	HCO_3
Normal value	7.35 – 7.45	35 – 45 mmHg	22 – 26 mEq/L
Metabolic acidosis	↓	Normal	↓
Metabolic alkalosis	↑	Normal	↑
Respiratory acidosis	↓	↑	Normal
Respiratory alkalosis	↑	↓	Normal

Acid-Base Balance

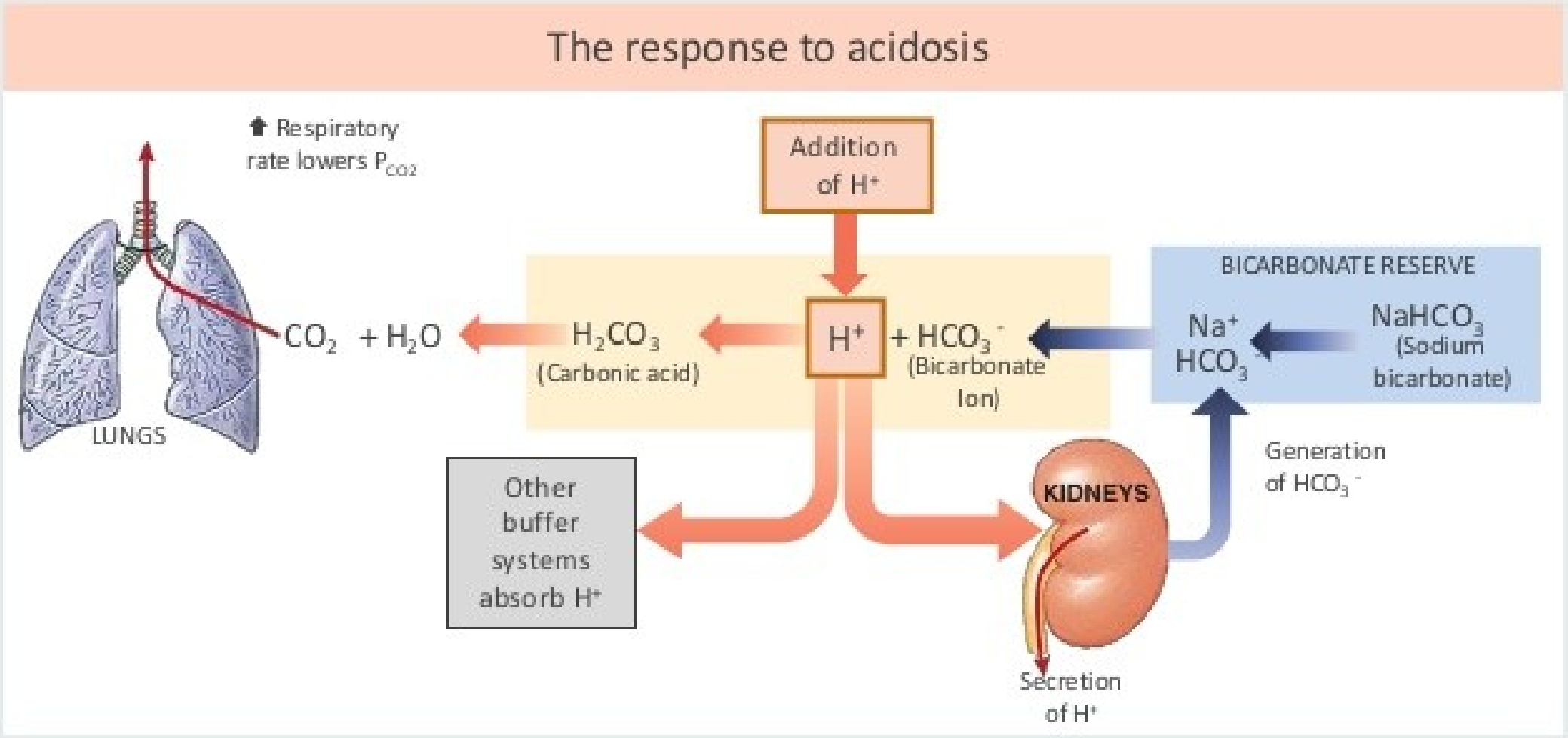
ROME:

- Respiratory: Opposite [in respiratory imbalances, the affected values are inverse]
- Metabolic: Equal [in metabolic imbalances, the affected values move in the same direction]

Regulation of acid-base balance is primarily controlled by:

- Lungs [regulate carbonic acid through respiration]
- Kidneys [regulate bicarbonate by retention or excretion]

The response to Acid–Base Imbalance



Interactions among the Carbonic Acid–Bicarbonate Buffer System and Compensatory Mechanisms in the Regulation of Plasma pH.

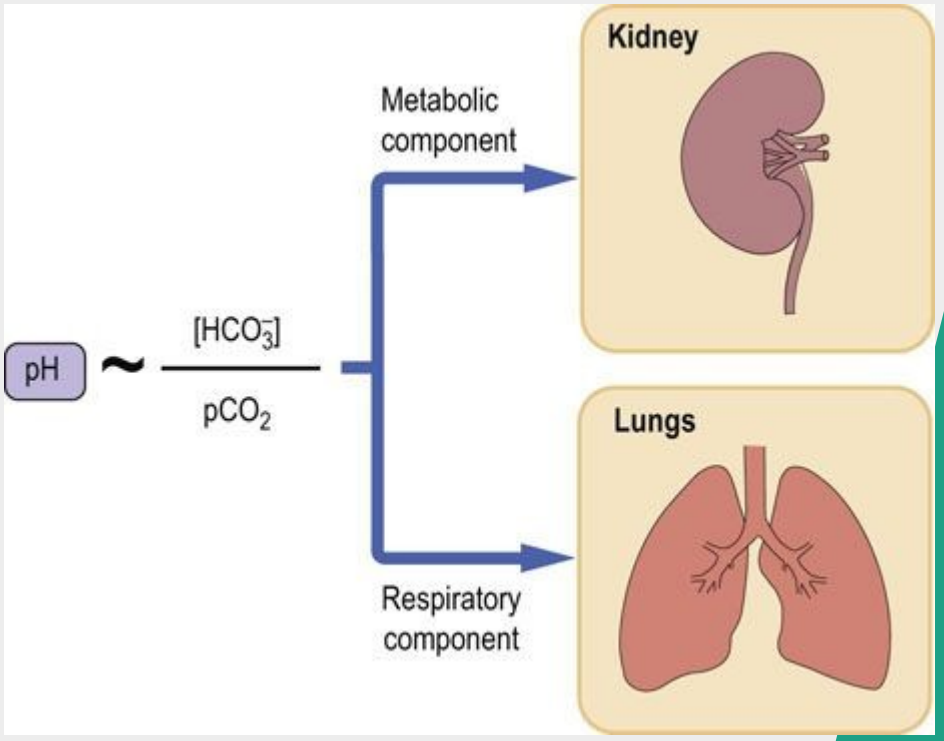
Acid-base disorders

Acidosis

- Metabolic acidosis (due to ⬇ in bicarbonate)
- **Respiratory acidosis (due to ⬆ in carbonic acid)**

Alkalosis

- Metabolic alkalosis **(due to ⬆ in** bicarbonate**)**
- **Respiratory alkalosis (due to ⬇ in carbonic acid)**



Respiratory Acidosis

- **Symptoms**:
  - fatigue, shortness of breath, and confusion.
- **Causes**:
  - chest deformities or injuries
  - chronic lung and airway diseases
  - overuse of sedatives
  - obesity

- Potential **complications** of untreated respiratory acidosis include;
  - respiratory failure
  - organ failure
  - shock

Metabolic Acidosis

- **Symptoms**:
  - rapid breathing
  - fatigue
  - confusion
- **Complication**:
  - severe cases lead to shock

- **Causes**:
  - **Diabetic acidosis or diabetic ketoacidosis** (buildup of ketone bodies) - due to uncontrolled type 1 diabetes.
  - **Hyperchloremic acidosis** - body loses too much sodium bicarbonate, often after severe diarrhea.

Metabolic Acidosis

- **Causes**:
  - **Lactic acidosis** (too much lactic acid builds up) can be due to:
    - prolonged exercise
    - lack of oxygen
    - certain medications including salicylates
    - low blood sugar or hypoglycemia
    - alcohol
    - seizures
    - liver failure
    - cancer
    - kidney disease
    - severe dehydration
    - poisoning from consuming too much aspirin, ethylene glycol, and methanol

Respiratory Alkalosis

- **Symptoms**:
  - muscle twitching, hand tremor, muscle spasms
  - numbness and tingling
  - nausea
  - vomiting
  - lightheadedness
  - confusion
- **Causes**:
  - lack of oxygen
  - high altitude
  - fever
  - lung disease
  - liver disease
  - salicylate poisoning

Metabolic Alkalosis

- **Cause**:
  - Severe vomiting
- **Complication**:
  - In severe cases, alkalosis can lead to heart arrhythmias or coma.