Online Physiology 2130 – Acid/Base Homeostasis

Introduction

Hey! Thanks for opening up this Physiology 2130 resource, and welcome. The education team at WebStraw has put together comprehensive review sheets for you that cover all the major learning outcomes for the **Acid/Base Homeostasis of Physiology 2130**.

Members of our team have taken the course in previous years, and we understand better than anyone else what specific ideas and concepts tend to trip students up throughout the course. **We are able to essentially offer you the key takeaways from the course after having completed the course ourselves**. We also have representatives currently enrolled in the course as well to keep us up to date on specific topic coverage.

Before you read further, also keep in mind that **these resources are not meant to be a tool for you to learn the course from scratch**. The content presented below was designed with the assumption that you already have a preliminary understanding of the course content. Our goal is to provide you with **a resource in order to quickly review key concepts and easily refer to course content**. We have added a few questions for each module in order to give you some practice and a feel for exam type questions. Please refer to the course material provided by your instructors if there are any discrepancies between the content found in these review sheets and the course content.

With that said, best of luck in your studying! Remember to make good use of your time, but to also take breaks as well.

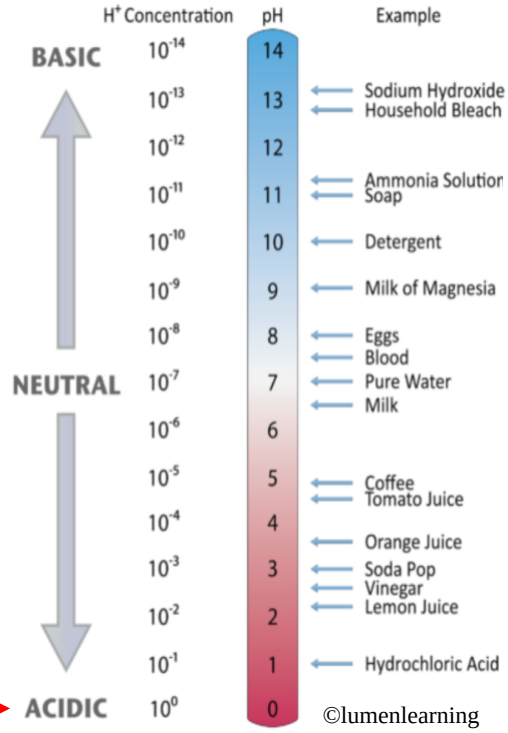
The WebStraw Education Team

Module 12 - Acid/Base Homeostasis

Acid – any molecule that will ***release*** H+ when placed in a solution
- pH < 7
- E.g. HCl (hydrochloric acid)

Base – any molecule that will ***accept*** H+ when placed in a solution
- pH > 7
- E.g. HCO_3^- (bicarbonate)

The pH scale – is used to quantify the concentration of H+ in any given solution.



$$pH = -log_{10}[H^+]$$

Acidic: pH < 7
Neutral: pH = 7
Basic/Alkaline: pH > 7

Normal pH of the body is 7.4.

Acidosis: pH < 7.4
Alkalosis: pH > 7.4

Hydrogen-ion Concentration

- Measured in mol/L or pH units
- Determines the acidity of the solution

*Hydrogen-ion concentration is **inversely** proportional to any given pH value.*

Lower [H+] = Higher pH = Basic solution
Higher [H+] = Lower pH = Acidic solution

Regulation of Hydrogen Ion Concentration

1. Buffers in body fluids bind free H^+
   - Body's first line of defense
   - Binds up free H^+, stabilizing the pH until the balance is re-established

   **Buffers DO NOT directly remove H^+ from the body*
   **Buffers DO NOT alter the pH*
2. The respiratory system can regulate H^+ concentrations from **volatile acids**
3. The kidneys have control over H^+ concentrations from **non-volatile acids**

Volatile Acid

- Can be converted into a gaseous state, therefore it can be ***eliminated by the lungs***
- Made up of acids such as carbonic acid (H_2CO_3) which is formed when carbon dioxide (CO_2) combines with water (H_2O)
- ***Respiratory system*** can regulate H+ concentration from this acid

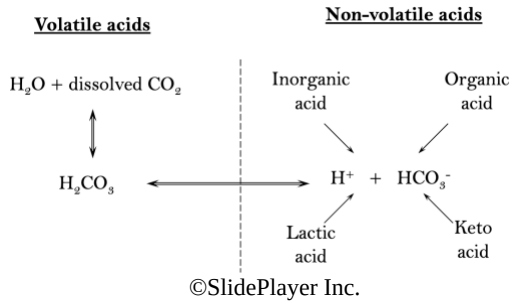
Non-Volatile Acid

- Acids that are derived from amino acids that contain sulphur and phosphorous compounds, and ***cannot be eliminated by the lungs***
- ***Kidneys*** have an extremely powerful control over H^+ concentrations
- Responds slower and occurs over a period of time

Buffer
- Any molecule that can reversibly bind/release free hydrogen ions
- Free H^+ can bind with buffers in the intracellular and extracellular fluid

Buffers bind free H^+, reducing the amount of free H^+ in solution which stabilizes the pH.

Example: bicarbonate ions (strongest extracellular buffer) and hemoglobin (Hb)



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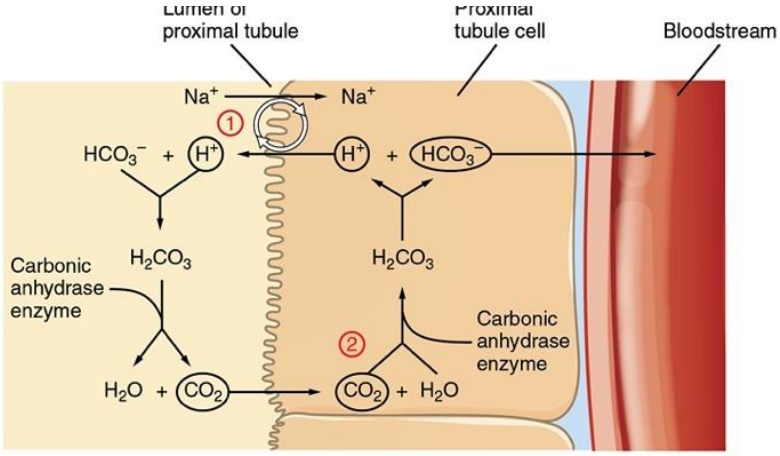
Respiratory System

- Controls blood pH by release of CO_2
- CO_2 is mildly acidic and its accumulation in blood causes decrease in pH
- **Central and peripheral chemoreceptors** detect changes in CO_2 levels and pH
- CO_2 increases → chemoreceptors initiate increased ventilation → more CO_2 removed at the lungs → blood CO_2 levels return to normal
- Brain and lungs regulate blood pH by adjusting the ***speed and depth of breathing***



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Kidneys

Respond more slowly (hours or days)

- Excrete H^+ that come from non-volatile acids
- Reabsorb bicarbonate ions filtered at the glomerulus
  - Converted into CO_2 and then reabsorbed by the cells
  - In the cell, CO_2 combines with H_2O, producing bicarbonate and H^+
  - Bicarbonate ions diffuse out of the tubule cell
  - Remaining H^+ is secreted into the lumen
  - *For every bicarbonate reabsorbed, one H^+ is secreted*
- Create new bicarbonate ions which get absorbed into circulation
  - H^+ secreted in late distal tubule and collecting duct
  - *Secretes one H^+ for every 1 ATP*
  - Secretes about ***5%*** of total H^+ in filtrate
  - *For every H^+ secreted, a new bicarbonate ion is reabsorbed into circulation*
- H^+ excreted in urine > HCO_3^- reabsorbed → **body pH increases**
- HCO_3^- excreted in urine > H^+ excreted in urine → **body pH decreases**

Acidosis – body fluids when the pH is ***below 7.4***

- Too many hydrogen ions or too little bicarbonate ions

Respiratory acidosis

- *Decreased ventilation and increased PCO_2*
- Can occur if:
  - Respiratory centers in brain stem are damaged
  - Lungs are damaged → decreased ability to remove CO_2
- Counteracted by ***buffers in the blood*** and ***excretion*** of excess H^+ by kidney

Metabolic acidosis

- Decrease in extracellular bicarbonate
- Kidney failure results in inability to excrete acids
- Formation of excess metabolic acids in body
- Ingestion of acids (aspirin, methyl alcohol)
- Loss of bicarbonate in diarrhea

Alkalosis - body fluids when the pH is *above 7.4*

- Too much bicarbonate in the body or too little acid (H^+)

Respiratory alkalosis

- *Increased ventilation and decreased PCO_2*
- Caused by stress or emotionally induced hyperventilation
- ***High altitudes*** (low O_2 in air → low PCO_2 in blood → hyperventilation)
  - Counteracted by excretion of bicarbonate

Metabolic alkalosis

- Buildup of bicarbonate ions or loss of H^+
- Loss of HCl from stomach from ***vomiting***
- Ingestion of ***alkaline drugs***

Review Questions

1. A blood pH of 7.1 is considered:
    a. Neutral
    b. Basic/Alkaline
    c. Acidic
    d. Homeostatic

2. Which of the following is FALSE?
        1. Buffers bind free bicarbonate ions and bring them to the kidney for excretion
        2. Kidneys cannot reabsorb or create buffers
        3. Carbonic anhydrase converts bicarbonate ions into H^+ ions
        4. The respiratory system can regulate H^+ concentration from volatile acids.

    a. 1, 2, and 3 only
    b. 1 and 3 only
    c. 2 and 4 only
    d. 4 only

3. A non-volatile substance has a_____ vapor pressure and a _____ boiling point.
    a. High; low
    b. High; high
    c. Low; high
    d. Low; low

4. Which of the following can cause metabolic alkalosis?
    a. Alkaline drugs
    b. High Altitudes
    c. Vomiting
    d. Both A and C are correct

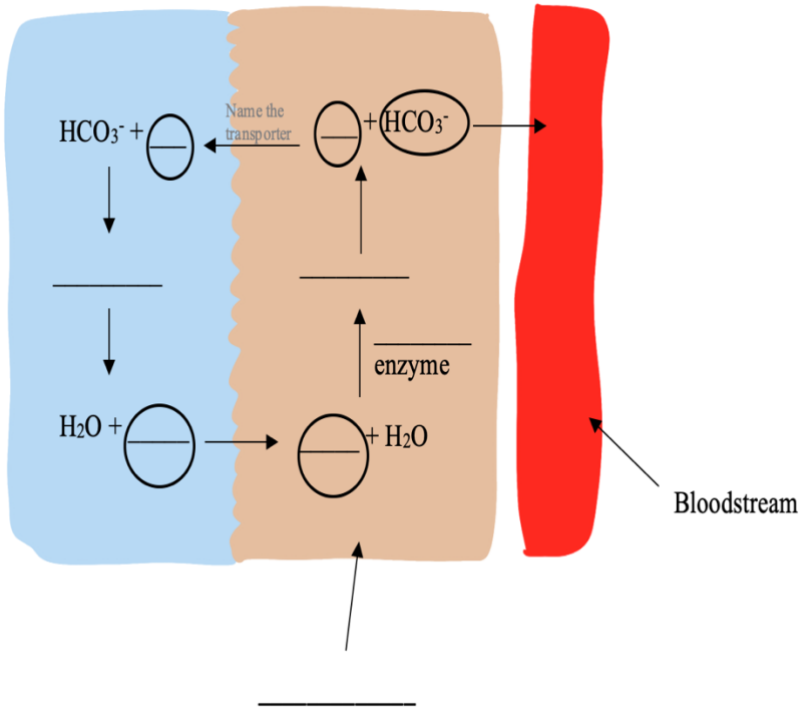
5. Which of the following is correct regarding buffer systems of the body?
    a. Increase in H^+ excretion will decrease body pH
    b. Bicarbonate ions leave the tubule cell using an ATP pump
    c. Increase in H^+ excretion will increase body pH
    d. Bicarbonate ions are reabsorbed at the tubule cells

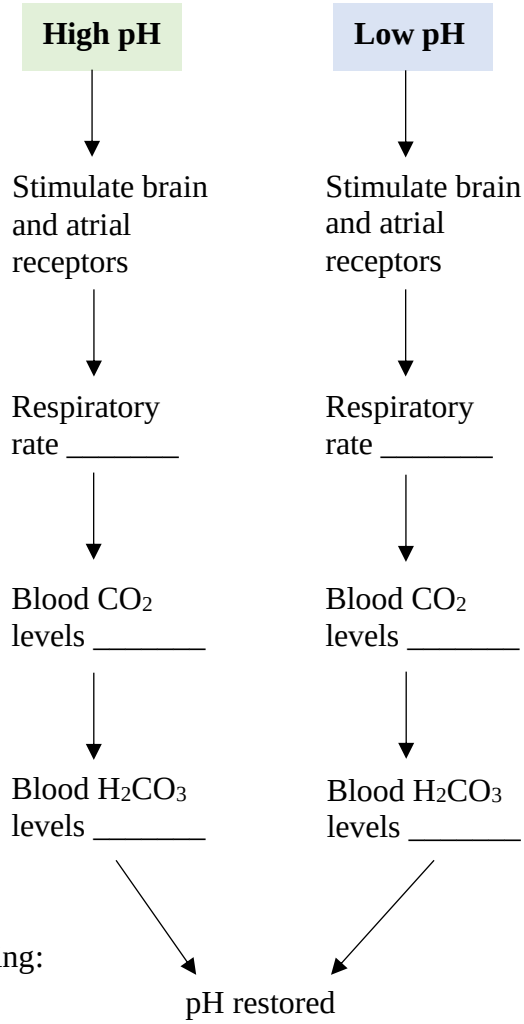
6. Which of the following options is correct regarding renal acid-base regulation?
    a. Bicarbonate ions can freely diffuse into the tubule cells
    b. For every bicarbonate reabsorbed at the glomerulus, 1 H^+ ion is secreted
    c. Body pH increases when HCO_3^- excreted in urine is greater than H^+ excreted in urine
    d. The renal system works *rapidly* to balance body pH

Answers
1.C 2.A 3.C 4.D 5.C 6.B

Module 12 - Acid/Base Homeostasis

1. Volatile Acids are made from acids such as _____, which is made from CO_2 and H_2O.
    a. These are eliminated by the _____
2. Non-volatile Acids are made from acids derived from _____ that contain _____ and phosphorous compounds
    a. Their concentrations are controlled by _____





Conceptual Questions

1. Hyperventilation during a panic attack causes which of the following:
    a. Increase in H^+
    b. Increase in blood pH
    c. Increase in partial pressure of CO_2
    d. Both B and C are correct
2. Describe the process of bicarbonate conservation by the renal system.

Think About This: Relationship between Potassium Balance and Acid/Base Homeostasis
Prolonged acidosis and alkalosis can have a very severe effect on plasma K^+ balance, causing hyperkalemia and hypokalemia. During *acidosis*, the H^+/K^+ ATPase antiporter on the apical membrane pumps H^+ into the lumen and K^+ into the cell. The increase K^+ concentration in the cell drives its reabsorption through the leak channels on the basolateral membrane. This leads to an increase plasma K^+ concentration or ***hyperkalemia***. The opposite happens during *alkalosis*. Can you think of how increased pH can lead to ***hypokalemia***?

Answers

1. B