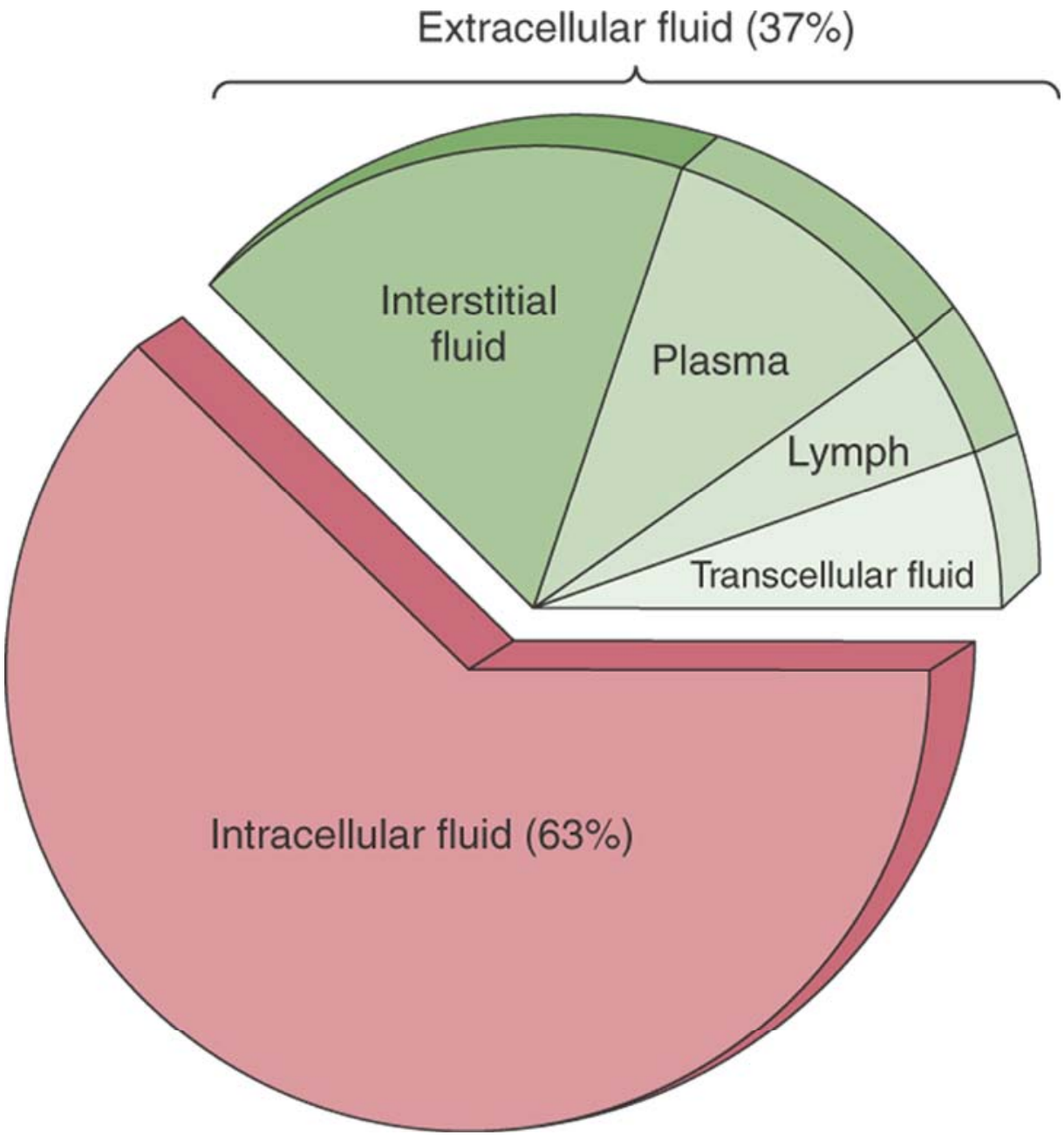
Water, Electrolyte & acid & base Balance

Rita Carey-Nita

Distribution of Body Fluids

- Water & electrolytes are distributed in two major compartments:
  - Intracellular: located inside cells; 63% of all
  - Extracellular: located outside cells; 37%
- Extracellular includes:
  - Interstitial fluid: fluid between cells; tissue
  - Intravascular fluid: within the blood & lymph vessels; blood & lymph
  - Transcellular fluid includes:
    - Cerebrospinal fluid
    - Aqueous & vitreous humor
    - Snyovial fluid
    - Serous fluid in body cavities
    - Glandular secretions
  - Interstitial & intravascular make up most of extracellular

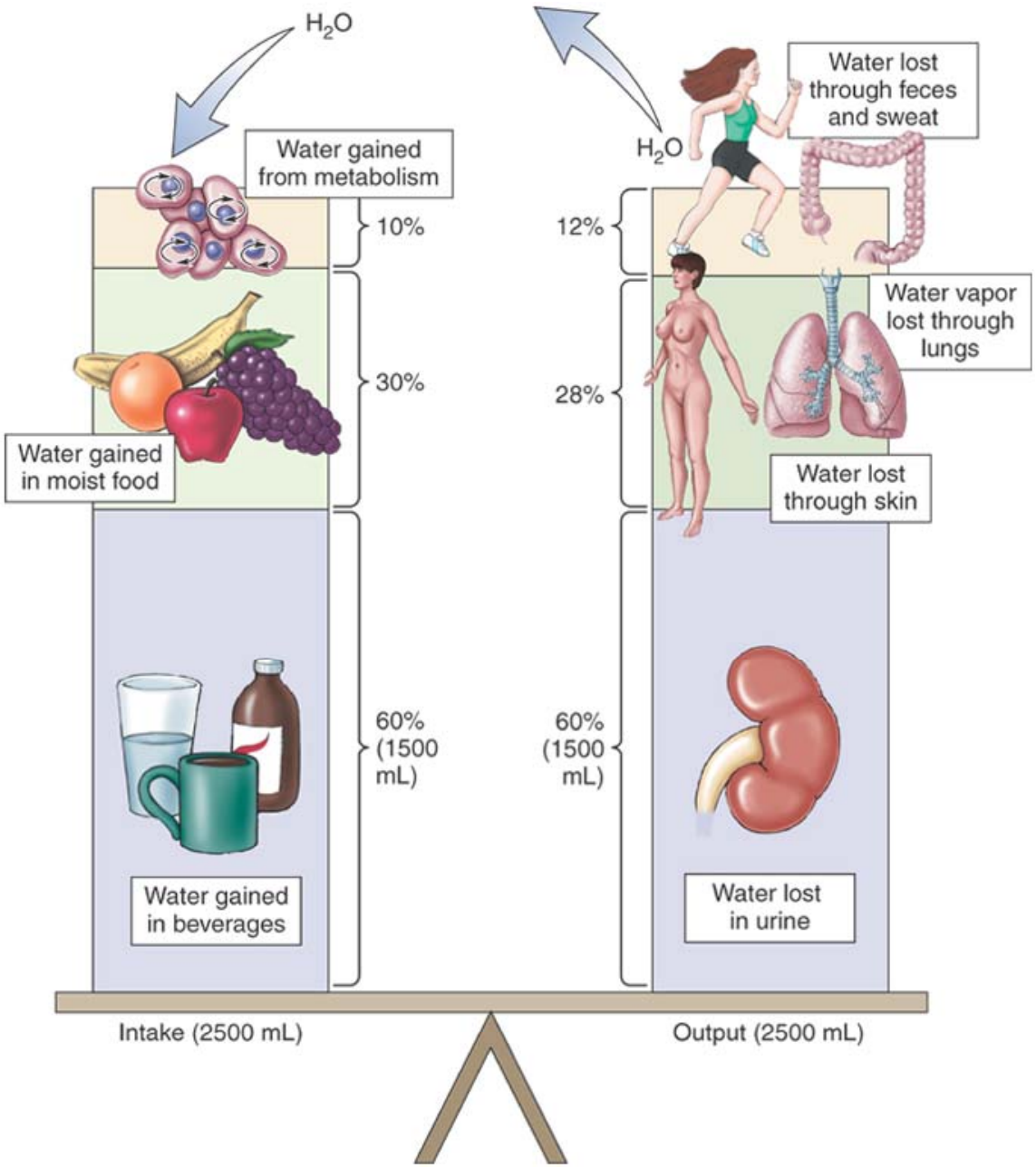

Extracellular fluid (37%)
Interstitial fluid
Plasma
Lymph
Transcellular fluid
Intracellular fluid (63%)

Composition of body fluids

- Intracellular & Extracellular fluids vary in their concentration of various electrolytes
- Extracellular fluids contain high concentration of sodium(NA+), chloride(Cl-), & bicarbonate (HCO_3-) ions
- Intracellular fluids contain high concentration of potassium(K+), phosphate($PO_4$3-) & magnesium(Mg_2+) ions
- Movement of electrolytes in & out of compartment is regulated

Water balance

- Water intake usually equals water output creating a water balance
- Water Intake:
  - Average adult consumption of water equals 2,500ml in 24 hours
    - 60% from drinking
    - 30% from food
    - 10% from digestion called water of metabolism
- Water output:
  - Should average 2,500ml if 2,500ml taken in
    - Kidneys excrete 60% as urine
    - Skin & lungs 28%
    - Feces is 6%
    - Sweat is 6%


H_2O
Water gained from metabolism
10%
30%
Water gained in moist food
60% (1500 mL)
Water gained in beverages
Intake (2500 mL)
H_2O
Water lost through feces and sweat
12%
Water vapor lost through lungs
28%
Water lost through skin
60% (1500 mL)
Water lost in urine
Output (2500 mL)

Water deficiency

- A deficiency of body water is called dehydration
- Dehydration develops when water output exceeds water intake due to:
  - Excessive sweating, vomiting, diarrhea & diurectics
- Measured by skin tugor which involves pinching the skin; if poor skin tugor skin will take longer to flatten out; due to depleted interstitial fluid

Water excess

- Water excess is caused by overhydration
- Due to excessive intake or decreased urinary output
- Excess body water can accumulate in various parts of the body resulting in edema
  - Excessive fluid in blood causes heart failure creating hypoxemia & cyanosis
    - Accumulates in lungs; pulmonary edema
    - Accumulates in feet; pedal edema

Electrolyte balance

- Electrolyte balance exists when the amount of the various electrolytes gained by the body equal the amount lost
- Electrolyte imbalances are a common medical issue
- Kidneys play role in the regulation of body fluids by excretion of electrolytes

Quick review

- Ion: an element or compound that carries an electrical charge
- Cation is a positively charged ion
- Anion is a negative charged ion
- Electrolyte is substances that form ions when they dissolve in water
- Ionization is the chemical reaction caused when two ions split

Important ions

- Sodium (Na+)
  - Chief extracellular cation
  - Accounts for 90% of positively charged ions
  - Necessary for nerve impulse conduction & body fluid balance
  - Aldosterone controls sodium concentration
  - Aldosterone stimulates the renal tubules to reabsorb sodium
  - When sodium moves, water moves
  - Most diurectics block the renal absorption of sodium which in turn affects water reabsorption
  - Normal Na+ plasma level 136-145mEq/l

Important ions

- Potassium (K+)
  - Chief intracellular cation
  - Plays role in nerve impulse conduction
  - Aldosterone regulates potassium concentration
  - Aldosterone stimulates the kidney to excrete potassium
  - Alterations of potassium can cause serious dysrhythmias
  - Hyperkalemia refers to excess potassium in blood
  - Hypokalemia refers to decrease potassium in blood
  - Some diurectics (kaliuretic) causes excretion of K called kaliuresis
  - These patients require close observation of K levels

Important ions

- Calcium (Ca^{2+})
  - Necessary for bone & teeth formation, muscle contraction, nerve impulse transmission & blood clotting
  - Parathyroid hormone regulates Ca+ plasma level
  - Normal Ca+ plasma level 4.5-5.8 mEq/L
- Magnesium (Mg^{2+})
  - 2^{nd} most abundant cation in the intracellular fluid
  - Responsible for heart, muscle & nerve function
  - Normal Mg+ plasma level 1.5-2.5mEq/L

Important Ions

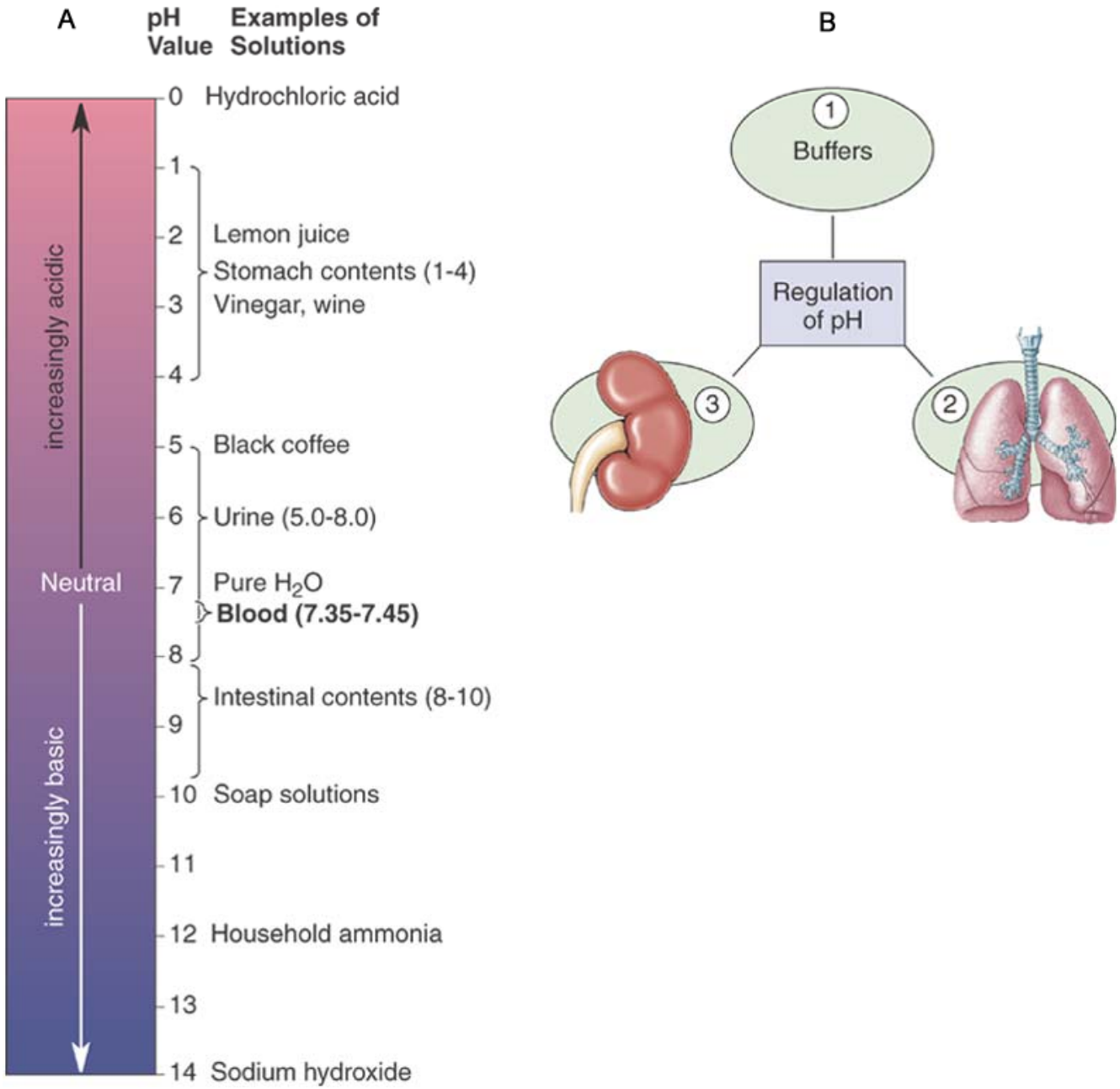
- Chloride (Cl-)
  - Chief extracellular anion
  - Usually follows sodium (Na+) passively into the peritubular capillaries
  - Normal plasma level 95-108 mEq/L
- Bicarbonate (HCO^-_3)
  - Important for acid-base balance
  - Alkaline substance that helps remove excess acid from the body
  - CO2 is transported in the form of bicarbonate in the blood
  - Excretion is controlled by the kidneys

Acid & base balance

- The body requires a normal acid-base balance
- The body is very sensitive to acid-base balance
- Too high a plasma level of hydrogen ion causes the neurons to become more excitable which can cause seizures
- Too low a plasma level of hydrogen ion causes the neurons to become decreased which can create comatose

Ph scale

- pH scale is a unit of measure that indicates the number of hydrogen in a solution
- As the number of hydrogen ions increases, the pH decreases, the more acidic the solution
- As the number of hydrogen ions decreases, the pH increases, the more alkaline the solution
- A plasma pH less than 7.35 is acidosis
- A plasma pH more than 7.45 is alkalosis


A
pH Value
Examples of Solutions
0 Hydrochloric acid
1
2 Lemon juice
Stomach contents (1-4)
3 Vinegar, wine
4
5 Black coffee
6 Urine (5.0-8.0)
7 Pure H_2O
Blood (7.35-7.45)
8
9 Intestinal contents (8-10)
10 Soap solutions
11
12 Household ammonia
13
14 Sodium hydroxide
increasingly acidic
Neutral
increasingly basic
B
1
Buffers
Regulation of pH
3
2

Acid-base

- Most hydrogen ions come from the body's chemical reactions during metabolism
- When glucose is metabolized in the presence of oxygen, it produces CO2, water & energy
- CO2 & water combine & form carbonic acid
- When glucose is metabolized in the absence of oxygen, it forms lactic acid
- When fatty acids are metabolized too fast that form ketoacids
- When proteins are metabolized, some yield sulfuric acid
- All of these acids are produced by metabolizing cells
- To maintain acid-base balance the body must eliminate these acids

Regulation of ph

- Three mechanisms help regulate pH:
  - Buffers
  - Respirations
  - Kidney function

Regulation of ph

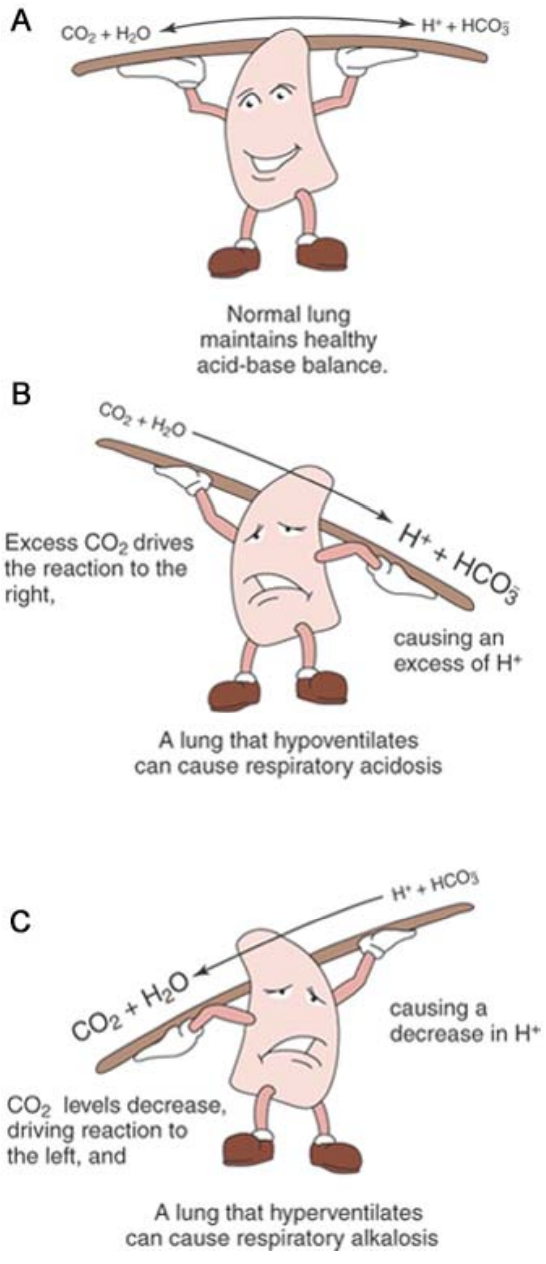
- Buffers
  - First line of defense
  - A buffer is a chemical substance that prevents large changes in pH
  - There are two parts to a buffer, called buffer pair; includes taker & giver
  - If H+ concentration increases in blood, the taker buffer removes H+ from the blood
  - If H+ concentration decreases in blood, the giver donates a H+ to the blood
  - The adding or removing of H+ the buffer pair maintains normal blood pH
  - The important buffers in the body are bicarbonate buffers, phosphate buffers, hemoglobin & plasma proteins

Regulation of ph

- Respiration
  - The respiratory system is the second line of defense in the regulation of pH
  - Carbon dioxide can combine with water to form carbonic acid
  - Respiration can affect H+ concentration or blood pH
  - Decreasing the respiratory rate causes the body to retain carbon dioxide
    - The CO2 combines with water to form hydrogen ions
    - Increase in hydrogen ions causes the pH to decrease
    - This is the basis of respiratory acidosis
  - Increasing the respiratory rate causes the body to blow off carbon dioxide
    - The decrease in carbon dioxide causes a decrease in hydrogen ions causing increase in pH

Regulation of ph

- The brain senses plasma hydrogen (H+) concentration
- As the plasma concentration of H+ increases, the respiratory center is stimulated which causes an increase in the rate & depth of breathing
- The increase in respirations cause increase excretion of CO2 by the lungs causing an increase in pH
- As the plasma hydrogen concentration decreases, the respiratory center sends a message to decrease the rate of breathing which causes the retention of CO2 in plasma which forms hydrogen


A
$CO_2 + H_2O$
$H^+ + HCO_3^-$
Normal lung maintains healthy acid-base balance.
B
$CO_2 + H_2O$
$H^+ + HCO_3^-$
Excess CO_2 drives the reaction to the right,
causing an excess of H^+
A lung that hypoventilates can cause respiratory acidosis
C
$H^+ + HCO_3^-$
$CO_2 + H_2O$
causing a decrease in H^+
CO_2 levels decrease, driving reaction to the left, and
A lung that hyperventilates can cause respiratory alkalosis

Regulation of Ph

- Kidneys
  - Third line of defense
  - Helps to regulate pH by reabsorption or excretion of hydrogen as needed
  - The kidneys also help regulate bicarbonate, a major buffer
  - The kidneys can reabsorb bicarbonate when it is needed & can eliminate bicarbonate in urine
  - With renal failure, patients are often acidotic

Acid-base imbalance

- When the body is unable to regulate pH, acid-base imbalances result
- The imbalance in the blood is called acidosis or alkalosis
- The imbalance is life threatening
- Types include:
  - Respiratory acidosis
  - Respiratory alkalosis
  - Metabolic acidosis
  - Metabolic alkalosis

Respiratory acidosis

- Respiratory acidosis
  - A decrease in plasma pH below 7.35 is acidosis
  - Caused by any condition that decreases the respiratory system effectiveness or hypoventilation
  - Diseases such as emphysema, brain injury affecting the respiratory center causing a decrease in respirations, narcotics
  - There is an increase in plasma levels of CO2 causes increase in hydrogen concentration which in turn decreases pH creating acidosis
  - Need the help of the buffer system & kidneys to regulate the imbalance since the lungs can not correct the issue

Metabolic acidosis

- Metabolic acidosis
  - Decrease in the pH due to non-respiratory conditions
  - Causes include:
    - Kidney disease
    - Uncontrolled diabetes due to build up of ketoacids
    - Prolonged vomiting of intestinal contents or severe diarrhea (loss of bicarbonate)
  - Body attempts to compensate by the buffer system & respiratory system
  - The respiratory system attempts through hyperventilation or Kussmaul respiration(related to uncontrolled diabetes as cause)
  - Increase in respiratory activity is called respiratory compensation

Respiratory alkalosis

- Respiratory alkalosis
  - Develops from hyperventilation which results in the decrease in hydrogen ions in blood plasma
  - Causes include:
    - Anxiety
    - Aspirin poisoning
  - The body will try to compensate by the use of the kidneys & the buffer system
  - The buffer will donate H+ to plasma which will decrease pH
  - The kidneys decrease the excretion of H+ which decreases pH
  - The kidneys also increase the excretion of bicarbonate
  - The kidneys ability to correct respiratory alkalosis is called renal compensation of respiratory alkalosis

Metabolic alkalosis

- Metabolic alkalosis
  - An increase in pH caused by a non-respiratory disorder
  - Causes include:
    - Overuse of antacids
    - Bicarbonate-containing drugs
    - Persistent vomiting of stomach contents (loss of HCL)
    - NG suctioning (loss of HCL)
  - Body attempts to correct with the buffer system & the respiratory system
  - The buffer system will donate H+ causing a decrease in pH
  - The kidneys will decrease the excretion of H+
  - The respiratory system corrects the pH by hypoventilation causing retention of CO_2 & creation

Compensatory function

- Compensatory function refers to the respiratory system & the renal system ability to correct pH imbalance
- The respiratory system can both cause & correct an acid-base imbalance
- The renal system can both cause & correct an acid-base imbalance