

## Water, Electrolyte & acid & base Balance

Rita Carey-Nita

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## 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
    - Synovial fluid
    - Serous fluid in body cavities
    - Glandular secretions
  - Interstitial & intravascular make up most of extracellular

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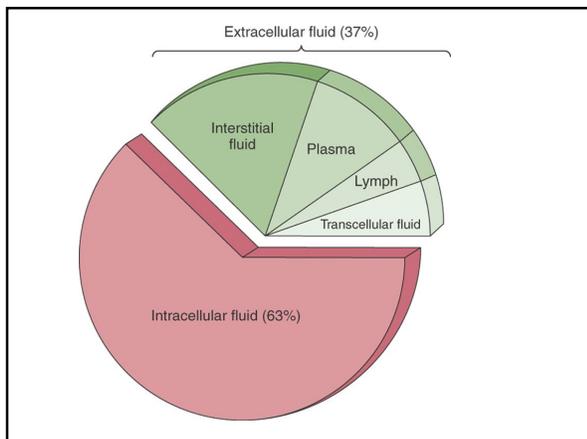
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## Composition of body fluids

- Intracellular & Extracellular fluids vary in their concentration of various electrolytes
- Extracellular fluids contain high concentration of sodium( $\text{Na}^+$ ), chloride( $\text{Cl}^-$ ), & bicarbonate ( $\text{HCO}_3^-$ ) ions
- Intracellular fluids contain high concentration of potassium( $\text{K}^+$ ), phosphate( $\text{PO}_4^{3-}$ ) & magnesium( $\text{Mg}^{2+}$ ) ions
- Movement of electrolytes in & out of compartment is regulated

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## 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%

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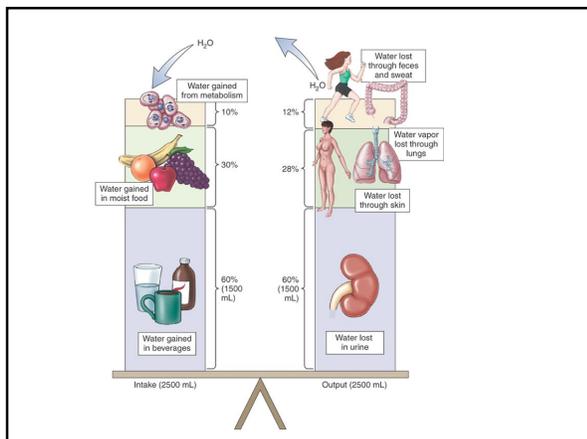
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### Water deficiency

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

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### Water excess

- Water excess is caused by over-hydration
- 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

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### 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

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### 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

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### 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

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### 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
  - Normal K+ plasma level 3.5-5.0 mEq/L

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### 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<sup>nd</sup> most abundant cation in the intracellular fluid
  - Responsible for heart, muscle & nerve function
  - Normal  $Mg_{+}$  plasma level 1.5-2.5mEq/L

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### 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
  - $CO_2$  is transported in the form of bicarbonate in the blood
  - Excretion is controlled by the kidneys
  - Can be either excreted or reabsorbed depending on the bodies needs

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### 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

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## 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

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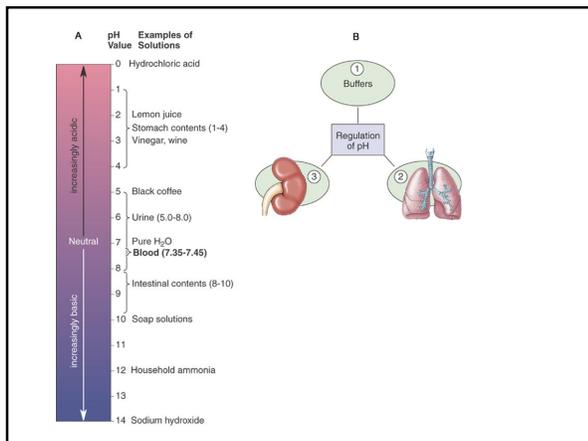
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## Acid-base

- Most hydrogen ions come from the body's chemical reactions during metabolism
- When glucose is metabolized in the presence of oxygen, it produces CO<sub>2</sub>, water & energy
- CO<sub>2</sub> & 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

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## Regulation of pH

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

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## 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<sup>+</sup> concentration increases in blood, the taker buffer removes H<sup>+</sup> from the blood
  - If H<sup>+</sup> concentration decreases in blood, the giver donates a H<sup>+</sup> to the blood
  - The adding or removing of H<sup>+</sup> the buffer pair maintains normal blood pH
  - The important buffers in the body are bicarbonate buffers, phosphate buffers, hemoglobin & plasma proteins

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## 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<sup>+</sup> concentration or blood pH
  - Decreasing the respiratory rate causes the body to retain carbon dioxide
    - The CO<sub>2</sub> 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
    - This is the basis of respiratory alkalosis

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## Regulation of pH

- The brain senses plasma hydrogen (H<sup>+</sup>) concentration
- As the plasma concentration of H<sup>+</sup> increases, the respiratory center is stimulated which causes an increase in the rate & depth of breathing
- The increase in respirations cause increase exhalation of CO<sub>2</sub> 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 CO<sub>2</sub> in plasma which forms hydrogen causing a decrease in pH

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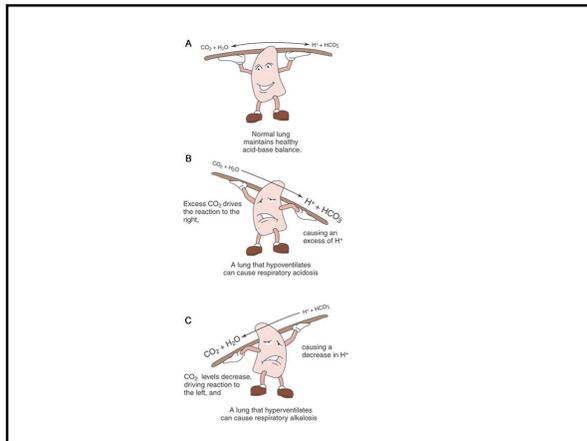
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## Regulation of Ph

- 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

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### 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

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### 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 CO<sub>2</sub> 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
  - The kidneys ability to correct respiratory acidosis is called renal compensation

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### 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

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## 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

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## 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 of  $H^+$  which decreases pH

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## 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

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