Chapter 27: Water, Electrolytes, and Acid-Base Balance

I. Body Fluids

A. Intracellular Fluid Compartment

1. The intracellular fluid compartment includes all the fluid in _____

   _____

2. The intracellular fluid from all cells has a _____ composition
3. Intracellular fluid accounts for how much of the total body weight? _____

B. Extracellular Fluid Compartment

1. The extracellular fluid compartment includes all of the fluid _____

   _____ and constitutes about _____ of total body weight

2. The extracellular fluid compartment is subdivided into _____
   a. The two major subcompartments are:
      1. _____
      2. _____
   b. Other subcompartments include:
      1. _____
      2. _____
      3. _____
3. Where is interstitial fluid found? _____

   _____

4. Where is plasma found? _____
5. All the other subcompartments constitute relatively _____

C. Movement Between Subcompartments

1. How does the composition of extracellular fluid compare in different subcompartments? _____
2. Movement does occur between subcompartments:
   a. Water _____
   b. Small molecules and ions _____

      _____
   c. Large molecules _____

II. Regulation of Body Fluid Concentration and Volume

A. Regulation of Water Content

1. The total volume of the water in the body _____
    a. Volume of water taken into body equals _____
2. Changes in the water volume in the body fluids alter:
    a. Osmolality _____
    b. Blood _____
    c. Interstitial _____
3. About 90% of the water entering the body comes from _____ and some comes from _____
4. About 10% of the water entering the body comes from _____ _____
5. The movement of water across the wall of the gastrointestinal tract depends on _____
6. The volume of water entering the body depends on _____
    a. If a large volume of dilute liquid is consumed _____ _____
    b. If a small volume of concentrated liquid is consumed _____
7. The sensation of thirst results from:
    a. Increase in the _____
    b. Reduction in _____
        1. Detected by cells in the _____ within _____
        2. Initiate activity in neural circuits that results in _____ _____
    c. When do baroreceptors influence the sensation of thirst? _____ _____
8. Angiotensin II opposes a decrease in blood pressure by:
    a. Acting on the brain to _____
    b. Acting on the adrenal cortex _____
    c. Acting on blood vessels _____

9. When dehydrated people drink, they do not usually drink large volumes of water all at once but drink _____
    a. This is because the thirst sensation is temporarily interrupted by:
        1. Wetting of the oral mucosa causes sensory neurons to _____ _____
        2. Stretch of the gastrointestinal wall:
            a. Initiates _____
            b. Sensory neurons _____
            c. Temporarily _____
    b. Since water absorption from the gastrointestinal tract takes _____ temporarily suppressing thirst prevents _____
    c. When osmolality and blood pressure are within normal ranges _____ _____
10. Water loss from the body occurs through three major routes:
    a. 61% is lost through _____
    b. 35% of water loss occurs through _____ from:
        1. _____
        2. Water that _____
        3. _____
    c. 4% is lost in the _____
11. The volume of water lost through the respiratory system depends on:
    a. _____ & _____ of the air
    b. Body _____
    c. Volume _____
12. What is insensible perspiration? _____
    a. It plays a role in _____
    b. How much water is lost for each degree of body temperature? _____
13. Sweat or sensible perspiration is secreted by the _____ and contains _____
    a. The composition of sweat resembles _____

b. Solutes in the sweat include:
    1. _____ 3. _____
    2. _____ 4. _____
        a. The major solute component is _____

14. What determines the volume of sweat produced? _____
    _____
    a. The volume produced increases substantially under:
        1. Conditions of _____
        2. Elevated _____ or
        3. _____
15. The loss of a large volume of hyposmotic sweat causes:
    a. Decrease in _____
    b. Increase in _____
    c. Fluid volume is lost primarily from _____ leads to
        1. Increased _____
        2. Reduction in _____
        3. Increase in _____
    d. During severe dehydration this can cause blood viscosity to
        a. _____
            1. This causes the heart to have an _____
16. Why is little water lost from the gastrointestinal tract? _____
    _____
    a. A large volume of fluid loss can occur due to severe _____ and _____
17. What are the primary organs for regulating the composition and volume of body fluids? _____

B. Regulation of Extracellular Fluid Osmolality
    1. The osmolality, or concentration of a solution, is changed by:
        a. Adding water _____
        b. Removing water _____

2. An increase in the osmolality of the extracellular fluid triggers _____ and _____ secretion
    a. Water that is consumed, as a result of thirst, is _____ _____ and enters _____
    b. ADH acts on the _____ and _____ to _____ from _____
        1. Both mechanisms result in increased water entering the extracellular fluid that causes a _____
    c. The ADH and thirst mechanisms are sensitive to _____ _____
    d. Larger increases in extracellular fluid osmolality results in _____ _____
3. A decrease in extracellular fluid osmolality inhibits _____ and _____ secretion
    a. Less water is _____
    b. Less water is _____ from _____
        1. Therefore, more water is lost as a _____
        2. Result is an _____ in osmolality of extracellular fluid

C. Regulation of Extracellular Fluid Volume
1. Even if the osmolality of the extracellular fluid is within a narrow range of values, the extracellular fluid volume can _____ or _____
2. What type of receptors are important in regulation of extracellular fluid volume? _____
    a. These receptors include:
        1. Carotid sinus and aortic arch _____ monitor _____
        2. Juxtaglomerular apparatuses monitor _____
        3. Receptors in the walls of the atria and large veins are sensitive to _____
3. These receptors activate _____ and _____ that regulate extracellular fluid volume

a. Neural Mechanisms
    1. What do neural mechanisms change? _____
    _____
    2. When baroreceptors detect an increase in arterial & venous pressure:
        a. Frequency of action potentials _____
        b. Afferent arterioles _____
        c. Increases _____
        d. Resulting in an _____
        e. Increase in _____ volume
        f. Increase in _____ volume
    3. When baroreceptors detect a decrease in arterial & venous pressure:
        a. Frequency of action potentials _____
        b. Afferent arterioles _____
        c. Decreases _____, _____ volume, and _____ volume
b. Renin-Angiotensin-Aldosterone Mechanism
    1. This mechanism responds to _____
    2. When juxtaglomerular cells detect increases in blood pressure:
        a. Decrease the rate of _____ secretion
        b. Results in decreased conversion of _____ to
        _____
        c. Reduced _____ causes
        d. Decrease in rate of _____ secretion from adrenal cortex
        e. Decreased _____ levels reduce the rate of
        _____ reabsorption
            1. Primarily in the _____ & _____
        f. Therefore more _____ remains in the filtrate
        g. This increases the _____ of the filtrate and reduces the ability of the kidney to _____
        h. The _____ remains with the excess _____ in the filtrate
        i. Volume of urine produced _____ and the extracellular fluid volume _____

j. Reestablishing homeostasis

3. When juxtaglomerular cells detect decreases in blood pressure:
   a. The increase in _____ secretion
   b. Results in increased conversion of _____ to _____
   c. Increased _____ causes an
   d. Increase in rate of _____ secretion from the adrenal cortex
   e. Increased _____
   f. Increases the rate of _____ reabsorption
      1. Primarily from the _____ & _____
   g. Therefore, less _____ remains in the filtrate
   h. Decreases the _____ of the filtrate
   i. Increases the ability of the kidney to _____ & to increase _____
   j. The volume of urine produced _____ and the extracellular fluid volume and blood pressure _____

b. Atrial Natriuretic Hormone (ANH) Mechanism
   1. Most important in responding to _____
   2. An increase in atrial blood pressure usually results from an increase in _____
      a. Stimulates secretion of _____
      b. Decreases _____ in the _____ _____ & _____
      c. Increases the rate of _____ & _____ loss in the urine
      d. Therefore increased ANH secretion decreases _____ _____
   3. ANH does not respond strongly to _____
   4. A decrease in atrial blood pressure _____ the secretion of ANH
      a. Decreases the inhibition of _____ in the _____ _____ & _____
      b. Rate of _____ & _____ reabsorption increases

c. Which is consistent with _____ urine volume and _____ extracellular fluid volume

c. Antidiuretic Hormone (ADH) Mechanism
   1. Plays an important role in regulating _____ in response to _____
   2. An increase in blood pressure results in:
      a. Decrease in _____ secretion
      b. Reabsorption of _____ decreases in the _____ _____ & _____
      c. Results in a _____ volume of _____ urine
      d. Response helps decrease _____ & _____
   3. A decrease in blood pressure results in:
      a. Increase in _____ secretion
      b. Reabsorption of _____ increases in the _____ _____ & _____
      c. Resulting in a _____ volume of _____ urine
      d. Response helps increase _____ & _____

III. Regulation of Intracellular Fluid Composition

A. Plasma Membrane
   1. Plasma membranes are _____
      a. Relatively impermeable to _____ & other _____
      b. Have limited permeability to _____ & _____
   2. Most large molecules synthesized within cells remain _____ _____
   3. Some substances are _____ across the plasma membrane
      a. Their concentrations in the intracellular fluid are determined by:
         1. _____ &
         2. _____ difference across the plasma membrane

B. Water

1. What controls water movement across the plasma membrane? _____
2. Net movement of water is affected by changes in the _____ of _____ in the _____ & _____fluids
3. As dehydration develops:
    a. Concentration of solutes in extracellular fluid _____
    b. Results in water movement by osmosis from _____ to _____
        1. If enough water moves the cells may function _____
4. After dehydration, when water intake increases:
    a. Concentration of solutes in extracellular fluid _____
    b. Results in water movement _____

IV. Regulation of Specific Electrolytes in Extracellular Fluid

What are electrolytes? _____

A. Regulation of Sodium Ions

1. Sodium ions are the _____ cations
2. Because of their abundance they exert _____
    a. How much of extracellular osmotic pressure is due to Na^+ and associated anions? _____
3. The kidneys are the major route for Na^+ _____
    a. Na^+ readily passes through the filtration membrane so its concentration in the filtrate is the _____ in the plasma
    b. The concentration of Na^+ excreted in the urine is determined by _____ _____
    c. The rate of Na^+ transport in the proximal tubule is _____
    d. Na^+ transport mechanisms of the _____ & _____ _____ are under hormonal control
        1. When aldosterone is present _____ _____
        2. When aldosterone is absent _____

_____

4. Na^+ is also excreted from the body in _____
   a. Normally only a _____
   b. The amount increases during conditions of _____ in a _____
   c. As the body temperature increases:
      1. Thermoreceptor neurons within the _____
      2. Respond by increasing the _____
      3. As the rate of sweat production increases _____ _____ decreases to keep _____
5. The primary mechanisms that regulate Na^+ concentration in the extracellular fluid are sensitive to changes in:
   a. Extracellular _____
   b. Blood _____
6. If the quantity of Na^+ increases the osmolality of extracellular fluid _____
   a. Stimulates _____ secretion
   b. Increases the _____ by the kidney
   c. Causes a _____ volume of _____ urine to be produced
   d. It also increases the _____
   e. There is an _____ volume
7. If the quantity of Na^+ decreases the osmolality of extracellular fluid _____
   a. Inhibits _____ secretion
   b. Stimulates a _____ volume of _____ urine to be produced
   c. _____ the sensation of thirst
   d. Extracellular fluid volume _____
8. By regulating extracellular fluid osmolality and extracellular fluid volume the concentration of _____
9. Elevated blood pressure under resting conditions _____ _____
10. If blood pressure is low _____

a. Mechanisms such as the _____ are activated
    1. Increase _____ &
    2. Water _____ in the _____

11. ANH is secreted in response to _____ within the right atrium
    a. ANH acts on the kidneys to _____ urine production by _____ the reabsorption of _____
    b. ANH also inhibits _____ secretion and the effect of _____ on the _____ & _____ in the kidneys
12. What is hypernatremia? _____
13. What is hyponatremia? _____

B. Regulation of Chloride Ions
1. The electrical attraction of anions and cations makes it difficult to _____ _____
2. Therefore, the mechanisms that regulate concentration of cations in the extracellular fluid also _____
3. The mechanisms that regulate _____, _____, and _____ levels in the body are important in influencing _____

C. Regulation of Potassium Ions
1. The concentration gradient of K^+ across the plasma membrane has a major influence on the _____
    a. What cells are highly sensitive to changes in this concentration gradient? _____
2. An increase in extracellular K^+ leads to _____
3. A decrease in extracellular K^+ leads to _____
4. What is hyperkalemia? _____
5. What is hypokalemia? _____
6. In the kidney:
    a. _____ through the filtration membrane
    b. They are _____ in the proximal tubules
    c. They are _____ in the distal tubules & collecting ducts

1. Secretion in the distal tubules and collecting ducts is _____ _____ and primarily responsible for controlling the _____

7. Aldosterone plays a major role in regulating K^+ concentration in the extracellular fluid by _____
   a. Aldosterone secretion from the adrenal cortex is stimulated by:
      1. Elevated _____
      2. Increased _____
   b. Elevated aldosterone levels in the circulatory system:
      1. Increase _____
      2. Lowering _____
8. Circulatory system shock causes the extracellular K^+ to be more _____ _____
   a. This stimulates _____ from the adrenal cortex
   b. The low blood pressure associated with circulatory system shock will stimulate the _____ mechanism which also stimulates secretion of _____
   c. Homeostasis is reestablished as:
      1. _____ increases
      2. _____ and _____ reabsorption results in an increase in _____ that dilutes the _____
      3. Blood pressure _____ toward normal as
         a. Water _____
         b. Angiotensin II stimulates _____

D. Regulation of Calcium Ions
1. What is hypocalcemia? _____
2. What is hypercalcemia? _____
3. Decreases and increases in the extracellular concentration of Ca^{2+} markedly affect the _____
   a. Hypocalcemia _____ the permeability of plasma membranes to Na^+

1. This results in nerve and muscle tissues _____

   _____

b. Hypercalcemia _____ the permeability of plasma membranes to Na^+

1. Preventing normal _____

4. High extracellular Ca^{2+} levels cause the _____ in soft tissues, resulting in _____
5. What structures are important in maintaining extracellular Ca^{2+} levels?
   a. _____
   b. _____
   c. _____
6. How much of the total body calcium is contained in bone? _____
   a. Therefore part of extracellular Ca^{2+} regulation involves regulation of:
      1. _____ into bone
      2. _____ from bone
7. Long-term regulation of Ca^{2+} levels depends on a balance between:
   a. _____ in the intestinal tract
   b. _____ by the kidneys
8. Functionally parathyroid hormone:
   a. Increases _____
   b. Reduces _____
9. The rate of parathyroid secretion is regulated by _____
   a. Elevated Ca^{2+} levels _____ secretion
   b. Reduced Ca^{2+} levels _____ secretion
10. Actions of parathyroid hormone include:
    a. Increased _____ which results in the _____ of bone and the release of _____ and _____ into body fluids
    b. Increases the rate of _____ in the kidneys
    c. Increases the concentration of _____ in the urine
    d. Increases the rate of Vitamin D conversion to _____

       _____

1. Active vitamin D acts on the intestinal tract to _____

   _____

11. A lack of parathyroid hormone secretion results in _____

    _____ that is caused by:

    a. Reduction in _____
    b. Increased _____ &
    c. Reduced _____
    d. Could result in death because of _____

12. Vitamin D

    a. Can be obtained from _____ or from _____
    b. Why does lack of exposure to sunlight decrease vitamin D biosynthesis?

       _____

    c. Without vitamin D, the transport of _____

       the intestinal tract is _____

       1. Leads to inadequate _____ even though the diet may contain large amounts

    d. Normal Ca^{2+} absorption depends on both:

       1. Consumption of _____ &
       2. Presence of _____

13. The hormone calcitonin _____ levels

    a. Calcitonin is most effective when _____
    b. Calcitonin has its major effect on _____ by:

       1. Inhibit _____ &
       2. Prolong _____

    c. By these actions calcitonin:

       1. Decreases bone _____
       2. Increases bone _____

    d. Calcitonin secretion is:

       1. Stimulated by _____
       2. Inhibited by _____

e. Increased secretion of calcitonin _____ of Ca^{2+} but it is not as important in controlling Ca^{2+} levels as _____

E. Regulation of Magnesium Ions

1. Most of the magnesium in the body is _____ or in the _____
2. How much magnesium is found in the extracellular fluid? _____
   a. About one-half of these are _____ and one-half are _____
3. Mg^{2+} are cofactors for _____ such as the _____ involved in _____
4. In the kidneys:
   a. Mg^{2+} passes through the _____ into the filtrate
   b. How much of these ions are reabsorbed? _____
   c. Where is most of the Mg^{2+} reabsorbed in the kidney? _____
   d. The capacity of the kidney to reabsorb Mg^{2+} is _____
      1. If the level of free Mg^{2+} increases in the extracellular fluid there is an _____
      2. If the level of free Mg^{2+} decreases in the extracellular fluid there is an _____
   e. Decreased extracellular concentration of Mg^{2+} causes a _____ _____ in the nephron

F. Regulation of Phosphate Ions

1. About 85% of phosphate is in the form of _____ in bone (_____) and teeth
2. Most of the remaining phosphate is _____
   a. Many phosphate ions are covalently bound to _____
   b. Phosphate ions are important components of _____, _____, & _____
   c. Phosphates also play important roles in regulation of _____
   d. Phosphate ions dissolved in the intracellular fluid act as _____
3. The capacity of the kidneys to reabsorb phosphate ions is _____
   a. Therefore if the level of phosphate ions increases in the extracellular fluid
      1. Excess _____ in the filtrate

2. Increase in the rate of _____ in the urine

4. Over time a low phosphate intake can _____
   a. Most of the phosphate that enters the filtrate _____
      _____
5. Parathyroid hormone can play a _____
   a. Promotes bone _____
   b. Large amounts of _____ & _____ are released
   c. PTH decreases the _____ from renal tubules so that a _____ is lost in urine
6. If phosphate levels in the extracellular fluid increase above normal levels, _____ in soft tissues

V. Regulation of Acid-Base Balance

A. Hydrogen Ions
   1. H^+ affect the activity of _____ & interact with _____
   2. Most chemical reactions are _____
   3. The major mechanisms that regulate H^+ concentration are:
      a. _____ c. _____
      b. _____

B. Acids and Bases
   1. What are acids? _____
   2. What are bases? _____
      a. Many bases release _____ which react with _____ to form _____
   3. Strong acids and bases completely _____
   4. Weak acids dissociate but most _____
      a. The proportion of weak acid molecules that release H^+ into solution is
         1. Very _____ & is
         2. Influenced by _____
   5. Weak acids are:
      a. Common in _____

b. Play important roles in _____

C. Buffer Systems

1. Buffers resist _____ of a solution
2. Buffers within body fluids _____ by chemically
   a. Binding to _____ when they are _____ to a solution
   b. Releasing _____ begins to fall
3. Carbonic Acid/Bicarbonate Buffer System
   a. Is carbonic acid a strong or weak acid? _____
   b. The carbonic acid/bicarbonate buffer system depends on the equilibrium that is _____ between:
      1. _____
      2. _____ &
      3. _____
   c. Adding a small amount of a strong acid to a solution containing H_2CO_3 increases H^+
      1. In response a large _____ binds to _____ to form _____ and only a small _____
         a. A large _____ is resisted by the buffer system
   d. Adding a small amount of a strong base to a solution containing H_2CO_3 removes H^+
      1. Many of the _____ form _____ and _____
         a. A large _____ is resisted by the buffer system
   e. The carbonic acid/bicarbonate buffer system quickly responds to:
      1. During exercise the addition of substances such as _____ & _____
      2. Increased _____ & _____ production
      3. Consumption of large amounts of _____
   f. The carbonic acid/bicarbonate buffer system plays an essential role in the control of body pH by both the _____ & the _____
4. Protein Buffer System

a. What protein molecules act as buffer molecules?
    1. _____
    2. _____
b. How much buffer capacity is provided by protein molecules? _____
c. Important intracellular proteins that act as buffers include:
    1. _____ in red blood cells
    2. _____ associated with nucleic acids
d. The capacity to act like buffers is due to functional groups such as:
    1. _____
    2. _____
e. Protein functional groups act like weak acids:
    1. As the H^+ concentration increases _____
    2. When the H^+ concentration decreases _____

5. Phosphate Buffer System
    a. Phosphate is an important _____ buffer system
    b. Phosphate containing molecules such as _____, _____, _____, as well as _____ ions in solution act as buffers
    c. Phosphate ions act as _____

D. Mechanisms of Acid-Base Balance Regulation
1. Mechanisms of acid-base regulation depend on the regulation of _____ and _____ function
    a. Which system responds more quickly? _____
    b. Which system has a greater capacity to respond? _____
2. Respiratory Regulation of Acid-Base Balance
    a. The respiratory system regulates acid-base balance by influencing the _____
    b. Carbon dioxide reacts with _____ to form carbonic acid which dissociates to form _____ and _____
        1. The chemical reaction is written as:

            _____

c. The reaction is in _____ but shifts in response to changes in _____ levels
    1. Increases in carbon dioxide:
        a. Cause CO_2 to join with _____ and form more _____
        b. The _____ then dissociates to _____ & _____
    2. Decreases in carbon dioxide cause the equilibrium to shift _____ _____
        a. _____ and _____ combine to form _____
        b. Which then forms _____ and _____
d. What is the function of carbonic anhydrase? _____ _____
e. Where is carbonic anhydrase located? _____ _____
f. Decreases in body fluid pH:
    1. Stimulate neurons in the _____
    2. Cause the rate and depth of ventilation to _____
    3. This eliminates _____ at a greater rate
    4. The concentration of _____ decreases in _____
    5. As CO_2 levels decline the carbonic acid/bicarbonate buffer system:
        a. _____ combine with _____ to form _____
        b. The _____ then forms _____ & _____
    6. This results in concentration of _____ (pH increases) toward its normal range as _____ exits the lungs
g. Increases in body fluid pH:
    1. Inhibit neurons in the _____
    2. Cause the rate and depth of ventilation to _____
    3. Causes less _____ to be eliminated
    4. As _____ increases due to metabolism
    5. Body fluid concentration of _____ also increases
    6. As the increased _____ dissociates the concentration of H^+ increases and the pH _____

3. Renal Regulation of Acid-Base Balance
    a. Cells of the kidney tubules directly regulate acid-base balance by increasing or decreasing the rate of:
        1. _____ into the filtrate
        2. _____ from the filtrate
    b. Carbonic anhydrase is present in the nephron cells and catalyzes the formation of _____ from _____ and _____
        1. The carbonic acid molecules dissociate to _____ & _____
        2. A countertransport system on the apical membrane then exchanges _____ for _____
            a. Secreting _____ into the filtrate
            b. Reabsorbing _____ from the filtrate
        3. The _____ and _____ are cotransported across the basal membrane and then diffuse into _____
    c. The reabsorbed _____ combine with excess _____ in the extracellular fluid to form _____
        1. This removes _____ and increases _____
    d. The rate of _____ secretion and _____ reabsorption increases when pH _____ and slows when pH _____
    e. Some of the H^+ secreted into the filtrate combines with HCO_3^- to form _____ (The bicarbonate entered the filtrate in the form of _____ through the filtration membrane)
        1. The H_2CO_3 then dissociates to form _____ and _____
        2. The _____ then diffuses from the _____ into the tubule cells
        3. Inside the tubule cells it reacts with _____ to form _____
        4. The H_2CO_3 subsequently dissociates into _____ and _____
            a. The _____ is transported into the filtrate in exchange for _____
            b. And the _____ enter the extracellular fluid
        5. Therefore, many of the HCO_3^- entering the filtrate through glomerular filtration reenter the _____

f. H^+ secreted into the nephron normally exceed the amount of _____ that enter through the filtration membrane
    1. Almost all of the HCO_3^- are _____
    2. Few HCO_3^- are lost in the urine unless _____
g. If the pH of the body fluids increases:
    1. The rate of H^+ secretion into the filtrate _____
    2. The rate of HCO_3^- reabsorption into the extracellular fluid _____
        a. As a result, the amount of bicarbonate filtered into the kidney tubules exceeds _____
        b. The excess _____ pass into the urine
        c. Diminishing the amount of _____ in the _____ fluid
            1. Allows extracellular _____ to increase and
            2. pH of body fluids _____ toward normal range
h. If pH of the filtrate drops below 4.5 it inhibits _____
    1. Buffers in the filtrate combine with _____
    2. What substances in the filtrate act as buffers?
        a. _____
        b. _____
        c. _____
i. NH_3 is produced in the cells of the nephron when amino acids like _____ are _____
    1. NH_3 diffuses from the nephron cells into _____ and combines with _____ to form _____
    2. The rate of NH_3 production increases when _____ _____ days
    3. The elevated ammonia production:
        a. Increases _____ filtrate
        b. Allowing secretion of _____ urine