

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. _____
2. _____
3. _____
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:
- Reduction in _____
 - Increased _____ &
 - Reduced _____
 - Could result in death because of _____
12. Vitamin D
- Can be obtained from _____ or from _____
 - Why does lack of exposure to sunlight decrease vitamin D biosynthesis?

 - Without vitamin D, the transport of _____
 the intestinal tract is _____
 - Leads to inadequate _____ even though the diet
 may contain large amounts
 - Normal Ca^{2+} absorption depends on both:
 - Consumption of _____ &
 - Presence of _____
13. The hormone calcitonin _____ levels
- Calcitonin is most effective when _____
 - Calcitonin has its major effect on _____ by:
 - Inhibit _____ &
 - Prolong _____
 - By these actions calcitonin:
 - Decreases bone _____
 - Increases bone _____
 - Calcitonin secretion is:
 - Stimulated by _____
 - 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. _____
 - b. _____
 - c. _____

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 CO₂ 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 CO₂ 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