Fluid and Acid-Base Balance

Chapter Overview

The theme continues. As changes occur, homeostasis is maintained by body systems responding to the changes. This chapter deals with two very important areas of change: water and pH.

Water is located primarily in two major compartments: extracellular fluid (plasma and interstitial fluid) and intracellular fluid. All of these have different amounts of water and ions. To regulate and maintain these fluid balances, adjustments are made in the extracellular volume and the extracellular osmolarity.

Acid-base balance is very critical in the survival of cells. The somewhat narrow pH range is maintained by four buffer systems: carbonic acid/carbonate buffer system, protein buffer system, hemoglobin buffer system, and the phosphate buffer system.

The buffers are the first line of defense against pH changes. The second line is the lungs. By removing carbon dioxide less carbonic acid is added to body fluids. The last line of defense in the prevention of change in pH is the kidney. The big role of the kidney is to excrete the necessary amounts of hydrogen ions, bicarbonate ions, and ammonium ions. Maintaining a relatively constant pH is truly remarkable considering the great variability of substances brought into and produced by the body.

Chapter Outline

FLUID BALANCE
Input must equal output if balance is to be maintained.

- If the quantity of a substance is to remain stable within the body, its input by means of ingestion or metabolic production must be balanced by an equal output by means of excretion or metabolic consumption.
- Known as the balance concept, this relationship is extremely important in the maintenance of homeostasis.
- If the body as a whole has a surplus or a deficit of a particular stored substance, the storage site can be expanded or partially depleted to maintain the extracellular fluid concentration of the substance within homeostatically prescribed limits.
- When total body input of a particular substance equals its total body output, a stable balance exists.
- When the gains via input exceed its losses via output, a positive balance exists.
- When the losses of a substance exceed its gains, a negative balance exists.

Body water is distributed between the intracellular and extracellular fluid compartments.

- The intracellular fluid compartment comprises about two-thirds of the total body water.
- The remaining one-third of the body water found in the extracellular fluid is further subdivided into plasma and interstitial fluid.
- Two other major categories are included in the extracellular fluid compartment: lymph and transcellular fluid.
- Transcellular fluid consists of a number of small specialized fluid volumes: cerebrospinal fluid, intraocular fluid, synovial fluid, pericardial fluid, pleural fluid, peritoneal fluid, and the digestive juices.
• Although these fluids are extremely important functionally, they represent an insignificant fraction of the total body water.

The plasma and interstitial fluid are separated by the blood vessel walls, whereas ECF and ICF are separated by cellular plasma membranes.

• Plasma and interstitial fluid are nearly identical in composition, except that interstitial fluid lacks plasma proteins.

• Any change in one of these ECF compartments is quickly reflected in the other compartment because they are constantly mixing.

• The composition of the ECF differs considerably from that of the ICF.

• Among the major differences are: (1) the presence of cellular proteins in the ICF that are unable to permeate the enveloping membranes to leave the cells, and (2) the unequal distribution of sodium and potassium and their attendant anions as a result of the action of the membrane-bound sodium-potassium ATPase pump that is present in all cells.

• Sodium is the primary ECF cation and potassium is primarily found in the ICF.

• In the extracellular fluid, sodium is accompanied primarily by the anion chloride and to a lesser extent by bicarbonate.

• The major intracellular anions are phosphate and the negatively charged proteins trapped within the cell.

• The movement of water between the plasma and the interstitial fluid across capillary walls is governed by relative imbalances between capillary blood pressure and colloid osmotic pressure.

• The net transfer of water between the interstitial fluid and the intracellular fluid across the cellular plasma membranes occurs as a result of osmotic effects alone.

Fluid balance is maintained by regulating ECF volume and ECF osmolarity.

• Any control mechanism that operates on the plasma in effect regulates the entire extracellular fluid.

• The ICF, in turn, is influenced by changes in the ECF to the extent permitted by the permeability of the membrane barriers surrounding the cells.

• The factors regulated to maintain fluid balance in the body are ECF volume and ECF osmolarity.

• Extracellular fluid volume must be closely regulated to help maintain blood pressure.

• Extracellular fluid osmolarity must be closely regulated to prevent swelling or shrinking of the cells.

Control of ECF volume is important in the long-term regulation of blood pressure.

• Two compensatory measures come into play to transiently adjust the blood pressure until the ECF volume can be restored to normal: (1) baroreceptor reflex mechanisms alter both cardiac output and total peripheral resistance through autonomic nervous system effects on the heart and blood vessels, and (2) fluid shifts occur temporarily and automatically between the plasma and interstitial fluid.

• A reduction in plasma volume is partially compensated for by a shift of fluid out of the interstitial compartment into the blood vessels, thereby expanding the circulating plasma volume at the expense of the interstitial compartment.

• Conversely, when the plasma volume is too large, much of the excess fluid is shifted into the interstitial compartment.

• Responsibility for long-term regulation of blood pressure rests with the kidneys and the thirst mechanism, which control urinary output and fluid intake.

Control of salt balance is primarily important in regulating ECF volume.

• The total mass of sodium salts in the ECF determines the ECF's volume, and, appropriately, regulation of the ECF volume depends primarily on controlling salt balance.

• To maintain salt balance at a set level, salt input must equal salt output.

• Since we typically consume salt in excess of our needs, it is obvious that salt intake in humans is not well controlled.
• The three avenues for salt output are obligatory loss of salt in sweat and feces and controlled excretion of salt in the urine.
• By regulating the rate of urinary salt excretion, the kidneys keep the total sodium mass in the ECF constant despite any notable changes in dietary intake of salt or unusual losses through sweating, diarrhea, or other means.
• The amount of sodium excreted in the urine represents the amount of sodium that is filtered but is not subsequently reabsorbed.
• The kidneys accordingly adjust the amount of salt excreted by controlling two processes: (1) the glomerular filtration rate, and (2) the tubular reabsorption of sodium.
• The afferent arterioles that supply the renal glomeruli are constricted as part of the generalized vasoconstriction aimed at elevating a reduced blood pressure.
• As a result of reduced blood flow into the glomeruli, the glomerular filtration rate decreases and, accordingly, the amount of sodium and accompanying fluid that are filtered decreases.
• Excretion of salt and fluid are diminished.
• An elevation in ECF volume and arterial blood pressure is reflexly countered by a baroreceptor reflex response that leads to an increase in glomerular filtration rate, which in turn results in enhanced salt and fluid excretion.
• Baroreceptors that monitor fluctuations in blood pressure are responsible for bringing about adjustments in the amounts of sodium filtered and eventually excreted.
• The main factor controlling the extent of sodium reabsorption in the distal and collecting tubules is the powerful renin-angiotensin-aldosterone system.
• A fall in arterial blood pressure brings about a twofold effect in the renal handling of sodium: (1) a reflex reduction in the glomerular filtration rate to decrease the amount of sodium filtered, and (2) a hormonally adjusted increase in the amount of sodium reabsorbed.
• A rise in arterial blood pressure brings about (1) increases in the amount of sodium filtered, and (2) a reduction in renin-angiotensin-aldosterone activity, which decreases salt and water reabsorption.

Control of ECF osmolarity prevents changes in ICF volume.
• The osmotic activity across the capillary wall is due to the unequal distribution of plasma proteins.
• Plasma proteins are present only in the plasma.
• Osmotic activity across the cellular plasma membranes is directly related to any differences in ionic concentration between the ECF and ICF.
• Plasma proteins play no role in osmosis of water across the cell membranes because they are absent in both the interstitial fluid and the ICF that are separated by cell membranes.
• Sodium and its attendant anions, being by far the most abundant solutes in the ECF in terms of numbers of particles, account for the vast majority of the ECF's osmotic activity.
• Potassium and its accompanying intracellular anions are responsible for the ICF's osmotic activity.
• Normally, the osmolarities of the ECF and ICF are the same.
• Hypertonicity of the ECF, or the excessive concentration of ECF solutes, is usually associated with dehydration, or a negative free water balance.
• Dehydration with accompanying hypertonicity can be brought about in three major ways: (1) insufficient water intake; (2) excessive water loss; and (3) diabetes insipidus.
• Whenever the ECF compartment becomes hypertonic, water moves out of the cells by osmosis into the more concentrated ECF until the ICF osmolarity equilibrates with the ECF.
• The cells shrink as water leaves them.
• Shrinking of brain neurons causes disturbances in brain function.
• Circulatory problems may range from slight reduction in blood pressure to circulatory shock and death.
• Hypotonicity of the ECF is usually associated with overhydration; that is, excess of free water is present.
Hypotonicity can arise in three ways: (1) Patients with renal failure who are unable to excrete a dilute urine become hypotonic when they consume relatively more water than solutes. (2) Hypotonicity can occur transiently in healthy people if water is rapidly ingested to such an excess that the kidneys are unable to respond quickly enough to eliminate the extra water. (3) Hypotonicity can occur when excess water without solute is retained in the body as a result of inappropriate secretion of vasopressin.

The resultant difference in osmotic activity between ECF and ICF induces water to move by osmosis from the more dilute ECF into the cells, with the cells swelling.

Pronounced swelling in brain cells also leads to brain dysfunction and circulatory disturbances, including hypertension and edema.

When an isotonic fluid is injected into the ECF compartment, the ECF volume increases, but the concentration of ECF solutes remains unchanged, the ECF and ICF are still in osmotic equilibrium.

In the case of an isotonic fluid loss such as occurs in hemorrhage, the loss is confined to the ECF with no corresponding loss of fluid from the ICF.

**Control of water balance by means of vasopressin and thirst is of primary importance in regulating ECF osmolarity.**

- Of the many sources of water input and output only two can be regulated to maintain water balance: (1) Control of water input by thirst and (2) control of water output in the urine by vasopressin.
- A thirst center is located in the hypothalamus in close proximity to the vasopressin-secreting cells.
- Thirst increases water input, whereas vasopressin, by reducing urine production, decreases water output.
- Vasopressin and thirst are both stimulated by a free water deficit and suppressed by a free water excess.
- The predominant excitatory input for both vasopressin secretion and thirst come from the hypothalamus osmoreceptors located near the vasopressin-secreting cells and thirst center.
- Left atrial volume receptors monitor the blood pressure, which is a reflection of the ECF volume.
- In response to a major reduction in ECF volume and arterial pressure, as during hemorrhage, the left atrial volume receptors reflexly stimulate both vasopressin secretion and thirst.
- The outpouring of vasopressin and increased thirst lead to decreased urine output and increased fluid intake.
- Vasopressin exerts a potent vasoconstrictor effect on arterioles in addition to having an effect on the kidney tubules.
- Vasopressin and thirst are both inhibited when the ECF/plasma volume and arterial blood pressure are elevated.
- Aldosterone controlled sodium reabsorption is the most important factor in regulating ECF volume, with the vasopressin and thirst mechanisms playing only a supportive role.
- Another stimulus for increasing both thirst and vasopressin is angiotensin II.
- Angiotensin II, in addition to stimulating aldosterone secretion, acts directly on the brain to give rise to the urge to drink and concurrently stimulates vasopressin to enhance renal water reabsorption.
- Several factors affect vasopressin secretion, but not thirst. Vasopressin is stimulated by stress-related inputs, such as pain, fear, and trauma, that have nothing directly to do with maintaining water balance.
- Alcohol inhibits vasopressin secretion and can lead to ECF hypertonicity by promoting excessive free water excretion.

**ACID-BASE BALANCE**

*Acids liberate free hydrogen ions whereas bases accept them.*

- Acids are a special group of hydrogen-containing substances that dissociate when in solution to liberate free hydrogen ions.
- A base is a substance that can combine with a free hydrogen ion thus removing it from solution.
• The pH equals the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration.
• The greater the hydrogen ion concentration, the lower the pH.
• Every unit change in pH actually represents a tenfold change in hydrogen ion concentration.
• Solutions having a pH less than 7.0 are considered to be acidic.
• Solutions having a pH greater than 7.0 are considered to be basic or alkaline.

Fluctuations in hydrogen-ion concentration have profound effects on body chemistry.
• Changes in excitability of nerve and muscle cells are among the major clinical manifestations of pH abnormalities.
• Hydrogen-ion concentration exerts a marked influence on enzyme activity.
• Changes in hydrogen-ion concentration influence potassium levels in the body.

Hydrogen ions are continually being added to the body fluids as a result of metabolic activities.
• Normally hydrogen is continually being added to the body fluids from the three following sources: (1) carbonic acid formation, (2) inorganic acids produced during the breakdown of nutrients, and (3) organic acids resulting from intermediary metabolism.
• Three lines of defense against changes in hydrogen ion concentration operate to maintain the hydrogen ion concentration of body fluids at a nearly constant level despite unregulated input: (1) the chemical buffer systems, (2) the respiratory mechanism of pH control, and (3) the renal mechanism of pH control.

Chemical buffer systems act as the first line of defense.
• A chemical buffer system is a mixture in a solution of two chemical compounds that minimize pH changes when either an acid or a base is added or removed from the solution.

• There are four buffer systems in the body: (1) the carbonic acid/bicarbonate buffer system, (2) the protein buffer system, (3) the hemoglobin buffer system, and (4) the phosphate buffer system.
• The carbonic acid/bicarbonate buffer pair is the most important buffer system in the ECF for buffering pH changes brought about by causes other than fluctuations in carbon dioxide-generated carbonic acid.
• The protein buffer system is primarily important intracellularly.
• The hemoglobin buffer system buffers hydrogen ion generated from carbonic acid.
• The phosphate buffer system is an important urinary buffer.
• The phosphate buffer system is composed of an acid phosphate salt and a basic phosphate salt.
• This system contributes significantly to intracellular buffering.
• The phosphate system serves as an excellent urinary buffer.
• All chemical buffer systems act immediately, within fractions of a second, to minimize changes in pH.

The respiratory system regulates hydrogen-ion concentration by controlling the rate of carbon dioxide removal from the plasma through adjustments in pulmonary ventilation.
• When arterial hydrogen ion concentration increases, the respiratory center in the brain stem is reflexly stimulated to increase pulmonary ventilation.
• When arterial hydrogen ion concentration falls, pulmonary ventilation is reduced.
• Carbon dioxide diffuses from the cells into the blood faster than it is removed from the blood by the lungs, so higher-than-usual amounts of acid-forming carbon dioxide accumulate in the blood, thus restoring hydrogen ion concentration toward normal.
• If a deviation in hydrogen ion concentration is not swiftly and completely corrected by the buffer systems, the respiratory system comes into action a few minutes later, thus serving as the second line of defense against changes in hydrogen ion concentration.
The kidneys contribute powerfully to control of acid-base balance by controlling both hydrogen ion and bicarbonate concentrations in the blood.

- By simultaneously removing acid from and adding base to the body fluids, the kidneys are able to restore the pH toward normal more efficiently than the lungs.
- Also contributing to the kidneys' acid-base regulatory potency is their ability to return the pH almost exactly to normal.
- The kidneys control the pH of the body fluids by adjusting three interrelated factors: (1) hydrogen excretion, (2) bicarbonate excretion, and (3) ammonia secretion.
- The magnitude of hydrogen secretion depends on a direct effect of the plasma acid-base status on the kidneys' tubular cells.
- When the hydrogen ion concentration of the plasma passing through the peritubular capillaries is elevated above normal, the tubular cells respond by secreting greater-than-usual amounts of hydrogen from the plasma into the tubular fluid to be excreted in the urine.
- When the plasma hydrogen ion concentration is lower than normal, the kidneys conserve hydrogen by reducing their secretion and subsequent excretion in the urine.
- The kidneys regulate plasma bicarbonate ion concentration by two interrelated mechanisms: (1) variable reabsorption of the filtered bicarbonate back into the plasma, and (2) variable addition of new bicarbonate to the plasma.
- When the plasma hydrogen ion concentration is increased above normal during acidosis, renal compensation includes the following: (1) increased secretion and subsequent increased excretion of hydrogen in the urine, thereby eliminating the excess hydrogen and decreasing plasma hydrogen ion concentration, and (2) reabsorption of all filtered bicarbonate, plus addition of new bicarbonate to the plasma, resulting in increased plasma bicarbonate ion concentration.
- When plasma hydrogen ion concentration is reduced below normal during alkalosis, renal responses include the following: (1) decreased secretion and subsequent reduced excretion of hydrogen in the urine, resulting in conservation of hydrogen and increased plasma hydrogen ion concentration, and (2) incomplete reabsorption of filtered bicarbonate and subsequent increased excretion of bicarbonate, resulting in reduction of plasma bicarbonate ion concentration.
- There are two important urinary buffers: (1) filtered phosphate buffers and (2) secreted ammonia.
- Normally, secreted hydrogen is first buffered by the phosphate buffer system.
- When acidosis exists, the tubular cells secrete ammonia into the tubular fluid once the normal urinary phosphate buffers are saturated.
- Ammonia enables the kidneys to continue secreting additional hydrogen ions because ammonia combines with free hydrogen in the tubular fluid to form ammonium ions.
- The tubular membranes are not very permeable to ammonium, so the ammonium ions remain in the tubular fluid and are lost in the urine, each one taking a hydrogen ion with it.

Acid-base imbalances can arise from either respiratory dysfunction or metabolic disturbances.

- Respiratory acidosis is the result of abnormal carbon dioxide retention arising from hypoventilation.
- The primary defect in respiratory alkalosis is excessive loss of carbon dioxide from the body as a result of hyperventilation.
- The following are the most common causes of metabolic acidosis: (1) severe diarrhea, (2) diabetes mellitus, (3) strenuous exercise, and (4) uremic acidosis.
- Metabolic alkalosis arises most commonly from the following: (1) vomiting and (2) ingestion of alkaline drugs.
**Key Terms**

Acidic
Acidosis
Acids
Alkalosis
Ammonia
Ammonium ions
Balance concept
Bases
Basic (alkaline)
Chemical buffer system
Dehydration
Diabetes insipidus
Dissociation constant
Henderson-Hasselbach equation

Hypothalamic osmoreceptors
Insensible loss
Left atrial volume receptors
Metabolic acidosis
Metabolic alkalosis
Negative balance
Osmolarity
Overhydration
Positive balance
Respiratory acidosis
Respiratory alkalosis
Stable balance
Thirst center
Transcellular fluid
Water intoxication

**Review Exercises**

*Answers are in the appendix.*

**True/False**

1. When the gains via input exceed its losses via output, a negative balance exists.

2. The ICF compartment comprises about one-half of the total body water.

3. Plasma is a transcellular fluid.

4. The major intracellular anions are phosphate ions.

5. Diabetes insipidus is a disease characterized by a deficiency in vasopressin.

6. Vasopressin decreases water output by reducing urine production.

7. Vasopressin gets its name because it exerts a potent vasoconstrictor effect on arterioles.

8. Bases are a special group of hydrogen containing substances that dissociate when in solution to liberate free hydrogen.

9. A base is a substance that can combine with free hydrogen and thus remove it from solution.

10. The greater the hydrogen ion concentration the lower the pH.

11. The first line of defense against change in pH is the respiratory control of pH.

12. Tubular cells secrete ammonium ions that can combine with free hydrogen to form ammonia.
13. Metabolic acidosis can be caused by diabetes insipidus.

14. Metabolic alkalosis can be caused by vomiting.

**Fill in the Blank**

15. When total body input of a particular substance equals its total body output, a(n) ______ exists.

16. _______ and ________________ are nearly identical in composition, except that ________________ lacks plasma proteins.

17. The movement of water between the plasma and interstitial fluid across capillary walls is governed by relative imbalances between ________________ and ________________.

18. The three avenues for salt output are ________________, __________, and controlled excretion of salt in the __________.

19. The main factor controlling the extent of sodium reabsorption in the distal tubule and collecting tubule is the powerful ________________ system.

20. Dehydration with accompanying hypertonicity can be brought about in three major ways:
   (1) ________________, (2) ________________ and (3) ________________.

21. The predominant excitatory input for both vasopressin secretion and thirst comes from ________________.

22. The ______ equals the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration.

23. The ________________ serves as an excellent urinary buffer.

24. Respiratory acidosis is the result of abnormal carbon dioxide retention arising from ____________.

25. Uremic acidosis causes ________________.

26. Vomiting causes ________________.

27. Bicarbonate cannot buffer urinary hydrogen as it does in the ECF because bicarbonate is not excreted in the urine simultaneously with ________________.
28. The kidneys control the pH of the body fluids by adjusting three interrelated factors:

(1) ____________________, (2) ____________________, and (3) ____________________.

Matching
Match the cause on the left to the acid-base condition on the right.

_____ 29. diabetes mellitus  a. metabolic alkalosis
_____ 30. hyperventilation  b. respiratory acidosis
_____ 31. vomiting  c. metabolic acidosis
_____ 32. ingesting of alkaline drugs  d. respiratory alkalosis
_____ 33. strenuous exercise
_____ 34. uremic acidosis
_____ 35. hypoventilation
_____ 36. severe diarrhea

Multiple Choice

37. Which of the following disorders is characterized by a deficiency of vasopressin?
   a. diabetes mellitus
   b. hemorrhage
   c. hypotonicity
   d. colloidal isotonicity
   e. diabetes insipidus

38. Which of the following disorders or symptoms can be caused by hypotonicity?
   a. diabetes insipidus
   b. hypertension and edema
   c. hemorrhage
   d. diarrhea
   e. diabetes mellitus

39. Which of the following disorders or symptoms causes changes in the ECF but not in the ICF?
   a. diabetes insipidus
   b. hypertension and edema
   c. hemorrhage
   d. dehydration
   e. overhydration
40. Which of the avenues for salt output eliminates the most salt per day?
   a. tears  
   b. feces  
   c. hemorrhage  
   d. sweat  
   e. controlled excretion in urine

41. Which is the primary cation found in the ECF?
   a. bicarbonate  
   b. phosphate  
   c. sodium  
   d. chloride  
   e. potassium

42. Which is the primary cation found in the ICF?
   a. bicarbonate  
   b. sodium  
   c. chloride  
   d. phosphate  
   e. potassium

43. Which of the following organs is responsible for long-term regulation of blood pressure?
   a. lungs  
   b. heart  
   c. spleen  
   d. kidneys  
   e. intestines

44. Which fluid compartment has the greatest percentage of body fluid?
   a. lymph  
   b. plasma  
   c. ICF  
   d. ECF  
   e. transcellular fluid

45. Which fluid compartment represents the greatest percentage of body fluid within the ECF?
   a. lymph  
   b. interstitial fluid  
   c. synovial fluid  
   d. plasma  
   e. cerebrospinal fluid

46. When the plasma volume is too large, to which fluid compartment is the excess fluid shifted?
   a. lymph  
   b. interstitial fluid  
   c. transcellular fluid  
   d. cerebrospinal fluid  
   e. none of the above
47. Variations in percent body water among individuals is primarily due to differences in
   a. amount of adipose tissue.
   b. total muscle mass.
   c. vasopressin secretion
   d. drinking habits.
   e. glomerular filtration rate.

48. The tissue in the body containing the lowest percentage of water is the
   a. skin
   b. skeleton.
   c. muscle.
   d. internal organs.
   e. adipose (fat).

49. The component that constitutes the largest percentage of body weight is
   a. protein.
   b. water.
   c. sodium.
   d. carbohydrate.
   e. phospholipid.

50. Which of the following conditions would be a cause of metabolic acidosis?
   a. Severe diarrhea.
   b. Severe vomiting.
   c. Aspirin poisoning.
   d. Emphysema.
   e. None of the above are correct.

Modified Multiple Choice

Indicate which fluid imbalance is being described by writing the appropriate letter in the blank using the answer code below.

A = overhydration
B = dehydration
C = both overhydration and dehydration
D = neither overhydration or dehydration

51. ____ Symptoms include dry skin, parched tongue, and sunken eyeballs.
52. ____ Water enters the cells by osmosis.
53. ____ The body fluids have a lower concentration of solutes than normal.
54. ____ ECF and ICF become hypertonic.
55. ____ Cells become swollen.
56. ____ No fluid shift occurs between the ECF and ICF.
57. ____ Occurs as a consequence of water deprivation.
58. ____ Cells shrink.
59. ____ ECF and ICF become hypotonic.
60. ____ Convulsions and coma may occur.
61. ____ Occurs as a consequence of diabetes insipidus.
62. ____ Occurs as a consequence of heavy vomiting.
63. ____ Osmolarity of the body fluids is decreased.
64. ____ Occurs as a consequence of excessive fluid intake.
65. ____ Occurs as a consequence of excessive vasopressin secretion.
66. ____ Vasopressin secretion is stimulated as a compensatory mechanism.
67. ____ Increased urinary output as a compensatory mechanism.

Indicate which type of acid-base imbalance might occur in each of the following situations by writing the appropriate letter in the blank.

A = respiratory acidosis  
B = respiratory alkalosis  
C = metabolic acidosis  
D = metabolic alkalosis

68. ____ Fever  
69. ____ Excessive ingestion of alkaline drugs.  
70. ____ Aspirin poisoning.  
71. ____ Anxiety  
72. ____ Severe exercise.  
73. ____ Uremia  
74. ____ Damage to the respiratory center.  
75. ____ Severe diarrhea.  
76. ____ Pneumonia  
77. ____ Excessive vomiting of gastric contents.  
78. ____ Diabetes mellitus.

When a person has diarrhea, s/he loses excessive salt and water from the body. This fluid loss results in sodium depletion, dehydration, a decreased extracellular fluid volume, a reduction in plasma volume, and a decreased systemic arterial blood pressure. The following refers to a sequence of events that occur to compensate for this fluid loss. Indicate whether each factor listed

A = exhibits no change.  
B = is increased to compensate for fluid loss.  
C = is decreased to compensate for fluid loss.

79. ____ Sympathetic activity to the afferent arterioles of the nephrons.  
80. ____ Caliber of the afferent arterioles.  
81. ____ Glomerular capillary blood pressure.  
82. ____ Net filtration pressure.  
83. ____ GFR.  
84. ____ Amount of sodium and water filtered.  
85. ____ Renin secretion.  
86. ____ Angiotensin I and II production.  
87. ____ Aldosterone secretion.  
88. ____ Amount of sodium reabsorbed.  
89. ____ Amount of sodium secreted.  
90. ____ Vasopressin secretion  
91. ____ Permeability of distal and collecting tubules to water.  
92. ____ Amount of water reabsorbed.
93. _____ Amount of water excreted.
94. _____ Urinary volume.
95. _____ Thirst.
96. _____ Amount of potassium lost

*Indicate which acid-base abnormality is represented by the $[HCO_3^-] / [CO_2]$ ratio by writing the appropriate letter in the blank.*

A = uncompensated respiratory acidosis  
B = uncompensated metabolic acidosis  
C = uncompensated respiratory alkalosis  
D = uncompensated metabolic alkalosis

97. _____ 20/2  
98. _____ 40/1  
99. _____ 10/1  
100. _____ 20/0.5

**Points to Ponder**

1. As you shop in your favorite grocery store you may select a meat product that has been “sugar cured.” How does this process protect the meat and make it safe for you to eat?

2. At present one of the makers of a common antacid boasts that their product uses calcium instead of sodium and this is better. Do you find any truth in this advertisement? Explain.

3. Most Americans are aware of the caffeine in those popular drinks: coffee, tea, and most soft drinks. How are the other ingredients related to this chapter? Are these drinks diuretics? Are these beverages acidic or basic? How does your body handle these fluids?

4. What forces control the movement of water between the plasma and the interstitial fluid?

5. What are the two main forces that move water between compartments?

6. How is water intake regulated?

7. Why can’t humans drink sea water to quench our thirst?

8. What is the role of thirst in regulating fluid intake?

9. What is meant by fluid balance?

10. Define the term body fluid.
Clinical Perspective

1. The patient has lost a lot of blood due to the traumatic injuries received in an auto accident. Intravenous fluids are administered. Start with the hemorrhage and explain the sequence of events with reference to this chapter.

2. What causes a blister?

3. Why do high sodium diets tend to cause a person to gain weight?

4. For the sake of convenience, long-distance truck drivers often limit their intake of fluids, such as coffee. During this time, the urine becomes very dark in color. What makes it dark?

5. With respect to the above question (#4), if the truck driver drinks several glasses of water, the urine will be much lighter in color. Why does increased fluid intake lighten the urine?

6. How could a person go into hypochloremia? Hyponatremia?

7. How are alkalosis and acidosis compensated and treated?

8. What are the main physiological affects of acidosis and alkalosis?

9. What are some common causes of respiratory acidosis?

10. What are some characteristics of hypocalcemia?

Experiment of the Day

Equipment:

- 3 glasses
- 3 dried prunes
- sugar
- salt

1. Place water in all three glasses. Place several spoons of salt into one glass and several spoons of sugar into still another. The third glass has plain water. Drop a prune into each glass. Note time. Explain the results.
Chapter 15: Fluid and Acid-Base Balance

True/False

1. False—Positive balance.
2. False—Two-thirds.
3. False—Extracellular fluid.
4. True
5. True
6. True
7. True
9. True
10. True
11. False—Chemical buffer system.
12. False—Reversed, ammonia combines with hydrogen to form ammonium ions.
14. True

Fill in the Blank

15. Stable balance
16. Plasma, interstitial fluid, interstitial fluid
17. Capillary blood pressure, colloid osmotic pressure
18. Obligatory loss of salt in sweat, feces, urine
19. Renin-angiotensin-aldosterone
20. Insufficient water intake, excessive water loss, diabetes insipidus
21. Hypothalamic osmoreceptors
22. pH
23. Phosphate buffer system
24. Hypoventilation
25. Metabolic acidosis
26. Metabolic alkalosis
27. Hydrogen
28. Hydrogen excretion, bicarbonate excretion, ammonia secretion

Matching

29. c
30. d
31. a
32. a
33. c
34. c
35. b
36. c

Modified Multiple Choice

79. b
80. c
81. c
82. c
83. c
84. c
85. b
86. b
87. b
88. b
89. c
90. b
91. b
92. b
93. c
94. c
95. b
96. b
97. a
98. d
99. b

Multiple Choice

37. e
38. b
39. c
40. e
41. c
42. e
43. d
44. b
45. b
46. b
47. a
48. e
49. b
50. a
51. b
52. a
53. a
54. b
55. a
56. d
57. b
58. b
59. a
60. c
61. b
62. b
63. a
64. a
65. a
66. b
67. a
68. b
69. d
70. b
71. b
72. c
73. c
74. a
75. c
76. a
77. d
78. c