Chapter 23

Digestive and Excretory Systems

23.1 Lesson 23.1: Food and Nutrients

Lesson Objectives

- Identify classes of macronutrients and describe their roles in the body.
- Describe balanced eating and explain how it helps prevent obesity.
- State functions and food sources of vitamins and minerals.
- Describe eating disorders, their causes, and treatment.

Introduction

Did you ever hear the saying, "You are what you eat"? It's not just a saying. It's actually true. What you eat plays an important role in your health. Eating a variety of healthful foods promotes good physical health and provides energy for growth and activity. Many common diseases and their symptoms can be prevented or helped with healthful eating. Knowing what your body needs can help you choose foods to meet those needs.

Nutrients, Energy, and Building Materials

Nutrients are chemical elements or compounds that the body needs for normal functioning and good health. There are six main classes of nutrients: carbohydrates, proteins, lipids, water, vitamins, and minerals. The body needs these nutrients for three basic purposes: energy, building materials, and control of body processes.

A steady supply of energy is needed by cells for all body functions. Carbohydrates, proteins, and lipids provide this energy. Chemical bonds in molecules of these nutrients contain energy. When the bonds are broken during digestion to form simpler molecules, the energy is released. Energy is measured in units called kilocalories (kcal), commonly referred to as Calories.

Molecules that make up the body are continuously broken down or used up, so they must be replaced. Some nutrients, particularly proteins, provide the building materials for this purpose. Other nutrients—including proteins, vitamins, and minerals—are needed to regulate body processes. One way is by helping to form enzymes. Enzymes are compounds that control the rate of chemical reactions in the body.

Nutrients can be classified in two groups based on how much of them the body needs:

- **Macronutrients** are nutrients that the body needs in relatively large amounts. They include carbohydrates, proteins, lipids, and water.
- **Micronutrients** are nutrients the body needs in relatively small amounts. They include vitamins and minerals.

The exact amount of a macronutrient an individual needs depends on many factors, including gender and age. Recommended daily intakes of three macronutrients for young people of both genders are shown in **Table** 23.1.

Table 23.1: **Recommended Daily Intakes of Carbohydrates, Proteins, and Water**

GenderAnd Age	Carbohydrates(grams/day)	Proteins(grams/day)	Water*(liters/day)
Males 9–13 years	130	34	2.4
14–18 years	130	52	3.3
Females 9–13 years	130	34	2.1
14–18 years	130	46	2.3

- Includes water in foods as well as beverages

Carbohydrates

Carbohydrates are organic (or carbon-containing) compounds consisting of the elements carbon, hydrogen, and oxygen. The elements are arranged in small molecules called saccharides. Carbohydrates are classified as either simple or complex, based on the number of saccharides they contain.

Simple carbohydrates contain just one or two saccharides. They are all sugars. Examples of sugars in the diet include fructose, which is found in fruit, and lactose, which is found in milk. The main function of simple carbohydrates is to provide the body with energy. One gram of carbohydrate provides four kilocalories of energy. Glucose is the sugar that is used most easily by cells for energy. It circulates in the blood, providing energy to cells throughout the body. Glucose is the only source of energy used by the brain.

Complex carbohydrates, called polysaccharides, generally contain many saccharides. They include starches and fiber. Starches are found in plant foods such as vegetables and grains. They are broken down during digestion to form sugars that provide energy. Fiber consists of indigestible starches and other materials such as cellulose. It is present in all plant foods.

Fiber may be soluble or insoluble.

- Soluble fiber dissolves in water as it passes through the large intestine. It helps form substances that keep blood levels of glucose stable and blood levels of harmful lipids low (see below).
- Insoluble fiber does not dissolve but attracts water as it passes through the large intestine. This helps keep waste moist and moving easily through the intestine.

Proteins

Proteins are relatively large organic compounds containing carbon, hydrogen, oxygen, and nitrogen. The elements are arranged in small molecules called amino acids. Amino acids are the building blocks of proteins. They bond together to form long chains, called polypeptides. Proteins consist of one or more polypeptides.

Proteins play many vital roles in the body, including:

- Making up the majority of muscle tissue.
- Regulating many body processes.
- Forming antibodies that destroy bacteria and other "foreign invaders."
- Regulating the salt-water and acid-base balance in body fluids.
- Transporting nutrients and other vital substances in the blood.

Dietary proteins are broken down during digestion to provide the amino acids that cells need to make proteins for the body. Twenty different amino acids are needed for this purpose. Ten of these amino acids can be synthesized by cells from simple components. The other ten cannot be synthesized and must be obtained from foods. They are called essential amino acids because they are essential in the diet.

Proteins that contain all ten essential amino acids are referred to as complete proteins. They are found in animal foods such as milk and meat. Proteins that are missing one or more essential amino acids are referred to as incomplete proteins. They are found in plant foods such as legumes and rice. By eating a variety of different plant foods containing incomplete proteins, you can include all ten essential amino acids in your diet.

If you eat more protein than needed for the synthesis of new proteins by cells, the excess is used for energy or stored as fat. One gram of protein provides four kilocalories of energy. This is the same amount of energy that one gram of carbohydrate provides.

Lipids

Lipids, or fatty acids, are organic compounds that consist of repeating units of carbon, hydrogen, and oxygen. They provide the body with energy. The heart and skeletal muscles rely mainly on lipids for fuel. One gram of lipids provides nine kilocalories of energy, more than twice the amount provided by carbohydrates or proteins. Lipids have several other functions as well. Lipids form an insulating sheath around nerve cells that helps nerve messages travel more quickly. Lipids also help form substances that regulate blood pressure, blood clotting, and blood lipid levels. In addition, lipids make up the membranes that surround cells.

The term fat is often used interchangeably with the term lipid, but fats are actually a particular type of lipid, called **triglycerides**, in which three fatty acids are bound to a compound called glycerol. Fats are important in the body. They are the main form in which the body stores energy. Stored body fat is called adipose tissue. Stored fat not only provides an energy reserve but also cushions and protects internal organs. In addition, stored fat insulates the body and helps prevent heat loss in cold weather.

Although lipids and fats are necessary for life, they may be harmful if they are present in the blood at high levels. Both triglycerides and the lipid called cholesterol are known to damage blood vessels if their concentrations in the blood are too high. By damaging blood vessels, triglycerides and cholesterol also increase the risk of heart disease.

Lipids are classified as either saturated fatty acids or unsaturated fatty acids. This classification is based on the number of chemical bonds between carbon atoms in lipid molecules.

- **Saturated fatty acids** have only single bonds between carbon atoms. This gives them properties that make them unhealthful. Their amount in the diet should be kept as low as possible. If consumed in excess, they contribute to high blood levels of cholesterol and triglycerides. Saturated fatty acids are found in animal foods, such as meat, whole milk, and eggs.
- **Unsaturated fatty acids** have at least one double bond between carbon atoms. This gives them properties that make them more healthful. Eaten in appropriate amounts, they may help lower blood levels of cholesterol and triglycerides and decrease the risk of cardiovascular disease. They are found mainly in plant foods.

The human body can synthesize all but two of the fatty acids it needs: omega-3 fatty acids and omega-6 fatty acids. Both are unsaturated fatty acids. They are called essential fatty acids because they must be present in the diet. They are found in salmon, vegetable oil, flaxseed, eggs, and whole grains. Small amounts of these two fatty acids may help lower blood pressure as well as blood levels of harmful lipids.

Unsaturated fatty acids known as trans fatty acids (or trans fats), are manufactured from plant oils and do not occur naturally. They are added to foods to extend their shelf life. Trans fats have properties like saturated fats and may increase risk of cardiovascular disease. They should be avoided in balanced eating. Many manufacturers no longer add trans fats to food products, and their use in restaurants has been banned in some cities.

Water

You may not think of water as a food, but it is a nutrient. Water is essential to life because it is the substance within which all the chemical reactions of life take place. An adult can survive only a few days without water. **Table 1**, above, shows water requirements for young people.

Water is lost from the body in exhaled air, sweat, and urine. Dehydration occurs when a person does not take in enough water to replace the water that is lost. Symptoms of dehydration include headaches, low blood pressure, and dizziness. If dehydration continues, it can quickly lead to unconsciousness and even death. When you are very active, particularly in the heat, you can lose a great deal of water in sweat. To avoid dehydration, you should drink extra fluids before, during, and after exercise.

Taking in too much water—especially without consuming extra salts—can lead to a condition called hyponatremia. In this condition, the brain swells with water, causing symptoms such as nausea, vomiting, headache, and coma. Hyponatremia can be fatal, so it requires emergency medical care.

Balanced Eating

Balanced eating is a way of eating that promotes good health. It includes eating several medium-sized meals regularly throughout the day. It also includes eating the right balance of different foods to provide the body with all the nutrients it needs. **Table 1**, above, lists macronutrient needs for young people, and you just read about foods that provide each of these macronutrients. How much of these foods should you eat to get the right balance of nutrients? Two tools for choosing foods that provide balanced nutrition are MyPyramid and nutrition labels on food packages.

MyPyramid

MyPyramid was developed by the U.S. Food and Drug Administration. It shows how much you should eat each day of foods in different food groups. MyPyramid is shown in **Figure**

23.1. You can visit the MyPyramid.gov website for more details or to customize MyPyramid for your gender, age, activity level, and other factors.

Figure 23.1: MyPyramid is visual representation of how much you should eat each day of foods in different food groups. (4)

Guidelines for Using MyPyramid

1. The six colored bands represent six food groups:

- Brown = Grains—At least half should be whole grains.
- Green = Vegetables—Choose a variety of vegetables, including dark green and orange vegetables, dry beans and peas.
- Red = Fruits—Include a variety of fruits, and consume whole fruits instead of fruit juices.
- Yellow = Oils—Choose mainly unsaturated nut and vegetable oils.
- Blue = Milk—Dairy products should be low-fat or fat-free choices.
- Purple = Meat and Beans—Choose fish and low-fat meats, as well as beans, peas, nuts, and seeds.

2. The width of each colored band shows the proportion of food that should come from each food group.

3. The figure climbing stairs reminds you to balance food with exercise: 30–60 min/day of moderate-to-vigorous activity is recommended for most people.

Each food group represented by a colored band in MyPyramid is a good source of nutrients. The wider the band, the more you should eat from that food group. For example, the brown band is widest, so the largest proportion of foods should come from the grains group. The white tip of MyPyramid represents foods that should be eaten only in very small amounts or very infrequently. They include foods such as ice cream and potato chips that contain few nutrients and may contribute excess kilocalories to the diet.

The figure "walking" up the side of MyPyramid in **Figure** 23.1 represents the role of exercise in balanced eating. Daily exercise helps you burn any extra energy that you consume in foods. The more active you are, the more energy you use. Light activities, such as golfing, typically use only a few hundred kilocalories per hour. Strenuous activities, such as running, may use over 900 kilocalories per hour.

Harvard University recently developed an alternative healthy eating pyramid, which is shown in **Figure** 23.2. It differs from MyPyramid in placing more emphasis on exercise and a greater focus on eating fruits, vegetables, and healthy plant oils. It moves red meats and starchy, low-nutrient foods, such as white bread and white rice, to the category of foods to eat in very limited amounts. Some experts think that the Harvard pyramid is less confusing than MyPyramid and represents an even healthier way of eating.

Food Labels

Packaged foods are required by law to carry a nutrition facts label, like the one in **Figure** 23.3, showing the nutrient content and ingredients in the food.

Reading nutrition facts labels can help you choose foods that are high in nutrients such as protein and low in nutrients such as fat. Nutrition facts labels can also help you choose foods that are nutrient dense. Nutrient density is the ratio of nutrient content, measured in grams, to total energy content in kilocalories.

Table 23.2: **Consider the following two foods:**

Food A Protein: 15 g Energy: 300 kcal Nutrient Density: 15g/300 kcal = 0.05 g/kcal	**Food B** Protein: 10 g Energy: 120 kcal Nutrient Density: 10g/120 kcal = 0.08 g/kcal

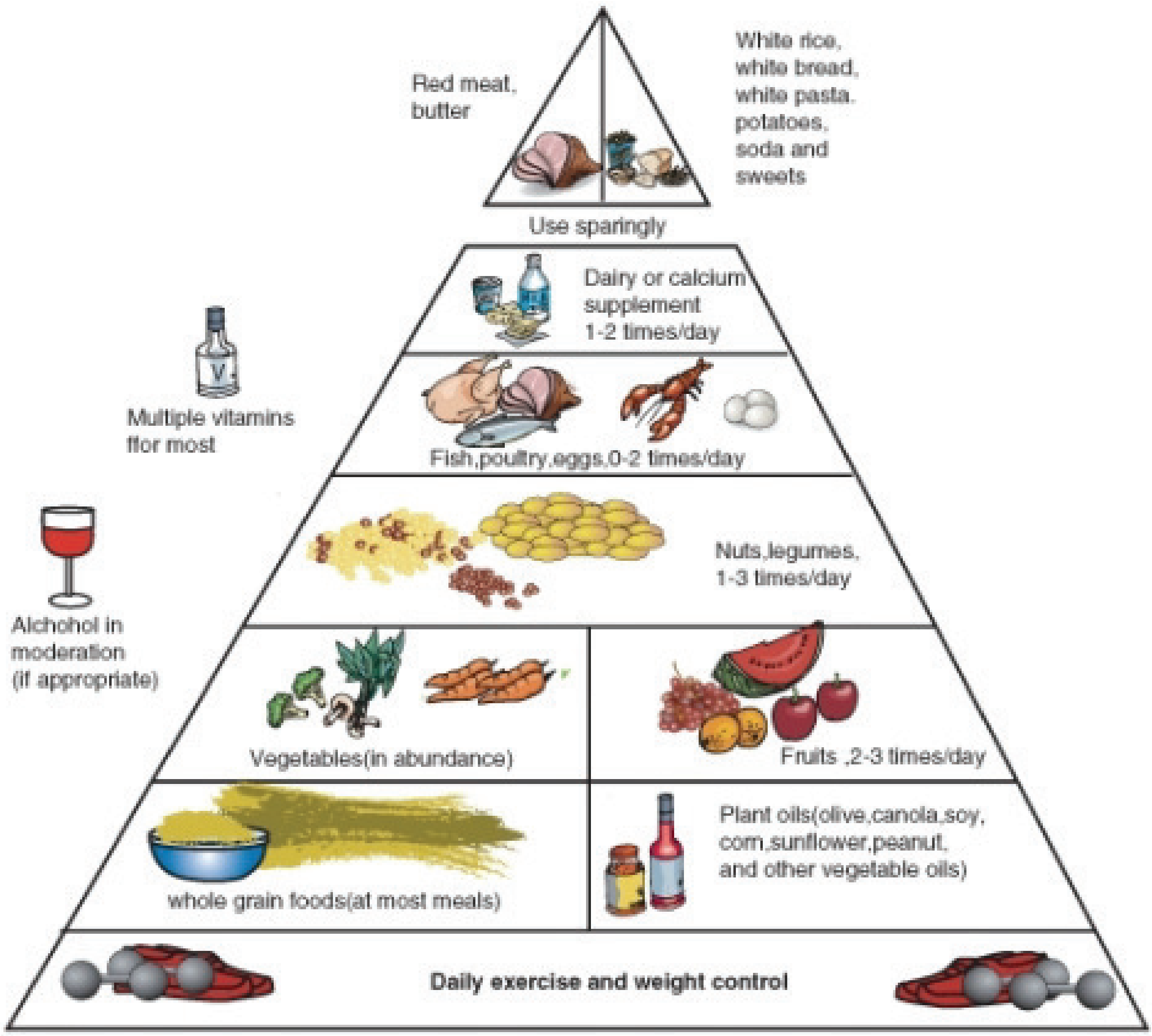

Figure 23.2: Healthy eating pyramid. (3)

Nutrition Facts

Serving Size	½ cup (52 g)
Servings Per Container	8
Amount Per Serving	
Calories 200	Calories from Fat 45
Daily Value*	
Total Fat 5 g	**8 %**
Saturated Fat 2.5 g	**13 %**
Trans fat 0 g	
Cholesterol 0 mg	**0 %**
Sodium 160 mg	**7 %**
Total Carbohydrate 37 g	**12 %**
Dietary Fiber 1 g	**4 %**
Sugars 17 g	
Protein 2 g	

Vitamin A	0 %	Vitamin C	0 %	Calcium	0 %
Iron	10 %	Thiamin	10 %	Riboflavin	0 %
Niacin	20 %	Vitamin B_6	0 %	Folic Acid	10 %

*Percent Daily Values are based on a 2000 Calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Ingredients: Enriched wheat flour (wheat flour, iron, Vitamin B_1, folic acid), high fructose corn syrup, vegetable oil (canola and soybean oil, partially hydrogenated palm kernel oil), sugar, salt, raisins, cornstarch, whole grain oats, baking soda, artificial flavor, caramel color

Reading a Nutrition Facts Label:

1. Energy

There are 200 Calories (kilocalories) in one serving. One serving is ½ cup. Therefore, there are 200 kilocalories in ½ cup.

2. Macronutrients

a. The grams on the left show the amounts of macronutrients that are supplied by one serving. For example, 5 grams of total fat are supplied by one serving.

b. The percents on the right show the percents of macronutrient needs that are supplied by one serving. Percents are based on a 2000-kilocalorie/day diet. If you need more than 2000 kilocalories/day, one serving supplies a smaller percent of each macronutrient. If you need less than 2000 kilocalories/day, one serving supplies a larger percent of each macronutrient.

3. Micronutrients

Percents of selected vitamins and minerals supplied by one serving are listed near the bottom of the label.

4. Ingredients

Ingredients in the food are listed in descending order. Those listed first are present in the largest amounts.

Figure 23.3: Nutrition facts label. (5)

In terms of protein, Food B is more nutrient dense than Food A, because it provides more protein per kilocalorie. Eating nutrient-dense foods helps you to get enough of each nutrient without taking in too many kilocalories.

Reading the ingredients list on food labels can also help you choose healthful foods for balanced eating. At the top of the list, look for ingredients such as whole grains, vegetables, and fruits. These are foods you need the most of in a balanced diet. Avoid foods that contain processed ingredients, such as white flour or white rice. Processing removes nutrients. As a result, processed foods generally supply fewer nutrients than whole foods, even when they have been enriched or fortified with added nutrients.

Weight Gain and Obesity

Any unneeded energy in food, whether it comes from carbohydrates, proteins, or lipids, is stored in the body as fat. An extra 3,500 kilocalories of energy results in the storage of one pound (0.45 kg) of fat. People who consistently consume more food energy then they need gain weight. People who continue to store fat and gain weight may eventually become obese.

Obesity occurs when the body mass index is 30.0 kg/m_2 or greater. Body mass index (BMI) is a simple way to estimate the percentage of fat in the body. It is calculated by dividing an individual's weight (in kilograms) by the square of the individual's height (in meters). For example, a man who weighs 88 kilograms and is 1.7 meters tall has a BMI of:

$88 \text{ kg} \div (1.7 \text{ m})^2 = 30.4 \text{ kg/m}^2$.

Compare this BMI with the BMI values in **Table** 23.3. The man's BMI is greater than 29.9 kg/m^2, so he would be considered obese.

Table 23.3: **Body Mass Index and Weight Status**

BMI Value (kg/m^2)	Weight Status
<18.5	Underweight
18.5–24.9	Normal weight
25.0–29.9	Overweight
>29.9	Obese

People who are obese are at greater risk of many serious health problems, including metabolic syndrome. Metabolic syndrome is a cluster of conditions that together greatly increase the risk of cardiovascular disease. The conditions include type 2 diabetes, high blood pressure, and high blood levels of LDL cholesterol and triglycerides. A wide range of other disorders may also be related to obesity, including menstrual disorders in females, certain types of cancer, osteoarthritis, and depression. In addition, people who are obese have a lower life expectancy.

From 1980 to 2002, the number of obese adults in the U.S. doubled. By 2004, almost one-third of U.S. adults aged 20 years or older were obese. The prevalence of obesity in the U.S. is the highest in the developed world. Given its prevalence and serious health risks, obesity is now a leading public health problem in this country.

The combination of eating too much and moving too little generally causes obesity. The best way to lose weight and avoid obesity is to eat less and exercise more. However, many factors may play a role in obesity, making it difficult for most people to eat wisely and lose weight. These factors may be genetic or environmental.

Several genes have been identified that control appetite and may contribute to some cases of obesity. An important environmental factor that contributes to obesity is the availability of high-fat, high-Calorie fast foods. Other environmental factors that may influence eating habits and contribute to obesity include stress, cultural traditions, and food advertisements. Some people who are obese have an eating disorder called binge eating. Eating disorders are discussed below.

Vitamins and Minerals

Unlike the major macronutrients, micronutrients—including vitamins and minerals—do not provide energy. Nonetheless, adequate amounts of micronutrients are essential for good health. The needed amounts generally can be met with balanced eating. However, many people do not eat enough of the right foods to meet their requirements. They may need vitamin or mineral supplements to increase their intake of micronutrients.

Vitamins

Vitamins are organic compounds that are needed by the body to function properly. There are 13 vitamins that humans need. They are described in **Table** 23.4, which also includes recommended daily vitamin intakes for teens.

Vitamins play many roles in good health, ranging from helping maintain vision to helping form red blood cells. Many vitamins are components of enzymes. For example, vitamin K is a component of enzymes involved in blood clotting. Several vitamins, including vitamins C and E, act as antioxidants. An antioxidant is a compound that neutralizes chemicals called free radicals. Free radicals are produced naturally during cellular activities and may cause some types of cancer. Neutralizing free radicals makes them harmless.

Some vitamins, including vitamin B_6, are produced by bacteria that normally live in the intestines, where they help digest food. Vitamin D is synthesized in the skin when it is exposed to UV radiation in sunlight. Most other vitamins must be obtained from foods because the body is unable to synthesize them. Good food sources of vitamins are listed in the table below. They include whole grains, vegetables, fruits, milk, and nuts.

Consuming inadequate amounts of vitamins can cause deficiency diseases. For example, consuming inadequate amounts of vitamin D causes soft bones. In children this is called rickets. It can cause permanent bone deformities. Consuming too much of some vitamins can also be dangerous. Overdoses of vitamins can cause problems ranging from diarrhea to birth defects and even death.

Vitamins are either fat-soluble or water-soluble. This determines whether they can accumulate in the body and lead to overdoses.

- Vitamins A, D, E, and K are fat soluble. Excess intakes of these vitamins are stored in fatty tissues of the body. Because they are stored in the body, they can build up to toxic levels, especially if they are taken improperly in supplements.
- Vitamin C and all the B vitamins are water soluble. Excess amounts of these vitamins are excreted in the urine, so they are unlikely to reach toxic levels in the body.

Table 23.4: **Vitamins**

Vitamin (Chemical Name)	Functions in the Body	Good Food Sources	Recommended Daily Intakes f or Ages 14–18 yr
Vitamin A (Retinoids)	Needed for good vision, reproduction, and fetal development	Carrots, spinach, milk, eggs	Males: 900 g Females: 700 g
Vitamin B_1 (Thiamine)	Helps break down macronutrients; essential for proper functioning of nerves	Whole wheat, peas, beans, fish, peanuts, meats	Males: 1.2 mg Females: 1.0 mg
Vitamin B_2 (Riboflavin)	Helps the body process amino acids and fats; acts as antioxidant	Milk, liver, green leafy vegetables, almonds, soybeans	Males: 1.3 mg Females: 1.0 mg
Vitamin B_3 (Niacin)	Helps release energy from macronutrients; needed for healthy skin and nerves	Beets, beef liver, pork, turkey, fish, sunflower seeds, peanuts	Males: 16 mg Females: 14 mg

Table 23.4: (continued)

Vitamin (Chemical Name)	Functions in the Body	Good Food Sources	Recommended Daily Intakes f or Ages 14–18 yr
Vitamin B_5, (Pantothenic Acid)	Helps form critical enzymes for synthesis of macronutrients	Whole grains, legumes, eggs, meat	Males: 5 mg* Females: 5mg*
Vitamin B_6 (Pyridoxine)	Forms enzymes needed for amino acid synthesis and energy storage	Cereals, yeast, liver, fish, avocadoes, nuts, green beans	Males: 1.3 mg Females: 1.2 mg
Vitamin B_7 (Biotin)	Enables synthesis of fatty acids; helps store energy; keeps level of blood sugar stable	None	Males: 25 g* Females: 25 g*
Vitamin B_9 (Folate)	Needed to make red blood cells	Liver, green leafy vegetables, dried beans and peas	Males: 400 g Females: 400 g
Vitamin B_{12} (Cyanocobalamin)	Needed for normal functioning of nervous system and formation of blood	Meat, liver, milk, shellfish, eggs	Males: 2.4 g Females: 2.4 g
Vitamin C (Ascorbic Acid)	Needed to make many biological chemicals; acts as antioxidant	Citrus fruits such as oranges, red peppers, broccoli, kiwi	Males: 75 mg Females: 65 mg
Vitamin D (Ergocalciferol and Cholecalciferol)	Helps maintain blood levels of calcium; needed for healthy bones and teeth	Salmon, tuna, eggs, mushrooms	Males: 5 g Females: 5 g

Table 23.4: (continued)

Vitamin (Chemical Name)	Functions in the Body	Good Food Sources	Recommended Daily Intakes f or Ages 14–18 yr
Vitamin E (Tocopherol)	Acts as antioxidant; protects cell membranes from LDL cholesterol damage	Vegetable oils, nuts, green leafy vegetables, whole grains, fish	Males: 15 mg Females: 15 mg
Vitamin K (Naphthoquinone)	Helps transport calcium; helps blood clot	Kale, spinach, Brussels sprouts, milk, eggs, soy products	Males: 75 g* Females: 75 g*

- Recommended daily intakes not established; figures given are adequate daily intakes.

Minerals

Dietary minerals are chemical elements that are essential for body processes. Minerals are inorganic, meaning they do not contain carbon. Minerals needed by humans in relatively large amounts (greater than 200 mg/day) are listed in **Table** 23.5. Minerals not listed in the table are called trace minerals because they are needed in very small amounts. Trace minerals include chromium, iodine, iron, molybdenum, selenium, and zinc.

Table 23.5: **Minerals**

Mineral Name (Symbol)	Functions in the Body	Good Food Sources	Recommended Daily Intakes (mg) for Ages 14–18 yr
Calcium (Ca)	Needed for nerve and muscle action; builds bone and teeth; helps blood clot	Milk, soy milk, green leafy vegetables, sardines	Males: 1300* Females: 1300*
Chloride (Cl)	Helps maintain water and pH balance; helps form stomach acid	Table salt, most processed foods	Males: 2300* Females: 2300*

Table 23.5: (continued)

Mineral Name (Symbol)	Functions in the Body	Good Food Sources	Recommended Daily Intakes (mg) for Ages 14–18 yr
Magnesium (Mg)	Needed to form several enzymes	Whole grains, green leafy vegetables, nuts, seeds	Males: 410 Females: 360
Phosphorus (P)	Component of bones, teeth, lipids, and other important molecules in the body	Meat, poultry, whole grains	Males: 1250 Females: 1250
Potassium (K)	Needed for muscle and nerve function; helps maintain salt-water balance in body fluids	Meats, grains, orange juice, potatoes, bananas	Males: 4700* Females: 4700*
Sodium (Na)	Needed for muscle and nerve function; helps maintain salt-water balance in body fluids	Table salt, most processed foods	Males: 1500* Females: 1500*
Sulfur (S)	Necessary component of many proteins	Whole grains, meats, seafood, eggs	Males: 1300* Females: 1300*

- Recommended daily intakes not established; figures given are adequate daily intakes.

Minerals play many important roles in the body. Most are found in the blood and cytoplasm of cells, where they control basic functions. For example, calcium and potassium regulate nerve and muscle activity. Several minerals, including zinc, are components of enzymes. Other minerals, including calcium, form the bulk of teeth and bones.

Minerals cannot be synthesized by the body. Good food sources of minerals are listed in **Table** 23.5. They include dairy products, green leafy vegetables, and legumes. Mineral deficiencies are uncommon, but inadequate intakes of a few minerals may lead to health problems. For example, an inadequate intake of calcium may contribute to osteoporosis, a disease in which bones become brittle and break easily.

Some minerals may be toxic in excess, but overdoses of most minerals are uncommon. Overdoses are more likely when mineral supplements are taken. Salt (sodium chloride) is added to many foods, so the intake of sodium may be too high in many people. Too much sodium in the diet can cause high blood pressure in some individuals.

Other Micronutrients

Recently, new micronutrients called phytochemicals have been found in plants. They occur primarily in colorful fruits and vegetables, like those shown in **Figure** 23.4. Thousands of phytochemicals have been discovered, and some have already been shown to lower the risk of certain diseases. For example, the phytochemical lutein helps reduce the risk of macular degeneration, an eye disease that leads to blindness. Lutein is found in many yellow and orange fruits and vegetables. Several phytochemicals, including some found in berries, have proven to be powerful antioxidants.

Figure 23.4: Good sources of phytochemicals. (9)

Eating Disorders

Eating disorders are psychiatric illnesses that involve abnormal patterns of eating. A person with an eating disorder has a compulsion to eat in a way that causes physical, mental, and emotional health problems. Typically, the person has an obsession with food and weight. Eating disorders are more common in females. One reason may be society's focus on female appearance. The most common eating disorders are binge eating disorder, anorexia nervosa, and bulimia nervosa.

Binge Eating Disorder

Binge eating disorder is characterized by compulsive overeating. People with the disorder typically eat very large quantities of food in a short period of time. They may use food as a way to deal with painful emotions or stress. Many people with the disorder are overweight or obese. The disorder is rapidly increasing in prevalence and is now the most common eating disorder in the U.S. The rise in binge eating disorder is one reason for the dramatic increase in obesity in this country

Anorexia Nervosa

Anorexia nervosa is characterized by greatly restricted food intake and low body weight (BMI less than 17.5 kg/m^2). People with anorexia nervosa usually have a distorted body image. They think they are too fat when they are actually too thin. They have an obsessive fear of gaining weight and voluntarily starve themselves. They may also exercise excessively to help keep their weight low. Females with anorexia nervosa usually stop having menstrual periods. The disorder mainly affects teenage girls and is extremely serious. At least 10 percent of people with anorexia nervosa die from factors related to the disorder.

Bulimia Nervosa

Bulimia nervosa is characterized by cycles of binge eating followed by purging to eliminate the food from the body. Purging may be achieved through intentional vomiting or excessive use of laxatives. People with this disorder typically have normal weight or weight slightly greater than normal. Repeated purging can lead to dehydration. Excessive vomiting can damage the teeth and organs of the digestive system. Bulimia nervosa occurs most often in teenage girls and young women.

Causes and Treatment

People with eating disorders usually have other mental health problems as well, most commonly depression. Both depression and eating disorders may have the same underlying physiological cause: low levels of the brain chemical serotonin. The process of eating causes serotonin to be released and may lead to a temporary "high." The process of purging may also have this effect in people with bulimia nervosa.

Environmental factors play a role in most cases of eating disorders, as they do with depression and other mental health problems. Childhood abuse may be one of these environmental factors. Many people with eating disorders report having been abused as children.

Eating disorders can be treated with psychiatric therapy or psychological counseling. Medications may also be prescribed. Treatment usually includes resolving underlying emotional problems, as well as treating depression or other mental health disorders that are also present. In patients with anorexia nervosa, weight gain is also an important goal of treatment.

Lesson Summary

- Macronutrients include carbohydrates, proteins, and lipids. They are needed in relatively large amounts to supply the body with energy and building materials.
- Balanced eating can provide the body with the nutrients it needs without causing weight gain. Balanced eating includes eating a wide variety of healthful foods.
- Vitamins and minerals are micronutrients. They are needed in relatively small amounts to control many body processes.
- Eating disorders are serious but treatable psychiatric illnesses. They involve abnormal eating patterns and an obsession with food and weight.

Review Questions

1. Which classes of nutrients provide the body with energy?
2. How is obesity diagnosed?
3. Identify the two main classes of micronutrients and give an example of each.
4. What is an eating disorder?
5. If Jera is a 15-year-old female, how many grams of carbohydrates and proteins should she eat each day?
6. How can MyPyramid help you have a balanced diet?
7. Why is it more dangerous to consume too much of a fat-soluble vitamin than a water-soluble vitamin?
8. Compare and contrast anorexia nervosa and bulimia nervosa.

Further Reading / Supplemental Links

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Vocabulary

anorexia nervosa Eating disorder characterized by greatly restricted food intake and low body weight.

bulimia nervosa Eating disorder characterized by cycles of binge eating followed by purging to eliminate the food from the body.

binge eating disorder Eating disorder characterized by compulsive overeating. People with the disorder typically eat very large quantities of food in a short period of time.

carbohydrates Organic (or carbon-containing) compounds consisting of the elements carbon, hydrogen, and oxygen; provides the body with energy.

complete proteins Contain all ten essential amino acids; found in animal foods such as milk and meat.

eating disorder Psychiatric illnesses that involve abnormal patterns of eating.

essential amino acids Amino acids that cannot be synthesized and must be obtained from the diet.

hyponatremia A condition in which the brain swells with water, causing symptoms such as nausea, vomiting, headache, and coma.

incomplete proteins Proteins that are missing one or more essential amino acids; found in plant foods such as legumes and rice.

lipids (fatty acids) Organic compounds that consist of repeating units of carbon, hydrogen, and oxygen; provide the body with energy.

macronutrients Nutrients that the body needs in relatively large amounts; include carbohydrates, proteins, lipids, and water.

metabolic syndrome A cluster of conditions that together greatly increase the risk of cardiovascular disease; include type 2 diabetes, high blood pressure, and high blood levels of LDL cholesterol and triglycerides.

micronutrients Nutrients the body needs in relatively small amounts; include vitamins and minerals.

minerals Inorganic chemical elements that are essential for body processes.

MyPyramid A visual representation of how much you should eat each day of foods in different food groups.

nutrients Chemical elements or compounds that the body needs for normal functioning and good health.

obesity Occurs when the body mass index is 30.0 kg/m_2 or greater.

proteins Relatively large organic compounds containing carbon, hydrogen, oxygen, and nitrogen; made of amino acids.

saturated fatty acids Fatty acids with only single bonds between carbon atoms.

triglyceride Fat; a particular type of lipid in which three fatty acids are bound to a compound called glycerol.

unsaturated fatty acids Fatty acids with at least one double bond between carbon atoms.

vitamins Organic compounds that are needed by the body to function properly. There are 13 vitamins that humans need.

Points to Consider

- You need nutrients for energy and building materials. Balanced eating provides you with foods that contain the nutrients you need. How does your body obtain the nutrients from food?
- What processes break down food and make nutrients available to the body? What organs carry out the processes?

23.2 Lesson 23.2: Digestive System

Lesson Objectives

- Describe the organs and major functions of the digestive system.
- Explain how the mouth, esophagus, and stomach start the digestion of food.
- Explain how the small intestine completes digestion and absorbs nutrients.
- State the functions of the large intestine and the roles of intestinal bacteria.
- Identify and describe diseases of the digestive system.

Introduction

Suppose you are studying and having trouble concentrating. You decide to eat an apple for energy. How does energy stored in the apple get into your cells? What organs and processes break down the apple into nutrients that the body can use for fuel? What organs and processes let the nutrients enter your bloodstream so they can travel to the cells where they are needed? The basic processes involved are digestion and absorption. The organs involved are the organs of the digestive system.

Organs and Functions of the Digestive System

Organs that make up the digestive system are shown in **Figure** 23.5. Most of the organs form the gastrointestinal tract. Other digestive organs are called accessory organs. As you read about the organs below, refer to **Figure** 23.5 for reference.

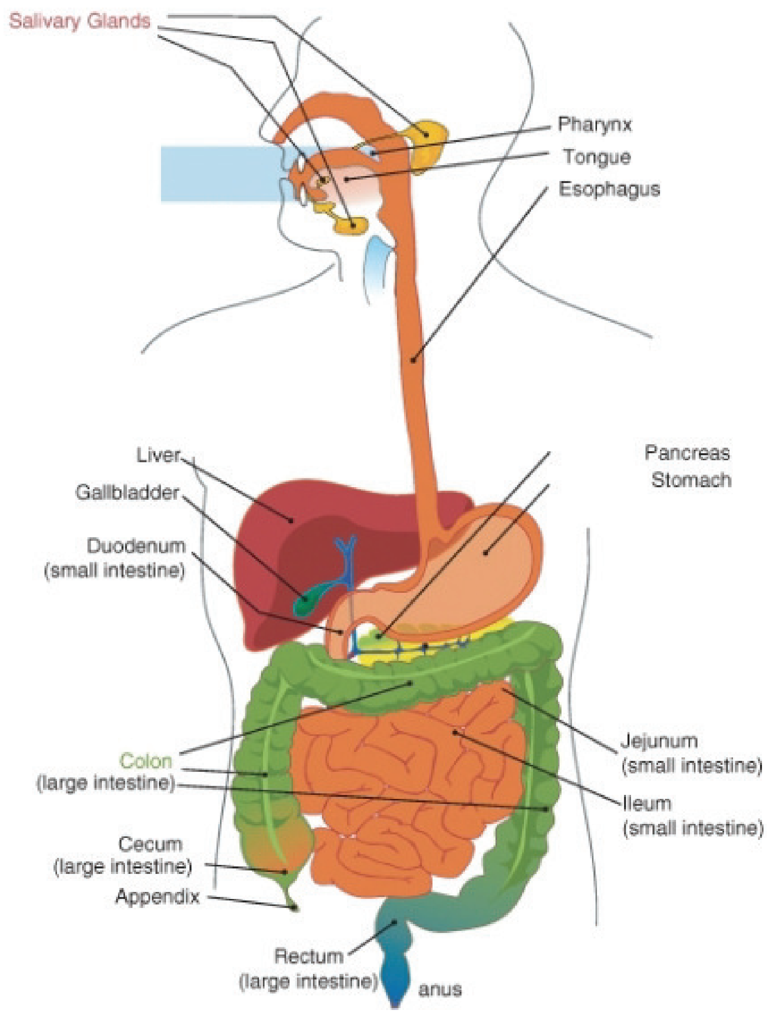

Figure 23.5: Organs of the digestive system. (13)

Gastrointestinal Tract

The gastrointestinal (GI) tract is a long tube that connects the mouth with the anus. It is more than 9 meters long in adults. The GI tract can be divided into an upper and lower part. The upper GI tract includes the mouth, esophagus, and stomach. The lower GI tract includes the small and large intestines. Food enters the mouth, passes through the upper and lower GI tracts, and then exits the body as feces through the anus.

The organs of the GI tract are covered by two layers of muscles that enable peristalsis. Peristalsis is a rapid, involuntary, wave-like contraction of muscles. It pushes food through the GI tract. The inside of GI tract is lined with mucous membranes. Mucous membranes are moist tissues that can secrete and absorb substances. The ability to secrete and absorb substances is necessary for the functions of the digestive system. See http://en.wikipedia.org/wiki/File:Peristalsis.gif for an animation of peristalsis.

Accessory Organs of the Digestive System

In the lower GI tract, additional organs play important roles in digestion. They are called accessory organs. Food does not pass through them, but they make or store substances needed for digestion. The accessory organs are the liver, gall bladder, and pancreas.

- The liver is a large organ next to the stomach. It produces digestive substances that are carried by ducts, or tubes, to the small intestine and gall bladder.
- The gall bladder is a small, pear-shaped structure below the liver. It stores substances from the liver until they are needed by the small intestine.
- The pancreas is a gland below the stomach. It produces digestive substances that are carried by a duct to the small intestine.

The Liver

The liver is a vital organ that has many functions, including detoxification of blood, protein synthesis, and production of biochemicals necessary for digestion. The liver is also involved in glucose balance. The liver produces bile which breaks down lipids.

The liver performs several roles in carbohydrate metabolism, which help in the balance of blood glucose levels:

- Gluconeogenesis: the synthesis of glucose from certain amino acids, lactate or glycerol
- Glycogenolysis: the breakdown of glycogen into glucose
- Glycogenesis: the formation of glycogen from glucose.

The liver is one of the most important organs in the body when it comes to blood filtering and detoxification. The liver is involved in getting rid of foreign substances and toxins, especially from the gut. The toxins are usually excreted in bile or urine. Breaking down toxins is referred to as drug metabolism, and is usually done using specialized enzymes produced in the liver. Most of the blood being filtered by the liver is from the portal vein, which carries blood from the intestines. The liver can remove a broad range of microorganisms such as bacteria, fungi, viruses and parasites from the blood. Infections and parasites can come from contaminated water and food, and then find their way into your gut and blood stream. Luckily the blood then goes to the liver for filtering.

The liver also performs several roles in lipid metabolism including cholesterol synthesis and the production of triglycerides (fats). The liver produces coagulation factors I (fibrinogen), II (prothrombin), V, VII, IX, X and XI, as well as protein C, protein S and antithrombin.

Functions of the Digestive System

The digestive system has three main functions: digestion of food, absorption of nutrients, and elimination of solid waste. Digestion is the process of breaking down food into components the body can absorb. There are two types of digestion: mechanical and chemical.

- Mechanical digestion is the physical breakdown of chunks of food into smaller pieces. It takes place mainly in the mouth and stomach.
- Chemical digestion is the chemical breakdown of large, complex food molecules into smaller, simpler nutrient molecules that can be absorbed by the blood. It takes place mainly in the small intestine.

Chemical digestion could not take place without the help of digestive enzymes. Enzymes are substances that speed up chemical reactions. Digestive enzymes speed up the reactions of chemical digestion. Digestive enzymes are secreted by glands in the mucous membranes of the mouth, stomach, small intestine, and pancreas. Different digestive enzymes help break down different types of food molecules, including carbohydrates, proteins, and lipids.

The name of a digestive enzyme typically ends with the suffix -*ase*, which means "enzyme". The rest of the name refers to the type of food molecules the enzyme helps digest. For example, the enzyme lipase helps digest lipid molecules, and the enzyme lactase helps digest molecules of the sugar lactose.

After food is digested, the resulting nutrients are absorbed. Absorption is the process in which substances pass into the blood stream, where they can circulate throughout the body. Absorption occurs mainly in the small intestine. Any remaining indigestible matter that cannot be absorbed passes into the large intestine as waste. The waste later passes out of the body through the anus in the process of elimination.

The Start of Digestion: The Mouth to the Stomach

The upper GI tract is the primary site of mechanical digestion. The chemical digestion of carbohydrates and proteins also begins in the upper GI tract.

The Mouth

The mouth is the first organ in the digestive tract, but digestion may start even before you put the first bite of food in your mouth. Why? The sight or aroma of an appetizing dish can stimulate the release of digestive enzymes by salivary glands inside your mouth. The major salivary enzyme is amylase. Once you start eating, amylase begins the chemical digestion of carbohydrates in the food. It helps break down complex starch molecules into simpler sugar molecules.

The mouth also plays an important role in mechanical digestion. The teeth help to digest food mechanically by breaking it into smaller pieces. Human teeth have different shapes and functions. As you can see in **Figure** 23.6, the incisors and canines at the front of the mouth are relatively thin and sharp. They shear and tear food when you bite into it. The premolars and molars at the back of the mouth are larger and broader. They grind food into smaller pieces as you chew.

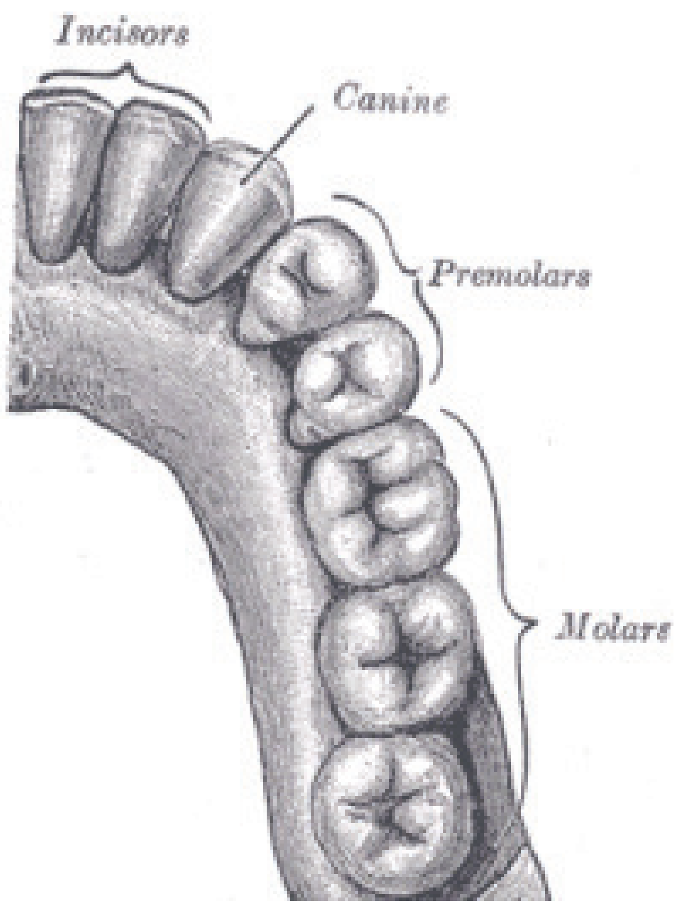

Figure 23.6: Types of human teeth. (12)

Saliva from the salivary glands moistens the food and makes it easier to chew. The muscular tongue helps mix the food with saliva and the enzymes it contains. When you swallow, the lump of chewed food, now called a bolus, passes into the pharynx.

The pharynx connects the mouth to the rest of the digestive tract. It also connects the mouth and nose to the rest of the respiratory system. As food is pushed to the back of the mouth by the tongue, it sets off an automatic response that closes the pharynx off from the respiratory system. This prevents you from accidentally inhaling food when you swallow.

Esophagus

From the pharynx, the bolus moves into the esophagus. The esophagus is a narrow tube about 20 centimeters long in adults. It begins at the pharynx, passes through the chest, and ends at the opening to the stomach. The function of the esophagus is to pass food from the mouth to the stomach. This takes only a few seconds. The esophagus does not produce digestive enzymes and does not have any other digestive functions.

Food moves through the esophagus due to peristalsis. At the end of the esophagus, a muscle called a sphincter controls the entrance to the stomach. The sphincter opens to let food into the stomach and then closes again to prevent the food from passing back into the esophagus.

Stomach

The stomach is a saclike organ located between the end of the esophagus and the beginning of the small intestine. In the stomach, food is further digested both mechanically and chemically. Churning movements of the stomach's thick muscular walls break down food mechanically. The churning movements also mix the food with fluids secreted by the stomach. These fluids include hydrochloric acid and digestive enzymes.

- Hydrochloric acid gives the stomach a very acidic environment. This helps destroy any bacteria that have entered the stomach in foods or beverages. An acidic environment is also needed for the stomach's digestive enzymes to work.
- Digestive enzymes secreted in the stomach help break down proteins into smaller molecules called peptides. The main digestive enzyme in the stomach is pepsin.

Water, alcohol, salt, and simple sugars can be absorbed through the lining of the stomach. Most other substances need further digestion in the small intestine before they can be absorbed. The stomach stores the food until the small intestine is ready to receive it. It may hold up to four liters of food when fully expanded. When the small intestine is empty, a sphincter opens between the stomach and small intestine. This allows the partially digested food, now called chyme, to enter the small intestine.

Digestion and Absorption: The Small Intestine

The small intestine is narrow tube about seven meters long in adults. It is the site of most chemical digestion and virtually all absorption. As you can see from Figure 1, the small intestine is much longer than the large intestine. It is called "small" because it is smaller in diameter than the large intestine. Like the rest of the GI tract, the small intestine pushes food along with peristalsis. The small intestine is made up of three parts: the duodenum, jejunum, and ileum. Each part has a different function.

Digestion in the Small Intestine

The **duodenum** is the first part of the small intestine. It is only about 25 cm long, but most chemical digestion occurs here. Many enzymes are active in the duodenum, and several are listed in **Table** 23.6. Some of the enzymes are produced by the duodenum. The rest are produced by the pancreas and secreted into the duodenum.

Table 23.6: **Digestive Enzymes Active in the Duodenum**

Name of Enzyme	Nutrient It Digests	Site of Production
Amylase	carbohydrates	pancreas
Trypsin	proteins	pancreas
Lipase	lipids	pancreas
Maltase	carbohydrates	small intestine
Peptidase	proteins	small intestine
Lipase	lipids	small intestine

How does the pancreas "know" when to secrete enzymes into the small intestine? The pancreas is controlled by compounds called hormones. Hormones are chemical messengers in the body. They regulate many body functions, including secretion of digestive enzymes. When food enters the stomach, a hormone called gastrin is secreted by the stomach. Gastrin, in turn, stimulates the pancreas to secrete its digestive enzymes.

The liver produces fluid called bile, which is secreted into the duodenum. Some bile goes to the gall bladder, where it is stored and becomes more concentrated. In the duodenum, bile breaks up large globules of lipids into smaller globules that are easier for lipase enzymes to break down chemically.

Bile also reduces the acidity of the chyme entering from the highly acidic stomach. This is important for digestion, because digestive enzymes in the duodenum require a neutral environment in order to work. The pancreas also contributes to the neutral environment of the duodenum by secreting bicarbonate, a basic substance that neutralizes acid.

Absorption in the Small Intestine

The **jejunum** is the second part of the small intestine. It is about 2.5 meters long. This is where most nutrients are absorbed into the blood.

As shown in **Figure** 23.7, the mucous membrane lining the jejunum is covered with microscopic, fingerlike projections called **villi** (singular: villus). Each villus, in turn, has thousands of even smaller projections called microvilli (singular: microvillus). The villi contain capillaries, which are tiny blood vessels. Nutrients are absorbed into these capillaries across the surface of the villi and microvilli. Because there are millions of these tiny projections, they greatly increase the surface area for absorption. In fact, villi and microvilli increase the absorptive surface of the small intestine to the size of a tennis court! This allows far greater absorption of nutrients.

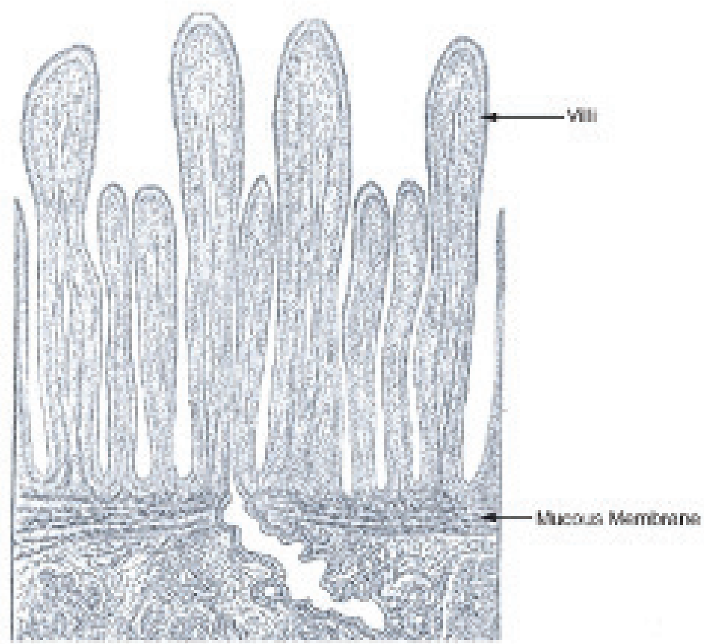

Figure 23.7: Magnified image of villi lining the jejunum (small intestine). (2)

The **ileum** is the third part of the small intestine. It is about 3.5 meters long. A few remaining nutrients are absorbed in the ileum. Salts that form from liver bile are also absorbed there. Like the jejunum, the ileum is covered with villi and microvilli that increase the area for absorption.

The Large Intestine and Its Functions

From the small intestine, any remaining food waste passes into the large intestine. The large intestine is a relatively wide tube that connects the small intestine with the anus. It is about

1.5 meters long. The large intestine consists of three parts: the cecum, colon, and rectum.

Absorption of Water and Elimination of Wastes

The cecum is the first part of the large intestine, where waste enters from the small intestine. The waste is in a liquid state. As the waste passes through the colon, which is the second part of the large intestine, excess water is absorbed. After the excess water is absorbed, the remaining solid waste is called feces. Feces contain indigestible food substances such as fiber.

Feces accumulate in the rectum, which is the third part of the large intestine. As the rectum fills, the feces become compacted. The feces are stored in the rectum until they are eliminated from the body. A sphincter controls the anus and opens to let feces through to the outside. It normally takes from 12 to 24 hours for wastes to enter the cecum, move through colon, accumulate in the rectum, and pass from the body as feces.

Bacteria in the Large Intestine

Other functions of the large intestine are to provide a home for intestinal bacteria and to absorb the vitamins they produce. Trillions of bacteria normally live in the large intestine. Some of these bacteria are harmful to the body if they grow out of control. However, most of the bacteria are helpful. They produce several vitamins, including vitamins B_{12} and K. Intestinal bacteria play other helpful roles, as well. For example, they:

- control the growth of harmful bacteria.
- break down toxins before they can poison the body.
- break down indigestible food components.
- produce substances that help prevent colon cancer.

Diseases of the Digestive System

A number of diseases can affect the entire gastrointestinal tract. Other diseases affect particular organs of the GI tract. Still others affect accessory organs of the digestive system.

Diseases of the Gastrointestinal Tract

A group of diseases that affect the GI tract is called inflammatory bowel disease. Inflammatory bowel disease is inflammation of the large intestine and, in some cases, other parts of the GI tract. Inflammation is a normal reaction of the immune system to injury or infection that causes swelling, redness, and pain.

The two main forms of inflammatory bowel disease are Crohn's disease and ulcerative colitis. Both have similar symptoms, including abdominal pain, diarrhea, and weight loss. Crohn's disease is caused by the immune system reacting to the body's own tissues, but the cause of ulcerative colitis is not known. A tendency to develop the diseases may be inherited. Ulcerative colitis is confined to the colon and sometimes can be cured with surgery. Crohn's disease may occur anywhere in the GI tract and has no known cure, although treatment can control the symptoms.

Food allergies can also affect the entire GI tract. Food allergies are disorders that occur when the immune system reacts to substances in food as though they were harmful "foreign invaders." Foods that are most likely to cause allergies are nuts, eggs, milk, fish, and shellfish. Symptoms of food allergies may include tingling in the mouth, vomiting, and diarrhea. Food allergies can also cause skin rashes and difficulty breathing. An estimated eight percent of children and two percent of adults have food allergies.

Diseases of the Stomach and Esophagus

A layer of mucus normally protects the lining of the stomach from damage by hydrochloric acid. An infection by bacteria of the species *Helicobacter pylori* can weaken this mucus layer, allowing acid to get through to the delicate mucous membranes underneath. The acid may cause gastritis or stomach ulcers, both of which can be treated with medication.

- Gastritis is inflammation of the lining of the stomach. It causes abdominal pain.
- A stomach ulcer is a sore in the lining of the stomach. It causes severe abdominal pain and bleeding.

Stomach acid may also damage the lining of the esophagus. This can occur when the sphincter between the stomach and esophagus does not close properly. This lets acid from the stomach enter the esophagus. The acid may cause esophagitis, or inflammation of the esophagus. A common symptom of esophagitis is heartburn, which is a painful, burning sensation in the throat or chest. Esophagitis can be treated with medication and changes in diet. It is important to treat the condition because it sometimes leads to cancer of the esophagus if not treated.

Diseases of the Small Intestine

Diseases that affect the small intestine include ulcers, infections, and celiac disease. Ulcers of the small intestine occur mainly in the duodenum, because stomach acid enters the duodenum during digestion. If an infection by *Helicobacter pylori* weakens the mucous layer in the duodenum, the stomach acid can damage the mucous membranes underneath. Symptoms and treatment of duodenal ulcers are similar to those of stomach ulcers.

Other bacteria may also cause infections in the small intestine, including Salmonella and *E. coli*. The bacteria can enter the body in contaminated foods or beverages. Symptoms of bacterial infections include abdominal pain, cramping, vomiting, and diarrhea. Such infections typically clear up on their own without medical treatment.

Celiac disease is an immune reaction to a food protein called gluten, which is found in grains. A tendency to have celiac disease can be inherited. Symptoms of the disease include abdominal pain, diarrhea, and bloating. The symptoms can be prevented by eating a gluten-free diet, but there is no cure for the disease.

Diseases of the Large Intestine

Diseases that affect the large intestine include irritable bowel syndrome, colitis, and appendicitis. Irritable bowel syndrome (IBS) is a disorder in which the large intestine is easily irritated. It is one of the most common gastrointestinal disorders. The cause of IBS is unknown, but may be due to excessive bacteria in the intestine. Symptoms of the disorder include abdominal pain, cramping, constipation, and diarrhea. Symptoms can often be controlled with medication, stress management, and changes in diet. However, there is no cure for IBS.

Colitis is inflammation of the colon. It has many possible causes, ranging from bacterial infections to immune reactions against the body's own tissues. Symptoms of colitis include pain and tenderness in the abdomen. Treatment of colitis may include medication, surgery, and changes in diet.

Appendicitis is inflammation of the appendix. It is most common in children and teens. The appendix is a small, fingerlike pouch that extends from the cecum (see **Figure** 23.5). Inflammation of the appendix is usually caused by a bacterial infection. Symptoms include abdominal pain, loss of appetite, fever, and vomiting. Appendicitis is most often treated with surgery to remove the infected appendix. Without treatment, an infected appendix can be fatal.

Diseases of the Accessory Organs

Accessory organs of digestion can also be affected by disease, and this may interfere with normal digestion. A disease that affects the pancreas is cystic fibrosis. Cystic fibrosis (CF) is an inherited disease in which the body produces abnormally thick and sticky mucous. In the pancreas, the mucus blocks the duct to the duodenum, preventing pancreatic enzymes from reaching it. As a result, proteins and lipids cannot be digested properly. People with CF may take digestive enzymes by mouth to improve their digestion. However, the disease has no known cure. (For more information on CF, see chapter titled *Human Genetics.*)

Hepatitis is inflammation of the liver. It is usually caused by a viral infection. Several different viruses can cause hepatitis. Some of the viruses spread through contaminated foods or beverages, others through sexual contact. Symptoms of hepatitis include fever, headache, vomiting, and abdominal pain. Another symptom is jaundice, which is yellowing of the skin and eyes. If the symptoms are mild, the disease may clear up without treatment. If the symptoms are more severe, the disease may damage the liver so it can no longer produce bile. This interferes with the digestion of lipids. Medications are available to treat hepatitis. Some types of hepatitis can also be prevented with vaccines.

Gall bladder problems occur mainly in adults. They are often caused by gall stones (**Figure** 23.8). Gall stones are crystals that form in the bile in the gall bladder. There are many possible reasons why gall stones form, including abnormal body chemistry and too much fat in the diet. Gall stones start out as small as a grain of sand but may grow to the size of a golf ball. There may be one large stone or many small ones. If gall stones block the duct that carries bile to the duodenum, they may cause inflammation of the gall bladder and severe abdominal pain. Generally, the only way to treat these problems is to surgically remove the gall stones or the entire gall bladder.

Figure 23.8: Gall stones. (1)

Lesson Summary

- The digestive system includes the gastrointestinal tract and accessory organs such as the pancreas. The major functions of the digestive system are to digest food, absorb nutrients, and eliminate solid waste.
- Both mechanical and chemical digestion of food start in the mouth. The esophagus

carries the food to the stomach, and the stomach continues mechanical and chemical digestion.
- Most chemical digestion takes place in the small intestine with the help of several digestive enzymes. Virtually all absorption of nutrients also takes place in the small intestine.
- The large intestine removes excess water from waste and eliminates waste from the body. It also provides a home for helpful intestinal bacteria.
- Many diseases affect the digestive system and may interfere with digestion. They include food allergies, infections, and inherited conditions.

Review Questions

1. Name, in sequence, the digestive organs that food passes through in the gastrointestinal tract, from the mouth to the anus.
2. Describe two ways that the mouth helps digest food.
3. How do villi and microvilli help the small intestine absorb nutrients?
4. What are two functions of helpful bacteria in the large intestine?
5. Describe what happens to carbohydrates as they pass through the organs of the GI tract.
6. Antibiotics are medications that destroy bacteria. Explain how antibiotics might help treat stomach ulcers.
7. Why is it important for digestive system functions that mucous membranes can secrete and absorb substances?
8. Compare and contrast two digestive enzymes that work in the duodenum.

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Vocabulary

absorption The process in which substances pass into the blood stream, where they can circulate throughout the body; occurs mainly in the small intestine.

amylase The major salivary enzyme is amylase; begins the chemical digestion of carbohydrates in the food; helps break down complex starch molecules into simpler sugar molecules.

cecum The first part of the large intestine, where waste enters from the small intestine.

celiac disease An immune reaction to a food protein called gluten, which is found in grains.

chemical digestion The chemical breakdown of large, complex food molecules into smaller, simpler nutrient molecules that can be absorbed by the blood; takes place mainly in the small intestine.

colon The second part of the large intestine, where excess water is absorbed. After the excess water is absorbed, the remaining solid waste is called feces.

duodenum The first part of the small intestine; site where most chemical digestion occurs.

esophagus A narrow tube - begins at the pharynx, passes through the chest, and ends at the opening to the stomach. The function of the esophagus is to pass food from the mouth to the stomach.

gall bladder A small, pear-shaped structure below the liver; stores substances from the liver until they are needed by the small intestine.

gastritis Inflammation of the lining of the stomach.

gastrointestinal (GI) tract Organ of the digestive system; a long tube that connects the mouth with the anus.

ileum The third part of the small intestine. A few remaining nutrients are absorbed in the ileum, as are salts that form from liver bile.

inflammatory bowel disease Inflammation of the large intestine and, in some cases, other parts of the GI tract; includes Crohn's disease and ulcerative colitis.

irritable bowel syndrome (IBS) A disorder in which the large intestine is easily irritated.

jejunum The second part of the small intestine; where most nutrients are absorbed into the blood.

large intestine A relatively wide tube that connects the small intestine with the anus; consists of three parts: the cecum, colon, and rectum.

liver A large organ next to the stomach; produces digestive substances that are carried by ducts, or tubes, to the small intestine and gall bladder.

lower GI tract Segment of the GI tract that includes the small and large intestines.

mechanical digestion The physical breakdown of chunks of food into smaller pieces; takes place mainly in the mouth and stomach.

mucous membranes Moist tissues that can secrete and absorb substances.

pancreas A gland below the stomach; produces digestive substances that are carried by a duct to the small intestine.

peristalsis A rapid, involuntary, wave-like contraction of muscles; pushes food through the GI tract.

pharynx Connects the mouth to the rest of the digestive tract; also connects the mouth and nose to the rest of the respiratory system.

rectum The third part of the large intestine; where feces accumulates. As the rectum fills, the feces become compacted. The feces are stored in the rectum until they are eliminated from the body.

small intestine A narrow tube leading away from the stomach; made up of three parts: the duodenum, jejunum, and ileum; the site of most chemical digestion and virtually all absorption.

stomach A saclike organ located between the end of the esophagus and the beginning of the small intestine. In the stomach, food is further digested both mechanically and chemically.

stomach ulcer A sore in the lining of the stomach.

upper GI tract Segment of the GI tract that includes the mouth, esophagus, and stomach.

Points to Consider

- The large intestine eliminates the waste that remains after food is digested. More waste is produced when cells break down nutrients for energy and building materials. How is this waste removed from the body? Is it eliminated by the large intestine? Is it removed in some other way?

23.3 Lesson 23.3: Excretory System

Lesson Objectives

- Define homeostasis and excretion, and explain why they are necessary for life.
- Describe the urinary system, kidneys, and nephrons; summarize the processes involved in excretion.
- Identify roles of the kidneys in homeostasis.
- Name diseases of the urinary system, and explain how dialysis helps treat kidney failure.

Introduction

If you exercise on a hot day, you are likely to lose a lot of water in sweat. Then, for the next several hours, you may notice that you do not pass urine as often as normal and that your urine is darker than usual. Do you know why this happens? Your body is low on water and trying to reduce the amount of water lost in urine. How does the body know when it is low on water? How does it control the amount of water lost in urine? The answers to both questions are the kidneys and the glands that control them.

Homeostasis and Excretion

The kidneys are the body's main organs of homeostasis and excretion. Homeostasis is the body's attempt to maintain a constant internal environment. One of the major ways the body achieves homeostasis is through excretion. Excretion is the process of removing wastes and excess water from the body.

Homeostasis

Homeostasis is a fundamental characteristic of all living things. Internal body conditions must be kept within certain limits for the normal functioning of cells. Homeostasis involves keeping many internal factors at more or less constant levels. The factors include body temperature and properties of the blood. For example, the blood must have certain levels of acidity, salts, and nutrients in order for cells to function normally.

A variety of homeostatic mechanisms help maintain stability of the internal environment. Each mechanism involves the interaction of at last three components: a receptor, a control center, and an effector.

- The receptor senses changes in the internal environment and sends the information to the control center.
- The control center processes the information, determines the appropriate action, and sends a command to the effector.
- The effector responds to the command and changes conditions in the internal environment.

An example of a homeostatic mechanism in humans is the regulation of body temperature. This is represented by the diagram in **Figure** 23.9. Temperature receptors in the skin send information about skin temperature to the brain. The brain is the control center. It determines whether the temperature is too high or too low and sends appropriate commands to effectors that control body temperature. Effectors include blood vessels near the surface of the body. If the temperature is too high, the brain commands the blood vessels to dilate, which helps the body lose heat. If the temperature is too low, the brain commands the blood vessels to constrict, which helps the body retain heat. These actions help return body temperature to normal.

Negative Feedback and Body Temperature

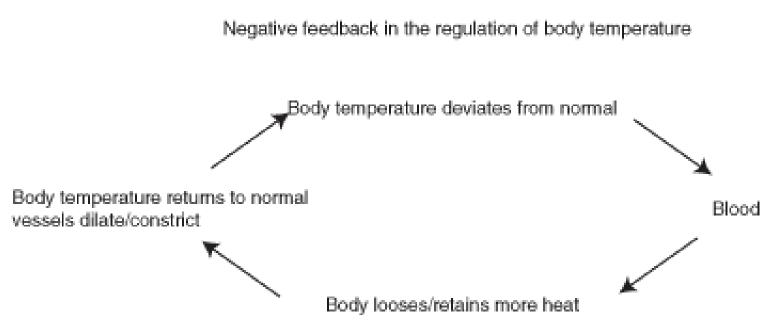

Figure 23.9: Regulation of body temperature is an example of negative feedback. When body temperature deviates from normal, this information feeds back to the brain and sets in motion changes that return body temperature to normal. (8)

The regulation of body temperature is an example of negative feedback. Negative feedback is a type of homeostatic mechanism in which change in one direction results in a counteractive change in the opposite direction. Negative feedback reverses the direction of change to bring conditions back to normal. Most of the mechanisms that control homeostasis in the human body involve negative feedback.

Positive feedback mechanisms also exist, but they are not common in the human body. Positive feedback accelerates or amplifies a change and pushes levels farther away from normal. One example of a positive feedback mechanism in the body is blood clotting, which is described in the chapter titled *Circulatory and Respiratory Systems*.

If homeostasis is disturbed, a homeostatic imbalance results. This may result in cells getting too much or not enough of certain substances. Many diseases are caused by homeostatic imbalances. For example, diabetes mellitus is a disease in which the blood contains too much glucose. This can have serious consequences for cells throughout the body. It may lead to damaged blood vessels, heart disease, blindness, and kidney failure.

Excretion

Excretion is an essential process in all forms of life. When cells metabolize—or break down—nutrients, waste products are produced. For example, when cells metabolize proteins and nucleic acids, nitrogen wastes such as ammonia, urea and uric acid are produced. Ammonia is a toxic substance and must be removed from the blood and excreted from the body. Urea is removed through urine, which is produced in the kidney. Excretion is also necessary to remove excess water, salts, and many other substances from the body.

Although the kidneys are the main organs of excretion of wastes from the blood, several other organs are also involved in excretion, including the large intestine, liver, skin, and lungs.

- The large intestine eliminates solid wastes that remain after the digestion of food in the gastrointestinal tract (as discussed in Lesson 23.2: Digestive System).
- The liver breaks down excess amino acids in the blood to form ammonia, and then converts the ammonia to urea, a less toxic substance. The liver also breaks down other toxic substances in the blood, including alcohol and drugs.
- The skin eliminates water and salts in sweat.
- The lungs exhale water vapor and carbon dioxide.

Kidneys and Excretion

The kidneys are part of the urinary system. The kidneys work together with other urinary system organs in the function of excretion. The urinary system is shown in **Figure** 23.10.

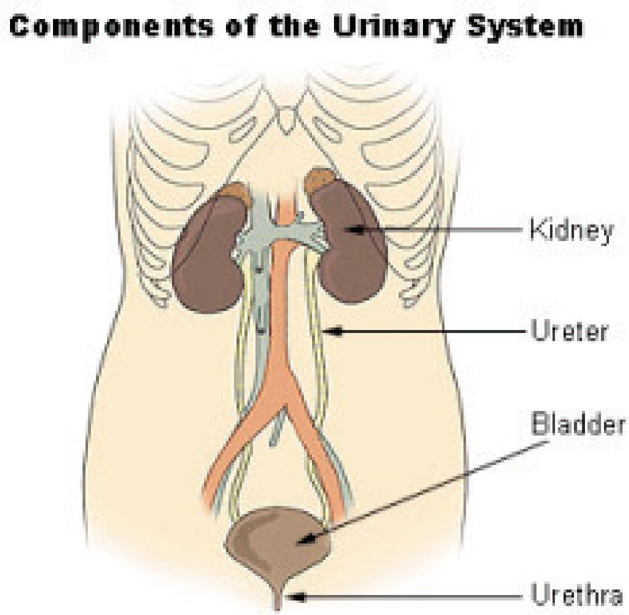

Figure 23.10: The urinary system. (10)

Urinary System

In addition to the kidneys, the urinary system includes the ureters, bladder, and urethra. The main function of the urinary system is to filter waste products and excess water from the blood and remove them from the body. The two kidneys, which are described in detail below, filter the blood and form urine. Urine is the liquid waste product of the body that is excreted by the urinary system.

From the kidneys, urine enters the ureters, which carry it to the bladder. Each ureter is a muscular tube about 25 centimeters long. Peristaltic movements of the muscles of the ureter send urine to the bladder in small spurts.

The bladder is a hollow organ that stores urine. It can stretch to hold up to 500 milliliters. When the bladder is about half full, the stretching of the bladder sends a nerve impulse to the sphincter that controls the opening to the urethra. In response to the impulse, the sphincter relaxes and lets urine flow into the urethra.

The urethra is a muscular tube that carries urine out of the body. Urine leaves the body through another sphincter in the process of urination. This sphincter and the process of urination are normally under conscious control.

Kidneys

The kidneys participate in whole-body homeostasis. As mentioned above, one of the promary roles of the kidney is to remove nitrogenous wastes. The kidneys are a pair of bean-shaped, reddish brown organs about the size of a fist. They are located just above the waist at the back of the abdominal cavity, on either side of the spine. As shown in **Figure** 23.10, the kidneys are protected by the ribcage. They are also protected by a covering of tough connective tissues and two layers of fat, which help cushion them.

Located on top of each kidney is an adrenal gland, also shown in **Figure** 23.10. The two adrenal glands secrete several hormones. Hormones are chemical messengers in the body that regulate many body functions. The adrenal hormone aldosterone helps regulate kidney functions.

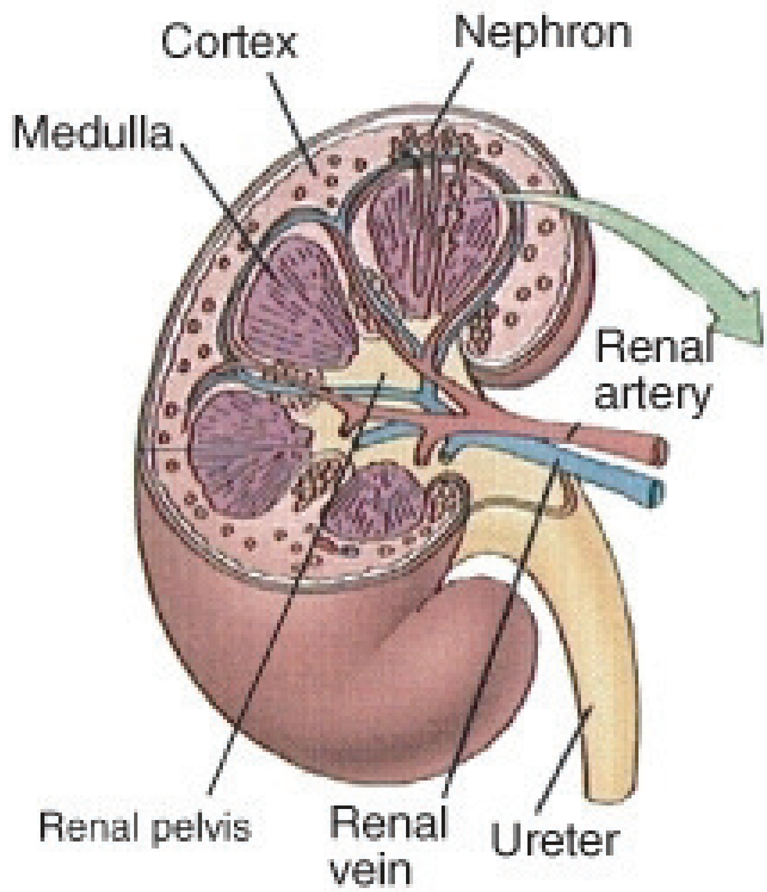

Figure 23.11: The human kidney. (14)

In **Figure** 23.11, you can see that the kidney has three layers. The outer layer is the renal cortex, and the middle layer is the renal medulla. The inner layer, the renal pelvis, is where the renal artery enters the kidney and the renal vein exits the kidney. The renal artery carries blood to the kidney to be filtered, and the renal vein carries the filtered blood away from the kidney. Structures in the kidney called nephrons are also seen in **Figure** 23.11. Each nephron extends from the cortex down into the medulla.

Nephrons

Nephrons are the structural and functional units of the kidneys. A single kidney may have more than a million nephrons. The diagram in **Figure** 23.12 represents an individual nephron and shows its main structures and functions. The structures include the glomerulus, Bowman's capsule, and renal tubule.

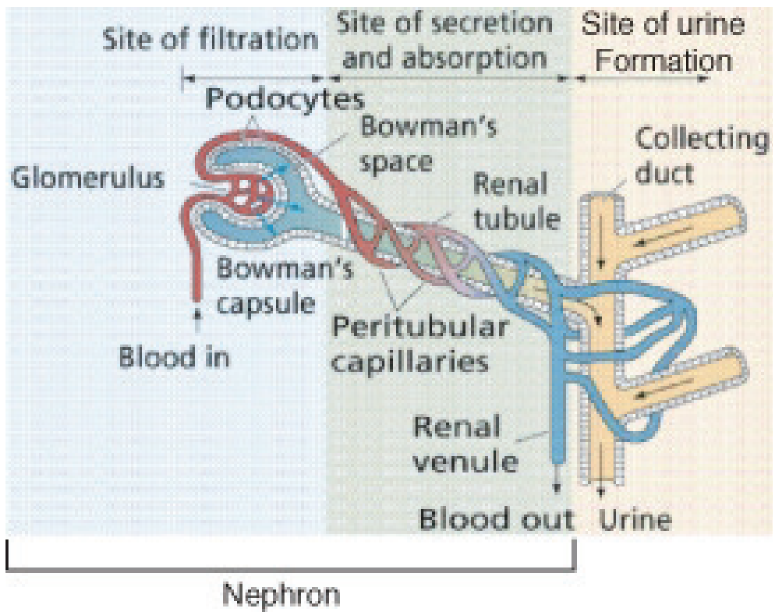

Figure 23.12: Nephron structures and functions. (6)

- The glomerulus is a cluster of arteries that filters substances out of the blood.
- Bowman's capsule is a cup-shaped structure around the glomerulus that collects the filtered substances.
- The renal tubule is a long, narrow tube surrounded by capillaries that reabsorbs many of the filtered substances and secretes other substances.

Filtration, Reabsorption, and Secretion

The renal arteries, which carry blood into the kidneys, branch into the capillaries of the glomerulus of each nephron. The pressure of blood moving through these capillaries forces some of the water and dissolved substances in the blood through the capillary walls and into

Bowman's capsule. Bowman's capsule is composed of layers. The space between the layers, called Bowman's space, fills with the filtered substances.

The process of filtering substances from blood in the glomerulus is called filtration. The fluid that collects in Bowman's space is called filtrate. It is composed of water, salts, glucose, amino acids, and urea. Larger structures in the blood—including protein molecules, blood cells, and platelets—do not pass into Bowman's space. Instead, they return to the main circulation.

From Bowman's space, the filtrate passes into the renal tubule. The main function of the renal tubule is reabsorption. Reabsorption is the return of needed substances in the filtrate back to the bloodstream. It is necessary because some of the substances removed from the blood by filtration—including water, salts, glucose, and amino acids—are needed by the body. About 75 percent of these substances are reabsorbed in the renal tubule.

As shown in **Figure** 23.13, the renal tubule is divided into three parts: the proximal tubule, the Loop of Henle, and the distal tubule.

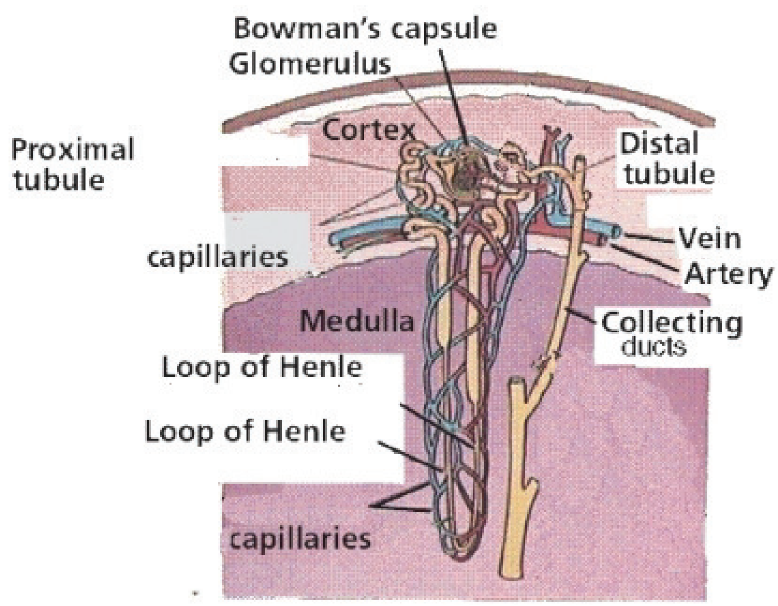

Figure 23.13: Parts of the renal tubule and other nephron structures. (11)

- Filtrate first enters the proximal tubule. This is where that most reabsorption takes place. Tiny projections called microvilli line the proximal tubule and increase the surface area for reabsorption. From the proximal tubule, the filtrate passes through the loop of Henle.
- The loop of Henle carries the filtrate from the cortex down into the medulla and then back up to the cortex again. Its primary purpose is to reabsorb water and salt from the fluid. The remaining fluid enters the distal tubule.

- The distal tubule carries the fluid, now called tubular fluid, from the loop of Henle to a collecting duct. As it transports the fluid, the distal tubule also reabsorbs or secretes substances such as calcium and sodium. The process of secreting substances into the tubular fluid is called secretion.

Urine Formation

The collecting ducts are the site of urine formation. This process is crucial for water conservation in the body. The collecting ducts reabsorb water from tubular fluid and return it to the blood. The remaining fluid, called urine, has a smaller volume and a greater concentration than tubular fluid. From the collecting ducts, urine enters a ureter and is eventually excreted from the body.

The reabsorption of water by the collecting ducts is controlled by a negative feedback mechanism. The mechanism involves a hormone secreted by the pituitary gland, called antidiuretic hormone (ADH). ADH makes the collecting ducts more permeable to water, allowing more water to be reabsorbed from tubular fluid. When there is not enough water in the blood, more ADH is secreted, more water is reabsorbed from tubular fluid, and less water is excreted in urine. The opposite happens when there is too much water in the blood.

Kidneys and Homeostasis

The kidneys play many vital roles in homeostasis. As you have already read, the kidneys filter blood and excrete liquid waste. In fact, the kidneys filter all the blood in the body about 16 times a day, producing approximately 180 liters of filtrate and about 1.5 liters of urine. The kidneys also control the amount of water in the blood by excreting more or less water in urine.

Balancing the Blood

The kidneys are responsible for maintaining balance in the blood in other ways, as well. For example, they control the acid-base balance in the blood, mainly by secreting hydrogen ions into tubular fluid and reabsorbing bicarbonate ions from tubular fluid as needed. The kidneys also regulate blood concentrations of many other ions—including sodium, potassium, calcium, and magnesium—by the controlling the amounts that are excreted in urine.

Secreting Hormones

The kidneys also secrete various hormones to help maintain homeostasis. Hormones secreted by the kidneys include erythropoietin and rennin.

- Erythropoietin is secreted when the blood does not have enough red blood cells to carry adequate oxygen. The hormone stimulates the production of red blood cells by the bone marrow.
- Rennin is secreted when blood pressure falls. The hormone stimulates the secretion of aldosterone by the adrenal gland. Aldosterone, in turn, stimulates the kidneys to reabsorb more sodium ions and water. This increases the volume of the blood, which causes an increase in blood pressure.

Kidney Disease and Dialysis

A person can live a normal, healthy life with just one kidney. However, at least one kidney must function properly to maintain life. Diseases that threaten the health and functioning of the kidneys include kidney stones, infections, and diabetes.

Kidney Stones

Kidney stones are crystals of dissolved minerals that form in urine inside the kidneys. They may start out as small as a grain of salt and grow to be as large as a grapefruit. There may be one large stone or many small ones. Small kidney stones often pass undetected through the urinary tract and out of the body in urine. However, kidney stones may grow large enough before passing to block a ureter. This can cause a buildup of urine above the blockage and severe pain. Large kidney stones can sometimes be broken into smaller pieces that wash out of the urinary tract in urine. The stones are shattered by high-intensity sound waves focused on them from outside the body. Another alternative is to remove kidney stones surgically.

Infections

Bacterial infections of the urinary tract are very common. In fact, urinary tract infections (UTI) are the second most common type of bacterial infections seen by health care providers. Typical organisms that cause UTIs include *Escherichia coli* and *Staphylococcus saprophyticus*. The organisms may infect any part of the urinary tract.

The most common type of UTIs are bladder infections. They can be treated with antibiotics prescribed by a doctor. However, if a bladder infection is not treated, it may spread to the kidney and cause a kidney infection, or pyelonephritis. This is the most serious type of UTI. It can damage the kidney and interfere with normal kidney function. Kidney infections can also be treated with antibiotics but may require other treatments as well.

Diabetes

Two different types of diabetes can involve the kidneys: diabetes insipidus and diabetes mellitus. Diabetes insipidus is a disease characterized by the inability to concentrate urine. A person with this disease typically produces many liters of very dilute urine each day. Diabetes insipidus can be caused by a deficiency of ADH (antidiuretic hormone) or by the kidneys failing to respond to ADH. If the cause of diabetes insipidus can be treated, it may cure the disease.

In diabetes mellitus, the kidneys try to reduce the high glucose level in the blood by excreting more glucose in urine. This causes frequent urination and increased thirst. If blood glucose levels are not controlled by medication or diet, they may damage capillaries of the glomerulus and interfere with the kidney's ability to filter blood. Eventually, high glucose levels may lead to kidney failure, in which kidney function is greatly reduced. Kidney failure leads to high levels of urea and other wastes in the blood and may require treatment with dialysis.

Dialysis and Transplantation

Dialysis is a medical procedure in which blood is filtered with the help of a machine. One type of dialysis treatment is shown in **Figure** 23.14. Blood from the patient's vein enters the dialysis machine through a tube. Inside the machine, excess water, wastes, and other unneeded substances are filtered from the blood. The filtered blood is then returned to the patient's vein through another tube. A dialysis treatment usually lasts three to four hours and must be repeated three times a week. Dialysis is generally performed on patients who have kidney failure. Dialysis helps them stay alive, but does not cure their failing kidneys.

The only cure for most people with kidney failure is a kidney transplant. To be suitable for transplantation, the donated kidney must come from a donor who has the same blood and tissue types as the recipient. Even then, the recipient must take medication to suppress the immune system so it does not reject the new kidney.

Lesson Summary

- Homeostasis is the body's attempt to maintain a constant internal environment. Excretion helps achieve homeostasis by removing wastes, excess water, and other unneeded substances from the body. Both processes are essential for life.
- The urinary system includes the kidneys and other structures that excrete liquid waste. The kidneys are the main organs of excretion of wastes in the blood, and nephrons are structural and functional units of the kidneys. The kidneys filter blood, reabsorb and secrete substances, and form urine.
- The kidneys are the main organs of homeostasis. In addition to excretion, they regulate acid-base balance and ion concentrations in the blood. They also secrete hormones that

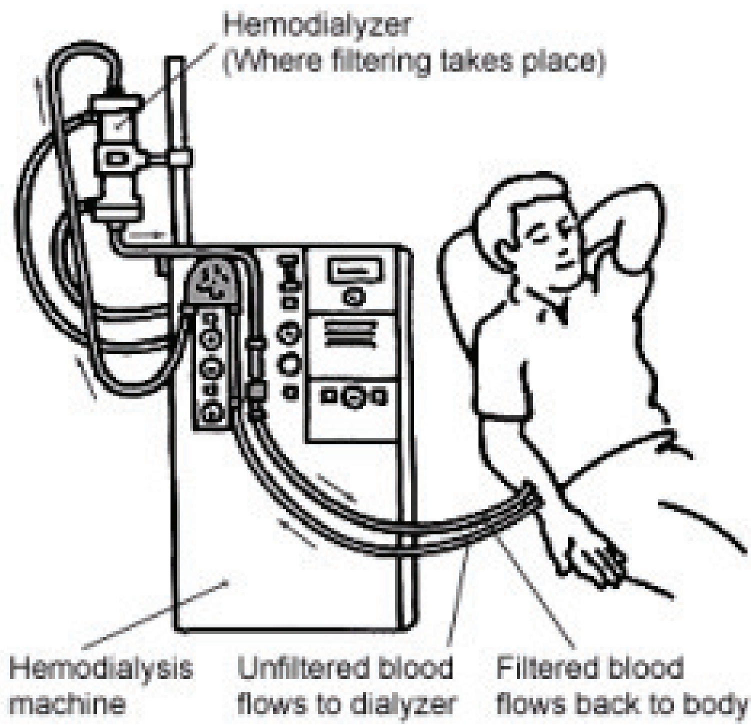

Figure 23.14: Patient receiving dialysis treatment. (7)

control other body processes.
- Diseases of the urinary system include kidney stones, infections, and diabetes, which may lead to kidney failure. Kidney failure can be treated with dialysis, in which a machine filters the blood.

Review Questions

1. What are homeostasis and excretion?
2. Identify three organs of excretion and one substance that each organ excretes.
3. Why do the kidneys reabsorb some of the substances they filter from the blood?
4. Describe how urine forms in the collecting ducts of the kidneys.
5. How does ADH control the amount of water in urine? How is this an example of negative feedback?
6. Does an otherwise healthy person with just one kidney need dialysis? Why or why not?
7. Summarize the processes and structures involved in excretion by the kidneys.
8. Contrast the effects on the kidneys of diabetes insipidus and diabetes mellitus.

Further Reading / Supplemental Links

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Vocabulary

bladder A hollow organ that stores urine.

Bowman's capsule A cup-shaped structure around the glomerulus that collects the filtered substances; part of the nephron.

control center Involved in maintaining homeostasis; processes the information, determines the appropriate action, and sends a command to the effector.

dialysis A medical procedure in which blood is filtered with the help of a machine.

effector Involved in maintaining homeostasis; responds to the command and changes conditions in the internal environment.

erythropoietin Hormone secreted by the kidney when the blood does not have enough red blood cells to carry adequate oxygen; stimulates the production of red blood cells by the bone marrow.

excretion The process of removing wastes and excess water from the body.

filtration The process of filtering substances from blood in the glomerulus.

glomerulus Part of the nephron; a cluster of arteries that filters substances out of the blood.

homeostasis The body's attempt to maintain a constant internal environment.

kidney Organ that filters the blood and forms urine.

kidney stones Crystals of dissolved minerals that form in urine inside the kidneys.

loop of Henle Carries the filtrate from the cortex down into the medulla and then back up to the cortex again; primary purpose is to reabsorb water and salt from the fluid.

negative feedback A type of homeostatic mechanism in which change in one direction results in a counteractive change in the opposite direction; reverses the direction of change to bring conditions back to normal.

nephrons The structural and functional units of the kidneys; includes the glomerulus, Bowman's capsule, and renal tubule.

positive feedback Accelerates or amplifies a change and pushes levels farther away from normal; not common in the human body.

reabsorption The return of needed substances in the filtrate back to the bloodstream.

receptor Involved in maintaining homeostasis; senses changes in the internal environment and sends the information to the control center.

renal tubule A long, narrow tube surrounded by capillaries that reabsorbs many of the filtered substances and secretes other substances; part of the nephron.

rennin Hormone secreted by kidney when blood pressure falls; stimulates the secretion of aldosterone by the adrenal gland. Aldosterone, in turn, stimulates the kidneys to reabsorb more sodium ions and water.

urethra A muscular tube that carries urine out of the body.

urinary system System in which the main function is to filter waste products and excess water from the blood and remove them from the body.

urine The liquid waste product of the body that is excreted by the urinary system.

Points to Consider

- A transplanted kidney may be rejected unless medication is taken to suppress the immune system. Why does the immune system reject transplanted organs?
- How does the immune system recognize transplanted organs as foreign to the body?
- What happens when the immune system "attacks" a transplanted organ?

Image Sources

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