Chapter 3  The Human Body: A Nutrition Perspective

Chapter Outline

Student Learning Outcomes

Chapter 3 is designed to allow you to:

3.1 Understand some basic roles of nutrients in human physiology.
3.2 Identify the functions of the common cellular components.
3.3 Define tissue, organ, and organ system.
3.4 Identify the role of the cardiovascular and lymphatic systems in nutrition.
3.5 List basic characteristics of the nervous system and its role in nutrition.
3.6 List basic characteristics of the endocrine system, especially the pancreas, and its role in nutrition.
3.7 List basic characteristics of the immune system and its role in nutrition.
3.8 Outline the overall processes of digestion and absorption in the mouth, stomach, small intestine, and large intestine, as well as the roles played by the liver, gallbladder, and pancreas.
3.9 List basic characteristics of the urinary system and and its role in nutrition.
3.10 Understand the importance of the body storage areas for nutrients.
3.11 Understand the emerging field of nutrigenomics.
3.12 Identify the major nutrition-related gastrointestinal health problems and approaches to treatment.

What Would You Choose?

For spring break, you are volunteering to help build a house with Habitat for Humanity. You are carpooling with some friends and staying in a retreat house. Unfortunately, the travel, budget, living accommodations, and your building schedule won’t allow for home-cooked meals this week. Being out of your normal routine and relying on fast-food sandwiches and pizza have left you feeling constipated. This reminds you that you will need to make smarter choices at fast-food establishments. To decrease your constipation which menu combination would you choose from a pizza buffet?

- a) 2 slices of pepperoni pizza, 2 cups of tossed salad
- b) 2 slices of veggie pizza, 1 cup of bean and pasta soup
- c) 2 slices of ham and pineapple pizza, 1 cup of pasta with Alfredo sauce
- d) 2 slices of cheese pizza, 1 garlic breadstick with marinara sauce

Think about your choices as you read Chapter 3, then see our recommendations at the end of the chapter. To learn more about the connection between our diets and our bodies, check out the Connect site: www.mcgrawhillconnect.com
Merely eating food won’t nourish you. You must first digest the food by breaking it down into usable forms of the essential nutrients that can be absorbed into the bloodstream. Once nutrients are taken up by the bloodstream, they can be distributed to and used by body cells.

We rarely think about, let alone control, digesting and absorbing foods. Except for a few voluntary responses—such as deciding what and when to eat, how well to chew food, and when to eliminate the remains—most digestion and absorption processes control themselves. As suggested in the comic in this chapter, we don’t consciously decide when the pancreas will secrete digestive substances into the small intestine or how quickly foodstuffs will be propelled down the intestinal tract. Various hormones and the nervous system mostly control these functions. Your only awareness of these involuntary responses may be a hunger pang right before lunch or a “full” feeling after eating that last slice of pizza.

Let’s examine digestion and absorption as well as other aspects of human physiology that support nutritional health. In the process you will become acquainted with the basic anatomy (structure) and physiology (function) of the circulatory system, nervous system, endocrine system, immune system, digestive system, urinary system, and storage capabilities of the human body.
Confirming Pages

Some popular (fad) diets suggest not combining meat and potatoes to improve digestion and that fruit should only be eaten before noon. These diets might also claim that foods get stuck in the body and in turn putrefy and create toxins. Are there any scientific reasons to suggest that the timing of our food intake should optimize digestion? Do certain food practices improve digestion and subsequent absorption? This chapter provides some answers.

FRANK AND ERNEST reprinted by permission of Newspaper Enterprise Association, Inc.

3.1 Nutrition’s Role in Human Physiology

Overall, the human body is a coordinated unit of many highly structured organ systems (Fig. 3-1). Together, these system are composed of trillions of cells. Each cell is a self-contained, living entity. Cells of the same type normally join together, using intercellular substances to form tissues, such as muscle tissue. One, two, or more tissues then combine in a particular way to form more complex structures, called organs. All organs contribute to nutritional health, and a person’s overall nutritional state determines how well each organ functions. At a still higher level of coordination, several organs can cooperate for a common purpose to form an organ system, such as the digestive system.

Chemical processes (reactions) occur constantly in every living cell: The production of new substances is balanced by the breaking down of older ones. An example is the constant formation and degradation of bone. For this turnover of substances to occur, cells require a continuous supply of energy in the form of dietary carbohydrate, protein, and/or fat. Cells also need water; building supplies, especially protein and minerals; and chemical regulators, such as the vitamins. Almost all cells also need a steady supply of oxygen. These substances enable the tissues, made from individual cells, to function properly.

Getting an adequate supply of all nutrients to the body’s cells begins with a healthy diet. To assure optimal use of nutrients, the body’s cells, tissues, organs, and organ systems also must work efficiently.

tissues  Collections of cells adapted to perform a specific function.
organ  A group of tissues designed to perform a specific function—for example, the heart, which contains muscle tissue, nerve tissue, and so on.
organ system  A collection of organs that work together to perform an overall function.
Chapter 3 covers the anatomy and physiology of the cell and major organ systems, especially as they relate to human nutrition. The information you are about to study is limited to the components of the various organ systems specifically influenced by the more than 45 essential nutrients discussed in this text.

### 3.2 The Cell: Structure, Function, and Metabolism

The cell is the basic structural and functional component of life. Living organisms are made of many different kinds of cells specialized to perform particular functions, and all cells are derived from preexisting cells. In the human body, all cells have certain common features. These cells have compartments and specialized structures that perform particular functions; these components are called **organelles** (Fig. 3-2). There are at least 15 different organelles. Eight of the most important organelles will be discussed. The numbers following the names of the cell structures correspond to the structures illustrated in Figure 3-2. Metabolism, the chemical processes that take place in body cells, will also be discussed.

#### Cell (Plasma) Membrane

There is an outside and inside to every cell, separated by the cell (plasma) membrane. This membrane holds the cellular contents together and regulates the direction and flow of substances into and out of the cell. Cell-to-cell communication also occurs by way of this membrane.
The cell membrane, illustrated in Figure 3-2(b), is a lipid bilayer (or double membrane) of phospholipids with their water-soluble heads facing both the interior of the cell and the exterior of the cell. Their water-insoluble tails are tucked into the center portion of the cell membrane.

Cholesterol is another component of the cell membrane. It is fat soluble, so it is embedded within the bilayer. This cholesterol provides rigidity and thus stability to the membrane.

There are also various proteins embedded in the cell membrane. Proteins provide structural support, act as transport vehicles, and function as enzymes that affect chemical processes within the membrane (see the later section on digestion for more

**phospholipid** Any of a class of fat-related substances that contain phosphorus, fatty acids, and a nitrogen-containing component. Phospholipids are an essential part of every cell.

**enzyme** A compound that speeds the rate of a chemical process but is not altered by that process. Almost all enzymes are proteins.
about enzymes). Some proteins form open channels that allow water-soluble substances to pass into and out of the cell. Proteins on the outside surface of the membrane act as receptors, snagging essential substances that the cell needs and drawing them into the cell. Other proteins act as gates that open and close to control the flow of various particles into and out of the cell.

In addition to the lipid and protein, the membrane also contains carbohydrates that mark the exterior of the cell. These carbohydrates are combined either with protein or fat, and they help send messages to the cell’s organelles and act as identification markers for the cell. In addition, they detect invaders and initiate defensive actions. In sum, these carbohydrates provide tags that are important to cellular identity and interaction.

**Cytoplasm**

The **cytoplasm** is the combination of fluid material and organelles within the cell, not including the nucleus. A small amount of energy for use by the cell can be produced by chemical processes that occur in the cytoplasm. This contributes to the survival of all cells and is the sole source of energy production in red blood cells. This energy production is called **anaerobic** metabolism because it doesn’t require oxygen.

**Organelles.** Included within the cytoplasm are organelles. As described in the next two pages, they carry out vital roles in cell functions.

**Mitochondria**

Mitochondria are sometimes called the “power plants,” or the powerhouse of the cell. These organelles are capable of converting the food energy in energy-yielding nutrients (carbohydrate, protein, and fat) to a form of energy that cells can use. This is an **aerobic** process that uses the oxygen we inhale, as well as water, enzymes, and other compounds (see Chapter 10 for details). With the exception of red blood cells, all cells contain mitochondria; only the size, shape, and quantity vary.

**Cell Nucleus**

With the exception of the red blood cell, all cells have one or more nuclei. The **cell nucleus** is bounded by its own double membrane. The nucleus contains the genetic material responsible for controlling actions that occur in the cell. The genetic material consists of **genes** on **chromosomes** made up of **deoxyribonucleic acid** (DNA). DNA is the “code book” that contains directions for making substances, specifically proteins, the cell needs. This code book remains in the nucleus of the cell, but sends its information to other cell organelles by way of a similar “messenger” molecule called **ribonucleic acid** (RNA). The information on the DNA is copied onto the RNA through the process of **transcription** and then moves out to the cytoplasm through pores in the nuclear membrane. The RNA carries the transcribed DNA code to protein-synthesizing sites called **ribosemes**. There, the RNA code is used in the process of **translation** to make a specific protein (see Chapter 6 for details on protein synthesis). This process is also known as **gene expression**.

All of the DNA in a cell is copied during cell replication. DNA is a double-stranded molecule, and when the cell begins to divide, each strand is separated and an identical copy of each is made. Thus, each new DNA contains one new strand of DNA and one strand from the original DNA. In this way, the genetic code is preserved from one cell generation to the next. (The mitochondria contain their own DNA, so they reproduce themselves within a cell independent of action in the cell’s nucleus.)
Endoplasmic Reticulum (ER) 5
The outer membrane of the cell nucleus is continuous with a network of tubes called the endoplasmic reticulum (ER). Part of the endoplasmic reticulum (termed the rough [as opposed to smooth] endoplasmic reticulum) contains the ribosomes, where the RNA code is translated into proteins during protein synthesis. Many of these proteins play a central role in human nutrition. Parts of the endoplasmic reticulum also are involved in lipid synthesis, detoxification of toxic substances, and calcium storage and release in the cell.

Golgi Complex 6
The Golgi complex is a packaging site for proteins used in the cytoplasm or exported from the cell. It consists of sacs within the cytoplasm in which proteins are “packaged” as secretory vesicles for secretion by the cell.

Lysosomes 7
Lysosomes are the cell’s digestive system. They are sacs that contain enzymes for the digestion of foreign material. Sometimes known as “suicide bags,” they are responsible for digesting worn-out or damaged cell components. Certain cells associated with immune functions contain many lysosomes (see the later section on the immune system).

Peroxisomes 8
Peroxisomes contain enzymes that detoxify harmful chemicals. Peroxisomes get their name from the fact that hydrogen peroxide (H₂O₂) is formed as a result of such enzyme action. Peroxisomes also contain a protective enzyme called catalase, which prevents excessive accumulation of hydrogen peroxide in the cell, which would be very damaging. Peroxisomes also play a minor role in metabolizing one possible source of energy for cells—alcohol.

Cell Metabolism
Metabolism refers to the entire network of chemical processes involved in maintaining life. It encompasses all the sequences of chemical reactions that occur in the body's cells. These biochemical reactions take place in the cell cytoplasm and organelles that we have just discussed. They enable us to release and use energy from foods, synthesize one substance from another, and prepare waste products for excretion.

The reactions of metabolism that take place within your body can be categorized into one of two types. One type of reaction, anabolic, puts different molecules together and, therefore, requires energy. The other type of reaction, catabolic, takes molecules apart and, therefore, releases energy. The metabolism of the nutrients, carbohydrates, proteins, and fats are interrelated and yield energy. The other nutrients, vitamins and minerals, contribute to the enzyme activity that supports metabolic reactions in the cell.

The metabolism of energy production begins in the cytoplasm with the initial anaerobic breakdown of glucose. The remaining aerobic steps of energy production take place in the mitochondria. Ultimately, the cells of the body use these interconnected processes to convert the energy found in food to energy stored in the high-energy compound, adenosine triphosphate (ATP). You will learn more about the metabolism of energy sources in Chapter 10, “Nutrition: Fitness and Sports.”
3.3 Body Systems

As noted earlier, when groups of similar cells work together to accomplish a specialized task, the arrangement is referred to as a tissue. Humans are composed of four primary types of tissue: epithelial, connective, muscle, and nervous. Epithelial tissue is composed of cells that cover surfaces both inside and outside the body. For example, the lining of the respiratory tract is made up of epithelial cells. These cells of epithelial tissue secrete important substances, absorb nutrients, and excrete waste. Connective tissue supports and protects the body, stores fat, and produces blood cells. Muscle tissue is designed for movement. Nervous tissue found in the brain and spinal cord is designed for communication. These four types of tissues then go on to form various organs, and ultimately, organ systems (Table 3-1).

We will focus primarily on the digestive system in Chapter 3. The nutrients we consume in food are unavailable until such time as they have been processed by the digestive system. This employs chemical and mechanical means to alter food so that the nutrients can be released and absorbed into the body for distribution to body tissues.

Sometimes organs within a system can serve another system. For example, the basic function of the digestive system is to convert the food we eat into absorbable nutrients. At the same time, the digestive system serves the immune system by preventing dangerous pathogens from invading the body and causing illness. As you study nutrition, you will note the multiple roles played by many organs (Fig. 3-3).

The overriding theme of human nutrition is to understand the actions of nutrients as they affect different cells, tissues, organs, and organ systems. Each type of organ system is impacted by nutrient intake and simultaneously determines how each nutrient is used.

Our task now is to explore the key systems in the body as they specifically relate to the study of human nutrition: circulatory (cardiovascular and lymphatic), nervous, endocrine, immune, digestive, and urinary systems. This part of Chapter 3 will set the stage for a more detailed look at these and other organ systems in later chapters covering various aspects of human nutrition.

Also in this chapter, we will introduce the emerging area of genetics and nutrition. Throughout this book, discussions will point out how you can personalize nutrition advice based on your genetic background. In this way, you can identify and avoid the “controllable” risk factors that would contribute to development of genetically linked diseases present in your family.

3.4 Cardiovascular System and Lymphatic System

The body has two separate organ systems that circulate fluids in the body: the cardiovascular system and the lymphatic system. The cardiovascular system consists of the heart and blood vessels. The lymphatic system consists of lymphatic vessels and
Cardiovascular System

The heart is a muscular pump that normally contracts and relaxes 50 to 90 times per minute when the body is at rest. This continual pumping, measured by taking your pulse, keeps blood moving through the blood vessels. The blood that flows through the cardiovascular system is composed of plasma, red blood cells, white blood cells, platelets, and many other substances. It travels two basic routes. In the first route, blood circulates from the right side of the heart, through the lungs, and then back to the heart. In the lungs, blood picks up oxygen and releases carbon dioxide. After this exchange of gases has taken place, blood is said to be oxygenated and returns to the left side of your heart. In the second route, the oxygenated blood circulates from the left side of the heart to all other body cells, eventually returning back to the right side of the heart (Fig. 3-4). After blood has circulated throughout the body, it is deoxygenated. (As you review the cardiovascular system, recall from your previous studies of biology that left and right designations of the heart refer to the left and right sides of your body, not of the page in your textbook.)
In the cardiovascular system, blood leaves the heart via *arteries*, which branch into *capillaries*, a network of tiny blood vessels. Exchange of nutrients, oxygen, and waste products between the blood and cells occurs through the minute, web-like pores of the capillaries (Fig. 3-5). Capillaries service every region of the body via individual capillary beds only one cell layer thick. The blood then returns to the heart via the *veins*.

The cardiovascular system distributes nutrients absorbed from food and oxygen from the air to all body cells (review Fig. 3-3). Other functions include delivery of hormones to their target cells, maintenance of a constant body temperature, and distribution of white blood cells throughout the body to protect against pathogens as part of the immune system (see the later section, “Immune System”).

**Portal Circulation in the Gastrointestinal Tract.** Water and nutrients are transferred to the circulatory system through capillary beds. Once absorbed through the stomach or intestinal wall, nutrients reach one of two destinations. Some nutrients are taken up by cells in the intestines and portions of the stomach to nourish those organs. Most of the nutrients from recently eaten foods, however, are transferred into *portal circulation*. To enter portal circulation, the nutrients pass from the intestinal capillaries into veins that eventually merge into a very large vein called a *portal vein*. Unlike most veins in the body—which carry blood back to the heart—this portal vein leads directly to the liver. This enables the liver to process absorbed nutrients before they enter the general circulation of the bloodstream. Overall, portal circulation represents a special form of circulation in the cardiovascular system.

**Lymphatic System**

The *lymphatic system* is also a circulatory system. It consists of a network of lymphatic vessels and the fluid (lymph) that moves through them. Lymph is similar to

---

**Terms:**
- *Artery*: A blood vessel that carries blood away from the heart.
- *Capillary*: A microscopic blood vessel that connects the smallest arteries and veins; site of nutrient, oxygen, and waste exchange between body cells and the blood.
- *Vein*: A blood vessel that carries blood to the heart.
- *Portal circulation*: The portion of the circulatory system that uses a large vein (portal vein) to carry nutrient-rich blood from capillaries in the intestines and portions of the stomach to the liver.
- *Urea*: Nitrogenous waste product of protein metabolism; major source of nitrogen in the urine.
blood, consisting largely of blood plasma that has found its way out of capillaries and into the spaces between cells. It contains a full array of the various white blood cells that play an important role in the immune system. However, neither red blood cells nor platelets are present. Lymph is collected in tiny lymph vessels all over the body and moves through even larger vessels until it eventually enters the cardiovascular system through major veins near the heart. This flow is driven by muscle contractions arising from normal body movements.

**FIGURE 3-4** Blood circulation through the body. Figure (a) shows the heart and some examples of the major arteries and veins of the cardiovascular system. Figure (b) shows the paths that blood takes from the heart to the lungs (1–3), back to the heart (4), and through the rest of the body (5–9). The red color indicates blood richer in oxygen; blue is for blood carrying more carbon dioxide. Keep in mind that arteries and veins go to all parts of the body.
FIGURE 3-5 Capillary and lymph vessels. (a) Exchange of oxygen (O₂) and nutrients for carbon dioxide (CO₂) and waste products occurs between the capillaries and the surrounding tissue cells. (b) Lymph vessels are also present in capillary beds, such as in the small intestine. Lymph vessels in the small intestine are also called lacteals. The lymph vessels have closed ends and are important for fat absorption.

Lymphatic Circulation in the Gastrointestinal Tract. Besides contributing to the defense of the body against invading pathogens, lymphatic vessels that serve the small intestine play an important role in nutrition. These vessels pick up and transport the majority of products of fat digestion and fat absorption. These fat-related products are too large to enter the bloodstream directly and therefore are generally emptied into the bloodstream only after passing through the lymphatic system. The lymph vessels also take up excess fluid that collects between cells and returns it to the bloodstream.

CONCEPT CHECK

Blood is transported from the right side of the heart to the capillaries in the lungs. Carbon dioxide is removed and oxygen is taken up by red blood cells. The oxygenated blood returns to the left side of the heart. Here it is pumped into general circulation. In the capillaries, oxygen is released from the red blood cells and delivered through pores in the capillaries to the surrounding cells. Nutrients also are distributed from the bloodstream to body cells via the capillaries. Carbon dioxide released from cells travels through the capillary pores to the blood.

The lymph system serves several purposes: the transport of absorbed dietary fats, the uptake and return to the bloodstream of excess fluid that collects between cells, and the defense of the body against invading pathogens.

3.5 Nervous System

The nervous system is a regulatory system that centrally controls most body functions. The nervous system can detect changes occurring in various organs and the external environment and initiate corrective action when needed to maintain a constant internal body environment. The nervous system also regulates activities that change almost instantly, such as muscle contractions and perception of danger. The body has many receptors that receive information about what is happening within the body and in the outside environment. For the most part these receptors are found in our
eyes, ears, skin, nose, and stomach. We act on information from these receptors via the nervous system.

The basic structural and functional unit of the nervous system is the **neuron**. These are elongated, highly branched cells. The body contains about 100 billion neurons. Neurons respond to electrical and chemical signals, conduct electrical impulses, and release chemical regulators. Overall, neurons allow us to perceive what is occurring in our environment, engage in learning, store vital information in memory, and control the body’s voluntary (and involuntary) actions.

The brain stores information, reacts to incoming information, solves problems, and generates thoughts. In addition, the brain plans a course of action based on the other sensory inputs. Responses to the stimuli are carried out mostly through the rest of the nervous system.

Simply put, the nervous system receives information through stimulation of various receptors, processes this information, and sends out signals through its various branches for an action that needs to be taken. Actual transmission of the signal occurs through a change in the concentration of two nutrients, sodium and potassium, in the neuron. There is an influx of sodium into the neuron and a loss of potassium as the message is sent. Concentrations of these minerals are then restored to normal amounts in the neuron after the signal passes, making it ready to conduct another message.

When the signal must bridge a gap (**synapse**) between the branches of different neurons, the message is generally converted to a chemical signal called a **neurotransmitter**. The neurotransmitter is then released into the gap, and its target may be another neuron or another type of cell, such as a muscle cell (Fig. 3-6). If the signal is sent to another neuron, this allows it to continue on to its final destination. The neurotransmitters
used in this process are often made from common nutrients found in foods, such as amino acids. The amino acid tryptophan is converted to the neurotransmitter serotonin, and the amino acid tyrosine is converted to the neurotransmitters norepinephrine and epinephrine (also called adrenaline).

Other nutrients also play a role in the nervous system. Calcium is needed for the release of neurotransmitters from neurons. Vitamin B-12 plays a role in the formation of the myelin sheath, which provides insulation around specific parts of most neurons. Finally, a regular supply of carbohydrate in the form of glucose is important for supplying fuel for the brain. The brain can use other calorie sources, but generally relies on glucose.

### 3.6 Endocrine System

The endocrine system plays a major role in the regulation of metabolism, reproduction, water balance, and many other functions by producing hormones in the endocrine glands of the body and subsequently releasing them into the blood (Table 3-2). The term hormone comes from the Greek word for “to stir or excite.” A true hormone is a regulatory compound that has a specific site of synthesis from which it then enters the bloodstream to reach target cells. Hormones are the messengers of the body. They can be permissive (turn on), antagonistic (turn off), or synergistic (work in cooperation with another hormone) in performing a task. Some compounds must undergo chemical changes before they can function as hormones. For example, vitamin D, synthesized in the skin or obtained from food, is converted into an active hormone by chemical changes made in the liver and kidneys.

The hormone insulin, synthesized in and released from the pancreas, helps control the amount of glucose in the blood (Fig. 3-7). Insulin is mostly produced when glucose in the blood rises to a certain level, usually after a meal. At this point, insulin is released and it travels to the muscle, adipose, and liver cells of the body. Among its many functions, insulin allows for the movement of glucose from the blood into muscle and adipose cells. In the liver cells, insulin causes an increase in stored glycogen by stimulating the synthesis of glycogen from glucose. Once a sufficient amount of glucose has been cleared from the blood, the production of insulin lessens. The hormones epinephrine, norepinephrine, glucagon, and growth hormone have just the opposite effect on blood glucose. They all cause an increase in blood glucose through a variety of actions (Table 3-2). Thyroid hormones, synthesized in and released from the thyroid gland

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Gland/Organ</th>
<th>Target</th>
<th>Effect</th>
<th>Role in Nutrition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin</td>
<td>Pancreas</td>
<td>Adipose (fat) and muscle cells</td>
<td>Decreased blood glucose</td>
<td>Uptake and storage of glucose, fat, and amino acids by cells</td>
</tr>
<tr>
<td>Glucagon</td>
<td>Pancreas</td>
<td>Liver</td>
<td>Increased blood glucose</td>
<td>Release of glucose from liver stores, release of fat from adipose tissue</td>
</tr>
<tr>
<td>Epinephrine, Norepinephrine</td>
<td>Adrenal glands</td>
<td>Heart, blood vessels, brain, lungs</td>
<td>Increased body metabolism and blood glucose</td>
<td>Release of glucose and fat into the blood</td>
</tr>
<tr>
<td>Growth hormone</td>
<td>Pituitary gland</td>
<td>Most cells</td>
<td>Promotion of amino acid uptake by cells, increased blood glucose</td>
<td>Promotion of protein synthesis and growth, increased fat use for energy</td>
</tr>
<tr>
<td>Thyroid hormones</td>
<td>Thyroid gland</td>
<td>Most organs</td>
<td>Increased oxygen consumption, overall growth, brain development of the nervous system</td>
<td>Protein synthesis, increased body metabolism</td>
</tr>
</tbody>
</table>
Hormones are not taken up by all cells in the body, but only those with the correct receptor protein. These binding sites are highly specific for a certain hormone. They are generally found on the cell membrane. The hormone attaches to its receptor on the cell membrane. This binding activates additional compounds called second messengers within the cell to carry out the assigned task. This is true of insulin. A few hormones can penetrate the cell membrane and eventually bind to receptors on the DNA in the nucleus (e.g., thyroid hormone and estrogen).

**CONCEPT CHECK**

The functional unit of the nervous system is the neuron. Communication between neurons themselves, and other types of cells, is via neurotransmitters released into the synapse between the cells.

In the endocrine system, hormones are produced by glands in response to a change in the internal or external environment of the body. The gland secretes the hormone into the blood, and the blood delivers it to target cells. The hormone either attaches to receptors in the cell membrane and, through the action of second messengers, causes changes within the cell, or enters the cell and binds to the DNA in the cell to cause changes within the cell.
3.7 Immune System

Many types of body cells and body components work in cooperation as part of the **immune system** to maintain a defense against infection (Fig. 3-8). The components that work as part of the immune system include the skin, intestinal cells, and white blood cells. Several nutrients, including protein; minerals iron, copper, and zinc; and vitamins A, B-6, B-12, C, and folate have important roles in the immune system. These nutrients are key factors in the synthesis, growth, development, and activity of immune cells and additional factors that kill pathogens. It is easy to demonstrate the importance of nutritional health for immune function. Early humans were plagued by famine and thus, malnutrition; this contributed to infections, often leading to death. Today, largely because of better nutrition, most of the world avoids that cycle.

We are born with most aspects of immune function; these are termed **non-specific** (or innate) because the targets are a variety of microorganisms. In contrast, white blood cells produce **immunoglobulins**, also called **antibodies**, that target specific organisms or foreign proteins called **antigens**. These immunoglobulins constitute **specific** (or adaptive) immune function. Once exposed, a memory is created such that a second exposure to the substance will produce a more vigorous and rapid attack.

**Skin**

The skin is a large component of the immune system, forming an almost continuous barrier surrounding the body. Invading microorganisms have difficulty penetrating the skin. However, if the skin is split by lesions, bacteria can easily penetrate this barrier. Skin health is poor during deficiencies of such nutrients as essential fatty acids, vitamin A, niacin, and zinc. Vitamin A deficiency also decreases gland secretions in the skin that contain the enzyme **lysozyme**, capable of killing bacteria. Bacterial eye infections are common in developing countries, often as a result of a vitamin A deficiency.

**Intestinal Cells**

The cells of the intestines form an important barrier to invading microorganisms. The cells are packed closely together, producing a physical barrier to microorganisms. In addition, specialized cells that produce immune factors—such as immunoglobulins—are scattered throughout the intestinal tract. These immune factors bind to the invading microorganisms, preventing them from entering the bloodstream. These factors are part of the mucosal membrane aspect of immunity.

Nutrient deficiencies can cause the intestinal cells to break down weakening the mucosal membrane so that microorganisms more easily enter the body and cause infections. Thus, two common results of undernutrition related to an impaired immune system are diarrhea and bacterial infections of the bloodstream. To protect the health of the intestinal tract, an adequate nutrient intake is necessary—especially of protein, vitamin A, vitamin B-6, vitamin B-12, vitamin C, folate, and zinc.

**MAKING DECISIONS**

**Immune Status**

Although many studies show that a healthy nutritional state is associated with good immune status, other studies show that an overabundance of certain nutrients can harm the immune system. For example, taking too much zinc may decrease immune function (see Chapter 9).
White Blood Cells

Once a microorganism enters the bloodstream, **white blood cells** move in to attack it. Several types of white blood cells participate in this response and function in unique ways. For example, a class called **phagocytes** circulates throughout the circulatory system and ingests and sometimes digests microorganisms and foreign particles (via lysosomes present in the cells) in a process called **phagocytosis** (Fig. 3-9). Other white blood cells participate in **cell-mediated immunity**, achieved when certain immune cells recognize foreign cells or proteins and directly attack and destroy them. Immunoglobulins, also known as antibodies and made by these cells, elicit an antibody-antigen response that binds microorganisms and proteins that are foreign to the body and destroys them, and then creates a template (memory) that allows future recognition of the microorganism or foreign protein. Recognition allows more rapid attacks in the future.

Some white blood cells live only a few days. Their constant resynthesis requires steady nutrient intake. The immune system needs the following nutrients: (1) iron to produce an important killing factor; (2) copper for synthesis of a specific type of white blood cell; and (3) protein, vitamin B-6, vitamin B-12, vitamin C, and folate for general cell synthesis and, later, cell activity. Zinc and vitamin A are also needed for the overall growth and development of immune cells.

**CONCEPT CHECK**

Many types of body cells and body components work in cooperation as part of the immune system to maintain a defense against infection. The skin forms an almost continuous barrier surrounding the body. Cell secretions contain the enzyme lysozyme. Specialized cells in the intestines and certain white blood cells secrete antibodies (immunoglobulins). Phagocytes roam throughout the circulatory system and ingest and sometimes digest microorganisms and foreign particles. Other white blood cells participate in cell-mediated immunity. This occurs when certain immune cells recognize foreign cells and directly attack them. Many nutrients, including protein, iron, copper, zinc, vitamin B-6, B-12, C, and folate, are needed for the overall growth and development of immune cells.

### 3.8 Digestive System

The foods and beverages we consume, for the most part, must undergo extensive alteration by the **digestive system** to provide us with usable nutrients. The processes of digestion and absorption take place in a long tube that is open at both ends and extends from the mouth to the anus. This tube is called the **gastrointestinal (GI) tract** (Fig. 3-10). Nutrients from the food we eat must pass through the walls of the GI tract—from the inside to the outside—to be absorbed into the bloodstream. The organs that make up the GI tract, as well as some additional accessory organs located nearby, are collectively known as the digestive system.

In the digestive system, food is broken down mechanically and chemically. Mechanical digestion takes place as soon as you begin chewing your food and continues as muscular contractions simultaneously mix and move food through the length of the GI tract (as part of a process known as **motility**). Chemical digestion refers to the chemical breakdown of foods by substances secreted into the GI tract. Finally, the digestive system eliminates wastes. In addition to nutrients that arise from digestion of food, the bacteria that live in the large intestine produce vitamin K and the vitamin biotin, some of which we can absorb and use.

Most of the processes of digestion and absorption are under autonomic control; that is, they are involuntary. Almost all of the functions involved in digestion and absorption are controlled by signals from the nervous system, hormones from the
Many common ailments arise from problems with the digestive system. Several of these digestive problems are discussed in the "Nutrition and Your Health" section at the end of this chapter.

The digestive system is composed of six separate organs; each organ performs one, or more, specific job(s). Let’s look briefly at the role of each organ. These organs are listed in Figure 3-10 and in the flowchart on the next page. More detailed descriptions of digestive processes will be explained in later chapters as each nutrient is introduced.

**Mouth**

The mouth performs many functions in the digestion of food. Besides chewing food to reduce it to smaller particles, the mouth also senses the taste of the foods we consume. The tongue, through the use of its taste buds, identifies foods on the basis of their specific flavor(s). Sweet, sour, salty, bitter, and umami comprise the primary taste sensations we experience. Surprisingly, the nose and our sense of smell greatly contribute to our ability to sense the taste of food. When we chew a food, chemicals are released that stimulate the nasal passages. Thus, it makes perfect sense that when we eat something, we can sense it as we chew it.

**gastrointestinal (GI) tract** The main sites in the body used for digestion and absorption of nutrients. It consists of the mouth, esophagus, stomach, small intestine, large intestine, rectum, and anus. Also called the digestive tract.

**motility** Generally, the ability to move spontaneously. It also refers to movement of food through the GI tract.

**umami** A brothy, meaty, savory flavor in some foods. Monosodium glutamate enhances this flavor when added to foods.
we have a cold and our noses are stuffed up and congested, even our most favorite foods will not taste as good as they normally do.

The taste of food, or the anticipation of it, signals the rest of the GI tract to prepare for the digestion of food. Once in the mouth, mechanical and chemical digestion begins. Salivary glands produce saliva, which functions as a solvent so that food particles can be further separated and tasted. In addition, saliva contains a starch-digesting enzyme, salivary amylase (see Chapter 4 for more on starch-digesting enzymes).

Enzymes are a key part of digestion. Each enzyme is specific to one type of chemical process. For example, enzymes that recognize and digest table sugar (sucrose) ignore milk sugar (lactose). Besides working on only specific types of chemicals, enzymes are sensitive to acidic and alkaline conditions, temperature, and the types of vitamins and minerals they require. Digestive enzymes that work in the acidic environment of the stomach do not work well in the alkaline environment of the small intestine. Overall, enzymes work to hasten certain events that take place in the body (Fig. 3-11).

The pancreas and the small intestine produce most of the digestive enzymes; however, the mouth and the stomach also contribute their own enzymes to digestion. Mucus, another component of saliva, makes it easy to swallow a mouthful of food. The food then travels to the esophagus. The important secretions and products of digestion are listed in Table 3-3.

**MAKING DECISIONS**

**Enzymes and Digestion**

The authors of some popular (fad) diet books contend that eating certain combinations of foods, such as meats and fruits together, hinders the digestive process. However, does this make sense in light of our newly gained knowledge about GI tract physiology? The body is able to increase the production of certain digestive enzymes in response to the type of diet consumed. The GI tract can respond to the nutritional makeup and amount of food consumed because of this fine-tuning. Once consumed, foods are attacked by multiple enzymes to release nutrients and other compounds for absorption.
TABLE 3-3 Important Secretions and Products of the Digestive Tract

<table>
<thead>
<tr>
<th>Secretion</th>
<th>Site of Production</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saliva</td>
<td>Mouth</td>
<td>Partial starch digestion using salivary amylase, lubrication of food for swallowing</td>
</tr>
<tr>
<td>Mucus</td>
<td>Mouth, stomach, small intestine, large intestine</td>
<td>Protects GI tract cells, lubricates food as it travels through the GI tract</td>
</tr>
<tr>
<td>Enzymes</td>
<td>Mouth, stomach, small intestine, pancreas</td>
<td>Promote digestion of carbohydrates, fats, and proteins into forms small enough for absorption (Examples: amylases, lipases, proteases)</td>
</tr>
<tr>
<td>Acid</td>
<td>Stomach</td>
<td>Promotes digestion of protein among other functions</td>
</tr>
<tr>
<td>Bile</td>
<td>Liver (stored in gallbladder)</td>
<td>Aids fat digestion in the small intestine by suspending fat in water using bile acids, cholesterol, and lecithin</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>Pancreas, small intestine</td>
<td>Neutralizes stomach acid when it reaches the small intestine</td>
</tr>
<tr>
<td>Hormones</td>
<td>Stomach, small intestine, pancreas</td>
<td>Stimulate production and/or release of acid, enzymes, bile, and bicarbonate; help regulate peristalsis and overall GI tract flow (Examples: gastrin, secretin, insulin, cholecystokinin, glucagon)</td>
</tr>
</tbody>
</table>

**Esophagus**

The esophagus is a long tube that connects the pharynx with the stomach. Near the pharynx is a flap of tissue (called the epiglottis) that prevents the bolus of swallowed food from entering the trachea (wind pipe) (Fig. 3-12). During swallowing, food lands on the epiglottis, folding it down to cover the opening of the trachea. Breathing also stops automatically. These responses ensure that swallowed food will only travel down the esophagus. If food instead travels down the trachea, choking may occur (the victim will not be able to speak or breathe). A group of techniques to treat such a person are called the Heimlich maneuver (see [www.heimlichinstitute.org](http://www.heimlichinstitute.org) for details).

At the top of the esophagus, nerve fibers release signals to tell the GI tract that food has been consumed. This results in an increase in gastrointestinal muscle action, called peristalsis. These continual waves of muscle contractions, followed by muscle relaxation, force the food down the digestive tract from the esophagus onward (Fig. 3-13).

At the end of the esophagus is the lower esophageal sphincter, a muscle that constricts (closes) after food enters the stomach. The main function of sphincters is to prevent the backflow of GI tract contents. Sphincters respond to various stimuli, such as signals from the nervous system, hormones, acidic versus alkaline conditions, and pressure that builds up around the sphincter. The primary function of the lower esophageal sphincter is to prevent the acidic contents of the stomach from flowing back up into the esophagus—which can cause some of the health problems we will discuss in the “Nutrition and Your Health” section at the end of Chapter 3.

**Stomach**

The stomach is a large sac that can hold up to 4 cups (or 1 quart) of food for several hours until all of the food is able to enter the small intestine. Stomach size varies individually and can be reduced surgically as a radical treatment for obesity (more on this in Chapter 7). While in the stomach, the food is mixed with gastric juice,
Peristalsis. Peristalsis is a progressive type of movement, propelling material from point to point along the GI tract. To begin this, a ring of contraction occurs where the GI wall is stretched, passing the food mass forward. The moving food mass triggers a ring of contraction in the next region, which pushes the food mass even farther along. The result is a ring of contraction that moves like a wave along the GI tract, pushing the food mass down the tract.

The stomach is responsible for the breakdown of food into chyme, which contains water, a very strong acid, and enzymes. (Gastric is a term pertaining to the stomach.) The acid in the gastric juice maintains the acidity of the stomach contents and, thereby destroys the biological activity of proteins, converts inactive digestive enzymes to their active form, partially digests food protein, and makes dietary minerals soluble so that they can be absorbed. The mixing that takes place in the stomach produces a watery food mixture, called chyme, which slowly leaves the stomach a teaspoon (5 milliliters) at a time and enters the small intestine. Following a meal, the stomach contents are emptied into the small intestine over the course of 1 to 4 hours. The pyloric sphincter, located at the base of the stomach, controls the rate at which the chyme is released into the small intestine (Fig. 3-14). There is very little absorption of nutrients from the stomach, except for some alcohol.

You might wonder how the stomach prevents itself from being digested by the acid and enzymes it produces. First, the stomach has a thick layer of mucus that lines and protects it. The production of acid and enzymes also requires the release of a specific hormone (gastrin). This release happens primarily when we are eating or thinking about eating. Last, as the concentration of acid in the stomach increases, hormonal control causes acid production to taper off.

One other important function of the stomach is the production of a substance called intrinsic factor. This vital protein-like compound is essential for the absorption of vitamin B-12.

Small Intestine

The small intestine is about 10 feet (3 meters) long, beginning at the stomach and ending at the large intestine (colon) (Fig. 3-15). The small intestine is considered “small” because of its narrow (1 inch [2.5 centimeters]) diameter. Most of the digestion and absorption of food occurs in the small intestine. The chyme secreted from the stomach is moved through the small intestine by peristaltic contractions so that it can be well mixed with the digestive juices of the small intestine (review Fig. 3-13). These juices contain many enzymes that function in the breakdown of carbohydrates, protein, and fat, as well as in the preparation of vitamins and minerals for absorption.

The physical structure of the small intestine is very important to the body’s ability to digest and absorb the nutrients it needs. The lining of the small intestine is called the mucosa and is folded many times; within these folds are fingerlike projections called villi. These “fingers” are constantly moving, which helps them trap food to enhance absorption. Each individual villus (singular, villus) is made up of many absorptive cells, and each of these cells has a highly folded cap. The combined folds, villi, and caps in the small intestine increase its surface area 600 times beyond that of a simple tube (Fig. 3-16).
FIGURE 3-14 Physiology of the stomach. The interior surface mucous cells produce mucus for protection from stomach acid and enzymes. Parietal cells produce the hydrochloric acid (HCL), and chief cells produce the enzymes. Mucous neck cells, scattered among the cells in the gastric pits, also produce mucus. The exterior surface is made up of three types of muscle layers.

FIGURE 3-15 The small intestine and beginning of the large intestine. The three parts of the small intestine are the duodenum, jejunum, and ileum. Notice the smaller diameter of the small intestine, compared with the large intestine.

The absorptive cells have a short life. New intestinal absorptive cells are constantly produced in the crypts of the small intestine (Fig. 3-16) and appear daily along the surface of each villus “finger.” This is probably because absorptive cells are subjected to a harsh environment, so renewal of the intestinal cell lining is necessary. This rapid cell turnover leads to high nutrient needs for the small intestine. Fortunately, many of

**absorptive cells** Intestinal cells that line the villi; and participate in nutrient absorption.
the old cells can be broken down and have their component parts reused. The health of the cells is further enhanced by various hormones and other substances that participate in or are produced as part of the digestive process.

The small intestine absorbs nutrients through the intestinal wall through various means and processes, as illustrated in Figure 3-17:

- **Passive diffusion:** When the nutrient concentration is higher in the cavity (lumen) of the small intestine than in the absorptive cells, the difference in nutrient concentration drives the nutrient into the absorptive cells by diffusion. Fats, water, and some minerals are absorbed by passive diffusion.
Nutrient absorption relies on four major absorptive processes. Passive diffusion (in blue) is diffusion of nutrients across the absorptive cell membranes. Facilitated diffusion (in green) uses a carrier protein to move nutrients down a concentration gradient. Active absorption (in purple) involves a carrier protein as well as energy to move nutrients (against a concentration gradient) into absorptive cells. Phagocytosis and pinocytosis (in green and brown) are forms of active transport in which the absorptive cell membrane forms an indentation that engulfs a nutrient to bring it into the cell.

- **Facilitated diffusion**: Some compounds require a carrier protein to drive them into absorptive cells. This type of absorption is called facilitated diffusion. Fructose is one example of a compound that makes use of such a carrier to allow for facilitated diffusion.

- **Active absorption**: In addition to the need for a carrier protein, some nutrients also require energy input to move from the lumen of the small intestine into the absorptive cells. This mechanism makes it possible for cells to take up nutrients even when they are consumed in low concentrations. Some sugars, such as glucose, are actively absorbed, as are amino acids.

- **Phagocytosis and pinocytosis**: In a further means of active absorption, absorptive cells literally engulf compounds (phagocytosis) or liquids (pinocytosis). As described earlier, a cell membrane can form an indentation of itself so that when particles or fluids move into the indentation, the cell membrane surrounds and engulfs them. This process is used when an infant absorbs immune substances from human milk (see Chapter 14).

Once absorbed, water-soluble compounds such as glucose and amino acids go to the capillaries and then on to the portal vein. Recall that the liver is the end of this process. Most fats eventually go into the lymph vessels. In doing so, they can eventually enter the bloodstream (see the earlier section on the circulatory system for details; and review Figs. 3-4 and 3-5).

Undigested food cannot be absorbed into cells of the small intestine. Any undigested food that reaches the end of the small intestine must pass through the ileocecal sphincter on the way to the large intestine (Fig. 3-18). This sphincter prevents the contents of the large intestine from reentering the small intestine.

**Large Intestine**

When the contents of the small intestine enter the large intestine, the material left bears little resemblance to the food originally eaten. Under normal circumstances, only a minor amount (5%) of carbohydrate, protein, and fat escape absorption to reach the large intestine (Table 3-4).
Physiologically, the large intestine differs from the small intestine in that there are no villi or digestive enzymes. The absence of villi means that little absorption takes place in the large intestine in comparison to the small intestine. Nutrients absorbed from the large intestine include water, some vitamins, some fatty acids, and the minerals sodium and potassium. Unlike the small intestine, the large intestine has a number of mucus-producing cells. The mucus secreted by these cells functions to hold the feces together and to protect the large intestine from the bacterial activity within it. The large intestine is home to a large population of bacteria (over 500 different species). Whereas the stomach and small intestine have some bacterial activity, the large intestine is the organ most heavily colonized with bacteria. Starting at infancy, the diet plays a major part in determining the type of bacteria in our digestive tracts. The number and type of bacteria in the human colon recently has become of great interest. Research has shown that intestinal bacteria play a significant role in the maintenance of health, especially health of the colon. It is speculated that higher levels of beneficial organisms can reduce the activity of disease-causing bacteria. This is another illustration of the intestinal tract working as an important immune organ. The strains bifidobacteria and lactobacilli are typically associated with health, whereas clostridia are considered problematic. These bacteria are able to break down some of the remaining food products that enter the large intestine, such as the milk sugar lactose (in lactose intolerant people), and some components of fiber. The products of bacterial metabolism in the large intestine, which include various acids, can then be absorbed.

Foods containing certain live microorganisms such as lactobacilli have been linked to some health benefits, such as improving intestinal tract health. These microorganisms are called probiotics because once consumed, they take up residence in the large intestine.
intestine and confer a health benefit. You can find these probiotic microorganisms in certain forms of fluid milk, fermented milk, yogurt, and in pill form (see Further Reading 13). A related term is prebiotic. These are substances that increase growth of probiotic microorganisms. One example is fructooligosaccharides (see Table 1-5 in Chapter 1 for dietary sources). The beneficial organisms of the large intestine and their use as probiotics are highlighted in “Newsworthy Nutrition” and will be discussed further in Chapter 4 when we explore their use as probiotics.

Some water remains in the material that enters the large intestine because the small intestine absorbs only 70% to 90% of the fluid it receives, which includes large amounts of GI-tract secretions produced during digestion. The remnants of a meal also contain some minerals and some fiber. Because water is removed from the large intestine, its contents become semisolid by the time they have passed through the first two-thirds of it. What remains in the feces, besides water and undigested fiber, is tough connective tissues (from animal foods); bacteria from the large intestine; and some body wastes, such as parts of dead intestinal cells.

**Rectum**

The feces or stool remains in the last portion of the large intestine, the rectum, until muscular movements push it into the anus to be eliminated. The presence of feces in the rectum stimulates elimination. The anus contains two anal sphincters (internal and external), one of which is under voluntary control (external sphincter). Relaxation of this sphincter allows for elimination.

### TABLE 3-4 Major Sites of Absorption Along the GI Tract

<table>
<thead>
<tr>
<th>Organ</th>
<th>Primary Nutrients Absorbed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>Alcohol (20% of total)</td>
</tr>
<tr>
<td></td>
<td>Water (minor amount)</td>
</tr>
<tr>
<td>Small intestine</td>
<td>Calcium, magnesium, iron, and other minerals</td>
</tr>
<tr>
<td></td>
<td>Glucose</td>
</tr>
<tr>
<td></td>
<td>Amino acids</td>
</tr>
<tr>
<td></td>
<td>Fats</td>
</tr>
<tr>
<td></td>
<td>Vitamins</td>
</tr>
<tr>
<td></td>
<td>Water (70% to 90% of total)</td>
</tr>
<tr>
<td></td>
<td>Alcohol (80% of total)</td>
</tr>
<tr>
<td></td>
<td>Bile acids</td>
</tr>
<tr>
<td>Large intestine</td>
<td>Sodium</td>
</tr>
<tr>
<td></td>
<td>Potassium</td>
</tr>
<tr>
<td></td>
<td>Some fatty acids</td>
</tr>
<tr>
<td></td>
<td>Gases</td>
</tr>
<tr>
<td></td>
<td>Water (10% to 30% of total)</td>
</tr>
</tbody>
</table>

**prebiotic** Substance that stimulates bacterial growth in the large intestines.  
**rectum** Terminal portion of the large intestine.  
**anus** Last portion of the GI tract; serves as an outlet for that organ.  
**anal sphincters** A group of two sphincters (inner and outer) that help control expulsion of feces from the body.

**NEWSWORTHY NUTRITION**

**Link between gut bacteria and health and disease**

The benefits of probiotics and prebiotics have been confirmed in over 700 research studies. Probiotics, especially, are now recommended for the prevention and treatment of gastrointestinal tract disorders including inflammation, infections, and allergy. Evidence is available to support the growing interest in these microorganisms and to aid the development of intervention strategies and practical guidelines for their use.


Check out the Connect site [www.mcgrawhillconnect.com](http://www.mcgrawhillconnect.com) to further explore probiotics.
Accessory Organs

The liver, gallbladder, and pancreas work with the GI tract and are considered accessory organs to the process of digestion (review Fig. 3-10). These accessory organs are not part of the GI tract through which food passes, but they play necessary roles in the process of digestion. These organs secrete digestive fluids into the GI tract and enable the process of converting food into absorbable nutrients.

The liver produces a substance called bile. The bile is stored and concentrated in the gallbladder until the gallbladder receives a hormonal signal to release the bile. This signal is induced by the presence of fat in the small intestine. Bile is released and delivered to the small intestine via a tube called the bile duct (Fig. 3-19).

In action, bile is like soap. Components of the bile enable large portions of fat to break into smaller bits so that they can be suspended in water (Chapter 5 will cover this process in detail). Interestingly, some of the bile constituents can be “recycled” in a process known as enterohepatic circulation. These components of bile are reabsorbed from the small intestine, returned to the liver via the portal vein, and reused.

In addition to bile, the liver releases a number of other unwanted substances that travel with the bile to the gallbladder and end up in the small intestine and eventually in the large intestine for excretion. The liver functions in this manner to remove unwanted substances from the blood. (Other byproducts are excreted via the urine; see the next section, “Urinary System.”)

The pancreas manufactures hormones and pancreatic juice. The hormones include glucagon and insulin, which as noted earlier function in glucose regulation (review Fig. 3-7). Pancreatic juice contains water, bicarbonate, and a variety of digestive enzymes capable of breaking apart carbohydrates, proteins, and fats into small fragments. Bicarbonate is a base that neutralizes the acidity of chyme as it moves from the stomach into the small intestine. In contrast to the stomach, the small intestine does not have a protective layer of mucus, because mucus would impede nutrient absorption. Instead, the neutralizing capacity of bicarbonate from the pancreas protects the walls of the small intestine from erosion by acid, which would otherwise lead to formation of an ulcer (see the “Nutrition and Your Health” section at the end of Chapter 3).

CONCEPT CHECK

Digestion is a mechanical and chemical process mediated by enzymes and coordinated by hormones and nerves. Whereas swallowing and ultimate elimination of feces from the anus are voluntary, the majority of the digestive processes are involuntary. The stomach initiates the process of digestion by mixing food with gastric juice and converting this partially digested food into chyme. The products of digestion are molecules of the original food or beverages small enough to be absorbed into the villi of the small intestine and transferred to the blood or lymph. For the most part, nutrients are absorbed in the small intestine; only a few are absorbed in the large intestine. Any dietary component that escapes digestion by human or bacterial enzymes exits the body as feces.

3.9 Urinary System

The urinary system is composed of two kidneys, one on each side of the spinal column. Each kidney is connected to the bladder by a ureter. The bladder is emptied by way of the urethra (Fig. 3-20). The main function of the kidneys is to remove waste from the body. The kidneys are constantly filtering blood to control its composition. This results in the formation of urine, mostly water, along with dissolved waste products of metabolism such as urea, and excess and unneeded water-soluble vitamins and various minerals.
Together with the lungs, the kidneys also maintain the acid-base balance (pH) of the blood. The kidneys also convert a form of vitamin D into its active hormone form and produce a hormone that stimulates red blood cell synthesis (erythropoietin; see Chapter 12 for information on misuse of this hormone by some athletes). During times of fasting, the kidneys even produce glucose from certain amino acids. Thus, the kidneys perform many important functions related to nutrition and are a vital component of the body.

The proper function of the kidneys is closely tied to the strength of the cardiovascular system, particularly its ability to maintain adequate blood pressure, and the consumption of sufficient fluid. Uncontrolled diabetes, hypertension, and drug abuse are harmful to the kidneys.

### 3.10 Nutrient Storage Capabilities

The human body must maintain reserves of nutrients, otherwise we would need to eat continuously. Storage capacity varies for each different nutrient. Most fat is stored in adipose tissue, made up of cells designed specifically for this. Short-term storage of carbohydrate occurs in muscle and liver in the form of glycogen. The blood maintains a small reserve of glucose and amino acids. Many vitamins and minerals are stored in the liver, while other nutrient stores are found in other sites in the body.

When people do not meet certain nutrient needs, these nutrients are obtained by breaking down a tissue that contains high concentrations of the nutrient. For example, calcium is taken from bone and protein is taken from muscle. In cases of long-term deficiency, these nutrient losses weaken and harm these tissues.

Many people believe that if too much of a nutrient is obtained—for example, from a vitamin or mineral supplement—only what is needed is stored and the rest is excreted by the body. Though true for some nutrients, such as vitamin C, the large dosages of other nutrients frequently found in supplements, such as vitamin A and iron, can cause harmful side effects because they are not readily excreted. This is one reason why obtaining your nutrients primarily (or exclusively) from a balanced diet is the safest means to acquire the building blocks you need to maintain the good health of all organ systems.
3.11 Nutrition and Genetics

Once nutrients and other dietary components are taken up by cells, they may interact with our genes and have an effect on gene expression. The growth, development, and maintenance of cells, and ultimately of the entire organism, are directed by genes present in the cells. Each gene essentially represents a recipe, noting the ingredients (amino acids) and how those ingredients should be put together (to make proteins). The products (proteins) of all the recipes in the cookbook (the human genome) would then make up the human organism. The genome and the epigenome, the way the genome is marked and packaged inside a cell’s nucleus, control the expression of individual traits, such as height, eye color, and susceptibility to many diseases.

Epigenetics refers to inherited changes in gene expression caused by mechanisms other than changes in the underlying DNA sequence. While our genome contains the code for the proteins that can be made by our bodies, our epigenome is an extra layer of instructions that influences gene activity. In many cases it is the epigenome that can be repaired by treatments, or affected by diet, rather than the genetics.

The causes of chronic diseases are complex and include a significant genetic component. Fortunately, the science of genetics is moving swiftly such that medical breakthroughs are beginning to touch our lives. Genetic discoveries are leading to new drugs that disrupt disease processes at the molecular level and to tests that predict our risk for disease. In 2008, scientists discovered more than 100 genetic variations associated with many medical conditions associated with aging, including type 2 diabetes, Alzheimer’s disease, osteoporosis, high blood pressure, and heart disease.

The Emerging Field of Nutrigenomics

In the near future, genetic information will enhance the ability of health professionals to help individuals manage diseases and optimize health. Nutritional genomics or nutrigenomics is the study of how food impacts health through its interaction with our genes and its subsequent effect on gene expression. Nutrigenomics also includes the study of how genes determine our nutritional requirements. Research in this area highlights the fallacy of a “one-size-fits-all” approach to nutrition interventions for disease prevention and management. It is becoming clear that the general nutrient requirements do not apply to certain genetic subgroups. Research is very active in identifying these subgroups and classifying the human genetic variation that may affect nutrient utilization and physiological function and therefore their unique nutrient requirements (see Further Readings 5, 14, and 15).

In addition to the direct effect of genes on disease risk, in many cases, genes influence the effect of diet and nutrition on disease development and progression. In some cases, a food component can cause a gene to be turned on or off, thus manipulating the production of proteins that can affect—positively or negatively—development.
or progression of diseases. With a better understanding of the interactions between genes and our diet, it will not be long before dietary recommendations may be personalized to help those with various genetically-linked diseases (see Further Reading 7).

**Nutritional Diseases with a Genetic Link**

Studies of families, including those with twins and adopted children, provide strong support for the effects of genetics in various disorders. In fact, family history is considered to be an important risk factor in the development of many nutrition-related diseases.

**Cardiovascular Disease.** There is strong evidence that cardiovascular disease is the result of gene-environment interactions. About 1 of every 500 people in North America has a defective gene that greatly delays cholesterol removal from the bloodstream. As discussed in Chapter 1, elevated blood cholesterol is one major risk factor for development of cardiovascular disease. The gene-diet interactions being discovered for cardiovascular disease, particularly the cases of high blood lipid levels, will likely be the first to lead to nutrition plans personalized to decrease cardiovascular disease risk. Another genetic variation can cause abnormally high levels of an amino acid called homocysteine, which increases cardiovascular disease risk. Diet changes can help these people, but medications and even surgery are needed to address these problems.

**Obesity.** Most obese North Americans have at least one obese parent. This strongly suggests a genetic link. Findings from many human studies suggest that a variety of genes (likely 60 or more) are involved in the regulation of body weight. Little is known, however, about the specific nature of these genes in humans or how the actual changes in body metabolism (such as lower calorie-burning in general or fat use in particular) are produced.

Still, although some individuals may be genetically predisposed to store body fat, whether they do so depends on how many calories they consume relative to their needs. A common concept in nutrition is that nurture—how people live and the environmental factors that influence them—allows nature—each person’s genetic potential—to be expressed. Although not every person with a genetic tendency toward obesity becomes obese, those genetically predisposed to weight gain have a higher lifetime risk than individuals without a genetic predisposition to obesity.

**Diabetes.** Both of the two common types of diabetes—type 1 and type 2—have genetic links. Evidence for these genetic links comes from studies of families, including twins, and from the high incidence of diabetes among certain population groups (e.g., South Asians or Pima Indians). Diabetes, in fact, is a complex disease with more than 200 genes identified as possible causes. Only sensitive and expensive testing can determine who is at risk. Type 2 diabetes is the most common form of diabetes (90% of all cases), and also has a strong link to obesity. Typically a genetic tendency for type 2 diabetes is expressed once a person becomes obese but often not before, again illustrating that nurture affects nature.

**Cancer.** A few types of cancer (e.g., some forms of colon [large intestine] and breast cancer) have a strong genetic link, and genetics may play a role in others, such as prostate cancer. Because obesity increases the risk of several forms of cancer, a long-standing excess calorie intake is also a risk factor. Although genes are an important determinant in the development of cancer, environmental and lifestyle factors, such as excessive sun exposure and a poor diet, also contribute significantly to the risk profile.
Your Genetic Profile

From this discussion, you can see that your genes can greatly influence your risk of developing certain diseases. By recognizing your potential for developing a particular disease, you can avoid behavior that further raises your risk. How can you figure out your genetic profile? Genetic testing can be valuable if it confirms that you carry a gene for a disease that you can do something about in terms of protecting against it. Testing is also of interest when you do not know your family medical history or there are gaps in your family tree. About 1000 genetic tests have become available in recent years. It typically costs about $1000 to have your DNA read to reveal the diseases to which you are most susceptible. Many tests are covered by health insurance plans. The Genetic Information Nondiscrimination Act (GINA) became a law in May 2008, and prohibits health insurers from raising premiums or denying coverage based on genetic information and applies to people who have genes that carry the risk of disease. DNA testing includes providing a saliva sample from which your DNA will be separated. Certain areas of the genome are then read and measured in the process known as genotyping. After this 1-to-2-month process, you receive your DNA profile, which will supplement what you already know about your family history. You can also compare your DNA profile to future findings from DNA research.

Many of the genes involved in common diseases, such as diabetes, are still unknown. Although there are genetic tests available for some diseases, your family history of certain diseases is still a much better indicator of your genetic profile and risk of disease. Put together a family tree of illnesses and deaths by compiling a few key facts on your primary relatives: siblings, parents, aunts and uncles, and grandparents, as suggested in the “Rate Your Plate” section. In general, the greater number of your relatives who had a genetically transmitted disease and the closer they are related to you, the greater your risk. If there is a significant family history of a certain disease, lifestyle changes may be appropriate. For example, women with a family history of breast cancer should avoid becoming obese, should minimize alcohol use, and should obtain mammograms regularly.

Figure 3-22 shows an example of a family tree (also called a genogram). High-risk conditions include two or more first-degree relatives in a family with a specific disease (first-degree relatives include one’s parents, siblings, and offspring). Another sign of risk of inherited disease is development of the disease in a first-degree relative before the age of 50 to 60 years. In the family depicted in Figure 3-21, prostate cancer killed the man’s father. Knowing this, the man should be tested regularly for prostate cancer. His sisters should have frequent mammograms and other preventive
practices because their mother died of breast cancer. Because heart attack and stroke are also common in the family, all the children should adopt a lifestyle that minimizes the risk of developing these conditions, such as avoiding excessive animal fat and salt intake. Colon cancer is also evident, so careful screening throughout life is important.

Information about our genetic makeup will increasingly influence our dietary and lifestyle choices. Throughout this book we will discuss “controllable” risk factors that could contribute to development of genetically linked diseases present in your family. This information will help you personalize nutrition advice based on your genetic background and identify and avoid the risk factors that could lead to the diseases present in your family.

This review of human anatomy, physiology, and genetics from a nutrition perspective sets the stage for developing a more detailed understanding of the nutrients. Chapters 4, 5, and 6 will build on this information.

**FIGURE 3-21** Example of a family tree for Justin, designated as “Self” at the trunk of the tree. The gender of each family member is identified by color (blue squares for males, orange circles for females). Dates of birth (b) and death (d) are listed below each family member. If deceased, the cause of death is highlighted using white text against a red background. Other medical conditions the family members experienced are noted beneath each name. Create your own family tree of frequent diseases using the diagram in “Rate Your Plate” and this figure as a guide. Then show your family tree to your physician to get a more complete picture of what the information means for your health.
The fine-tuned organ system we call the digestive system can develop problems. Knowing about these common problems can help you avoid or lessen them. Two common GI tract-related problems are diverticulosis and lactose malabsorption and intolerance. These disorders will be discussed in Chapter 4 after you learn more about carbohydrates.

### Ulcers

A peptic ulcer can occur when the lining of the esophagus, stomach, or small intestine is eroded by the acid secreted by the stomach cells (Fig. 3-22). As the stomach lining deteriorates in ulcer development, it loses its protective mucus layer, and the acid further erodes the stomach tissue. Acid can also erode the lining of the esophagus and the first part of the small intestine, the duodenum. In young people, most ulcers occur in the small intestine, whereas in older people they occur primarily in the stomach.

Millions of North Americans develop ulcers during their lifetimes. As a result, billions of healthcare dollars are spent annually on the treatment of peptic ulcers and their complications. Fortunately, our understanding of ulcer formation has increased, resulting in a variety of improved treatment options. The typical symptom of an ulcer is pain about 2 hours after eating. Stomach acid acting on a meal irritates the ulcer after most of the meal has moved from the site of the ulcer.

Not long ago, the major cause of ulcer disease was thought to be excess acid. Therefore, neutralizing and curtailing the secretion of stomach acid were the logical treatment choices. Although acid is still a significant player in ulcer formation, the principal causes of ulcer disease are currently thought to be infection of the stomach by the acid-resistant bacteria, *Helicobacter pylori* (*H. pylori*); heavy use of nonsteroidal anti-inflammatory drugs (NSAIDs), such as aspirin; and disorders that cause excessive acid production in the stomach. Stress is regarded as a predisposing factor for ulcers, especially if the person is infected with *H. pylori* or has certain anxiety disorders. Cigarette smoking is also known to cause ulcers, increase ulcer complications such as bleeding, and lead to ulcer treatment failure.

The *H. pylori* bacteria is found in more than 80% of patients with stomach and duodenal ulcers. The bacteria is common but results in ulcer disease in only 10% to 15% of those infected. Although the mechanism of how *H. pylori* causes ulcers is not well understood, treatment of the infection with antibiotics heals the ulcers and prevents their recurrence. Two Australian physicians were awarded the Nobel Prize in 2005 “for their discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease.”

NSAIDs are medications for painful inflammatory conditions such as arthritis. Aspirin, ibuprofen, and naproxen are the most commonly used NSAIDs. NSAIDs reduce the mucus secreted by the stomach. Newer medications, called “Cox-2 inhibitors” (e.g., celecoxib [Celebrex]), have been used as a replacement for NSAIDs because they are less likely to cause stomach ulcers. They do offer some advantages over NSAIDs, but they may not be totally safe for some people, especially those with a history of cardiovascular disease or strokes.

The primary risk associated with an ulcer is the possibility that it will erode entirely through the stomach or intestinal wall. The GI contents could then spill into the body cavities, causing a massive infection. In addition, an ulcer may erode a blood vessel, leading to substantial blood loss. For these reasons, it is important not to ignore the early warning signs of ulcer development, including a persistent gnawing or burning near the stomach that may occur immediately following a meal or awaken you at night. In addition to the pain that may improve with food, other signs and symptoms of ulcers are weight loss, nausea, vomiting, loss of appetite, and abdominal bloating.

In the past, milk and cream therapy was used to help cure ulcers. Clinicians now know that milk and cream are two of the worst foods for an ulcer. The calcium in these foods stimulates stomach acid secretion and actually inhibits ulcer healing.

Today, a combination of approaches is used for ulcer therapy. People infected with *H. pylori* are given antibiotics as well as stomach acid-blocking medica-
tions called proton (proton is another name for the hydrogen ion that creates acidity) pump inhibitors (e.g., omeprazole [Prilosec], esomeprazole [Nexium], and lansoprazole [Prevacid]). In many cases, there is a 90% cure rate for \( H. pylori \) infections in the first week of this treatment. Recurrence is unlikely if the infection is cured, but an incomplete cure almost certainly leads to repeated ulcer formation (see Further Reading 2).

Antacid medications may also be part of ulcer care, as is a class of medicines called \( \text{H}_2 \) blockers. These include cimetidine (Tagamet), ranitidine (Zantac), nizatidine (Axid), and famotidine (Pepcid), all of which prevent histamine-related acid secretion in the stomach. Medications that coat the ulcer, such as sucralfate (Carafate), are also commonly used.

People with ulcers should refrain from smoking and minimize the use of NSAIDs. These practices reduce the mucus secreted by the stomach. Overall, a combination of lifestyle therapy and medical treatment has so revolutionized ulcer therapy that dietary changes are of minor importance today: Current diet-therapy approaches recommend avoiding foods that increase ulcer symptoms (Table 3-5).

When suffering from persistent heartburn or GERD, see a doctor if you have:
- Difficulty swallowing or pain when swallowing
- Heartburn that has persisted for more than 10 years
- Initial onset of heartburn after age 50
- Heartburn that resists treatment with medications
- Sudden, unexplained weight loss
- Chest pain
- Blood loss or anemia
- Blood in stool or vomit

\( \text{H}_2 \) blocker Medication, such as cimetidine (Tagamet®), that blocks the increase of stomach acid production caused by histamine.

Histamine A breakdown product of the amino acid histidine that stimulates acid secretion by the stomach and has other effects on the body, such as constriction of smooth muscles, increased nasal secretions, relaxation of blood vessels, and changes in relaxation of airways.
About half of North American adults experience occasional heartburn, also known as acid reflux (Fig. 3-23). This gnawing pain in the upper chest is caused by the movement of acid from the stomach into the esophagus. The recurrent and therefore more serious form of the problem is called gastroesophageal reflux disease (GERD). Unlike the stomach, the esophagus has very little mucus lining to protect it, so acid quickly erodes the lining of the esophagus, causing pain. Symptoms may also include nausea, gagging, cough, or hoarseness. GERD is characterized by the occurrence of such symptoms of acid reflux two or more times per week. People who have GERD experience occasional relaxation of the gastroesophageal sphincter. Typically it should be relaxed only during swallowing, but in individuals with GERD it is relaxed at other times as well.

The majority of heartburn sufferers say it significantly affects their quality of life, particularly their enjoyment of many favorite foods. On a more serious note, however, if left untreated, heartburn can, over time, damage the lining of the esophagus, leading to chronic esophageal inflammation and an increased risk of esophageal cancer (see Further Reading 8). Heartburn sufferers should follow the general recommendations given in Table 3-5.

For occasional heartburn, quick relief can be found with over-the-counter (OTC) antacids. Taking antacids will reduce the acid in the stomach but will not stop the acid reflux. For more persistent (few days a week or everyday) heartburn or GERD, the H2 blockers or PPIs, discussed in the previous section on ulcers, may be needed. PPIs provide long-lasting relief by reducing stomach acid production and should be taken before the first meal of the day because they take longer to work. If the proper medications are not effective at controlling GERD, surgery may be necessary.

### TABLE 3-5 Recommendations to Prevent Ulcers and Heartburn from Occurring or Recurring

<table>
<thead>
<tr>
<th>Ulcers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stop smoking if you are now a smoker.</td>
</tr>
<tr>
<td>2. Avoid large doses of aspirin, ibuprofen, and other NSAID compounds unless a physician advises otherwise. For people who must use these medications, FDA has approved an NSAID combined with a medication to reduce gastric damage. The medication reduces gastric acid production and enhances mucus secretion.</td>
</tr>
<tr>
<td>3. Limit consumption of coffee, tea, and alcohol (especially wine), if this helps.</td>
</tr>
<tr>
<td>4. Limit consumption of pepper, chili powder, and other strong spices, if this helps.</td>
</tr>
<tr>
<td>5. Eat nutritious meals on a regular schedule; include enough fiber (see Chapter 4 for sources of fiber).</td>
</tr>
<tr>
<td>6. Chew foods well.</td>
</tr>
<tr>
<td>7. Lose weight if you are currently overweight.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heartburn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Follow ulcer prevention recommendations.</td>
</tr>
<tr>
<td>2. Wait about 2 hours after a meal before lying down.</td>
</tr>
<tr>
<td>3. Don’t overeat. Eat smaller meals that are low in fat.</td>
</tr>
<tr>
<td>4. Elevate the head of the bed at least 6 inches.</td>
</tr>
</tbody>
</table>

**Heartburn**

**gastroesophageal reflux disease (GERD)** Disease that results from stomach acid backing up into the esophagus. The acid irritates the lining of the esophagus, causing pain.
Constipation and Laxatives

Constipation, difficult or infrequent evacuation of the bowels, is commonly reported by adults. Slow movement of fecal material through the large intestine causes constipation. As more fluid is absorbed during the extended time the feces stay in the large intestine, they become dry and hard.

Constipation can result when people regularly ignore their normal bowel reflexes for long periods. People may ignore normal urges when it is inconvenient to interrupt occupational or social activities. Muscle spasms of an irritated large intestine can also slow the movement of feces and contribute to constipation. Calcium, iron supplements, and medications such as antacids can also cause constipation.

Eating foods with plenty of fiber, such as whole-grain breads, cereals, and beans, along with drinking adequate fluid to avoid dehydration, is the best method for treating mild cases of constipation. Fiber stimulates peristalsis by drawing water into the large intestine and helping form a bulky, soft fecal output. Dried fruits are a good source of fiber and contain many of the B vitamins needed to strengthen the weakened esophageal sphincter (see Further Reading 3). A popular theory is that relaxation of the lower esophageal sphincter allows acid and stomach contents to flow back into the esophagus. This situation will be more of a problem when lying down.

Both pregnancy and obesity can lead to heartburn (see Further Reading 6). These conditions result in increased production of estrogen and progesterone, which relax the lower esophageal sphincter, making heartburn more likely. In obesity, adipose tissue turns certain circulating hormones into estrogen; thus, the more adipose tissue one has, the more estrogen produced.

Use of Laxatives

MAKING DECISIONS

Use of Laxatives

Perhaps you have heard that taking laxatives after overeating prevents deposition of body fat from excess calorie intake. This erroneous and dangerous premise has gained popularity among followers of numerous fad diets. You may temporarily feel less full after using a laxative because laxatives hasten emptying of the large intestine and increase fluid loss. Most laxatives, however, do not speed the passage of food through the small intestine, where digestion and most nutrient absorption take place. As a result, do you think you can count on laxatives to prevent fat gain from excess calorie intake?

Laxatives, as well as various other medications, can also lessen constipation. Some laxatives work by irritating the intestinal nerve junctions to stimulate the peristaltic muscles, while others that contain fiber draw water into the intestine to enlarge fecal output. The larger output stretches the peristaltic muscles, making them rebound and then constrict. Regular use of laxatives, however, should be supervised by a physician. Overall the bulk-forming fiber laxatives are the safest to use.

Hemorrhoids

Hemorrhoids, also called piles, are swollen veins of the rectum and anus. The blood vessels in this area are subject to intense pressure, especially during bowel movements. Added stress to the vessels from pregnancy, obesity, prolonged sitting, violent coughing or sneezing, or straining during bowel movements, particularly with constipation, can lead to a hemorrhoid. Hemorrhoids can develop unnoticed until a strained bowel movement precipitates symptoms, which may include pain, itching, and bleeding.

Itching, caused by moisture in the anal canal, swelling, or other irritation, is perhaps the most common symptom. Pain, if present, is usually aching and steady. Bleeding may result from a hemorrhoid and appear in the toilet as a bright red streak in the feces. The sensation of a mass in the anal canal after a bowel movement is symptomatic of an internal hemorrhoid that protrudes through the anus.

Anyone can develop a hemorrhoid, and about half of adults over age 50 do. Diet, lifestyle, and possibly heredity play a role in the development of hemorrhoids.
Irritable Bowel Syndrome

Many adults (25 million or more in the United States alone) have irritable bowel syndrome, noted as a combination of cramps, gassiness, bloating, and irregular bowel function (diarrhea, constipation, or alternating episodes of both). It is more common in younger women than in younger men. In older adults the ratio is closer to 50:50. The disease leads to about 3.5 million visits to physicians in the United States each year.

Symptoms associated with irritable bowel syndrome include visible abdominal distention, pain relief after a bowel movement, increased stool frequency, loose stools with pain onset, mucus in stool, and a feeling of incomplete elimination even after a bowel movement.

The cause is thought to be altered intestinal peristalsis coupled with a decreased pain threshold for abdominal distention—in other words, a minor amount of abdominal bloating causes pain that the average person would not sense. It is also noteworthy that up to 50% of sufferers report a history of verbal or sexual abuse.

Therapy is individualized and can include a trial of high-fiber foods (soluble fiber is more effective than insoluble fiber) or elimination diets that focus on avoiding dairy products and gas-forming foods, such as legumes, certain vegetables (cabbage, beans, and broccoli), and some fruits (grapes, raisins, cherries, and cantaloupe). Herbal formulations, certain probiotics, and cognitive behavioral therapy have been shown to decrease symptoms of irritable bowel syndrome and improve overall quality of life (see Further Reading 1). The patient should moderate or eliminate caffeine-containing foods/beverages altogether. Low-fat and more frequent, small meals may help because large meals can trigger contractions of the large intestine. Other strategies include a reduction in stress, psychological counseling, and certain antidepressant and other medications. Hypnosis has been shown to relieve symptoms in severe cases.

Referral to a registered dietitian can be beneficial, as many patients experience improvement with the elimination of specific problem foods. A good patient/physician relationship is also necessary for the treatment of irritable bowel syndrome; however, before any single treatment is applauded, note that response to placebo alone has been as high as 70% in this population. Although irritable bowel syndrome can be uncomfortable and upsetting, it is harmless as it carries no risk for cancer or other serious digestive problems. The website www.ibsgroup.org provides further information.

Diarrhea

Diarrhea, a GI tract disease that generally lasts only a few days, is defined as increased fluidity, frequency, or amount of bowel movements compared to a person’s usual pattern. Most cases of diarrhea result from infections in the intestines, with bacteria and viruses the usual offending agents. They produce substances that cause the intestinal cells to secrete fluid rather than absorb fluid. Another form of diarrhea can be caused by consumption of substances not readily absorbed, such as the sugar alcohol sorbitol found in sugarless gum (see Chapter 4) or large amounts of a high-fiber source such as bran. When consumed in large amounts, the unabsorbed substance draws much water into the intestines, in turn leading to diarrhea. Treatment of diarrhea generally requires drinking lots of fluid during the affected stage; reduced intake of the poorly absorbed substance also is important if that is a cause. Prompt treatment—within 24 to 48 hours—is especially important for infants and older people, as they are more susceptible to the effects of dehydration associated with diarrhea (see Chapters 15 and 16). Diarrhea that lasts more than 7 days in adults should be investigated by a physician as it can be a symptom of more serious intestinal disease, especially if there is also blood in the stool.

Gallstones

Gallstones are a major cause of illness and surgery, affecting 10% to 20% of U.S. adults. Gallstones are pieces of solid material that develop in the gallbladder when substances in the bile—primarily cholesterol (80% of gallstones)—form crystal-like particles. They may be as small as a grain of sand or as large as a golf ball. These stones are caused by a combination of factors, with excess weight being the primary modifiable factor, especially in women 20 to 60 years old. Other factors include genetic background (e.g., Native Americans), advanced age (> 60 years for both women and men), reduced activity of the gallbladder (contracts less than normal), altered bile composition (e.g., too much cholesterol or not enough bile salts), diabetes, and diet (e.g., low-fiber diets). In addition, gallstones may develop during rapid weight loss or prolonged fasting (as the liver metabolizes more fat, it secretes more cholesterol into the bile).

Attacks due to gallstones include intermittent pain in the upper right abdomen, gas and bloating, nausea or vomiting, or other health problems. Surgical removal of the gallbladder is the most common method for treating gallstones (500,000 surgeries per year in the United States).

Prevention of gallstones revolves around avoiding becoming overweight, especially for women. Avoiding rapid weight loss (> 3 pounds per week), limiting animal protein and focusing more on plant protein intake (especially some nut intake), and following a high-fiber diet can help as well. Regular physical
activity is also recommended, as is moderate to no caffeine and alcohol intake.

**Less Common Digestive Disorders**

In **cystic fibrosis**—an inherited disease of infants, children, and sometimes adults—the pancreas often develops thick mucus that blocks its ducts, and active cells then die. As a result, the pancreas is not able to effectively deliver its digestive enzymes into the small intestine. Digestion of carbohydrate, protein, and—most notably—fat then is impaired. Often the missing enzymes must be ingested in capsule form with meals to aid in digestion. Another intestinal problem gaining attention is **celiac disease**. People with this disease experience an allergic reaction to the protein gluten in certain cereals, such as wheat and rye. This reaction damages the absorptive cells, resulting in a much-reduced surface area due to flattening of the villi. Elimination of wheat, rye, and certain other grains from the diet typically cures the problem.

**Summary**

Overall, typical medical disorders of the GI tract arise from differences in anatomical features and lifestyle habits among individuals. Because of the importance of various nutrition and lifestyle habits, such as adequate fiber and fluid intake, as well as not smoking or abusing NSAID medications, nutrition and lifestyle therapy is often effective in helping treat GI tract disorders.

---

**Case Study Gastroesophageal Reflux Disease**

Caitlin is a 20-year-old college sophomore. Over the last few months, she has been experiencing regular bouts of heartburn. This usually happens after a large lunch or dinner. Occasionally she has even bent down after dinner to pick up something and had some stomach contents travel back up her esophagus and into her mouth. This especially frightened Caitlin, so she visited the University Health Center.

The nurse practitioner at the Center told Caitlin it was good that she came in for a checkup because she suspects Caitlin has a disease called gastroesophageal reflux disease (GERD). She tells Caitlin that this can lead to serious problems, such as a rare form of cancer if not controlled. She provides Caitlin with a pamphlet describing GERD and schedules an appointment with a physician for further evaluation.

Answer the following questions, and check your response in Appendix A.

1. What dietary and lifestyle habits likely contribute to Caitlin’s symptoms of GERD?
2. What is the dietary and lifestyle management advice that will help Caitlin cope with this health problem?
3. What types of medications have been especially useful for treating this problem?
4. Overall, how will Caitlin cope with this health problem, and will it ever go away?
5. Why is management of GERD so important?

> Caitlin was wise to see a health professional about her persistent heartburn.
Summary  (Numbers refer to numbered sections in the chapter.)

3.1 Cells join together to make up tissues, tissues unite to form organs, and organs work together as an organ system.

3.2 The basic structural unit of the human body is the cell. A most all cells contain the same organelles (nucleus, mitochondria, endoplasmic reticulum, lysosomes, peroxisomes, and cytoplasm), but cell structure varies according to the type of job they must perform.

3.3 Epithelial, connective, muscles, and nerves, are the four primary types of tissues in the human body. Each type of organ system is affected by nutrient intake.

3.4 Blood is pumped from the heart to the lungs, picking up oxygen. Blood delivers essential nutrients, oxygen, and water to all body cells. Nutrients and wastes are exchanged between blood and cells across the cell membrane. This exchange occurs in the capillaries. Water-soluble compounds absorbed by the small intestine cells enter the portal vein and travel to the liver. Fat-soluble compounds enter the lymphatic system, which eventually connects to the bloodstream.

3.5 The nervous system’s neurons are the body’s communication network. They control and manage all other organ systems of the body. Neurotransmitters are used to carry the message from one neuron to another (or to another cell).

3.6 The endocrine system produces hormones, which chemically regulate almost all other cells.

3.7 The immune system protects the body from invading pathogens. We activate immunity, such as production of antibodies (immunoglobulins), when we come in contact with a pathogen.

3.8 The gastrointestinal (GI) tract consists of the mouth, esophagus, stomach, small intestine, large intestine (colon), rectum, and anus. Spaced along the GI tract are ring-like valves (sphincters) that regulate the flow of foodstuffs. Muscular contractions, called peristalsis, move the foodstuffs down the GI tract. A variety of nerves, hormones, and other substances control the activity of sphincters and peristaltic muscles.

3.9 The urinary system, including the kidneys, is responsible for filtering the blood, removing body wastes, and maintaining the chemical composition of the blood.

3.10 Limited stores of nutrients are present in the blood for immediate use and stored to a greater or lesser extent in body tissues for later use when sufficient food is unavailable. When the body suffers a nutrient deficiency caused by a poor diet, it breaks down vital tissues for their nutrients, which can lead to ill health. Additionally, too much of any nutrient can be detrimental.

3.11 Genetic background influences the risk for many health-related diseases. Examining one’s family tree provides clues for an individual to such risks. Preventative measures are then important to implement, especially with respect to diet.

Check Your Knowledge  (Answers to the following questions are below.)

1. The stomach is protected from digesting itself by producing
   a. bicarbonate.
   b. a thick layer of mucus.
   c. hydroxyl ions to neutralize acid.
   d. antipepsin that destroys enzymes.

2. The lower esophageal sphincter is located between the
   a. stomach and esophagus.
   b. stomach and duodenum.
   c. ileum and the cecum.
   d. colon and the anus.

3. A muscular contraction that propels food down the GI tract is called
   a. a sphincter.
   b. enterohepatic circulation.
   c. gravitational pull.
   d. peristalsis.

4. Bicarbonate ions (HCO₃⁻) from the pancreas
   a. neutralize acid in the stomach.
   b. are synthesized in the pyloric sphincter.
   c. neutralize bile in the duodenum.
   d. neutralize the acid in the duodenum.

5. Most digestive processes occur in the
   a. mouth.
   b. stomach.
   c. small intestine.
   d. large intestine.
   e. colon.

6. Bile is formed in the__________, and stored in the__________.
   a. stomach, pancreas
   b. duodenum, kidney
   c. liver, gallbladder
   d. gallbladder, liver
7. Much of the digestion that occurs in the large intestine is caused by
   a. lipase. c. saliva.
   b. pepsin. d. bacteria.

8. Nexium ("the purple pill") acts as a(n)
   a. H₂ blocker.
   b. laxative.
   c. analgesic.
   d. proton pump inhibitor.

9. The study of how food impacts health through interaction with genes is
   a. nutrigenomics.
   b. epidemiology.
   c. immunology.
   d. genetics.

10. Energy production that takes place in the cytoplasm is anaerobic metabolism because it does not require
    a. water.
    b. oxygen.
    c. anabolic steroids.
    d. anaerobic bacteria.

---

**Study Questions** (Numbers refer to Learning Outcomes)

1. Identify at least one function of the 12 organ systems related to nutrition (LO 3.3)
2. Draw and label parts of the cell, and explain the function of each organelle as it relates to human nutrition. (LO 3.2)
3. Trace the flow of blood from the right side of the heart and back to the same site. How is blood routed through the small intestine? Which class of nutrients enters the body via the blood? Via the lymph? (LO 3.4)
4. Explain why the small intestine is better suited than the other GI tract organs to carry out the absorptive process. (LO 3.8)
5. Identify the four basic tastes. Give an example of one food that exemplifies each of these basic taste sensations. (LO 3.8)
6. What is one role of acid in the process of digestion? Where is it secreted? (LO 3.8)
7. Contrast the processes of active absorption and passive diffusion of nutrients. (LO 3.8)
8. Identify the two accessory organs that empty their contents into the small intestine. How do the digestive substances secreted by these organs contribute to the digestion of food? (LO 3.8)
9. In which organ systems would the following substances be found? chym (LO 3.8), plasma (LO 3.4), lymph (LO 3.4), urine (LO 3.9)
10. Describe the nutrition-related diseases for which genetics or family history is considered to be an important risk factor. (LO 3.11)

---

**What Would You Choose Recommendations**

Constipation results from slow movement of fecal material through the large intestine. Increasing fiber and water in your diet can often relieve constipation without the aid of an over-the-counter laxative. To boost your fiber intake, choose whole grains, fruits, vegetables, and legumes (beans). This can be a tough task when most of the menu options you will find in fast-food restaurants and convenience stores are low in fiber.

As you select your pizza, look for slices with extra vegetables or fruit. This will increase the fiber content by about 1 gram per slice. Pizza with whole-grain crust would add another 1 gram of fiber per slice. These are small improvements, so you will probably still need to look for additional fiber sources.

What about your side dish? Unless they are made with whole grains, the pasta and breadsticks will not add much fiber to your meal. A breadstick and a cup of pasta with Alfredo sauce provide about 1 and 2 grams of fiber, respectively. These carbohydrate-rich add-ons are supplying extra calories and would be better off skipped. The salad provides about 1 to 3 grams of fiber, depending on its size and ingredients. The core ingredients of tossed salad—lettuce, cucumbers, tomato—are mostly water and not particularly high in fiber. Toppings such as cheese, egg, or diced meat will not help relieve constipation. Instead, dried fruit (e.g., dried cranberries or raisins) and nuts supply some additional fiber.

An even better choice, however, is the soup! A cup of bean and pasta soup is just what the doctor ordered to help relieve constipation. It provides about 6 grams of fiber and some extra water, as well.

Lastly, be sure to drink plenty of water. Dehydration is an often overlooked cause of constipation. Water helps lubricate the digestive tract and adds bulk to the feces when absorbed by fiber in the large intestine.

> Whole-grain pasta and beans used in salads and soups are sources of fiber that can prevent intestinal issues such as constipation.
Further Readings


PPIs are the most widely prescribed medicines in the United States to treat heartburn and GERD in individuals who have symptoms that persist, are chronic or severe, or are unrelieved by antacids or H2 blockers. The seven available PPI medicines were found to be roughly equal in effectiveness and safety but differed in cost. The report recommended three of the less expensive drugs that are available without a prescription.

Study: Taking daily medication (Nexium) or undergoing a minimally invasive surgery to treat acid reflux disease control the worst symptoms of the disease in many people. More than 500 persons were studied and after 5 years, 92% of people in the medication group and 83% in the surgery group reported having no GERD symptoms, or symptoms that were easy to live with.

Epigenetics refers to inherited changes in gene expression caused by mechanisms other than changes in the underlying DNA sequence. Epigenetic information is like a code written in pencil in the margins around the DNA, which is written in indelible ink. In many cases it is the epigenome that can be repaired by treatments, or affected by diet.


7. Katsanis SH and others: A case study of personalized medicine. Science 320:53, 2008. Personalized medicine promises to revolutionize health care by tailoring treatments based on individual genetic information. The need for regulating personalized genomic medicine in a manner beneficial to public health is discussed. Currently, in most states companies are not required to demonstrate clinical validity before offering new genetic tests.

Esophageal cancer is aggressive and is commonly diagnosed at an advanced stage with a poor prognosis. Associations among the development of esophageal cancer, Helicobacter pylori infection and GERD are discussed. Despite increased use of proton pump inhibitors and eradication of H. pylori, the number of new cases of esophageal cancer continues to grow.

Herbal formulations, certain probiotics, elimination diets based on immunoglobulin G antibodies, cognitive behavioral therapy, and self-help books are discussed because they have been shown to decrease global symptoms of irritable bowel syndrome (IBS) and improve overall quality of life. Soluble fiber is more effective than insoluble fiber at improving IBS symptoms.

10. Muller-Lissner and others: Myths and misconceptions about constipation. American Journal of Gastroenterology 100:232, 2005. Increasing fiber intake and avoiding dehydration help in mild cases of constipation. More difficult cases require physician evaluation and likely the use of laxatives and other medications.

The complexity of the interaction between genes and diet is discussed as well as the reevaluation of criteria used to determine RDAs relative to the contribution of genetic variation to optimal nutrition for individuals.

13. Santos A and others: Probiotics and their potential health claims. Nutrition Reviews 64:265, 2006. This paper provides strong evidence of the ability of different probiotic strains to prevent and treat diarrhea, and some forms of irritable bowel syndrome.

14. Stover PJ: Influence of human genetic variation on nutritional requirements. American Journal of Clinical Nutrition 83:436S, 2006. Recognizing the complexity of the interaction between genes and dietary intake is discussed as well as the reevaluation of criteria used to determine RDAs relative to the contribution of genetic variation to optimal nutrition for individuals.

15. Stover PJ, Caudill MA: Genetic and epigenetic contributions to human nutrition and health: Managing genome-diet interactions. Journal of the American Dietetic Association 108:1480, 2008. This article discusses ways that nutritional genomics will facilitate the establishment of genome-informed nutrient and food-based dietary guidelines for disease prevention and healthful aging, individualized medical nutrition therapy for disease management, and targeted public health nutrition interventions that maximize benefits and minimize adverse outcomes within genetically diverse human populations.


To get the most out of your study of nutrition, go to McGraw-Hill’s online resources: Connect www.mcgrawhillconnect.com, where you will find NutritionCalc Plus, LearnSmart, and many other dynamic tools.
RATE YOUR PLATE

I. Are You Taking Care of Your Digestive Tract?

People need to think about the health of their digestive tracts. There are symptoms we need to notice, as well as habits we need to practice to protect it. The following assessment is designed to help you examine your habits and symptoms associated with the health of your digestive tract. Put a Y in the blank to the left of the question to indicate yes and an N to indicate no.

   1. Are you currently experiencing greater than normal stress and tension?
   2. Do you have a family history of digestive tract problems (e.g., ulcers, hemorrhoids, recurrent heartburn, constipation)?
   3. Do you experience pain in your stomach region about 2 hours after you eat?
   4. Do you smoke cigarettes?
   5. Do you take aspirin frequently?
   6. Do you have heartburn at least once per week?
   7. Do you commonly lie down after eating a large meal?
   8. Do you drink alcoholic beverages more than two or three times per day?
   9. Do you experience abdominal pain, bloating, or gas 1½ to 2 hours after consuming milk products?
  10. Do you often have to strain while having a bowel movement?
  11. Do you consume less than 9 (women) or 13 (men) cups of a combination of water and other fluids per day?
  12. Do you perform physical activity for less than 60 minutes or more on most or all days of the week (e.g., jog, swim, walk briskly, row, stair climb)?
  13. Do you eat a diet relatively low in fiber (recall that significant fiber is found in whole fruits, vegetables, legumes, nuts and seeds, whole-grain breads, and whole-grain cereals)?
  14. Do you frequently have diarrhea?
  15. Do you frequently use laxatives or antacids?

Add up the number of yes answers and record the total. If your score is from 8 to 15, your habits and symptoms put you at risk for experiencing future digestive tract problems. Take particular note of the habits to which you answered yes. Consider trying to cooperate more with your digestive tract.

II. Create Your Family Tree for Health-Related Concerns

Adapt this diagram to your family tree. Under each heading, list year born, year died (if applicable), major diseases that developed during the person’s lifetime, and cause of death (if applicable). Figure 3-21 provides one such example.

You are likely to be at risk for any diseases listed. Creating a plan for preventing such diseases when possible, especially those that developed in your family members before age 50 to 60 years, is advised. Speak with your physician about any concerns arising from this exercise.