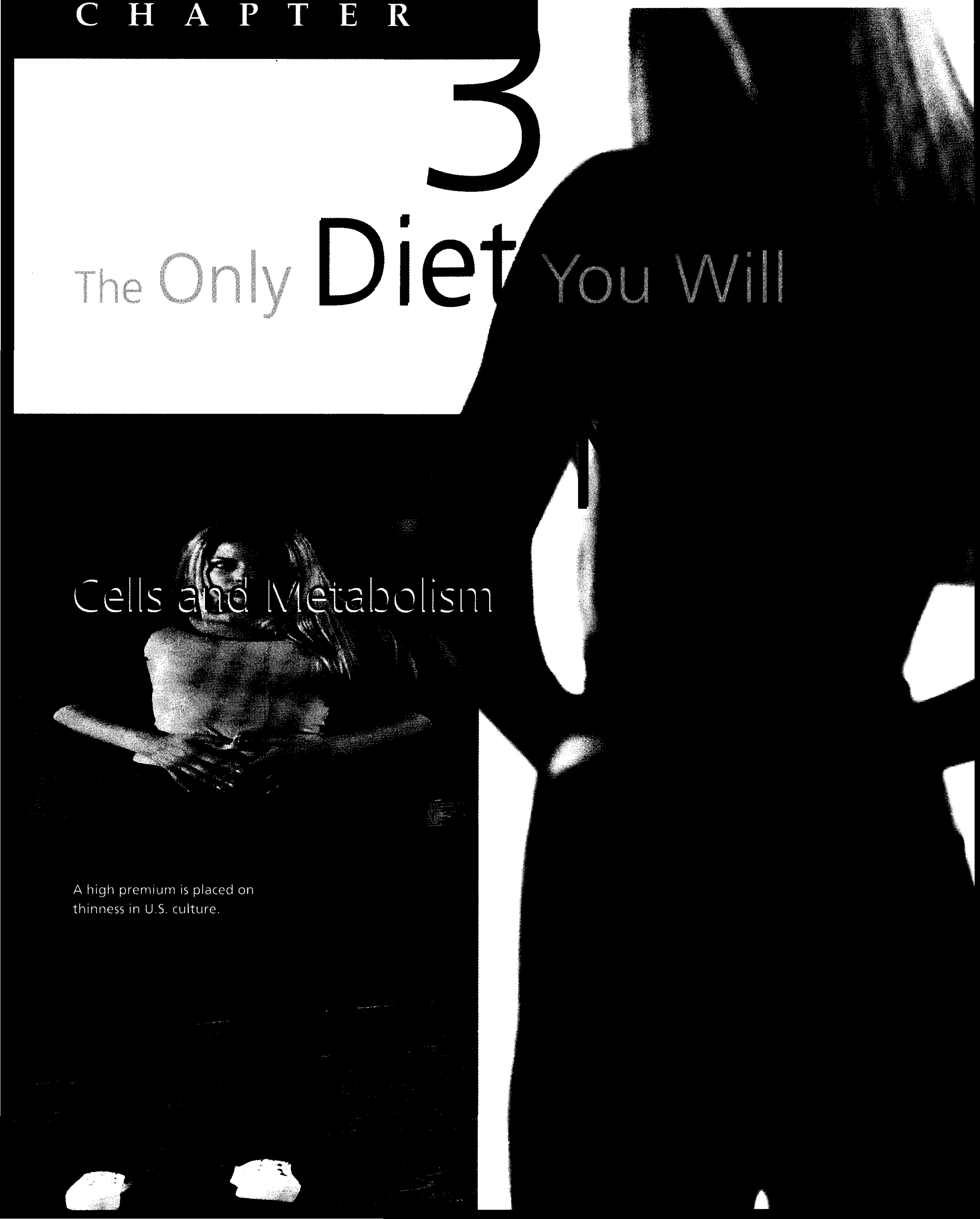
CHAPTER 3

The Only Diet You Will

Cells and Metabolism



A high premium is placed on thinness in U.S. culture.

Most college students are, for the first time, making all their own choices about food.

Making unhealthy choices now can lead to future health problems associated with obesity...

...or anorexia.

The average college student spends a lot of time thinking about his or her body and ways to make it more attractive. While people come in all shapes and sizes, attractiveness tends to be more narrowly defined by the images of men and women we see in the popular media. Nearly all media images equate attractiveness and desirability with a very limited range of body types.

For men, the ideal includes a tall, broad-shouldered, muscular physique with so little body fat that every muscle is visible. The standards for female beauty are equally unforgiving and include small hips; long, thin limbs; large breasts; and no body fat.

Into this milieu steps the average college student—worried about appearance, trying to find time to study, exercise, and socialize—and now making all of his or her own decisions about food, often on a limited budget.

Making choices that are good for long-term health is not easy. Typical meal-plan choices at college dining centers are often greasy and fat laden—and available in unlimited portions. Making healthful choices is further complicated by the presence of campus snack shops, vending machines, and conveniently located fast-food restaurants that offer time-pressed students easily accessible, inexpensive foods containing little nutrition.

Coupling tremendous pressure to be thin with a glut of readily available unhealthful foods can lead students to establish poor eating habits that persist far beyond college life. In many cases, these conflicting pressures may cause students to develop eating habits that result in lifelong battles with obesity or starvation.

Learning about the kinds and amounts of foods you should be eating, and understanding how much body fat is right for you, will help you make good decisions about eating that will set you up for a lifetime of good health.

3.1 Nutrients

The food that organisms ingest provides building-block molecules that can be broken down and used as raw materials for growth, for maintenance and repair, and as a source of energy. Another name for the substances in food that provide structural materials or energy is **nutrients**. Nutrients that are required in large amounts are called **macronutrients**. These include water, carbohydrates, proteins, and fats. Nutrients that are essential in minute amounts, such as vitamins and minerals, are called **micronutrients**.

Macronutrients

Macronutrients include water, carbohydrates, proteins, and fats.

Water and Nutrition. Most animals can survive for several weeks with no nutrition other than water. However, survival without water is limited to just a few days. Besides helping the body disperse other nutrients, water helps dissolve and eliminate the waste products of digestion. Water helps to maintain blood pressure and is involved in virtually all cellular activities.

A decrease in the body's required water level, called **dehydration**, can lead to muscle cramps, fatigue, headaches, dizziness, nausea, confusion, or increased heart rate. Large water deficits can result in hallucinations, heat stroke, and fatality. These symptoms occur because water in the circulatory system helps deliver oxygen and other nutrients to all parts of the body, including the brain. When water is low, this delivery becomes less effective. In addition, evaporation of water from the skin (sweating) helps maintain body temperature. When water is low and sweating decreases, the body temperature can rise to a harmful level.

Every day, humans lose about 3 liters of water as sweat, in urine, and in feces. To avoid the negative health impacts of dehydration, we must replace this water. We can replace some of it by consuming food that contains water. A typical adult obtains about 1.5 liters of water per day from food consumption, leaving a deficit of about 1.5 liters that he or she must drink to replenish.

In addition to obtaining a healthy dose of water every day, people must consume foods that contain carbohydrates, proteins, and fats. In Chapter 2, we explored the structure of these macromolecules, and now we will focus on how they function in the body.

Carbohydrates as Nutrients. Foods such as bread, cereal, rice, and pasta, as well as fruits and vegetables, are rich in sugars called carbohydrates. Carbohydrates are the major source of energy for cells. Energy is stored in the chemical bonds between the carbons, hydrogens, and oxygens that comprise carbohydrate molecules. Carbohydrates can exist as single-unit monomers or can be bonded to each other to produce longer-chain polysaccharide polymers.

Plants, such as potatoes, store their excess carbohydrates as polymers of starch. Animals store their excess carbohydrates as glycogen in muscles and the liver. Both starch and glycogen are polymers of glucose (Figure 3.1).

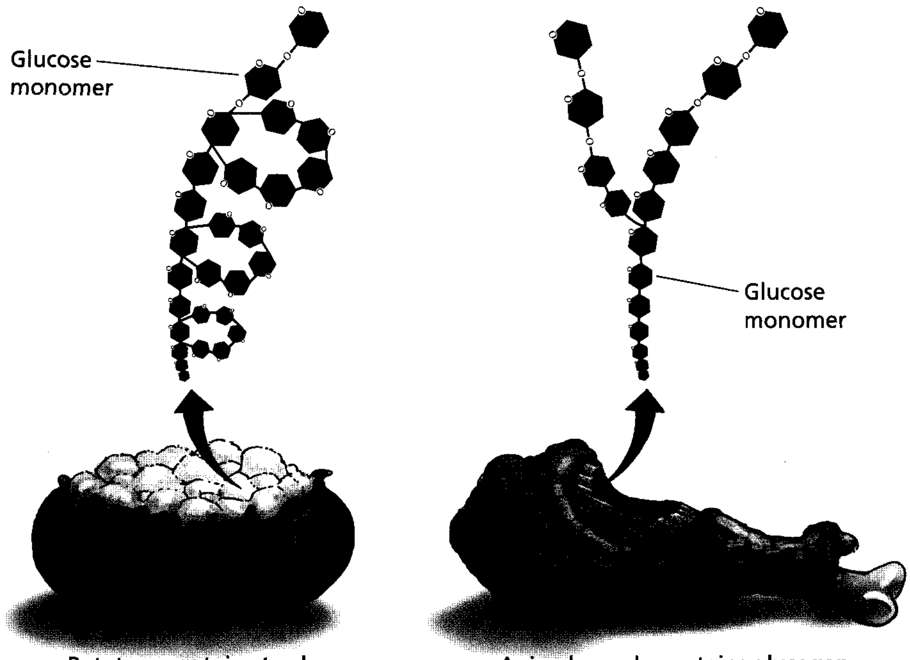


Figure 3.1 Stored carbohydrates. All cells contain carbohydrate, protein, and fat, but some have more than others. When carbohydrate is in excess, plants store the excess as starch, and animals store the excess carbohydrates as glycogen.

When multi-subunit sugars are composed of many different branching chains of sugar monomers, they are called **complex carbohydrates**. Complex carbohydrates, such as those found in fruits and vegetables, are often involved in storing energy for later use. The body digests complex carbohydrates more slowly than it does simpler sugars, because complex carbohydrates have more chemical bonds to break. Endurance athletes will load up on complex carbohydrates for several days before a race to increase the amount of easily accessible energy they can draw on during competition.

Nutritionists agree that most of the carbohydrates in a healthful diet should be in the form of complex carbohydrates and that we should consume only minimal amounts of refined and processed sugars. When you consume complex carbohydrates in fruits, vegetables, and grains, you are also consuming many vitamins and minerals as well as fiber.

Dietary fiber, also called roughage, is composed mainly of complex carbohydrates that humans cannot digest into component monosaccharides. For this reason, dietary fiber is passed into the large intestine; some fiber is digested by bacteria living there, and the remainder gives bulk to the feces.

Although fiber is not a nutrient, because it is not absorbed by the body, it is still an important part of a healthful diet. Fiber helps lower the amount of the membrane lipid, **cholesterol**, without changing the level of high-density lipoprotein (HDL, or "good" cholesterol); at the same time, it helps decrease low-density lipoprotein (LDL, the "bad" form of cholesterol-carrying molecules). Fiber may also decrease your risk of various cancers. Fruits and vegetables tend to be rich in dietary fiber.

Proteins as Nutrients. Protein-rich foods include beef, poultry, fish, beans, eggs, nuts, and dairy products such as milk, yogurt, and cheese.

Chapter 2 acquaints you with the idea that proteins are composed of amino acids and that amino acids differ from each other based on their side groups. Amino acids are bonded to each other in an infinite variety of combinations in order to produce a diverse array of proteins with many different functions.

Your body is able to synthesize many of the commonly occurring amino acids. Those your body cannot synthesize are called **essential amino acids** and must be supplied by the foods you eat. **Complete proteins** contain all the

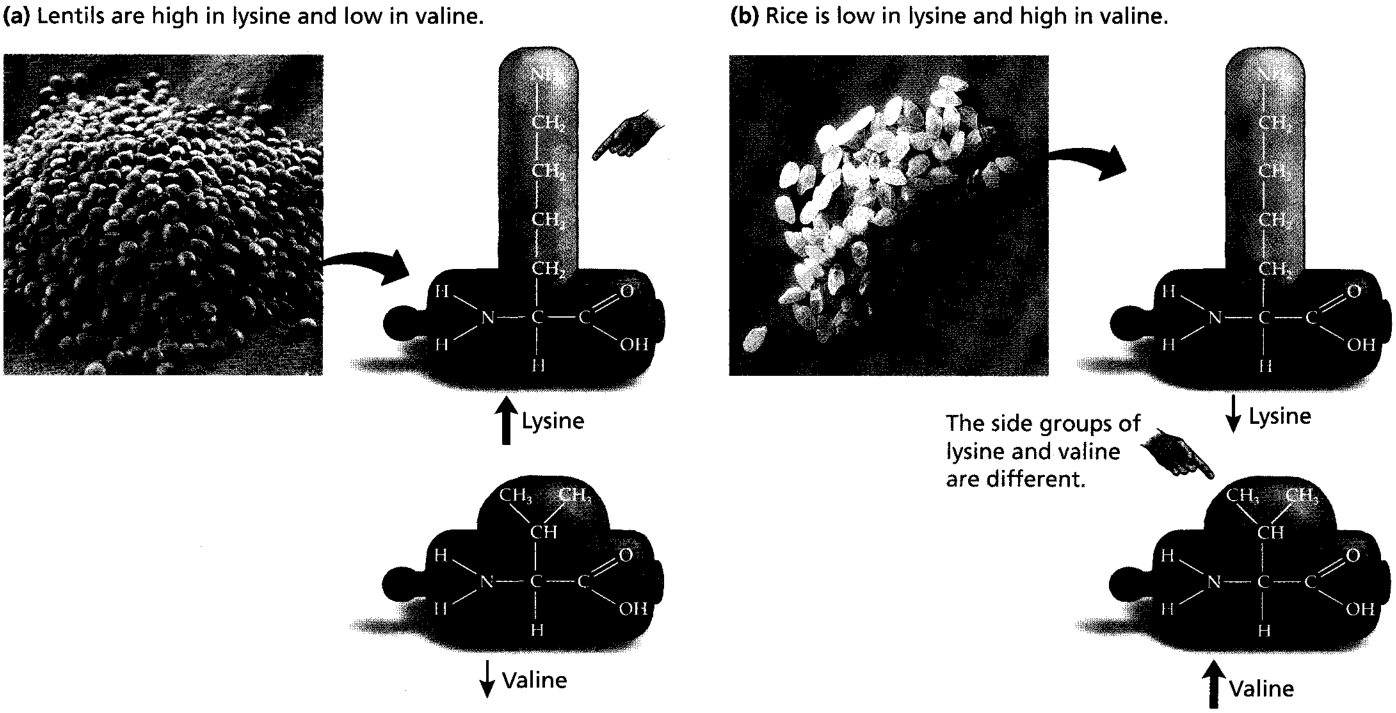


Figure 3.2 Essential amino acids. Essential amino acids, such as lysine and valine, cannot be synthesized by the body and must be obtained from the diet. Some proteins are high in one amino acid but low in another. Eating a wide variety of proteins thus ensures that all the necessary amino acids are available for growth, development, and maintenance.

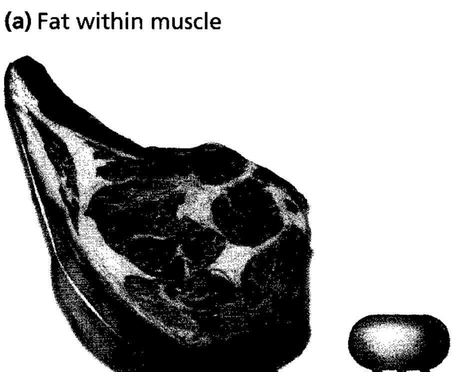


Figure 3.3 Fat storage. Fat can be intertwined with muscle tissue, as seen in this marbled piece of beef (a), or it can lie on the surface, as seen on this chicken breast (b).

essential amino acids your body needs. Proteins obtained by eating meat are more likely to be complete than are those obtained by eating plants; plant proteins can often be missing one or more essential amino acids (Figure 3.2).

In the past, some nutritionists believed that vegetarians might be at risk for deficiencies in certain amino acids. However, scientific studies have shown that there is little cause for concern. If a vegetarian's diet is rich in a wide variety of plant-based foods, the body will have little trouble obtaining all the amino acids it needs to build proteins.

Even though you can obtain all the proteins you need by eating a variety of plants, Americans tend to eat a lot of meat as well. In addition to being rich in proteins, meat tends to be rich in fat.

Fats as Nutrients. The body uses fat, a type of lipid, as a source of energy. Gram for gram, fat contains a little more than twice as much energy as carbohydrates or protein. This energy is stored in the carbon, oxygen, and hydrogen bonds of the fat molecule.

Foods that are rich in fat include meat, milk, cheese, vegetable oils, and nuts. Muscle is often surrounded by stored fat; but some animals store fat throughout muscle, leading to the marbled appearance of some red meat. Other animals—chickens, for example—store fat on the surface of the muscle, making it easy to remove for cooking (Figure 3.3). Most mammals store fat just below the skin, to help cushion and protect vital organs, insulate the body from cold weather and to store energy in case of famine. Some scientists believe that prehistoric humans often faced times of famine and may have evolved to crave fat.

Fats consist of a glycerol molecule with hydrogen and carbon-rich fatty acid tails attached. Your body can synthesize most of the fatty acids it requires. Those that cannot be synthesized are called **essential fatty acids**. Like essential amino acids, essential fatty acids must be obtained from the diet.

The fatty acid tails of a fat molecule can differ in the number and placement of double bonds (Figure 3.4a). When the carbons of a fatty acid are bound to as many hydrogens as possible, the fat is said to be a **saturated fat** (saturated in hydrogens). When there are carbon-to-carbon double bonds, the fat is not saturated in hydrogens, and it is therefore an **unsaturated fat** (Figure 3.4b). The more double bonds, the higher the degree of unsaturation. When it contains many unsaturated carbons, the fat is referred to as **polyunsaturated.** The double bonds in unsaturated fats make the structures kink instead of lying flat. This form prevents the adjacent fat molecules from packing tightly together, so unsaturated fat tends to be liquid at room temperature. Cooking oil is an example of an unsaturated fat. Unsaturated fats are more likely to come from plant sources. Saturated fats, with their absence of carbon-to-carbon double bonds, pack tightly together to make a solid structure. This is why saturated fats, such as butter, are solid at room temperature (Figure 3.4c).

Commercial food manufacturers sometimes add hydrogen atoms to unsaturated fats by combining hydrogen gas with vegetable oils under pressure. This process, called **hydrogenation**, increases the fat's level of saturation; it retards spoilage and solidifies liquid oils, thereby making food seem less greasy. Margarine is vegetable oil that has undergone hydrogenation.

When hydrogen atoms are on the same side of the carbon-to-carbon double bond, they are said to be in the cis configuration—naturally occurring unsaturated fats have their hydrogen atoms in cis configuration.

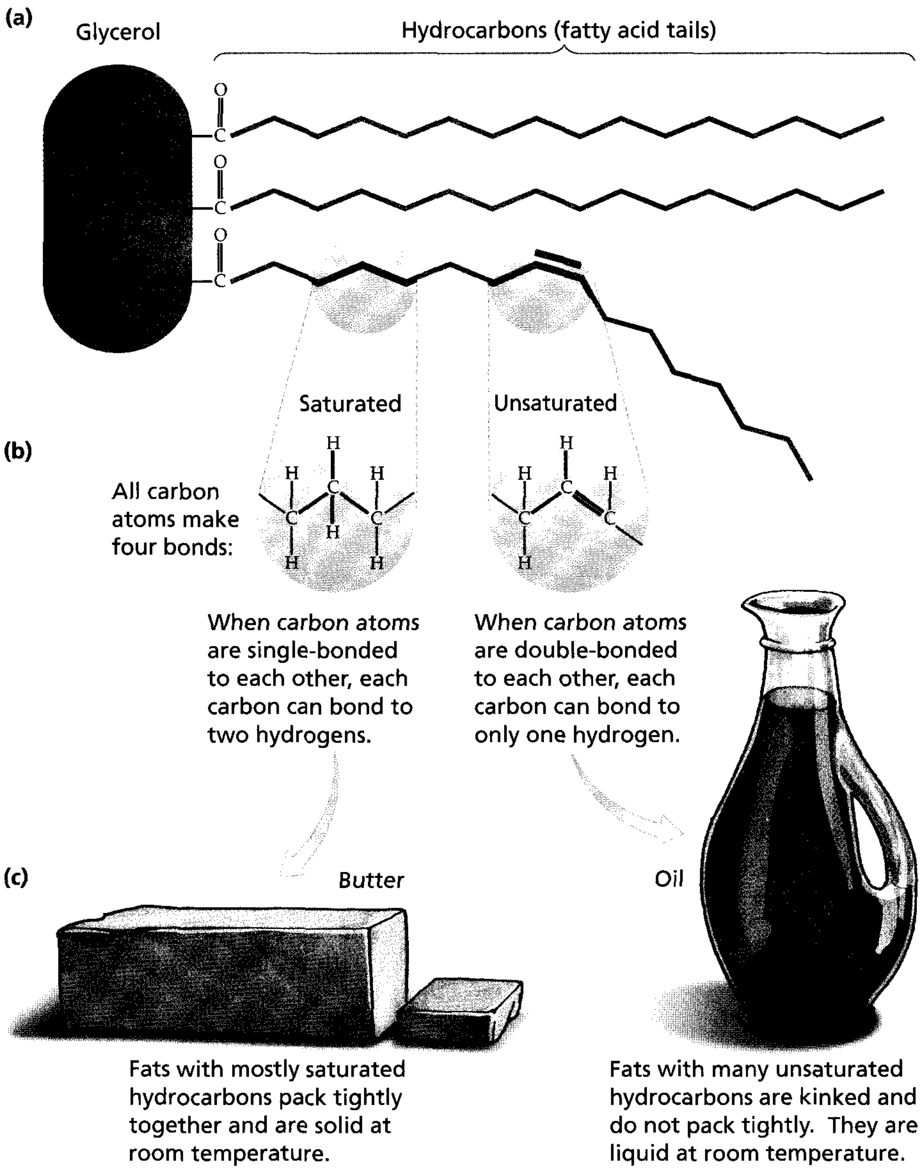


Figure 3.4 Saturated and unsaturated fats. (a) Fats are long chains of hydrogen and carbon (fatty acids) attached to a 3-carbon glycerol skeleton. Fatty acids differ in length and the placement of double bonds. (b) Carbon can make chemical bonds with up to 4 other atoms. The carbon atoms in a saturated fat are bonded to 4 other atoms. The carbon atoms in an unsaturated fat are double-bonded to other carbon atoms. (c) Saturated fats are solid at room temperature. Unsaturated fats are liquids at room temperature.

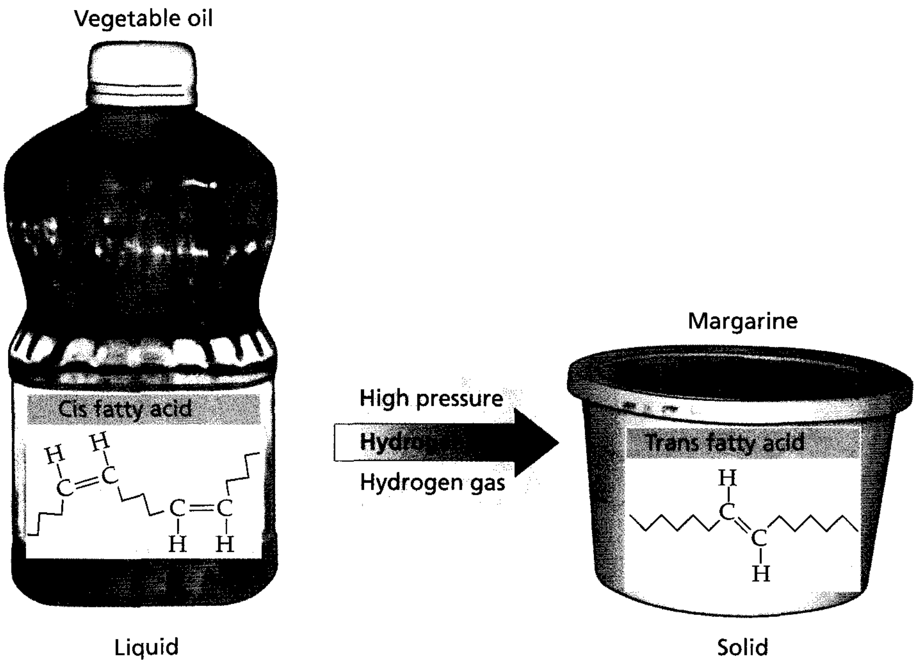


Figure 3.5 Hydrogenation. Adding hydrogen gas to vegetable oil forces the addition of hydrogen atoms to the fatty acid chains, some of which are incorporated in the unnatural trans configuration. The addition of hydrogens means that there are fewer double bonds; hence liquids can be solidified by this process.

When hydrogen atoms are on opposite sides of the double bond, they are said to be in the trans configuration (Figure 3.5). This form of fatty acid is not found in nature. During hydrogenation, there is no way to control whether hydrogen atoms bond in the cis or trans configuration.

While definitive studies are currently under way, the potential health risks of consuming foods rich in trans-fatty acids, common in fast foods, include increased risk of clogged arteries, heart disease, and diabetes. Because fat contains more stored energy per gram than carbohydrate and protein do, and because excess fat intake is associated with several diseases, nutritionists recommend that you limit the amount of fat in your diet.

Micronutrients

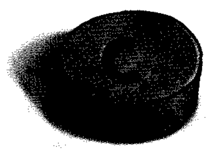
Micronutrients are required in very small amounts and include vitamins and minerals. They are neither destroyed by the body during use nor burned for energy.

Vitamins. Vitamins are organic substances (*organic* means "carbon containing"), most of which the body cannot synthesize. Most vitamins function as **coenzymes**, or molecules that help enzymes, and thus speed up the body's chemical reactions. When a vitamin is not present in sufficient quantities, deficiencies can affect every cell in the body because many different enzymes, all requiring the same vitamin, are involved in many different bodily functions. Vitamins also help with the absorption of other nutrients; for example, vitamin C increases the absorption of iron from the intestine. Some vitamins may even help protect the body against cancer and heart disease, and slow the aging process.

Vitamin D, also called calcitrol, is the only vitamin your cells can synthesize. Because sunlight is required for synthesis, people living in cold climates can develop deficiencies in vitamin D. All other vitamins must be supplied by the foods you eat. Many vitamins are water soluble, so boiling causes them to leach out into the water—this is why fresh vegetables are more nutritious than cooked ones. Steaming vegetables or using the vitamin-rich broth of canned vegetables when making soup helps preserve the vitamin content. Because the body does not store them, water-soluble vitamins are more likely than fat-soluble vitamins to be the source of dietary deficiencies. Vitamins A, D, E, and K are fat soluble and build up in stored fat; allowing an excess of these vitamins to accumulate in the body can be toxic. Table 3.1 lists some vitamins and their roles in the body.

Table 3.1 **Vitamins.** *Water-soluble and fat soluble vitamins.*

Water-soluble vitamins



- Small organic molecules (containing carbon)
- Will dissolve in water
- Cannot be synthesized by body
- Supplements packaged as pressed tablets
- Excesses usually not a problem because water-soluble vitamins are excreted in urine, not stored

Vitamin	Sources	Functions	Effects of Deficiency
Thiamin (B_1)	Pork, whole grains, leafy green vegetables	Required component of many enzymes	Water retention and heart failure
Riboflavin (B_2)	Milk, whole grains, leafy green vegetables	Required component of many enzymes	Skin lesions
Folic acid	Dark green vegetables, nuts, legumes (dried beans, peas, and lentils), whole grains	Required component of many enzymes	Neural-tube defects, anemia, and gastrointestinal problems
B_{12}	Chicken, fish, red meat, dairy	Required component of many enzymes	Anemia and impaired nerve function
B_6	Red meat, poultry, fish, spinach, potatoes, and tomatoes	Required component of many enzymes	Anemia, nerve disorders, and muscular disorders
Pantothenic acid	Meat, vegetables, grains	Required component of many enzymes	Fatigue, numbness, headaches, and nausea
Biotin	Legumes, egg yolk	Required component of many enzymes	Dermatitis, sore tongue, and anemia
C	Citrus fruits, strawberries, tomatoes, broccoli, cabbage, green pepper	Collagen synthesis; improves iron absorption	Scurvy and poor wound healing
Niacin (B_3)	Nuts, leafy green vegetables, potatoes	Required component of many enzymes	Skin and nervous system damage

Fat-soluble vitamins

- Small organic molecules (containing carbon)
- Will not dissolve in water
- Cannot be synthesized by body (except vitamin D)
- Supplements packaged as oily gel caps
- Excesses can cause problems since fat-soluble vitamins are not excreted readily

Vitamin	Sources	Functions	Effects of Deficiency	Effects of Excess
A	Leafy green and yellow vegetables, liver, egg yolk	Component of eye pigment	Night blindness, scaly skin, skin sores, and blindness	Drowsiness, headache, hair loss, abdominal pain, and bone pain
D	Milk, egg yolk	Helps calcium be absorbed and increases bone growth	Bone deformities	Kidney damage, diarrhea, and vomiting
E	Dark green vegetables, nuts, legumes, whole grains	Required component of many enzymes	Neural-tube defects, anemia, and gastrointestinal problems	Fatigue, weakness, nausea, headache, blurred vision, and diarrhea
K	Leafy green vegetables, cabbage, cauliflower	Helps blood clot	Bruising, abnormal clotting, and severe bleeding	Liver damage and anemia

Minerals. Minerals are substances that do not contain carbon but are essential for many cell functions. Because they lack carbon, minerals are said to be inorganic. They are important for proper fluid balance, in muscle contraction and conduction of nerve impulses, and for building bones and teeth. Calcium, chloride, magnesium, phosphorus, potassium, sodium, and sulfur are all minerals. Like some vitamins, minerals are water soluble and can leach out into the water during boiling. Also like vitamins, minerals are not synthesized in the body and must be supplied through your diet. Table 3.2 lists the various functions of minerals that your body requires and discribes what happens when there is a deficiency or an excess in certain minerals.

Processed Versus Whole Foods

Food that has undergone extensive processing has been stripped of much of its nutritive value. For example, refined flour has had the nutrient-rich, outer parts of the grain (called bran) along with the nutrient-rich, inner germ portion removed during processing, resulting in the loss of many vitamins and minerals and much of the fiber. It is best to limit your consumption of processed foods in general. Likewise, sweets (highly processed, sugar-rich foods) should occupy a

Table 3.2 Minerals. The minerals we require and their roles in the body.

Minerals

- Will dissolve in water
- Inorganic elements (do not contain carbon)
- Cannot be synthesized by body
- Supplements packaged as pressed tablets

Mineral	Sources	Functions	Effects of Deficiency	Effects of Excess
Calcium	Milk, cheese, dark green vegetables, legumes	Bone strength, blood clotting	Stunted growth, osteoporosis	Kidney stones
Chloride	Table salt, processed foods	Formation of HCl acid in stomach	Muscle cramps, reduced appetite, poor growth	High blood pressure
Magnesium	Whole grains, leafy green vegetables, legumes, dairy, nuts	Required component of many enzymes	Muscle cramps	Neurological disturbances
Phosphorus	Dairy, red meat, poultry, grains	Bone and tooth formation	Weakness, bone damage	Impaired ability to absorb nutrients
Potassium	Meats, fruits, vegetables, whole grains	Water balance, muscle function	Muscle weakness	Muscle weakness, paralysis, and heart failure
Sodium	Table salt, processed foods	Water balance, nerve function	Muscle cramps, reduced appetite	High blood pressure
Sulfur	Meat, legumes, milk, eggs	Components of many proteins	None known	None known

very small portion of your diet because they provide no real nutrition, just calories. This is why sweets are often referred to as "empty" calories.

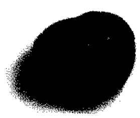
Foods that have not been stripped of their nutrition by processing are called **whole foods**. Eating a wide variety of whole foods such as fruits, vegetables, and grains gives you a much better chance of achieving a healthful diet than eating highly refined, fatty foods that are low in complex carbohydrates and vitamins—also known as junk food.

In addition to containing vitamins and minerals, whole foods contain substances called **antioxidants** that are thought to play a role in the prevention of many diseases, including cancer. Biologists are currently investigating antioxidants to see whether these substances can slow the aging process. Antioxidants protect cells from damage caused by highly reactive molecules that are generated by normal cell processes. These highly reactive molecules, called **free radicals**, have an incomplete electron shell, which makes them more chemically reactive than molecules with complete electron shells. Antioxidants are abundant in fruits and vegetables, nuts, grains, and some meats. Table 3.3 describes food sources of common antioxidants.

Table 3.3 Antioxidants. Antioxidants are being investigated for their disease-preventing abilities.

Antioxidants

- Present in whole foods
- Protect cells from damage caused by free radicals
- Thought to have a role in disease prevention

Antioxidant	Source
Beta-carotene 	Foods rich in beta-carotene are orange in color; they include carrots, cantaloupe, squash, mangoes, pumpkin, and apricots. Beta-carotene is also found in some leafy green vegetables such as collard greens, kale, and spinach.
Lutein 	Lutein, which is known to help keep eyes healthy, is also found in leafy green vegetables such as collard greens, kale, and spinach.
Lycopene 	Lycopene is a powerful antioxidant found in watermelon, papaya, apricots, guava, and tomatoes.
Selenium 	Selenium is a mineral (not an antioxidant) that serves as a cofactor for many antioxidant enzymes, thereby increasing their effectiveness. Rice, wheat, meats, bread, and Brazil nuts are major sources of dietary selenium.
Vitamin A 	Foods rich in vitamin A include sweet potatoes, liver, milk, carrots, egg yolks, and mozzarella cheese.
Vitamin C 	Foods rich in vitamin C include most fruits, vegetables, and meats.
Vitamin E 	Vitamin E is found in almonds, many cooking oils, mangoes, broccoli, and nuts.

3.2 Enzymes and Metabolism

In addition to eating a well-balanced diet rich in unprocessed foods, it is important for people to eat the right amount of food. All food, whether carbohydrate, protein, or fat, can be turned into fat when too much is consumed. In this manner, energy stored in the chemical bonds of food is converted into fat and stored for later use.

The amount of fat that a given individual will store depends partly on how quickly or slowly he or she breaks down food molecules into their component parts. **Metabolism** is a general term used to describe all of the chemical reactions occurring in the body.

Enzymes

All metabolic reactions are regulated by proteins called **enzymes** that speed up, or **catalyze**, the rate of reactions. Enzymes help your body break down the foods you ingest and liberate the energy stored in their chemical bonds.

To break chemical bonds, molecules must absorb energy from their surroundings, often by absorbing heat. This is why heating a chemical reaction will speed up the reaction. Heating cells to an excessively high temperature can damage or kill them. Enzymes help catalyze the body's chemical reactions without requiring heat for the reactants to break their chemical bonds. Therefore, by decreasing the energy required to start the reaction, enzymes allow chemical reactions to occur more quickly.

Activation Energy. The energy required to start the metabolic reaction serves as a barrier to catalysis and is called the **activation energy**. If not for the activation energy barrier, all of the chemical reactions in cells would occur relentlessly, whether the products of the reactions were needed or not. Because most metabolic reactions need to surpass the activation energy barrier before proceeding, they can be regulated by the presence or absence of enzymes. In other words, a given chemical reaction will occur only if the proper enzyme is available. How do enzymes decrease the activation energy barrier?

Induced Fit. The chemicals that are metabolized by an enzyme-catalyzed reaction are called the enzyme's **substrate**. Enzymes decrease activation energy by binding to their substrate and placing stress on its chemical bonds, decreasing the amount of initial energy required to break the bonds. The region of the enzyme where the substrate binds is called the enzyme's **active site**. Each active site has its own shape and chemistry. When the substrate binds to the active site, the enzyme changes shape slightly in order to envelop the substrate. This shape change by the enzyme in response to substrate binding is called **induced fit**, because the substrate induces the enzyme to change shape to conform to the substrate's contours. When the enzyme changes shape, it places stress on the chemical bonds of the substrate, making them easier to break. In this manner, the enzyme helps convert the substrate to a reaction product and then resumes its original shape so that it can perform the reaction again (Figure 3.6).

Different enzymes catalyze different reactions by a property called **specificity**. Enzymes are usually named for the reaction they catalyze and end in the suffix *–ase*. For example, sucrase is the enzyme that breaks down table sugar (sucrose). The specificity of an enzyme is the result of its shape and the shape of its active site. Different enzymes have unique

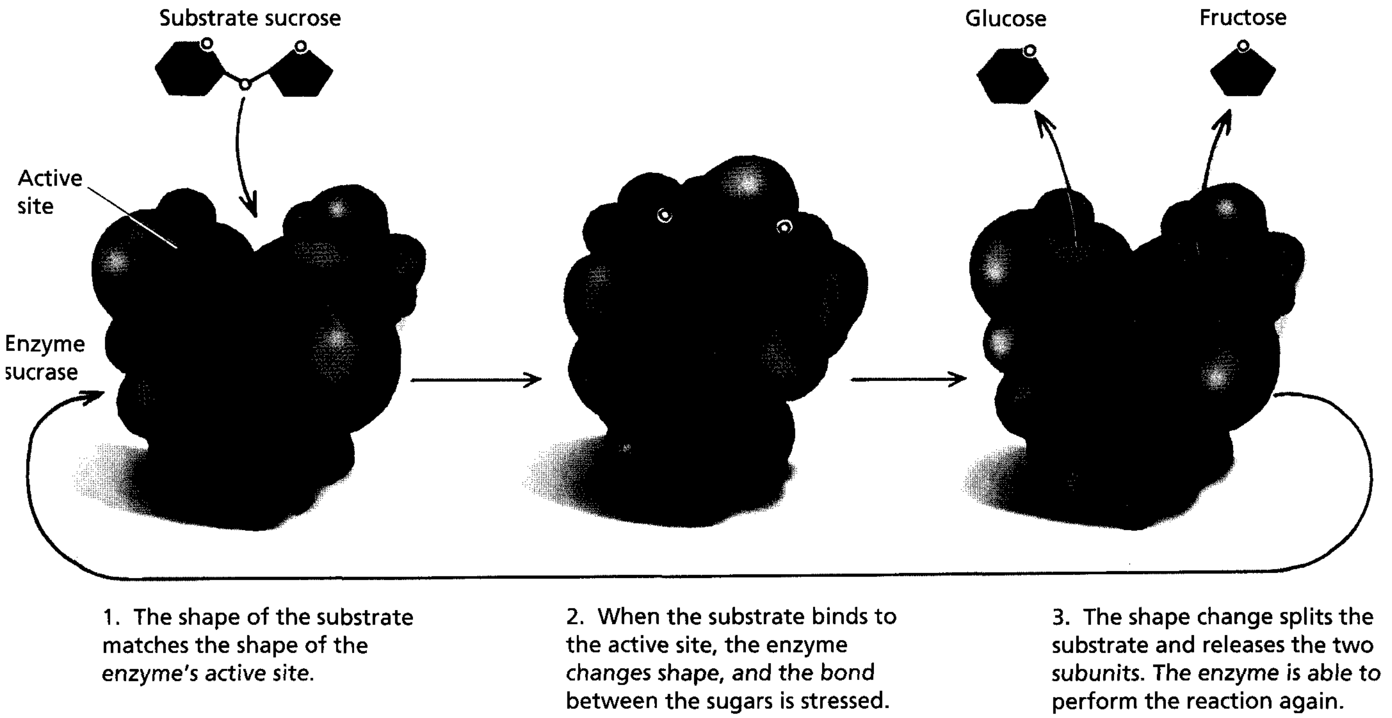


Figure 3.6 Enzymes. The enzyme sucrase is cleaving (splitting) the disaccharide sucrose into its monosaccharide subunits, fructose and glucose. The enzyme can then be recycled to perform the same reaction again and again.

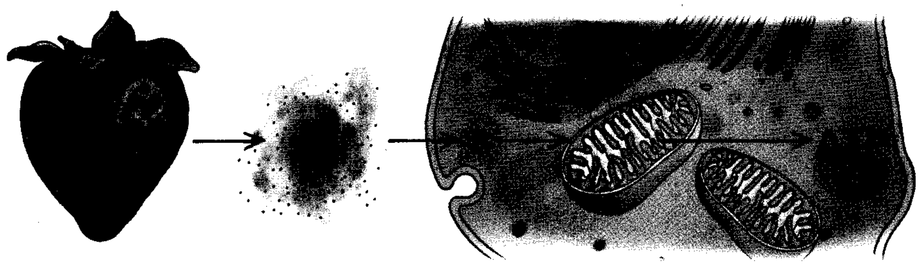
shapes because they are composed of amino acids in varying sequences. The 20 amino acids, each with its own unique side group, are arranged in distinct orders for each enzyme, producing enzymes of all shapes and sizes, each with an active site that can bind with its particular substrate. Although an infinite variety of enzymes could be produced, it is quite often the case that different organisms will utilize the same enzyme, likely due to their evolution from a common ancestor.

Lactose intolerance is a common dietary problem caused by an enzyme deficiency. People with lactose intolerance are unable to digest large amounts of lactose (the most common sugar in milk). This condition results from a shortage of the enzyme **lactase**, typically produced by the cells of the small intestine. Lactase breaks down lactose into simpler forms that can then be absorbed into the bloodstream. When there is not enough lactase available to digest lactose, bacteria in the intestine metabolize the sugar, producing lactic acid. The buildup of lactic acid causes bloating, gas, cramps, and diarrhea.

Most babies can digest milk sugars efficiently, but as they age, their ability to produce this enzyme declines. Scientists hypothesize that in the evolutionary past, the production of this enzyme after weaning was unnecessary, and most adults were probably lactose intolerant. However, with the addition of dairy products to the human diet, selective pressure now favors continuing to produce this enzyme into adulthood. Lactose intolerance can be treated by taking dietary supplements that contain the lactase enzyme.

Enzymes do more than just the break down milk sugars, they mediate all of the metabolic reactions occurring in an organism's cells. Enzymes even affect the rate of an individual's metabolism. This means that two similarly sized individuals might need to consume different amounts of food in order to meet their daily energy requirements.

Figure 3.7 Energy in food. The food you eat is broken down by the digestive system and transported into cells, where nutrients are used to make energy (ATP).



Calories and Metabolic Rate

Energy is measured in units called calories. A **calorie** is the amount of energy required to raise the temperature of 1 gram of water by 1 degree Celsius. In scientific literature, energy is usually reported in kilocalories, and 1 kilocalorie equals 1000 calories of energy. However, in physiology—and on nutritional labels—the prefix *kilo–* is dropped, and a kilocalorie is referred to as a **Calorie** (with a capital C). Calories are consumed to supply the body with energy to do work, which includes maintaining body temperature.

Balancing energy intake versus energy output means eating the correct amount of food to maintain health. When foods are eaten, they are broken down into their component subunits. The energy stored in the chemical bonds of food can be used to make a form of energy that the cell can use (Figure 3.7). Cells power their activities by using the chemical **adenosine triphosphate** or **ATP** as their energy currency. ATP, a nucleotide, is discussed in detail in Chapter 4 along with the process of cellular respiration, which uses the chemical energy stored in food to produce ATP. When the supply of Calories is greater than the demand, the excess Calories can be stored by the body as fat.

The speed and efficiency of many different enzymes will lead to an overall increase or decrease in the rate at which a person can metabolize food. Thus, when you say that your metabolism is slow or fast, you are actually referring to the speed at which enzymes catalyze chemical reactions in your body.

A person's **metabolic rate** is a measure of his or her energy use. This rate changes according to the person's activity level. For example, people require less energy when asleep than we do when exercising. The **basal metabolic rate** represents the resting energy use of an awake, alert person. The average basal metabolic rate is 70 Calories per hour, or 1680 Calories per day. However, this rate varies widely among individuals because many factors influence each person's basal metabolic rate: exercise habits, body weight, nutritional status, sex, age, and genetics. Overall nutritional status can also affect metabolism, because an enzyme that is missing its vitamin coenzyme may not be able to perform at its optimal rate.

Exercise requires energy, which allows you to consume more Calories without having to store them. As for body weight, a heavy person utilizes more Calories during exercise than a thin person does. Figure 3.8 shows the number of Calories used per hour for various activities based on body weight. Males require more Calories per day than females do because testosterone, a hormone produced in larger quantities by males, increases the rate at which fat breaks down. Men also have more muscle than women, which requires more energy to maintain than fat does.

Age and genetics also play a role in metabolic rate. Two people of the same size and sex, who consume the same number of Calories and exercise the

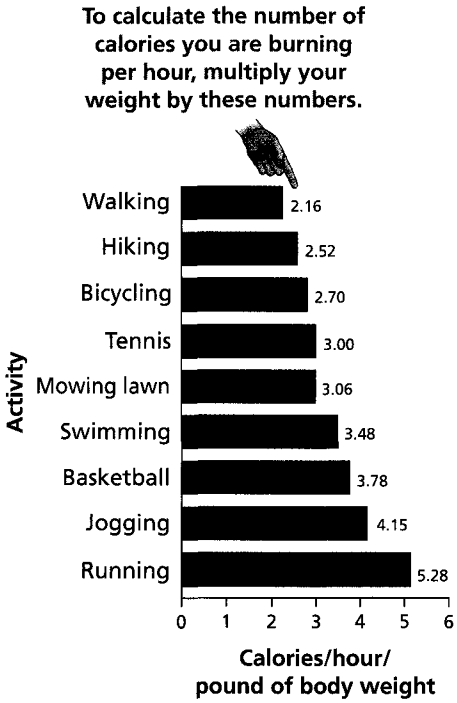


Figure 3.8 Energy expenditures for various activities. This bar graph can help you determine how many Calories you burn during certain activities.

same amount, will not necessarily store the same amount of fat. The rate at which the foods you eat are metabolized slows as you age, and some people are simply born with lower basal metabolic rates.

The properties of metabolic enzymes, like those of all proteins, are determined by the genes that encode them. Genes that influence a person's rate of fat storage and utilization are passed from parents to children. All of these variables help explain why some people seem to eat and eat and never gain an ounce, while others struggle with their weight for their entire lives.

To obtain a rough measure of how many Calories you should consume per day, multiply the weight you wish to maintain by 11 and add the number of Calories you burn during exercise (see Figure 3.8). If you are trying to lose weight, decrease your caloric intake and increase your exercise level. Losing 1 pound of fat requires you to burn 3500 more Calories than you consume. For example, reducing your intake by 300 Calories per day and increasing your exercise level to burn off an additional 200 Calories should result in a weight loss of 1 pound per week. To gain weight, increase the amount of Calories consumed.

To be fully metabolized, food is broken down by the digestive system and then transported to individual cells via the bloodstream (Figure 3.9). Once nutrients arrive at cells, they must traverse the membrane that surrounds cells, called the **plasma membrane**.

Figure 3.9 Nutrients move from the bloodstream to cells. Substances absorbed from the small intestine into the bloodstream make their way into individual cells. To do so, they must first cross the plasma membrane; once inside a cell, the food can be broken down further to release the energy stored in its chemical bonds.

3.3 Transport Across Membranes

Building-block molecules must cross the plasma membrane to gain access to the inside of the cell, where they can be used to synthesize cell components or be metabolized to provide energy for the cell. The chemistry of the membrane facilitates the transport of some substances and prevents the transport of others. The plasma membrane that surrounds cells is composed of two layers of phospholipids, called a **phospholipid bilayer**. The interior of the bilayer is water hating, or hydrophobic. Therefore, hydrophobic substances can pass through the membrane more easily than hydrophilic (water loving) ones. In this sense, the membrane of the cell is differentially permeable to the transport of molecules, allowing some to pass and blocking others from passing.

Passive Transport: Diffusion, Facilitated Diffusion, and Osmosis

Imagine opening a bottle of your favorite carbonated beverage. The hissing sound you hear when removing the bottle cap is the sound of carbon dioxide gas (CO_2) trickling out of the beverage and into the surrounding air. In fact, if you leave the top off for long enough, all the CO_2 will escape. So, why does the carbon dioxide leave the beverage? Because all molecules contain energy that makes them vibrate and bounce against each other, scattering around like billiard balls during a game of pool. In fact, molecules will bounce against each other until they are spread out over all the available area. In other words, molecules will move from their own high concentration (in the bottle) to their own low concentration (in the surrounding air). This movement of molecules from where they are in high concentration to where they are in low concentration is called **diffusion**. During diffusion, the net movement of molecules is *down* a concentration gradient. This movement does not require an input of outside energy; it is spontaneous.

Diffusion also occurs in living organisms. When substances diffuse across the plasma membrane, we call the movement **passive transport**. Passive transport has the name *passive* because it does not require an input of energy. The structure of the phospholipid bilayer that comprises the plasma membrane prevents many substances from diffusing across it. Only very small, hydrophobic molecules are able to cross the membrane by diffusion. In effect, these molecules dissolve in the membrane and slip from one side to the other (Figure 3.10a). The carbon dioxide present in carbonated beverages are molecules that can cross the membrane unaided, as can oxygen.

Hydrophilic molecules and charged molecules such as ions are unable to simply diffuse across the water-hating, hydrophobic core of the membrane. For example, when you have a meal of chicken, rich in charged amino acids, and a green salad, rich in hydrophilic carbohydrates and ions such as calcium (Ca^+), these amino acids, sugars, and ions cannot gain access to the inside of the cell on their own. Instead, these molecules are transported across membranes by proteins embedded in the lipid bilayer. This type of transport does not require an input of energy and is called **facilitated diffusion**. As with passive transport, facilitated diffusion moves substances with, or down, their concentration gradient. Facilitated diffusion is so named because the specific membrane proteins are helping or "facilitating" the diffusion of substances across the plasma membrane (Figure 3.10b).

The movement of water across a membrane is a type of passive transport called **osmosis**. Like other substances, water moves from its own high

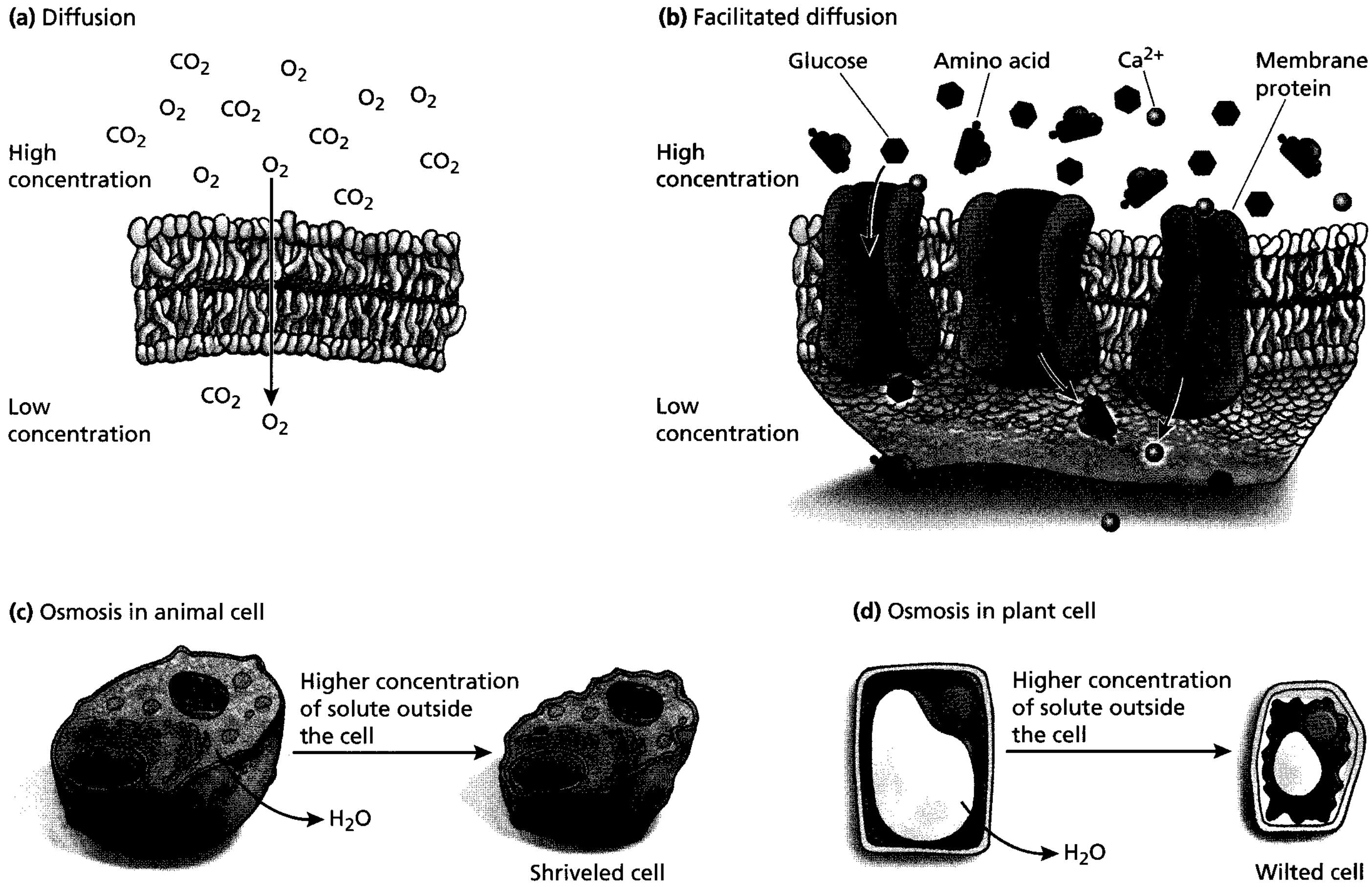


Figure 3.10 Passive transport. (a) Diffusion of molecules across the plasma membrane occurs with the concentration gradient and does not require energy. Small hydrophobic molecules, carbon dioxide, and oxygen can diffuse across the membrane. (b) Facilitated diffusion is the diffusion of molecules assisted by substrate specific proteins. Molecules move with their concentration gradient, which does not require energy. (c) Osmosis is the movement of water in response to a concentration gradient. Water moves toward a region that has more dissolved solute. When water leaves an animal cell, it shrinks. (d) When water leaves a plant cell, the plant wilts instead of shrinks due to the presence of the cell wall.

concentration to its own low concentration. Water can move through proteins in the membrane, called **aquaporins**, but even without these, water can still cross the membrane. When an animal cell is placed in a solution of salt water, water leaves the cell, causing the cell to shrivel (Figure 3.10c). Likewise, plants that are overfertilized wilt because water leaves the cells to equilibrate the concentration of water on either side of the plasma membrane (Figure 3.10d).

Active Transport: Pumping Substances Across the Membrane

In some situations, a cell will need to maintain a concentration gradient. For example, nerve cells require a high concentration of certain ions inside the cell in order to transmit nerve impulses. To maintain this difference in concentration across the membrane requires the input of energy. Think of a hill with a steep incline or grade. Riding your bike down the hill requires no energy, but riding your bike up the grade requires energy in the form of ATP. **Active transport** is transport that uses proteins, powered by the energy currency ATP, to move substances up a concentration gradient (Figure 3.11).

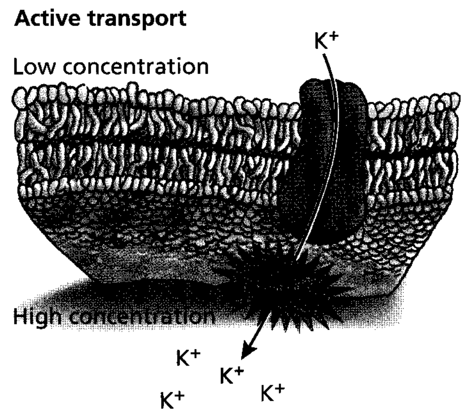
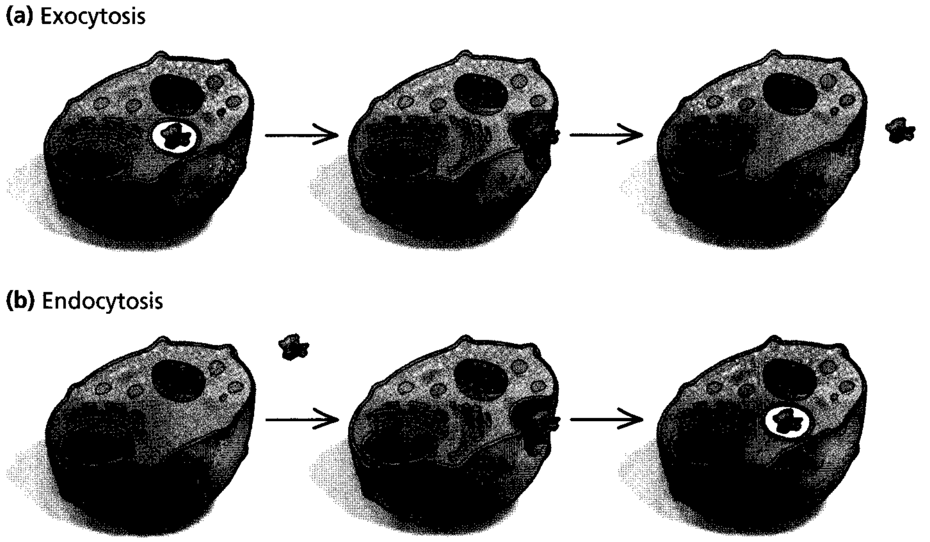


Figure 3.11 Active transport. Active transport moves substances against their concentration gradient and requires energy (ATP) to do so.

Figure 3.12 Movement of large substances. (a) Exocytosis is the movement of substances out of the cell. (b) Endocytosis is the movement of substances into the cell.



Exocytosis and Endocytosis: Movement of Large Molecules Across the Membrane

Larger molecules are often too big to diffuse across the membrane or to be transported through a protein, regardless of whether they are hydrophobic or hydrophilic. Instead, they must be moved around inside membrane-bound vesicles that can fuse with membranes. **Exocytosis** (Figure 3.12a) occurs when a membrane-bound vesicle, carrying some substance, fuses with the plasma membrane and releases its contents into the exterior of the cell. **Endocytosis** (Figure 3.12b) occurs when a substance is brought into the cell by a vesicle pinching inward, bringing the substance with it.

All the nutrients you consume and dismantle must find some way into your cells, so that they can be used for energy and to build cellular components. Knowing all this should give heightened meaning to the phrase, "you are what you eat" (Figure 3.13). Once inside your cells, nutrients will be used to build structural components and provide energy, or they can be stored for later use as fat.

3.4 Body Fat and Health

A clear understanding of how much body fat is healthful is hard to come by, because cultural and biological definitions of the term *overweight* differ markedly. Cultural definitions of overweight have changed over the years. Men and women who were considered to be of normal weight in the past might not be seen as meeting today's standards. In the United States, the evolution of this trend has been paralleled by changes in children's action figures and dolls and by Miss America pageant winners over the last several decades. You need only compare the physiques of action figures from the 1960s and 1970s to the physiques seen on today's action figures to see how the standards have changed for males (Figure 3.14a). Standards for women have also changed—the average weight of Miss America contestants has decreased significantly over the last few decades (Figure 3.14b). The unrealistic nature of these standards is illustrated by the fact that the average woman in the United States weighs 140 pounds and wears a size 12. The average model weighs 103 pounds and wears a size 4.

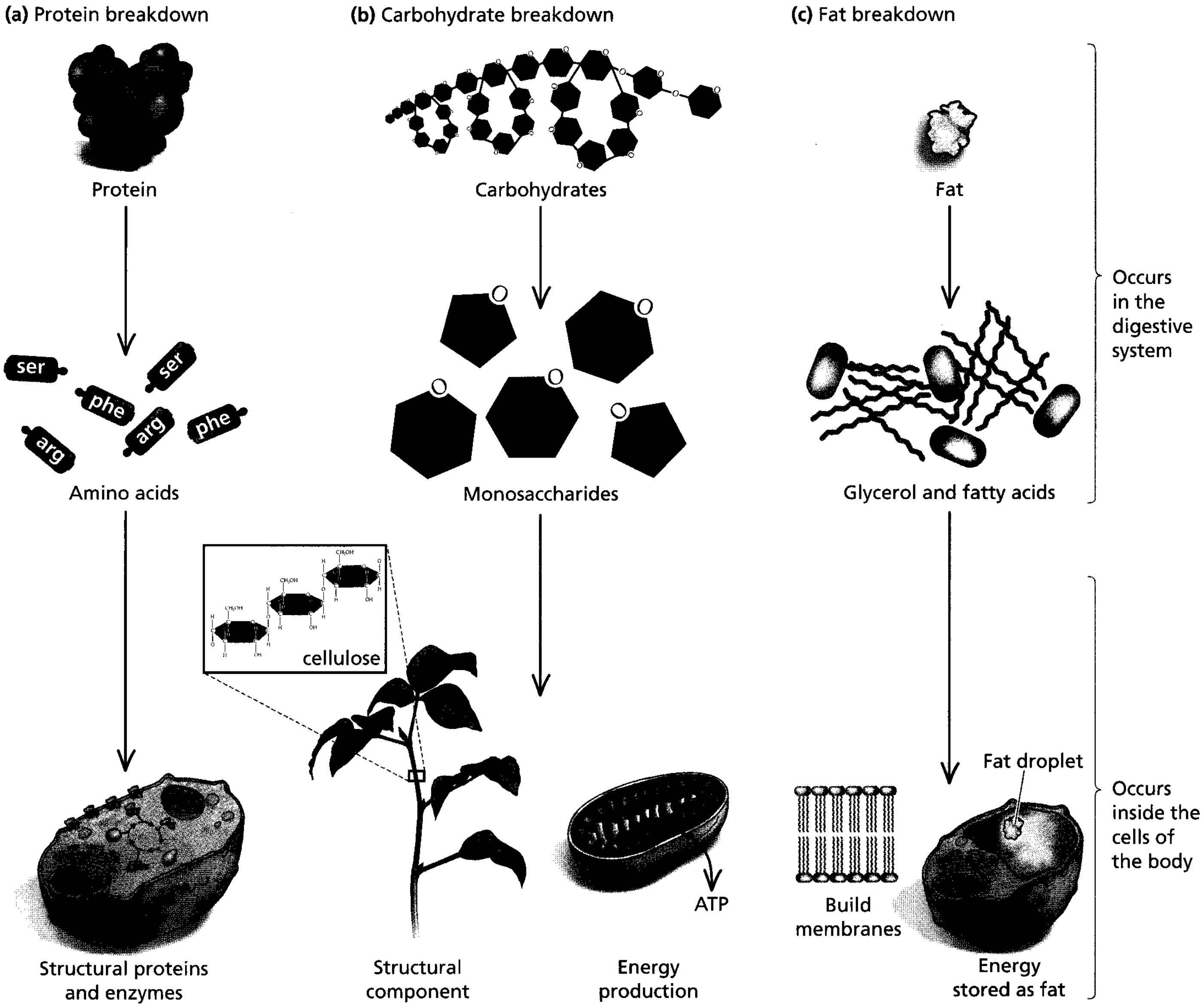


Figure 3.13 You are what you eat. Food is digested into component molecules that are used to build cellular structures and generate ATP.

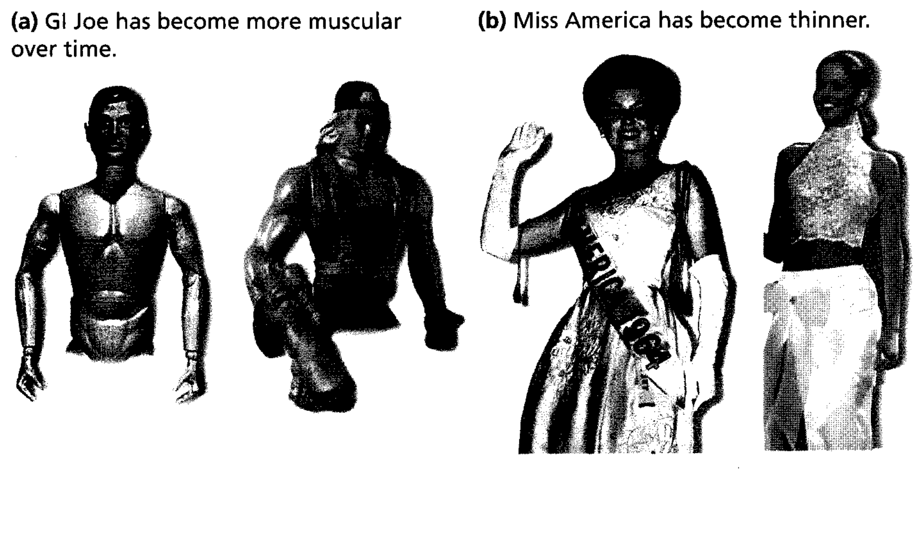


Figure 3.14 The perception of beauty. (a) GI Joe in 1964 and in 2005. (b) Miss America 1964, Donna Axum, and Miss America 2005, Deidre Downs.

The next time you read the newspaper, take note of advertisements for diets featuring men and women of healthful weights promoting diet products. It is often the case that "before" pictures show individuals of healthful weights, and "after" pictures show people who are too thin. With these distorted messages about body fat, it is difficult for average people to know how much body fat is right for them.

Evaluating How Much Body Fat Is Healthful

A person's sex, along with other factors, determines his or her ideal amount of body fat. Women need more body fat than men do to maintain their fertility. On average, healthy women have 22% body fat, and healthy men have 14%. To maintain essential body functions, women need at least 12% body fat but not more than 32%; for men, the range is between 3% and 29%. This difference between females and males, a so-called sex difference, exists because women store more fat on their breasts, hips, and thighs than men do. A difference in muscle mass leads to increased energy use by males because muscles use more energy than does fat.

Women also have an 8% thicker layer of tissue called the dermis under the outer epidermal layer of the skin as compared to men. This means that in a woman and a man of similar strength and body fat, the woman's muscles would look smoother and less defined than the man's muscles would.

A person's frame size also influences body fat—larger-boned people carry more fat. In addition, body fat tends to increase with age.

Determining Ideal Weight. Unfortunately, it is a bit tricky to determine what any individual's ideal body weight should be. In the past, you simply weighed yourself and compared your weight to a chart showing a range of acceptable weights for given heights. The weight ranges on these tables were associated with the weights of a group of people who bought life insurance in the 1950s and whose health was monitored until they died. The problem with using these tables is that the subjects may not have been representative of the whole population. As you learned in Chapter 1, generalizing results seen in one group to another group can lead to erroneous conclusions. People who had the money to buy life insurance tended to have the other benefits of money as well, including easier access to health care, better nutrition, *and* lower body weight. Their longer lives may have had more to do with better health care and nutrition than with their weight.

To deal with some of the ambiguities associated with the insurance company's weight tables, a new measure of weight and health risk, the **body mass index (BMI)**, has been developed. BMI is a calculation that uses both height and weight to determine a value that correlates an estimate of body fat with the risk of illness and death (Table 3.4).

Although the BMI measurement is a better approximation of ideal weight than are the insurance charts of the past, it is not perfect; BMI still does not account for differences in frame size, gender, or muscle mass. In fact, studies show that as many as one in four people may be misclassified by BMI tables, because this measurement provides no means to distinguish between lean muscle mass and body fat. For example, an athlete with a lot of muscle will weigh more than a similarly sized person with a lot of fat, because muscle is heavier than fat.

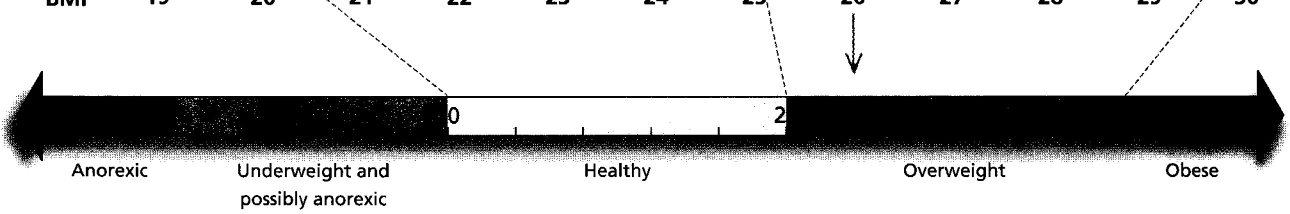
If your BMI falls within the healthy range (BMI of 20–25), you probably have no reason to worry about health risks from excess weight. If your BMI is high, you may be at increased risk for diseases associated with obesity.

Obesity

One in four Americans has a BMI of 30 or greater and is therefore considered to be obese. This crisis in **obesity** is the result you would expect when constant access to cheap, high-fat, energy-dense, unhealthful food is combined with

Table 3.4 Body Mass Index (BMI). A chart based on height and weight correlations.

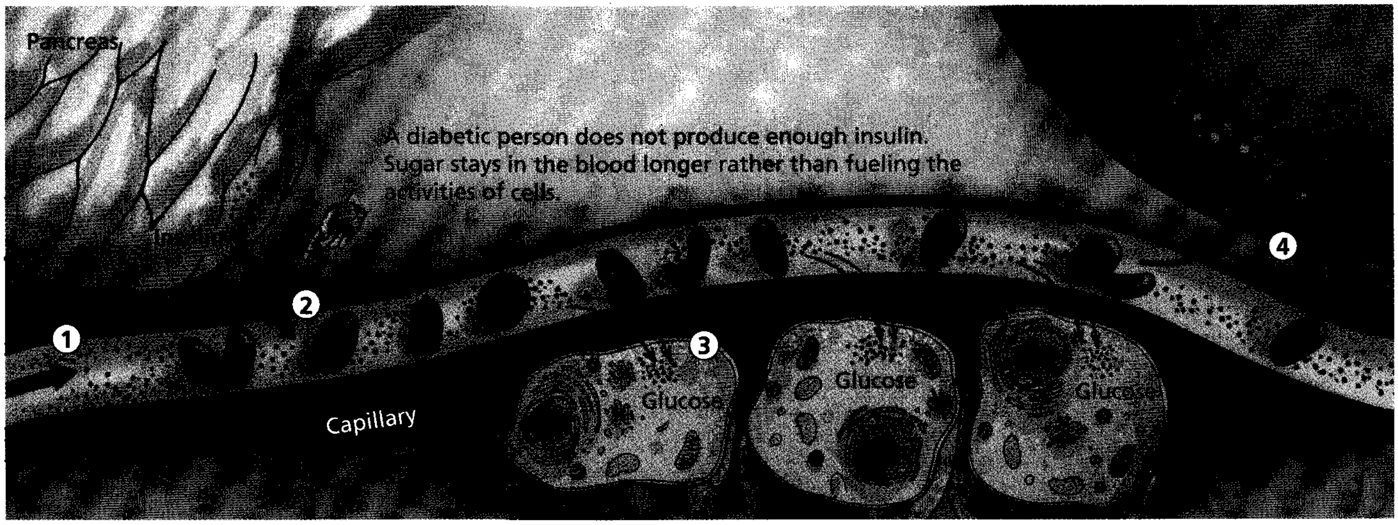
Height	Weight											
4'10"	91	96	100	105	110	115	119	124	129	134	138	143
4'11"	94	99	104	109	114	119	124	128	133	138	143	148
5'0"	97	102	107	112	118	123	128	133	138	143	148	153
5'1"	100	106	111	116	122	127	132	137	143	148	153	158
5'2"	103	109	115	120	126	131	136	142	148	153	158	164
5'3"	107	113	118	124	130	135	141	146	152	158	163	169
5'4"	110	116	122	128	134	140	145	151	157	163	169	174
5'5"	114	120	126	132	138	144	150	156	162	168	174	180
5'6"	117	124	130	136	142	148	155	161	167	173	179	186
5'7"	121	127	134	140	146	153	159	166	172	178	185	191
5'8"	125	131	138	144	151	158	164	171	177	184	190	197
5'9"	129	135	142	149	155	162	169	176	183	189	196	203
5'10"	132	139	146	153	160	167	174	181	188	195	202	207
5'11"	136	143	150	157	165	172	179	186	193	200	208	215
6'0"	140	147	154	162	169	177	184	191	198	206	213	221
6'1"	144	151	159	166	174	182	189	197	205	212	219	227
6'2"	148	155	163	171	179	186	194	202	210	218	225	233
6'3"	151	160	168	176	184	192	200	208	216	224	232	240
6'4"	156	164	172	180	189	197	205	213	221	230	238	246
BMI	19	20	21	22	23	24	25	26	27	28	29	30



lack of exercise. This relationship is clearly illustrated by the case of the Pima Indians.

Several hundred years ago, the ancestral population of Pima Indians split into two tribes. One branch moved to Arizona and adopted the American diet and lifestyle; the typical Pima of Arizona gets as much exercise as the average American and, like most Americans, eats a high-fat, low-fiber diet. Unfortunately, the health consequences for these people are more severe than they are for most other Americans—close to 60% of the Arizona Pima are obese and diabetic. In contrast, the Pima of Mexico maintained their ancestral farming life; their diet is rich in fruits, vegetables, and fiber. The Pima of Mexico also engage in physical labor for close to 22 hours per week and are on average 60 pounds lighter than their Arizona relatives. Consequently, diabetes is virtually unheard of in this group.

This example illustrates the impact of lifestyle on health: the Pima of Arizona share many genes with their Mexican relatives but have far less healthful lives due to their diet and lack of exercise. The example also shows that genes influence body weight because the Pima of Arizona have higher rates of obesity and diabetes than those of other Americans whose lifestyle they share.



(1) Blood sugar is higher following a meal.

(2) When blood sugar is high, a healthy pancreas secretes insulin into the bloodstream.

(3) Insulin triggers all the cells of the body to take up glucose.

(4) Excess glucose is stored in the liver as glycogen.

Figure 3.15 Diabetes. The cells of the pancreas secrete insulin, which helps glucose move into body cells. Because diabetics produce less insulin, sugar stays in the blood longer.

Whether obesity is the result of genetics, diet, or lack of exercise, the health risks associated with obesity are the same. As your weight increases, so do your risks of diabetes, hypertension, heart disease, stroke, and joint problems.

Diabetes. **Diabetes** is a disorder of carbohydrate metabolism characterized by the impaired ability of the body to produce or respond to insulin. **Insulin** is a hormone secreted by beta cells, which are located within clusters of cells in the pancreas. Insulin's role in the body is to trigger cells to take up glucose so that they can convert the sugar into energy. People with diabetes are unable to metabolize glucose; as a result, the level of glucose in the blood rises (Figure 3.15).

There are two forms of the disease. Type I, **insulin-dependent diabetes mellitus** (IDDM, formerly referred to as juvenile-onset diabetes), usually arises in childhood. People with IDDM cannot produce insulin, because their immune systems mistakenly destroy their own beta cells. When the body is no longer able to produce insulin, daily injections of the hormone are required. Type I diabetes is *not* correlated with obesity.

Type II, **non-insulin-dependent diabetes mellitus** (NIDDM, sometimes called adult-onset diabetes), usually occurs after 40 years of age and is more common in the obese. NIDDM arises either from decreased pancreatic secretion of insulin or from reduced responsiveness to secreted insulin in target cells. People with NIDDM are able to control blood-glucose levels through diet and exercise and, if necessary, by insulin injections.

Hypertension. **Hypertension**, or high blood pressure, places increased stress on the circulatory system and causes the heart to work too hard. Compared to a person with normal blood pressure, a hypertensive person is six times more likely to have a heart attack.

Blood pressure is the force, originated by the pumping action of the heart, exerted by the blood against the walls of the blood vessels. Blood vessels expand and contract in response to this force. Blood pressure is reported as two numbers: the higher number, called the **systolic blood pressure**, represents the pressure exerted by the blood against the walls of the blood vessels; the lower number, called the **diastolic blood pressure**, is the pressure that exists between contractions of the heart when the heart is relaxing. Normal blood pressure is around 120 over 80 (symbolized as 120/80). Blood pressure is considered to be high when it is persistently above 140/90.

Problematic weight gain is typically the result of increases in the amount of fatty tissue versus increases in muscle mass. Fat, like all tissues, relies on oxygen and other nutrients from food to produce energy. As the amount of fat on your body increases, so does the demand for these substances. Therefore, the amount of blood required to carry oxygen and nutrients also increases. Increased blood volume means that the heart has to work harder to keep the blood moving through the vessels, thus placing more pressure on blood-vessel walls and leading to increased heart rate and blood pressure.

Heart Attack and Stroke. A **heart attack** occurs when there is a sudden interruption in the supply of blood to the heart caused by the blockage of a vessel supplying the heart. A **stroke** is a sudden loss of brain function that results when blood vessels supplying the brain are blocked or ruptured. Heart attack and stroke are more likely in obese people because the elevated blood pressure caused by obesity also damages the lining of blood vessels and increases the likelihood that cholesterol will be deposited there. Cholesterol-lined vessels are said to be atherosclerotic.

Because lipids like cholesterol are not soluble in aqueous (water-based) solutions, cholesterol is carried throughout the body, attached to proteins in structures called lipoproteins. **Low-density lipoproteins (LDL)** have a high proportion of cholesterol (in other words, they are low in protein). LDLs distribute both the cholesterol synthesized by the liver and the cholesterol derived from diet throughout the body. LDLs are also important for carrying cholesterol to cells, where it is used to help make plasma membranes and hormones. **High-density lipoproteins (HDL)** contain more protein than cholesterol. HDLs scavenge excess cholesterol from the body and return it to the liver, where it is used to make bile. The cholesterol-rich bile is then released into the small intestine, and from there much of it exits the body in the feces. The LDL/HDL ratio is an index of the rate at which cholesterol is leaving body cells and returning to the liver.

Your physician can measure your cholesterol level by determining the amounts of LDL and HDL in your blood. If your total cholesterol level is over 200 or your LDL level is above 100 or so, then your physician may recommend that you decrease the amount of cholesterol and saturated fat in your diet. This may mean eating more plant-based foods and less meat, since plants do not have cholesterol, as well as reducing the amount of saturated fats in your diet. Saturated fat is thought to raise cholesterol levels by stimulating the liver to step up its production of LDLs and slowing the rate at which LDLs are cleared from the blood.

Cholesterol is not all bad; in fact, some cholesterol is necessary—it is present in cell membranes to help maintain their fluidity, and it is the building block for steroid hormones such as estrogen and testosterone. You do, however, synthesize enough cholesterol so that you do not need to obtain much from your diet.

For some people, those with a genetic predisposition to high cholesterol, controlling cholesterol levels through diet is difficult because dietary cholesterol makes up only a fraction of the body's total cholesterol. People with high cholesterol who do not respond to dietary changes may have inherited genes that increase the liver's production of cholesterol. These people may require prescription medications to control their cholesterol levels.

Cholesterol-laden, atherosclerotic vessels increase your risk of heart disease and stroke. Fat deposits narrow your heart's arteries, so less blood can flow to your heart. Diminished blood flow to your heart can cause chest pain, or angina. A complete blockage can lead to a heart attack. Lack of blood flow to the heart during a heart attack can cause the oxygen-starved heart tissue to die, leading to irreversible heart damage.

The same buildup of fatty deposits also occurs in the arteries of the brain. If a blood clot forms in a narrowed artery in the brain, it can completely block blood flow to an area of the brain, resulting in a stroke. If oxygen-starved brain tissue dies, permanent brain damage can result.

Anorexia and Bulimia

Eating disorders that make you underweight cause health problems that are as severe as those caused by too much weight (Table 3.5). **Anorexia**, or self- starvation, is rampant on college campuses. Estimates suggest that 1 in 5 college women and 1 in 20 college men restrict their intake of Calories so severely that they are essentially starving themselves to death. Others allow themselves to eat—sometimes very large amounts of food (called binge eating)—but prevent the nutrients from being turned into fat by purging themselves, often by vomiting. Binge eating followed by purging is called **bulimia**.

Anorexia has serious long-term health consequences. Anorexia can starve heart muscles to the point that altered rhythms develop. Blood flow is reduced, and blood pressure drops so much that the little nourishment present cannot get to the cells. The lack of fat accompanying anorexia can also lead to the cessation of menstruation, a condition known as amenorrhea. **Amenorrhea** occurs when a protein called **leptin**, which is secreted by fat cells, signals the brain that there is not enough body fat to support a pregnancy. Hormones (such as estrogen) that regulate menstruation are blocked, and menstruation ceases. Lack of menstruation can be permanent and causes sterility in a substantial percentage of anorexics.

The damage done by the lack of estrogen is not limited to the reproductive system—bones are affected as well. Estrogen secreted by the ovaries during the menstrual cycle acts on bone cells to help them maintain their strength and size. Anorexics reduce the development of dense bone and put themselves at a much higher risk of breaking their weakened bones, in a condition called **osteoporosis**.

Besides experencing the same health problems that anorexics face, bulimics can rupture their stomachs through forced vomiting. They often have dental and gum problems caused by stomach acid being forced into their mouths during vomiting, and they can become fatally dehydrated.

As you have seen, the health problems associated with obesity, anorexia, and bulimia are severe. You can avoid all of these problems—and improve your overall health—by focusing more on fitness and less on body weight.

Health problems resulting from OBESITY	Health problems resulting from ANOREXIA and BULIMIA
• Adult-onset diabetes	• Altered heart rhythms
• Hypertension (high blood pressure)	• Amenorrhea (cessation of menstruation)
• Heart attack	• Osteoporosis (weakened bones)
• Stroke	• Dental/gum problems
• Joint problems	• Ruptured stomach
	• Dehydration

Table 3.5 Obesity and anorexia or bulimia. Health problems result from being either overweight or underweight.

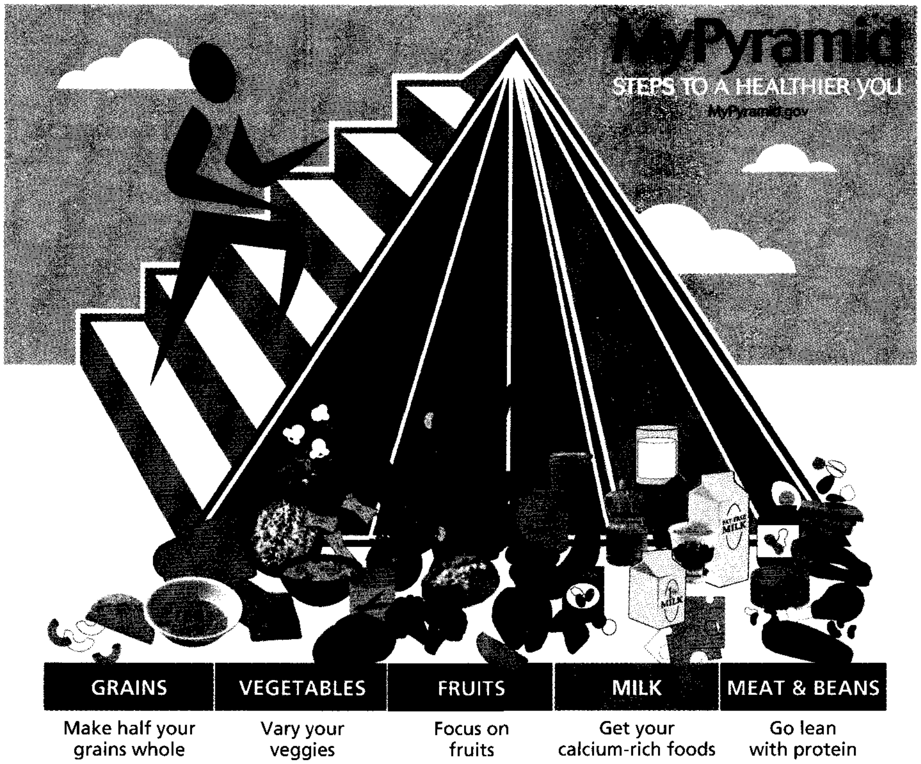


Figure 3.16 USDA Food Guide Pyramid. The newly designed pyramid stresses the importance of physical activity. The size of each triangle represents the relative proportion of your diet that should be composed of each food group.

As the newly designed USDA Food Guide Pyramid attempts to illustrate (Figure 3.16), working slowly toward being fit and eating healthfully rather than trying the latest fad diet are more realistic and attainable ways to achieve the positive health outcomes that we all desire. In fact, fitness may be more important than body weight in terms of health. Studies show that fit but overweight people have better health outcomes than unfit slender people. In other words, lack of fitness is associated with higher health risks than excess body weight. Therefore, it makes more sense to focus on eating right and exercising than it does to focus on the number on the scale.

CHAPTER REVIEW

Summary

3.1 Nutrients

- Nutrients provide structural units and energy for cells. Although not technically a nutrient, water is an important dietary constituent that helps dissolve and eliminate the waste and maintain blood pressure and body temperature (p. 46).
- Macronutrients are required in large amounts for proper growth and development. Macronutrients include carbohydrates, proteins, and fats. All of these molecules are composed of subunits that can be broken down for use by the cell (p. 46).
- Micronutrients are dietary substances required in minute amounts for proper growth and development; they include vitamins and minerals (p. 50).
- Vitamins are organic substances, most of which the body cannot synthesize. Many vitamins serve as coenzymes to help enzymes function properly (p. 50).
- Minerals are inorganic substances essential for many cell functions (p. 52).
- Processing foods decreases their nutritive value (p. 52).

3.2 Enzymes and Metabolism

- The chemical reactions that occur in cells to build up or break down macromolecules are called metabolic reactions (p. 54).

- Metabolism is governed by enzymes. Enzymes are proteins that catalyze specific cellular reactions, first by binding the substrate to the enzyme's active site. This binding causes the enzyme to change shape (induced fit), placing stress on the bonds of the substrate and thereby lowering the activation energy (p. 54).
- Energy is measured in units called Calories (p. 56).
- The energy stored in the chemical bonds of food can be released by metabolic reactions and stored in the bonds of ATP. Cells use ATP to power energy-requiring processes (p. 56).
- An individual's metabolic rate is affected by many factors, including age, sex, exercise level, body weight, and genetics (p. 56).

Web Tutorial 3.1 Enzymes

3.3 Transport Across Membranes

- To gain access to cells, nutrients move across the plasma membrane, which functions as a semipermeable barrier that allows some substances to pass and prevents others from crossing (p. 58).
- The plasma membrane is composed of two layers of phospholipids, in which are embedded proteins and cholesterol (p. 58).
- Passive transport mechanisms include simple diffusion and facilitated diffusion (diffusion through proteins). Passive transport always moves substances with their concentration gradient and does not require energy (p. 58).
- Osmosis, the diffusion of water across a membrane, can involve the movement of water through protein pores in the membrane (p. 58).
- Active transport is an energy requiring process which requires proteins in cell membranes to move substances against their concentration gradients (p. 59).
- Larger molecules move into and out of cells enclosed in membrane-bound vesicles (p. 60).

Web Tutorial 3.2 Transport Across Membranes
Web Tutorial 3.3 Exocytosis and Endocytosis

3.4 Body Fat and Health

- Determining ideal body weight is difficult with conventional methods (p. 62).
- Obesity is associated with many health problems, including hypertension, heart attack and stroke, diabetes, and joint problems (pp. 62–65).
- Anorexia and bulimia are very common on college campuses and result in serious long-term health problems (p. 66).

Learning the Basics

1. What is metabolism, and what factors affect an individual's metabolic rate?

2. What types of substances can pass through cell membranes unaided? What types require help to pass through membranes?

3. Macronutrients ________.

   A. include carbohydrates and vitamins; **B.** should comprise a small percentage of a healthful diet; **C.** are essential in minute amounts to help enzymes function; **D.** include carbohydrates, fats, and proteins; **E.** are synthesized by cells and not necessary to obtain from the diet

4. The function of low-density lipoproteins (LDL) is to ________.

   A. break down proteins; **B.** digest starch; **C.** transport cholesterol from the liver; **D.** carry carbohydrates into the urine

5. Which of the following is a *false* statement regarding enzymes?

   A. Enzymes are proteins that speed up metabolic reactions.; **B.** Enzymes have specific substrates.; **C.** Enzymes supply ATP to their substrates.; **D.** An enzyme may be used many times over.

6. Enzymes speed up chemical reactions by ________.

   A. heating cells; **B.** binding to substrates and placing stress on their bonds; **C.** changing the shape of the cell; **D.** supplying energy to the substrate

7. A substance moving across a membrane against a concentration gradient is moving by ________.

   A. passive transport; **B.** osmosis; **C.** facilitated diffusion; **D.** active transport; **E.** diffusion

8. A cell that is placed in salty seawater will ________.

   A. take sodium and chloride ions in by diffusion; **B.** move water out of the cell by active transport; **C.** use facilitated diffusion to break apart the sodium and chloride ions; **D.** lose water to the outside of the cell via osmosis

9. Which of the following forms of membrane transport require specific membrane proteins?

   A. diffusion; **B.** exocytosis; **C.** facilitated diffusion; **D.** active transport; **E.** facilitated diffusion and active transport

10. Water crosses cell membranes ________.

    A. by active transport; **B.** through protein channels called aquaporins; **C.** against its concentration gradient; **D.** in plant cells but not in animal cells

Analyzing and Applying the Basics

1. A friend of yours does not want to eat meat, so instead she consumes protein powders that she buys at a nutrition store. What would be the disadvantages of this practice?

2. Two people with very similar diets and similar exercise levels have very different amounts of body fat. Why might this be the case?

3. A friend has his cholesterol level checked and tells you that he is really relieved because his cholesterol is normal—that is, under 200. Should your friend actually have no health concerns about his cholesterol level, or does he need to consider other factors?

Connecting the Science

1. Why do you think that anorexia and bulimia are more common among women than men?

2. What would you say to a friend who believes that he is fat, even though his BMI places him in the "normal" range? How about a friend who qualifies as obese on a BMI chart but who exercises regularly and eats a well-balanced diet?