A hungry stomach will not allow its owner to forget it, whatever his cares and sorrows.

—Homer, 800 B.C.

Hunger is the first course of a good dinner.

—A French proverb

The motivation of behavior would not be possible if there were not an energetic body capable of being motivated. Thus, what is necessary for the motivation of body maintenance? This question and the following ones are presented for your consideration in this chapter:

1. What internal physiological changes motivate humans to adjust their body temperature, fluid balance, and food energy levels?
2. How do the psychological sensations of being cold, hot, thirsty, or hungry motivate behavior toward temperature regulation, drinking, and eating?
3. Is hunger the only motivation for eating, or do food characteristics also determine what and how much people eat?
4. Are there individual differences among people and their situations that also determine what and how much they eat?

Internal Factors of Body Regulation

Individual accounts of extreme food or water deprivation provide insights into hunger and thirst motivation. In the late 1800s, for example, the explorer Sven Hedin suffered the tortures of thirst on a journey across a desert during which men and camels died due to lack of water. What follows is his emotional reaction when he finally discovers a pool of water:

I stood on the brink of a little pool filled with fresh, cool water—beautiful water! It would be vain for me to try to describe the feelings which now overpowered me. They may be imagined; they cannot be described. Before drinking I counted my pulse: it was forty-nine. Then I took the tin box out of my pocket, filled it, and drank. How sweet that water tasted! Nobody can conceive it who has not been within an ace of dying of thirst. I lifted the tin to my lips, calmly, slowly, deliberately, and drank, drank, drank, time after time. How delicious! What exquisite pleasure! The noblest wine pressed out of the grape, the divinest nectar ever
made, was never half so sweet. My hopes had not deceived me. The star of my fortunes shone as brightly as ever it did. . . . I felt how that cold, clear, delicious water infused new energy into me. Every blood-vessel and tissue of my body sucked up the life-giving liquid like a sponge. My pulse, which had been so feeble, now beat strong again. . . . In a word, I felt my body was imbibing fresh life and fresh strength. It was a solemn, an awe-inspiring moment. (Wolf, 1958, p. 144)

Hedin’s strong pleasurable reaction to finding and drinking water indicates the interplay between his physiological and psychological demand for water, on the one hand, and the extreme satisfaction that water can provide, on the other.

The purpose of this section is to describe the physiological changes and psychological sensations that motivate temperature regulation, thirst and drinking, and hunger and eating.

**Homeostasis**

The belief that internal demands of the body serve as a source of motivation begins with an idea formulated by the French physiologist Claude Bernard (1878/1961). He hypothesized a stable *milieu interieur* (internal environment) of fluids that bathe the body’s 60 to 100 trillion cells. Many of the vital functions of life are conducted at this level, such as metabolism, growth, repair, and reproduction. In addition, he discovered that blood vessels constrict or dilate in response to temperature changes. Cold weather causes constriction, while warm weather causes dilation, and these processes maintain a constant internal temperature. Walter Cannon (1939), a Harvard physiologist, expanded the work of Bernard and coined the term *homeostasis* (*stasis* meaning staying and *homeo* meaning the same) to describe the constant conditions maintained in the body. Disturbances from both inside and outside the body, such as fluid loss by sweating or environmental temperature change, are counteracted by body processes to maintain a stable internal environment. Cannon considered homeostasis as part of the “wisdom of the body.”

**Negative Feedback System**

These illustrations from Bernard and Cannon, attest to the body’s wisdom for maintaining homeostasis—that is, a constant internal environment. The maintenance of homeostasis depends on a *negative feedback system*, a self-correcting process that reduces the discrepancy between a desired state and an actual state. A desired state or *set point* is a condition crucial for life, comfort, or safety. The actual state of the system is compared to the set point, and if a discrepancy is detected, a self-correcting process is initiated. The process ends when the discrepancy reaches zero. A household furnace is a common example (see Figure 5.1). The set point is the desired room temperature—for instance, 68°F. A comparator in the thermostat compares actual room temperature to the set point temperature, and a discrepancy between the two causes the furnace to be turned on. The heat from the furnace raises the room temperature, which is continuously fed back to the comparator for comparison to the set point temperature. When the discrepancy reaches zero, the comparator turns the furnace off. If an open door lets in cold air and lowers the room temperature, then another discrepancy results, causing the comparator to turn the furnace on again.
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Set Point: Desired room temperature (e.g., 68°F)

Comparator: Compares actual temperature to set point temperature

When discrepant

Heat generated by furnace raises house temperature

Feedback

Furnace on

FIGURE 5.1 Negative Feedback Mechanism. The operation of a house furnace illustrates how the negative feedback mechanism operates.

Usually, set point temperature does not remain constant during the year. It varies within a comfort zone ranging from cool at a lower set point to warm at an upper set point. A more complex house temperature control system would include an air conditioner as well as a furnace. For example, an open door in the winter lets in cold air, causing the temperature to fall below the lower set point. The furnace comes on to produce heat and raise the temperature. An open door in the summer, however, lets in hot air, causing the house temperature to rise above the upper set point. The air conditioner comes on to produce cold air to lower the temperature. Between the lower and upper set points is the comfort zone.

Effects of Deviation from Set Point

How does the negative feedback system apply to homeostasis? Humans have set points for various physiological states like body temperature and amount of water, food, and various nutrients. A discrepancy between the set point and the actual physiological state defines a physiological need. For example, humans have a physiological need to maintain a constant body temperature, salt concentration, fluid level, and blood glucose level.

Incentives that aid in reducing a need or in restoring homeostasis can also increase pleasure. Cabanac (1971) discovered that whether temperature, odor, and taste stimuli produced pleasant or painful sensations depends on the person’s internal state. Stimulus sensations are judged pleasant if they decrease deviations from homeostasis but are judged unpleasant if they increase the deviation from homeostasis. Cabanac coined the term alliesthesia (ethesia meaning sensation and allios meaning changed) to refer to changes in a person’s milieu interieur that determine whether a stimulus is judged as pleasant or unpleasant. Hedin’s description of drinking water as “delicious” and as “exquisite pleasure” illustrates how his strong need for water—that is, his changed internal state—caused water to have this sensation. Alliesthesia motivated him to drink to restore his body’s water level. Similarly, food is delicious to a hungry person and induces eating to restore the body’s energy supply.
Thermoregulation

During the summer an individual is more likely to feel hot and in winter to feel cold because actual body temperature deviates above and below the body’s set point temperature of 98.6°F. This thermal set point is crucial for life and is registered in one part of the hypothalamus of the brain. Actual temperature at many different sites of the body is measured by thermoreceptors, and this information is received by another part of the hypothalamus, where this information is integrated (Breugelmann, 1989; Franck et al., 1989). A discrepancy between set point temperature and actual temperature results in both involuntary and voluntary attempts to restore homeostasis. When a person is hot, blood vessels involuntarily dilate to dissipate heat, and sweating occurs for cooling by evaporation. When a person is cold, blood vessels constrict to conserve heat, and shivering occurs to produce heat. Sensations about being hot or cold drive voluntary behavior. When feeling cold, a person voluntarily puts on a sweater to reduce the cold sensation, or because “it feels good” to warm up. When feeling hot, a person voluntarily takes off a sweater to reduce the hot sensation, or because “it feels good” to become less hot. Whether the sweater feels good on or off depends on the person’s internal state, according to the alliesthesia concept.

Alliesthesia also plays a role in body temperature regulation by humans. To illustrate, Mower (1976) made male participants hypothermic (cold) by placing them up to their shoulders in a bath of cool (15 to 18°C) water or hyperthermic (warm) by placing them in a bath of warm (41 to 43°C) water. This procedure resulted in the participants’ core body temperatures decreasing or increasing by at least 1°C. Other participants were kept at normal body temperature. Next, participants dipped their hands into baths ranging from cool to warm and rated these baths on an unpleasantness-pleasantness scale. Ratings of the water baths depended on the participants’ core body temperature (see Figure 5.2). When participants were hypothermic (cold), they judged cooler baths as unpleasant and warmer baths as pleasant. When participants were hyperthermic (warm), however, they judged cooler baths as pleasant and warmer baths as unpleasant. Participants with normal core temperature judged a water bath as unpleasant only when it deviated greatly from normal skin temperature. Baths that restore body temperature to homeostasis are those that feel pleasant (Cabanac, 1971). Baths are felt to be unpleasant if they cause actual body temperature to deviate further from set point temperature.

Thirst and Drinking

Exercising on a hot day or eating salty foods soon reminds a person of the need for water. The sensation of thirst may drive an individual to drink more water.

Cellular Thirst. A cell is the smallest structure of the body capable of carrying out the functions necessary for life. In order for the trillions of cells composing the body to work properly, the amount of fluid they lose must be replaced by an equal amount. Water replaces lost fluids and is obtained through drinking and eating. Intracellular fluid refers to the 67% of water contained within the body’s cells. Extracellular fluid refers to the remaining water that helps provide the external environment around the cells. Both intracellular and extracellular fluids contain concentrations of salt particles (sodium and potassium) that are necessary for cells to carry out their functions. The concentration of salt on both sides of the cell walls must be carefully maintained. If the concentration of salt is too high inside the cells, then water will enter the cells; if it is too low, then water will exit (Memmler et al., 1992). Thirst can result from a loss of intracellular fluids caused by excessive salt in the extracellular fluid. For
example, eating a salty meal increases the salt concentration in the extracellular fluids. To restore the ideal state of salt concentration, fluids are drawn from within the cells, thereby decreasing intracellular fluids. The hypothalamus detects the cellular dehydration and registers it as thirst (Memmler et al., 1992). Thirst and drinking can also be prompted by loss of extracellular fluids surrounding the cells by evaporation from the skin, sweating, bleeding, urination, diarrhea, and exhalation. The hypothalamus also detects the loss of extracellular fluid and registers it as thirst. Besides the action of thirst to instigate drinking, the body also has automatic mechanisms to conserve water (Memmler et al., 1992; Pinel, 1997).

**Thirst Sensations.** The body’s need for water is registered as thirst, which regulates drinking. To investigate thirst sensations, Engell and associates (1987) dehydrated male participants by forcing them to lose 3, 5, or 7% of their body water weight. The researchers accomplished this by restricting the men’s drinking and eating and by having them do light exercise in a hot, dry environment. Participants’ ratings of the intensity of their local sensations (dry mouth and throat, scratchy throat) and general sensations (thirsty, tired, weary, dizzy) increased with deprivation. In other words, the inducement to drink became stronger and stronger. Early researchers thought that thirst resulted from a dry mouth and throat (Wolf, 1958) and that sensory loss to that area would eliminate thirst sensations. However, although patients who have had their larynx (upper part of windpipe containing vocal cords) surgically removed are less aware of thirst in that area, they nevertheless still experience thirst as a general sensation (Miyaoka et al., 1987).

**Water Deprivation and the Hedonics of Drinking.** Research has shown that the pleasure of replenishing fluids depends on the amount of fluid loss and on the temperature of the water. Hedin’s experience of drinking as “exquisite pleasure” resulted from his having

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**FIGURE 5.2 Core Body Temperature and Thermal Pleasantness.** This figure shows group mean category judgments of thermal pleasantness of water baths as a function of stimulus temperature under three conditions of internal body temperature.

suffered severe dehydration in the desert and because the water was cool. Sandick and associates (1984) had army personnel exercise on some days and rest on other days (the control). Following exercise or rest, participants were presented with water samples for drinking that ranged from cool, to room temperature, to warm. On exercise days participants preferred the cooler temperature more than the warmer temperature, whereas on control (rest) days these differences in preference were less pronounced. Participants also drank significantly more of the cooler water following exercise than following a rest day, although this difference disappeared with warmer water samples. Preference or hedonic ratings of the water (how much the water was liked) decreased as the temperature increased. The amount of water all participants drank followed their preference ratings, meaning that as preference decreased, the amount of water participants drank decreased. Cool water reduces core body temperature sooner than warm water and, hence, according to alliesthesia, is preferred.

Inhibitors of Thirst. The quenching of thirst from drinking occurs several minutes before water replenishes the cells. This observation implies that whatever physiological mechanism starts thirst, a different mechanism stops it, since water has not yet arrived where it is needed. Drinking is triggered by thirst and stopped by feedback from the mouth, throat, stomach, and eventually the absorption of water into the cells. In a series of experiments, Blass and Hall (1976) investigated the contribution these areas make to inhibiting drinking. In one experiment, they deprived rats of water for 12, 24, or 48 hours and then had them sham drink. In this procedure, water was not allowed to enter the stomach, since it was drained out by a fistula (a surgically implanted tube) before it reached the stomach. Rats sham drank twice as much following 48 hours of deprivation than following 12 or 24 hours. Since water only contacted the mouth and throat, the sensitivity to hours of deprivation showed that those areas play some role in eventually inhibiting drinking. The contribution of the stomach to inhibiting drinking was investigated by comparing sham drinking to drinking when water reaches, but is not allowed to leave, the stomach. Blass and Hall (1976) placed a noose around the exit portion of the rat’s stomach and tightened or loosened it to prevent or allow water to leave. When water remained in the stomach, the rats drank less compared to sham drinking but more compared to when water entered the intestines. The capacity of the stomach to hold water also inhibits drinking, since the rats drank less when water reached the stomach compared to sham drinking. The least amount of drinking occurred when water left the stomach, which shows that absorption into the cells from the intestines also inhibits drinking. Thus, feedback from the mouth, the stomach, and the intestines contributes to the inhibition of drinking before water reaches the cells.

Besides physiological signals of satiety, there are psychological ones that change with drinking (Engell et al., 1987). After being dehydrated (made thirsty) to different degrees, participants were given one hour to consume as much of a fruit-flavored drink as they wanted. The amount participants drank increased with the amount of dehydration but stopped before they were fully rehydrated. The disappearance of a dry mouth, chalk-like taste, and thirst inhibited drinking. For participants who had been the most severely dehydrated, the feeling of a full stomach also inhibited further drinking. Sandick and associates (1984) had U.S. Army enlisted personnel exercise for about 30 minutes and then allowed them to drink as much water as they wanted. Drinking stopped when the sensations that begin and maintain drinking were alleviated. For example, there was a tendency to quit drinking with the disappearance of a dry mouth, feeling warm, and sweating. Finally, as Hedin’s description in the opening paragraph implies, as the “deliciousness” of water diminishes, drinking stops.
The Body’s Energy Requirements

I have, on rare occasions, discovered the consequences of failing to attend to the gasoline gauge. As the fuel tank level indicator plummets below E, the car stutters and eventually comes to a stop. I have also discovered that feelings of fatigue follow failing to attend to lunch. The analogy here is that the human body, like a car, also requires fuel. Furthermore, “feelings of hunger,” like the fuel gauge, are indications that energy reserves are running low and that it is time to eat. This analogy between a car’s fuel requirements and the body’s energy requirements will help in understanding hunger motivation. Energy released from food is measured in terms of calories. A calorie is the amount of heat energy required to raise one gram of water one degree Celsius. College-age (18 to 22 years old) men require roughly 2,600–2,800 calories and college-age women require roughly 2,000–2,200 calories per day.

Metabolism. The body’s energy requirements can be divided into three components: resting metabolism, thermic effects, and physical activity. Energy used for resting metabolism is analogous to using gasoline to keep the engine idling while the car is in neutral. Resting metabolism refers to the use of energy for body maintenance, the pumping of blood by the heart, oxygen utilization, the work of individual cells, and neural activity in the brain. Resting metabolic rate is measured by the body’s heat production or oxygen consumption while a person is inactive and has not eaten for at least 12 hours. The thermic effect is analogous to the heat produced by running the car’s engine. It refers to the energy cost of digesting, storing, and absorbing food. Thermic or heat production can continue for several hours after a meal. The energy used for physical activity is analogous to the energy used in moving the car. Physical activity involves voluntary movement, which includes behaviors from studying to running. As individuals become more physically active, they expend more energy. Also included is spontaneous activity, such as fidgeting and the maintenance of body posture (Levine et al., 1999). Estimates of average energy expenditure for a 154-pound man follow: 60 to 75% is expended during resting metabolism, 10% is due to the thermic effects of food, and 15 to 30% is expended on physical activity (McArdle et al., 1996). Resting metabolism slows down at approximately 2% per decade as humans get older. Energy requirements for physical activity also decline with age as people become less active (McArdle et al., 1996; Van Itallie & Kissileff, 1990).

Energy Storage and Use. People do not eat constantly, but energy must always be available because our brain, heart, lungs, and cells are constantly working even during sleep. Consequently, energy is derived from recently eaten food or from reserves in the stomach, intestines, liver, and muscles and from fat storehouses. Thus, there must be a balance between energy intake, in the form of food, and various forms of energy expenditure. This balance is known as energy homeostasis (Woods et al., 2000). Energy stores are out of balance when food intake exceeds energy expenditure (weight gain) or falls short of energy expenditure (weight loss). A major source of energy is glucose, a simple sugar obtained from food carbohydrates. Insulin released from the pancreas aids in transporting glucose into the cells to be used for energy. Insulin also aids in the conversion of excess glucose to glycogen, which consists of glucose molecules linked together for storage in the liver and muscles. Glucose can also be converted to fat and stored in adipose (fat) cells. After several hours, however, a person runs out of easily available energy from the stomach and intestines. Now
the person begins to rely on stored muscle glycogen, which is reconverted there to glucose and used as energy. Glycogen from the liver can also be reconverted to glucose and released into the bloodstream. During longer periods of not eating or famine, a person can run completely out of glycogen. Consequently, the body converts its stored fat into fatty acids for energy use (McArdle et al., 1996; Sizer & Whitney, 1997).

**Short- and Long-Term Energy Regulation**

Fuel for a car’s engine is regulated by both short- and long-term supplies. Gasoline in the fuel tank represents a short-term supply, while gas waiting to be obtained from the local gas station represents a long-term supply. For the body, glucose levels are a short-term energy supply, while the amount of body fat is a long-term supply.

**Glucose and Short-Term Regulation.** As a short-term energy source, the amount of blood glucose is associated with hunger and eating. Campfield and associates (1985) suggest that a decline in blood glucose, at least in rats, may be causally related to eating. In a series of experiments, they continuously monitored blood glucose in rats who were allowed to eat freely. From this monitoring they found a correlation between a fall and rise in blood glucose with eating and food-related behaviors. For example, after blood glucose had reached its lowest level and then began to rise, rats searched for food and ate if food was available. However, if the glucose concentration had risen back to its normal level before finding food, then the rats would not eat (Campfield et al., 1985; Campfield & Smith, 1990). Should the decline in blood glucose be interpreted as a cause of eating? To test this possibility, Campfield and associates (1985) reasoned that if they could prevent the decline in blood glucose, then the rats should not be inclined to eat. In their experiment, when they detected the onset of a decline in glucose, they prevented further decline by injecting the rats with glucose. A control group of rats was injected with a saline solution that should have no effect in eliminating a decline in glucose. A third group was not injected with anything to determine the time between a declining glucose concentration and eating. The results showed that when a drop in blood glucose was prevented, eating was delayed for several hours. When blood glucose was allowed to decline normally in the other two groups, feeding occurred in about 12 minutes. These results imply that a decline in glucose instigates eating, while a sufficiently high level of glucose inhibits eating. Furthermore, only small fluctuations in glucose, not life-threatening changes, are needed by the brain in order to govern eating behavior (Woods et al., 2000).

**Set Point Model and Long-Term Regulation.** Long-term energy stores rely on a set point for either body weight or body fat. In his set point model, Keesey (1986) assumes that either body weight or body fat is set at a specific value, with a discrepancy below set point instigating hunger. This model is based on the assumption that the set point for a person’s body weight remains constant over a long period of time. For example, many people who have lost weight by dieting will tend to return to their prediet weight when ending their diet. One method the body uses to guard its set point from restricted food intake is to decrease its resting metabolic rate (McArdle et al., 1996). To illustrate, Elliot and associates (1989) measured the resting metabolic rate of obese women before, during, and after a weight-reducing diet. Although the women lost weight and body fat, their resting metabolic rate also decreased. Their bodies defended the fat set point from reduced food intake by decreasing energy consumption. A consequence of this decreased metabolic rate was that
individuals regained the weight they lost when they resumed their normal diet (Begley, 1991; Keesey & Hirvonen, 1997). Their energy intake had once again exceeded the amount of energy expended.

The reverse can also happen. Some individuals who are forced to gain weight by eating high-calorie meals return to their former weight when resuming their normal diet. An increased thermic effect is responsible, because overfeeding can lead to increased heat production in the digestion of food (Ravussin & Danforth, 1999). The excess calories are simply burned off, resulting in a return to normal weight. Other individuals when overfed burn off excess calories by increased fidgeting and spontaneous muscle contraction and by maintaining their body posture (Levine et al., 1999). The **carrying cost** is another factor that contributes to body weight set point. As an individual gains weight, more energy is required to carry that extra weight (Van Itallie & Kissileff, 1983). Carrying cost levels off an individual’s weight because the amount of energy required to carry the excess weight equals the amount of food energy that is consumed. Whether jogging, bicycling, swimming, or walking, a heavier person will burn more calories doing these activities than will a lighter person (McArdle et al., 1996, Appendix D).

**Energy Reservoir Model and Long-Term Regulation.** Another interpretation of long-term energy regulation is Van Itallie and Kissileff’s (1990) energy reservoir model of stored body fat. A reservoir containing a town’s water supply is analogous to our body’s fat storage. First, the amount of stored water depends on the size of the reservoir just as the amount of fat depends on the size and number of a person’s fat cells. Second, the amount of water stored in the reservoir will depend on the amount of rainfall. As rainfall increases, the amount of water available for storage increases. Similarly, as the amount of food intake increases, so does the amount that can be stored as fat in adipose tissue. Furthermore, as the reservoir begins to empty due to excessive water use or little rainfall, people begin to conserve water. They conserve water not because of an attempt to maintain a certain water level but so as not to run out completely. Similarly, when food supply is low during a diet, the amount of stored fat becomes lower and energy is conserved by reducing resting metabolic rate. Finally, when much water is used by the community, which is often the case in summertime, the level of the reservoir drops. Similarly when human energy expenditure is high, such as during long-distance running, fat deposits become quite low. Thus, the amount of body fat held in reserve depends on the amount of food minus the amount used for energy, just as the water level in a reservoir depends on the amount of rainfall minus the amount used by the town.

**Hunger Sensations**

A car has a single indicator that shows when the fuel supply is low. The body, in contrast, has many indicators to show when food energy is low.

**Sensations Indicating Energy Depletion.** Subjective sensations of hunger inform us that we are running low on energy. These sensations, although differing in intensity, are not located in one place but instead have varied locations (Friedman et al., 1999; Monello & Mayer, 1967). Friedman and coresearchers (1999) devised intensity ratings for sensations related to hunger and appetite, such as the ones in Table 5.1. They also devised intensity ratings for sensations that are associated with hunger, such as anxiety, dizziness, dry mouth,
TABLE 5.1 Ratings of Hunger and Related Sensations

Rate the intensity of your hunger and related sensations that you feel right now:

Hunger: Not at all hungry = 0 1 2 3 4 5 6 7 8 9 = As hungry as I have ever felt

Desire to eat: Very weak = 0 1 2 3 4 5 6 7 8 9 = Very strong

How much could you eat: Nothing at all = 0 1 2 3 4 5 6 7 8 9 = A large amount

How full is your stomach: Not at all = 0 1 2 3 4 5 6 7 8 9 = Very full

headache, stomachache, stomach growling, and weakness. Do the intensities of these sensations change with hours of food deprivation? To answer this question, the researchers recruited male and female participants to go without food for 22 hours from 6:00 P.M. to 4:00 P.M. the following day. At six different times during the 22 hours, participants rated the intensity of their sensations as listed in Table 5.1 and the intensity of other hunger-associated sensations. Participants rated their sensations twice at 4:00 P.M., just before and right after their meal. Figure 5.3 shows that sensations of hunger, the desire to eat, and the amount expected to eat all increased with hours of food deprivation and decreased after the meal. Ratings of stomach fullness showed the reverse pattern. Ratings of hunger-associated sensations showed similar patterns. For example, weakness, headache, dizziness, and stomach growl and ache increased with deprivation and then decreased after the meal.

**Hunger Indicates Size of Energy Stores.** Could the stomach be analogous to a car’s gasoline tank? Could hunger sensations indicate the number of calories remaining in the stomach, much like a car’s fuel gauge indicates how much gasoline is in the tank? To investigate this possibility, De Castro and Elmore (1988) correlated people’s hunger sensations with the number of calories of food they had in their stomachs. They asked men and women to record when, what, and how much they ate and drank for seven days and to record their degree of hunger before each meal. The amount of available energy in a person’s stomach was calculated from the fact that food leaves at a known rate. This rate is faster for large amounts of food and slower for small amounts. For example, if lunch consisted of a 12-ounce cola beverage (152 calories) and a quarter-pound hamburger (403 calories), then the person would have stored 555 calories. However, as time passes the stomach begins emptying so that fewer and fewer calories of food energy remain available. Thus, knowing the number of calories a person ate and the rate of stomach emptying, the stomach’s caloric content could be estimated before a participant’s next meal. De Castro and Elmore’s calculations showed that as stomach content decreases, hunger sensations increase. The energy content level of the stomach also correlates with the size of the next meal. Returning to the car analogy, as the gauge approaches E, it is time to fill up. Similarly, as hunger sensations become stronger, then it is time to eat. The link between hunger and needing calories, however, breaks down for long periods of fasting. People who go for days or weeks without food (Wolf, 1958) report that hunger sensations do not become more intense but instead disappear. As in a car, once the fuel tank is empty, the gas gauge is not going to fall further past the empty mark.
Feedback Mechanisms for Satiety

If hunger motivates us to eat, then what motivates us to stop? One answer is satiety, which refers to gratifying hunger, feeling content, and replenishing energy stores. Multiple physiological changes are associated with satiety.

Feeling Full. The stomach contributes to satiety especially when it is full or distended with food. In one experiment, Deutsch (1990) and coresearchers used a noose to close the exit portion of a rat’s stomach so that no milk could exit into the lower intestines. Some rats but not others were injected with a saline solution into their stomachs via tubes. Rats who had the extra solution injected into their stomachs quit drinking milk sooner regardless of whether the noose was open or closed. Deutsch and associates concluded that the upper limits of the stomach’s capacity to hold food, or stomach distension, is what inhibits eating. Humans similarly report that stomach distension inhibits eating. In a series of surveys asking college students why they usually stop eating a meal, the most common answer given was when “I feel full” (Mook & Votaw, 1992, p. 72).

Calorie Detectors. Besides stomach distension, sensing the caloric or energy value of food in the stomach is also effective in the inhibition of hunger. Deutsch and Gonzales had rats drink as much as they wanted of a high-calorie substance. When saline was pumped into the rats’ stomachs, however, they still drank the same amount of this high-calorie food compared to when saline had not been given. The results of this experiment show that rats sense

FIGURE 5.3 Hunger and Related Ratings. Ratings of hunger, desire to eat, and amount expected to eat increased with hours of deprivation and decreased with eating. Ratings of stomach fullness showed the reverse trend.

Note: Values are means ± SEM of 14 subjects.

the food energy content of food in their stomachs regardless of the volume that is there (Deutsch, 1990). Human infants have also developed the ability to alter their volume of intake based on the number of calories contained in their formulas. Fomon and associates (1969) provided mothers with a 3- to 4-day supply of infant formula that had either low- or high-caloric density. Mothers, without knowing the caloric density of the formula, were instructed to feed their infants until their children were satisfied. The infants drank more of the low-calorie than the high-calorie formula. In comparing the number of calories consumed, however, there was no difference. A larger volume of low-density formula was necessary to match the number of calories provided by a lesser volume of the high-density formula (Fomon et al., 1969). It appears from these experiments that the amount of food energy in the stomach is also monitored and inhibits hunger. Personal experience verifies this, since some meals are more filling than others, for example, pastas and rich desserts versus salads.

**Hormones.** Blood carries food nutrients to where they are needed but may also carry substances that promote either hunger or satiety. To investigate this possibility, Davis and associates (Davis et al., 1967, 1969) transfused blood from a hungry rat to a satiated one. They reasoned that perhaps a hungry rat carries a substance that produces hunger. However, this turned out not to be the case, since the satiated rat did not eat more following a blood transfusion from the hungry rat. Davis and associates also reversed the procedure and transfused blood from a satiated rat to a hungry rat in case there was a substance that inhibited hunger. In this instance, the hungry rat ate less compared to when it had not been given a blood transfusion. The researchers concluded that the blood of satiated animals contains a substance that inhibits eating in food-deprived animals. One possible explanation of these results is that following eating, a hormone is released into the bloodstream to inhibit further eating. It turns out that indeed there are hormones that inhibit but also stimulate hunger and eating.

**Cholecystokinin (CCK)** is a hormone released in the upper part of the small intestine after food intake and is involved in the short-term regulation of food energy. In an early experiment, injection of CCK in rats inhibited feeding (Gibbs et al., 1973). In further experiments, Canova and Geary (1991) found that the more CCK that was injected, the less milk the rats drank. Similar results were obtained with humans. Higher levels of CCK in the bloodstream were associated with higher degrees of satiety (Holt et al., 1992). CCK interacts with the amount of food to inhibit hunger and eating. Muurahainen and associates (1991) had male participants eat either 100 or 500 grams of soup followed by either an infusion of synthetic CCK or saline as a control substance. Next, the participants were allowed to eat as much as they wanted of a test meal of macaroni and beef. The amount participants ate depended both on CCK and on the size of the premeal soup. The CCK significantly inhibited eating of the test meal for those participants who had preloaded with the larger portion of premeal soup. The CCK, however, did not inhibit eating of the test meal for those participants who had the smaller amount of premeal soup. Thus, CCK may have an inhibitory effect on hunger but perhaps only when coupled with other satiety cues, such as feeling full.

**Leptin** is a hormone released by adipose tissue. Unlike CCK, which is sensitive to hunger and satiety, leptin is involved in the long-term regulation of energy as registered in adipose tissue or body fat (Baile et al., 2000; Friedman & Halaas, 1998). The amount of leptin circulation in the bloodstream correlates with the amount of body fat. For instance,
leptin declines as individuals lose weight. Obese individuals have greater levels of circulating leptin than lean individuals. It is thought that obesity may result from an insensitivity to leptin (Considine et al., 1996; Friedman & Halaas, 1998). Areas of the hypothalamus detect concentrations of leptin in the bloodstream and in turn help institute various changes to maintain the body fat set point. Thus, a decrease in leptin is associated with changes designed to conserve energy, such as a decrease in basal metabolism and an increase in appetite. An increase in leptin, however, is associated with changes designed to increase energy expenditure and decrease food intake (Baile et al., 2000; Friedman & Halaas, 1998).

**Ghrelin**, introduced in Chapter 1, is a hormone that stimulates hunger, eating, and images of food (Geary, 2004). Ghrelin is released into the stomach and rises to its highest point just prior to breakfast, lunch, and dinner. It then declines rapidly after eating, only to begin rising again until prior to the next meal. Furthermore, when humans receive an injection of ghrelin, they report greater hunger and eat more (Schmid et al., 2005; Wren et al., 2001). In addition, the success of gastric bypass surgery for the treatment of severe obesity is due in part to a reduction in the release of ghrelin. Thus, with lower levels of ghrelin, it is easier for these individuals to control their hunger and eating (Kojima & Kangawa, 2005). Hunger, eating, and satiation are partly a product of the complex interaction among these three hormones. They send signals to the brain regarding the energy status of the body. Ghrelin stimulates eating and CCK inhibits eating in the short run while leptin appears to have a more long-term involvement (Geary, 2004).

**Section Recap**

We have examined what physiological changes motivate adjustment in body temperature, fluid balance, and energy levels. We have also investigated how corresponding psychological sensations motivate behavior to regulate these variables. The body attempts to maintain a stable internal environment or **homeostasis**, which is accomplished with the aid of the negative feedback system. This system places the optimal set point for body temperature, fluid levels, and food energy stores within an upper and lower boundary. Deviations from set points define a physiological need for the incentive that will restore homeostasis. Changes in a person’s physiological interior alter sensations (alliesthesia) to stimuli that are relevant for restoring homeostasis. Incentives that restore homeostasis are pleasant, while those that disrupt homeostasis further are unpleasant. Different physiological systems are maintained under homeostasis. A drop in body temperature below set point produces involuntary shivering and blood vessel constriction to raise temperature. A rise in body temperature produces involuntary sweating and blood vessel dilation to lower temperature. In addition, the accompanying sensations of feeling cold and hot can result in voluntary actions like putting on or removing layers of clothing.

Thirst results from a loss of **intracellular fluids**, which occurs when water within the cells is drawn out due to a higher concentration of salt in extracellular fluid. Thirst also results from the loss of **extracellular fluid** through sweating, exhaling, and urinating. Cellular dehydration detectors are located in the hypothalamus, which on detecting fluid loss triggers thirst. Specific and global thirst sensations intensify with dehydration and cease with drinking even though fluids have not been completely replaced. Experiments with sham drinking indicate that receptors located in the mouth, stomach, and intestines monitor water intake.
Food energy measured in calories comes primarily from glucose. It is used during resting metabolism for maintaining the body, during thermic effects for digesting and storing food energy, and for physical activity or behavior. Heavier people burn more calories because the carrying cost of their weight is greater. Since we do not eat constantly, food energy is stored by converting glucose to glycogen as a short-term energy source. Fat storage is a long-term energy source regulated by the set point model for a specific amount of body fat. The energy reservoir model, however, likens level of fat stores to the amount of water in the town’s reservoir. Hunger sensations are experienced in the stomach and abdomen but also as dizziness, headache, and weakness. These sensations increase with hours of food deprivation and are linked to a fall in blood glucose, running out of food in the stomach, and running out of energy. Hunger motivates eating, and satiety, or feeling replenished, inhibits eating. Other factors that affect eating are a rise in blood glucose, an increased supply of calories, feeling full, and the release of the hormones cholecystokinin (CCK), leptin, and ghrelin.

Food Characteristics and Eating

By perusing photos in cookbooks, a person realizes that food must also be pleasing to the eye as well as to the taste buds. Restaurant chefs do not slop food into a bucket to give to their patrons. Instead, they arrange food on a plate and add garnish to make the meal look attractive to diners. The whole practice of meal planning emphasizes the importance of color, form, variety, texture, temperature, and flavor of food. These considerations to the details of food make it apparent that there is more to eating than just reaching satiety. People often eat beyond satiety, especially when it involves their favorite food or dessert.

The purpose of this section is to describe those food characteristics that also determine what and how much people eat.

Cephalic Responses

Food has the power to make us eat. It can evoke a set of physiological responses that are preparatory to eating, digesting, metabolizing, and storing food (Nederkoorn et al., 2000). Cephalic responses to the smell and taste of food involve the secretion of saliva, gastric juices, and insulin from the pancreas (Powley, 1977). In addition, food can also evoke hunger sensations and the desire to eat. To illustrate, Bruce and associates (1987) evoked a cephalic response in their participants following an overnight fast. They presented them with a combination of sweetened gum, sweetened water, and the sight and smell of an appetizing breakfast. Ingesting the sweet stimuli plus the sight and smell of food raised the participants’ insulin and lowered the level of blood glucose. Furthermore, the more glucose levels dropped in the participants, the more appetizing they rated the anticipated breakfast. Nederkoorn and associates (2000) exposed their participants to their favorite foods and measured the cephalic response. As a result of the exposure, participants’ hunger ratings and cravings increased along with their heart rate, blood pressure, salivation, and gastric activity. Marcelino and colleagues (2001) had participants visually inspect and smell four pizzas that differed in visual quality. Another group was not exposed to the pizzas. Appetite ratings were higher for individuals who saw and smelled the pizzas. Furthermore, the desire to eat a pizza also increased with its visual quality and the participant’s degree of hunger.
Palatability and Amount of Food

Both the quality and amount of food determine the urge to eat and the amount that is eaten. One type of food quality is referred to as palatability, which refers to its hedonic value as determined by variety, texture, temperature, aroma, and flavor (Young, 1961). Highly palatable food is appetizing, delicious, and a pleasure to eat. For example, Moskowitz and associates (1974) showed that palatability depends on flavor intensity. In their experiment, they varied the sucrose concentration, or sweetness intensity, of vanilla pudding, yellow cake, and a cherry-flavored beverage. Pleasantness ratings of these foods at first increased but then decreased as they became sweeter and sweeter. In other words, people like their desserts to be sweet but not too sweet.

Not only does sugar enhance palatability, but fat does also. Drewnowski and colleagues (1983, 1985) determined the contribution sweet and fat make to palatability for both fed and fasted participants. They had participants taste 20 different substances by a sip-and-spit technique, followed each time by rinsing the mouth. The 20 substances varied in five levels of fat (ranging from skim milk to heavy cream blended with safflower oil) and four levels of sweetness. Participants rated each substance for sweetness, fatness, creaminess, and for liking. Ratings of sweetness, fatness, and creaminess increased as fat and sugar content increased, demonstrating that participants were sensitive to these factors. Liking ratings, however, increased and then decreased as the sugar and fat content of the substances increased. The best-liked substance consisted of about 21% fat and about 8% sugar (Drewnowski et al., 1985). Thus, people like things sweet and fat but not too sweet and not too fat. Not only do we have a “sweet tooth” we also have a “fat tooth.”

In addition to palatability, quantity also factors into the motivating effects of food. One observation is that as the size of food portions increase, the amount eaten increases correspondingly. There is experimental evidence to support this claim. Rolls and co-researchers (2002) presented their male and female participants a lunch of macaroni and cheese in one of four different portions: 500, 625, 750, or 1,000 grams. Participants were instructed to eat as little or as much as they wanted. Prior to eating, the four groups did not differ in their hunger, thirst, and the amount they thought they could eat. Portion size, however, determined the amount they did eat. The results presented in Figure 5.4 show that amount consumed increased as portion sizes increased. This increase occurred equally for both men and women although men ate significantly more than women for all portion sizes. Increased portion sizes of meals provided in restaurants or in packaged foods have been blamed for the increase in the percent of overweight and obese individuals (see Figure 12.7, Harnack et al., 2000).

Sensory-Specific Satiety

Quantity interacts with food variety in determining eating. As suggested in many cookbooks, eating will be a more pleasurable experience if a variety of palatable foods are served in a fashion appealing to the eye (Crocker, 1961). Serving only one dish or eating the same food repeatedly is enough to blunt anyone’s appetite, which is the result of a process known as sensory-specific satiety. This process refers to a decreased liking and consumption of a particular food based on sensory characteristics, such as flavor, texture, and appearance (Raynor & Epstein, 2001). In an early experiment conducted by Rolls and associates (1981), participants tasted and then rated their liking of a number of foods, among which was
FIGURE 5.4 Portion Size Determines Amount Eaten. The amount eaten of a macaroni and cheese lunch increased as the serving portion increased. This increase occurred for both men and women. In addition, men ate more than women at all portion sizes.


cheese on crackers or sausage. Half of the participants had a lunch of cheese on crackers, while the other half had a lunch of sausage. Two minutes after the meal, participants were unexpectedly given a second course, which was either the same as the first course (cheese on crackers or sausage) or different (sausage or cheese on crackers). Participants also rated the liking of these foods during their second course. The ratings showed that the same food was liked less compared to a different food. In addition, if participants ate the same food during the second course as they did during the first, they tended to eat less than if the food was different between courses. For example, participants liked sausage less during the second course and ate less of it if they had also eaten sausage during the first course. Sensory-specific satiety means that satiety is specific to a food and does not generalize to other foods. Thus, although a person may quit eating one food, she will eat other foods, thereby ensuring that several varieties are eaten during one meal. A greater variety at meals provides greater enjoyment and increases the likelihood that a nutritionally balanced meal is eaten.

Food Preferences

Your innate dispositions toward food and the eating environment your parents provided jointly determined your current food likes and dislikes. In other words, food preferences result from the interaction between innate dispositions and environmental experiences (Birch, 1999).

Innate Food Preferences. As described in Chapter 3, humans are born liking certain tastes and foods and not others. For instance, Mennella and Beauchamp (1998) and Steiner (1977)
showed that infants innately prefer sweet substances and reject bitter and sour substances. Thus, humans appear innately ready to eat sweet-tasting foods, which are relatively high in calories, and reject bitter or sour-tasting foods, which are associated with poison and being spoiled. Rats show different facial gestures depending on their being exposed to sweet or bitter stimuli (Grill & Norgren, 1978). Rats also show an innate preference for salt (Schulkin, 1991). The same is true for humans. Leshem and colleagues (1999) induced salt loss through perspiration in one group by having them exercise, compared to a control group who did not exercise. When allowed to flavor a cup of tomato soup to their liking, exercisers preferred more than a 50% increase in salt (NaCl) compared to what nonexercisers preferred. These results support the notion that salt preference increases as salt level in the body decreases. Young infants, however, are indifferent to the taste of salt, while infants 4 to 24 months of age prefer salt solutions over plain water. Children 3 to 6 years old, although rejecting salty fluids, prefer salted soups (Beauchamp et al., 1986). Thus, rats and humans appear sensitive to and prefer food substances that are necessary for body growth, maintenance, and repair.

**Conditioned Food Preferences.** The recommendation that a variety of foods promotes appetite should not detract from the contribution that familiarity makes in liking certain foods. People often prefer the foods they ate while growing up simply because of their exposure to them. According to Zajonc’s (1968) *mere exposure effect*, people increase their positive evaluation of a stimulus because of repeated exposures. To illustrate this concept, Pliner (1982) had participants taste and swallow four different tropical fruit juices from zero to 20 times, each time rating their bitterness. Following the tasting, participants rated the juices for liking (from dislike to like). The rating outcomes were in accord with the mere exposure effect such that liking increased with the number of times a juice had been tasted. However, this effect did not last longer than one week. In another experiment, Birch and Marlin (1982) presented preschool children with three novel foods that consisted of sweet, salty, or plain tofu (soybean curd). The children tasted the foods up to 20 times over a series of days and each time rated how much they preferred them. Again, in accord with the mere exposure effect, as number of food tastings increased, preference ratings increased.

Liking a particular food can also be enhanced by associating it with a hedonically pleasant taste. Zellner and associates (1983) likened this association to a classical conditioning procedure. In their experiment, the flavor of tea served as a conditioned stimulus for either the presence or absence of sugar in the tea. Sugar was the unconditioned stimulus, which evoked an unconditioned response of a hedonically pleasant taste. After drinking either the sweetened or unsweetened teas, the participants rated the teas, now without any sugar, for how much they liked them. The flavors of the teas that had been sweetened were liked better than those teas that had not been sweetened. This effect was still present one week later. The fact that sugar enhances the liking for food has not been lost on parents. In many different cultures, sugar is added to the food of infants so that they will eat it more readily (Jerome, 1977). Boxes of some breakfast cereals at the grocery store list sugar as their second-highest ingredient.

The degree that food restores energy homeostasis also determines how much it is liked. For instance, both animals and humans learn to prefer the flavors of foods that are associated with restoring the body’s energy. In an illustrative animal experiment, Fedorchak and Bolles (1987, exp. 2) deprived some rats of food (hungry) and provided free food to others (not hungry). In addition, on some days both hungry and non-hungry rats had orange-flavored water available while on other days grape-flavored water with ethanol was available. The orange
flavor became associated with the absence of calories, since water does not provide any calories. The grape flavor became associated with the presence of calories, which were provided in the ethanol. The question was which flavor do rats learn to prefer: orange flavor associated with the absence of calories or grape flavor associated with the presence of calories? To answer this question, the rats were later given a choice between orange-flavored water versus grape-flavored water (ethanol was now absent). The results of the preference test showed that when hungry, rats chose the grape flavor that had been associated with calories from ethanol. They did not prefer the grape flavor simply because of its prior association with ethanol, since when not hungry they preferred both flavors equally.

Similar research with humans has led to the same conclusion. Appleton and coresearchers (2006) had one group of individuals report to the laboratory immediately after breakfast or lunch. This group was defined as having low-energy requirements—that is, they were not hungry. Another group of individuals reported to the laboratory immediately prior to lunch or prior to the evening meal. They were defined as having high-energy requirements—that is, they were hungry. In the laboratory, participants ate one of four novel-flavored yogurts that had either a low or high energy content. This procedure was repeated over a five-day period, during which non-hungry or hungry participants ate a low- or a high-energy yogurt. Prior and during conditioning, participants rated the yogurts for liking and pleasantness of taste. An analysis of these ratings showed that all flavors received higher liking and pleasantness ratings when they had been consumed under high-energy (hungry) compared to low-energy (not hungry) requirements. This finding was especially true for yogurt with a high energy content. These results replicate the experiments just cited with rats. Novel flavors that participants experienced while hungry were preferred over novel flavors that were experienced while not hungry.

The mere energy content of the food is also important for the development of taste preferences. In one illustrative experiment, Brunstrom and Mitchell (2007) had female participants eat two novel and distinctly flavored desserts: one with a high and the other with a low energy content. The desserts were eaten on alternate days over a six-day period. After eating a dessert, participants rated it for liking, desire, and enjoyment. Following the taste experiences, participants then tasted each dessert again. Both now had an intermediate level of energy. Did the preference for a particular dessert depend on its former energy content? Yes, the high-energy dessert was preferred. Initially, there were no differences in dessert preferences as shown by ratings collected on the first day. However, by the test day participants liked, enjoyed, and desired the high-energy flavored dessert more than the low-energy one. The pairing of a flavor with a high-energy content resulted in a preference for that flavor. The results of these experiments imply that people’s preferences develop as a result of a food’s ability to restore energy, which occurs when a hungry person eats high-energy food.

It is also common, however, for a person to not eat a particular food because of a strong taste aversion. This refers to a strong dislike because of the food’s association with nausea, which developed through classical conditioning (Bernstein, 1978; Garcia et al., 1966). Taste aversion in humans has several characteristics (Logue et al., 1981). First, the taste and smell of food and drink rather than their texture or appearance generally have more of an influence on taste aversion. Second, an aversion is more likely to develop to an unfamiliar or less-preferred food. Third, it does not matter whether nausea was the result of spoiled food or the stomach flu. Even if individuals do not know why they became ill, an aversion still develops. Aversion may also result from overindulgence, as in the case of alcohol. In a sample of university students,
Logue and associates (1981) found that approximately one-fourth had developed an aversion to alcohol. Of these aversions, approximately 69% were to hard liquor while 17% and 14% were to wine and beer, respectively. Lastly, once developed, an aversion can last for years. Although most prevalent in children, conditioned taste aversion does not last forever and declines with age (Garb & Stunkard, 1974). Eating the aversive food is a quicker way to overcome the aversion rather than just waiting for the passage of time (Logue et al., 1981).

**Section Recap**

This section addressed the question whether there are factors besides hunger that determine how much people eat. The answer is a definite “yes.” The palatability of food is a key factor, and refers to its appearance, texture, aroma, and flavor in creating a pleasurable taste experience. As food becomes more palatable it evokes greater cephalic responses, such as salivation and gastric secretions. Merely being exposed to food evokes cephalic responses and also increases the desire for food. Hunger levels also intensify cephalic responses. Humans have innate food preferences, especially for sweets and fat but also for salt, which becomes apparent when they are deprived of salt. Finally, repeated experiences with food also determine liking. Sensory-specific satiety refers to how eating a particular food decreases our preference for more of that particular food but not for all foods. The mere exposure effect, in contrast, refers to the finding that liking foods stems from our exposure to them. In addition, some foods are liked because they have become associated with pleasurable hedonic tastes. Animals and people also learn to prefer the novel flavors of foods that restore energy homeostasis—that is, foods that have a high-energy content and are eaten while hungry. Some foods are disliked because of taste aversion, an extreme dislike for a particular food because of the association of aroma and taste with nausea or illness.

**Person Characteristics and Eating**

When I eat something fattening it is easier to eat at night. So I look forward to eating a cookie, my one cookie, late at night—I eat it really slow, and I have to eat by myself. I wait until the night after I have eaten a big dinner. I am not hungry for the cookie, I’m still thinking about it: “Oh, that is the time when I get to eat my cookie, even if I’m not hungry for it.” . . . I get my only happiness from eating that cookie. Then I think I’m going to start eating to be happy. That gives me the fear that I will be unhappy about everything, and be happy about eating a cookie. Then it makes me afraid that I’m going to cure all my unhappiness by eating and eating cookies all the time, because my greatest fear is to lose control and to become fat. (Bruch, 1988, pp. 151–152)

These are the fears expressed by a young woman who suffers from anorexia nervosa, which is a disease characterized by emaciation because of extreme dieting.

The purpose of this section is to explore whether there are differences among people and situations associated with how much is eaten.

**Boundary Model of Eating**

As described earlier, the set point in the negative feedback system is located between two boundaries that define a comfort zone. For example, when the house temperature drops below the lower boundary in winter, the furnace heats the house. When the temperature goes
above the upper boundary in summer, the air conditioner cools the house. Between these two boundaries there exists a comfort zone. Herman and Polivy (1984) used this zone idea in their boundary model of hunger (lower boundary) and satiety (upper boundary). According to this model, if a person drops below the lower boundary, then she experiences aversive feelings of hunger, weakness, and an empty stomach; the further below the lower boundary, the greater the impetus to eat. Above the satiety (upper) boundary, a person stops eating when aversive physiological conditions begin to prevail, such as a full stomach. In between (upper and lower boundaries) is the zone of biological indifference, where instead of physiological reasons, social factors and the palatability of food determine how much is eaten.

The zone of biological indifference is different for normal eaters, dieters, binge eaters, and people with anorexia nervosa. Physiological factors largely govern when normal eaters start and stop eating. Dieters, however, have a wider zone of biological indifference. They strive to rely on a cognitively imposed diet boundary that determines how much they eat, often falling short of their satiety boundary (Herman & Polivy, 1984). For them, trying to lose weight, fitting into clothes, or achieving society’s ideal body image are factors that also control their eating. Herman and Polivy (1980) use the term restraint to refer to the cognitive effort used to resist the urge to eat. They have devised a 10-item Revised Restraint Scale (see Table 5.2) that measures the extent people restrain their eating. Individuals who

### Table 5.2 Revised Restraint Scale

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How often are you dieting? Never, rarely, sometimes, often, always (scored 0–4)</td>
</tr>
<tr>
<td>2</td>
<td>What is the maximum amount of weight (in pounds) that you have ever lost within one month? 0–4, 5–9, 10–14, 15–19, 20+ (scored 0–4)</td>
</tr>
<tr>
<td>3</td>
<td>What is your maximum weight gain within a week? 0–1, 1.1–2, 2.1–3, 3.1–5, 5.1+ (scored 0–4)</td>
</tr>
<tr>
<td>4</td>
<td>In a typical week, how much does your weight fluctuate? 0–1, 1.1–2, 2.1–3, 3.1–5, 5.1+ (scored 0–4)</td>
</tr>
<tr>
<td>5</td>
<td>Would a weight fluctuation of 5 lbs. affect the way you live your life? Not at all, slightly, moderately, very much (scored 0–3)</td>
</tr>
<tr>
<td>6</td>
<td>Do you eat sensibly in front of others and splurge alone? Never, rarely, often, always (scored 0–3)</td>
</tr>
<tr>
<td>7</td>
<td>Do you give too much time and thought to food? Never, rarely, often, always (scored 0–3)</td>
</tr>
<tr>
<td>8</td>
<td>Do you have feelings of guilt after overeating? Never, rarely, often, always (scored 0–3)</td>
</tr>
<tr>
<td>9</td>
<td>How conscious are you of what you are eating? Not at all, slightly, moderately, extremely (scored 0–3)</td>
</tr>
<tr>
<td>10</td>
<td>How many pounds over your desired weight were you at your maximum weight? 0–1, 1–5, 6–10, 11–20, 21+ (scored 0–4)</td>
</tr>
</tbody>
</table>

For self-scoring, sum your responses to the 10 questions.

**Note:** With their female participants, Herman and Polivy (1975) obtained a median of 17 and Spencer and Fremouw (1979) obtained a median of 16. A score below 16 falls in the “unrestrained” or “low-restraint eater” category. A score above 17 falls in the “high-restraint eater” category.

**Source:** Copyright © 1975 by The American Psychological Association. Adapted with permission. The official citation that should be used in referencing this material is Herman, C. P., & Polivy, J. (1975). Anxiety, Restraint, and Eating Behavior. *Journal of Abnormal Psychology, 84*, p. 669.
score high on the scale are defined as restrained eaters. They constantly think about what and how much they eat and then feel guilty when they have exceeded their diet. People who score low on the scale, however, are unrestrained. They eat when and however much they want. Restrained eaters, who are usually dieters, are described as having lower hunger boundaries and higher satiety boundaries than unrestrained eaters. For example, it takes a greater amount of food deprivation for them to admit being hungry, and they eat less food after equivalent periods of deprivation. Perhaps dieters become accustomed to experiencing hunger and to eating less than unrestrained eaters (Herman & Polivy, 1984).

Some dieters also binge on occasion and thus are described as having a wider zone of biological indifference than normal eaters. These individuals usually have an all-or-none view of their diet so that when they break it, binging results. Binge eating refers to the inability to stop eating, only doing so when running out of food, being interrupted, or reaching physiological capacity (Wilson et al., 1996). Polivy and Herman (1985) claim that binging is a likely consequence of dieting because of the possibility that dieting may make a person chronically hungry.

Cognitive Release of Diet Restraint

The diet boundary is set cognitively rather than physiologically. When the cognitive boundary or restraint is lifted, the result is overeating or binging for some previously restrained eaters (Herman & Polivy, 1984; Polivy & Herman, 1985; Ruderman, 1986). In one experimental demonstration, Fedoroff and coworkers (1997) divided individuals into unrestrained and restrained eaters based on their scores on the Revised Restraint Scale. Participants were informed that the study was about food preferences and that they would be asked to taste and to give their opinion on various foods. Prior to tasting and rating pizzas, half of the restrained and unrestrained eaters were exposed to the odor of baking pizza for 10 minutes, or were told to think about pizza for 10 minutes. The other half of the restrained and unrestrained eaters were not exposed to the pizza odors and could think about whatever they chose. Afterward, all participants were asked to taste and rate the quality of the pizza. As you might imagine, both the odor of the baking pizza and thinking about pizza increased pizza consumption, but this was only true for restrained eaters. The restrained eaters also reported an increased liking, craving, and desire to eat pizza as a result of the pizza cues. The unrestrained eaters were not affected by these temptations.

Stress-Induced Eating

In the paragraph opening this section, the young woman expressed her fears that eating cookies would be her only source of happiness. For some people eating is a way to relieve stress. What stress seems to do is to remove the diet boundary and cause eating, especially in restrained eaters, regardless of whether they are of normal weight or obese (Greeno & Wing, 1994; Ruderman, 1986). In a representative investigation, Ruderman (1985) tested whether failure-induced stress would inhibit dietary restraint. First, she measured the degree of dietary restraint in her female participants using the Revised Restraint Scale. During the experimental phase, half of her participants succeeded or failed at a concept-formation task. In the next phase, participants rated crackers for saltiness, knowing that afterward they could help themselves to any remaining crackers. The effects of failure and the degree of restraint affected the number of crackers eaten. The high-restraint participants
in the failure group ate more crackers. Low- and high-restraint participants in the success group, however, did not differ in the number of crackers they ate.

Although distress can remove diet boundaries, positive mood can also remove the diet boundary, at least in female restrained eaters. In one interesting experiment, Cools and associates (1992) had women watch a 20-minute film that was either neutral, comic, or of a horror genre to induce a neutral, positive, or negative mood. The researchers provided popcorn, since many people eat popcorn while at the movies. The real purpose in providing the popcorn was to determine how much of it would be eaten based on the type of film that was being watched. Figure 5.5 shows the amount of popcorn eaten during each film type by restrained or unrestrained eaters. Restrained eaters ate the most popcorn while viewing the horror film and the least while viewing the neutral film. They also ate more popcorn than unrestrained eaters during the comedy film and even more during the horror film. Unrestrained eaters, however, ate a similar amount of popcorn during each type of film.

**Hunger Boundary**

Is your hunger boundary well defined? Do you know the difference between hunger sensations and feelings of distress? Is your mind pushing your “start eating” boundary in one direction only to be opposed by your body pushing it in the other direction?

**Physiological Pressures.** Restrained eaters struggle between physiological pressures to eat and their cognitively placed diet boundary. Dieting makes this struggle more intense, since it may make an individual even more susceptible to eating, especially when faced with palatable foods. Klajner and associates (1981) had dieters and nondieters go without eating for five hours and then presented them with freshly baked chocolate chip cookies. For half the participants, the cookies were made unpalatable by having added green food coloring during preparation. Dieters salivated more to the palatable cookies than to the unpalatable
ones, while nondieters salivated the same amount to both types of cookies. In a prior experiment, dieters also salivated more to freshly baked pizza compared to nondieters. Dieters experience stronger cephalic responses to palatable food, perhaps making them more susceptible to eating than nondieters.

**Internal Cues and Eating Disorders.** The boundary model also describes individuals suffering from anorexia nervosa, who impose a very stringent diet boundary on themselves, even lower than that of regular dieters. Individuals most at risk for this condition are young women (15 to 29 years old), who comprise approximately 90% of the cases. They restrict their eating to the extent that they weigh less than 85% of what is normal for their age and height (American Psychiatric Association, 2000; Polivy & Herman, 2002).

There are risk factors that may eventually lead to anorexia nervosa in some women (Polivy & Herman, 2002; Stice, 2001). First, there are societal pressures that promote being thin and disparage being fat. This pressure comes from the media but may also come from parents and peers. Second, to the extent that thinness is accepted as a personal ideal, a young woman often develops a dissatisfaction with her own body. Third, this dissatisfaction can lead to dieting and, in more extreme cases, also purging. Women who diet so extensively as to develop anorexia nervosa (and fall below 85% of normal body weight) also have a distorted body image and usually view themselves as normal or fat when in actuality they have an emaciated appearance (Polivy & Herman, 2002). Depressed moods may also accompany body dissatisfaction, which may also lead to further dieting (Stice, 2001).

In her work with patients suffering from anorexia nervosa, Bruch (1988) observed that her patients were confused about their body sensations. For example, they might confuse anxiety or distress with hunger and respond with eating (Rebert et al., 1991). Women with anorexia nervosa who only restrict their food intake and those anorexics who also binge and purge are not as sensitive to internal signals of hunger and satiety. To illustrate, Halmi and Sunday (1991) examined the course of hunger and fullness during a meal for patients with eating disorders and for normal individuals. Following a 10-hour fast, these individuals rated how hungry and full they were immediately before, during, and after drinking a liquid breakfast meal. For normal eaters, as the meal progressed, they became more full and less and less hungry. Anorexic patients who restricted their diet rated themselves as full and not hungry at the start, during, and end of the meal. It was as if neither the 10-hour fast nor eating the liquid breakfast had any effect on their sense of hunger or satiety. Anorexic patients who also binged and purged showed an up-and-down hunger-fullness pattern during and after the meal. It was as if they had trouble detecting when they were hungry or full. Patients who specifically exhibited these abnormal hunger-fullness patterns also ate less of the liquid meal than patients who showed normal hunger-fullness patterns.

Patients with anorexia nervosa also develop adverse reactions to eating food, which is a condition known as the refeeding syndrome. As a result of extreme food deprivation, the body loses its ability to digest and absorb food. For example, food deprivation produces a sharp decline in phosphorous, which is an essential mineral within the body’s cells. With refeeding, there is a sudden uptake of phosphorous, which can set off a cascade of life-threatening complications, such as heart failure, coma, and breathing problems. In addition, because of food deprivation, the intestines become intolerant to food, which can result in nausea and diarrhea when food is eaten (Solomon & Kirby, 1990). These adverse reactions may mean that in regards to eating, food has a very low incentive value. However, food can have a positive incentive value
when it comes to manipulating, handling, and preparing it but not for eating it. The incentive value for eating food may be so low that an anorexic individual is unable to become motivated enough to eat (Pinel et al., 2000).

Information about anorexia nervosa and links to other relevant sites are available from the U.S. Department of Health & Human Services at http://womenshealth.gov/faq/easyread/anorexia-etr.htm

Section Recap
People differ in the extent they limit their eating. The boundary model defines the zone of biological indifference as situated between a hunger boundary and satiety boundary. Dieters and individuals suffering from anorexia nervosa have a hunger boundary that is lower and a satiety boundary that is higher than that of normal eaters. Dieters or restrained eaters also place a cognitive restraint, or diet boundary, on themselves, which is lower than their physiological satiety boundary. Unrestrained eaters, by contrast, rely on a higher physiological boundary for when to eat. Cognitive restraint can be released by making individuals break their diet boundary. The result is overeating. Both positive and negative stress can release diet restraints and lead to overeating in restrained individuals. In addition, dieting makes individuals more susceptible to eating palatable foods. Finally, young women suffering from anorexia nervosa, typified by extreme weight loss, distorted body image, and confused body sensations, have trouble distinguishing when they are hungry or full. As a result of extreme food deprivation, anorexics develop a negative reaction to eating food known as the refeeding syndrome. In addition, eating food attains a very low incentive value, so an individual is not motivated to eat.

ACTIVITIES

1. Both before and after a meal, rate yourself on the various indicators of hunger given in Table 5.1. Is cessation of eating simply the result of a change in these four sensations, or is it more than that? Are there changes in other body sensations? Is food less tasty?

2. Before the first bite of a meal, consider whether hunger merely results from the passage of time or whether food also has the ability to evoke hunger. Again, monitor the intensity of your hunger and its bodily symptoms at various intervals prior to that first bite. Was the change in hunger gradual, or was there a sharp increase in intensity that resulted from the sight and aroma of food?

3. Have you ever experienced taste aversion? If so, a. How long after eating the food did you become ill?

b. How long has your taste aversion existed?

c. How could you overcome this taste aversion? Do you even want to?

4. There are several other factors, not presented in this chapter, that determine what foods an individual eats. To illustrate, consider what factors determine whether or not you will eat a particular food.

a. Cultural beliefs: For instance, you are a vegetarian or people in your culture do not eat horses or steak tartare.

b. Religious beliefs: Certain foods are not to be eaten or they are not to be eaten during certain times of the year.