Carrie was a frail little baby. She nursed poorly, apparently because she was so weak. For several years she was underweight. Her motor development and cognitive development were much slower than normal, she often seemed to have trouble breathing, and her hands and feet were especially small. Finally, her appetite seemed to improve. She began gaining weight and soon surpassed other children of her age. Previously, she was passive and well behaved, but she became difficult and demanding. She also showed compulsive behavior—picking at her skin, collecting and lining up objects, and protesting violently when her parents tried to put things away.

The worst problem, though, was her appetite. She ate everything she could and never seemed satisfied. At first her parents were so pleased to see her finally gaining weight that they gave her food whenever she asked for it. But after a while it was clear that she was becoming obese. A specialist diagnosed her condition and told her parents that they would have to strictly limit Carrie’s food intake. Because of her weak muscles and low metabolic rate, she needed only 1200 calories per day to maintain a normal weight. But Carrie was constantly looking for food. She would raid the refrigerator until her parents installed a lock on it, as well as the cabinets where they stored food. They also had to be careful of how they disposed of leftover food, vegetable peels, or meat trimmings because Carrie would raid the garbage can and eat them.

When Carrie went to school, she began gaining weight once more. She would quickly eat everything on her tray and would then eat everything her classmates did not finish. If anyone dropped food on the floor near her, she would pick that up and eat it too. Because of Carrie’s special needs, the school appointed an aide to monitor her food intake to be sure that she ate only the low-calorie meal that she was served.

As the French physiologist Claude Bernard (1813–1878) said, “The constancy of the internal milieu is a necessary condition for a free life.” This famous quotation says succinctly what organisms must do to be able to exist in environments that are hostile to the living cells that compose them (that is, to live a “free life”): They must provide a barrier between their cells and the external environment—in the case of mammals, this barrier consists of skin and mucous membrane. Within the barrier, they must regulate the nature of the internal fluid that bathes the cells.

The physiological characteristics of the cells that constitute our bodies evolved long ago, when these cells floated freely in the ocean. In essence, what the evolutionary process has accomplished is the ability to make our own seawater for bathing our cells, to add to this seawater the oxygen and nutrients that our cells need, and to remove from it waste products that would otherwise poison them. To perform these functions, we have digestive, respiratory, circulatory, and excretory systems. We also have the behaviors necessary for finding and ingesting food and water.

Regulation of the fluid that bathes our cells is part of a process called homeostasis (“similar standing”). This chapter discusses the means by which we mammals achieve homeostatic control of the vital characteristics of our extracellular fluid through our ingestive behavior: intake of food, water, and minerals such as sodium. First, we will examine the general nature of regulatory mechanisms; then we will consider drinking and eating, as well as the neural mechanisms that are responsible for these behaviors. Finally, we will look at some research on the eating disorders.

**Physiological Regulatory Mechanisms**

A physiological regulatory mechanism maintains the constancy of some internal characteristic of the organism in the face of external variability—for example, keeping body temperature constant despite changes in the ambient temperature. A regulatory mechanism contains four essential features: the **system variable** (the characteristic to be regulated), a **set point** (the optimal value of the system variable), a **detector** that monitors the value of the system variable, and a **correctional mechanism** that restores the system variable to the set point.

An example of a regulatory system is a room in which temperature is regulated by a thermostatically controlled heater. The system variable is the room’s air temperature, and the detector for this variable is a thermostat. This device can be adjusted so that contacts of a switch will be closed when the temperature falls below a preset value (the set point). Closure of the contacts turns

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**homeostasis** *(home ee oh stay sɪs)* The process by which the body’s substances and characteristics (such as temperature and glucose level) are maintained at their optimal level.

**ingestive behavior** *(ɪn ɪˈʃɛs tɪv)* Eating or drinking.

**system variable** A variable that is controlled by a regulatory mechanism, for example, temperature in a heating system.

**set point** The optimal value of the system variable in a regulatory mechanism.

**detector** In a regulatory process, a mechanism that signals when the system variable deviates from its set point.

**correctional mechanism** In a regulatory process, the mechanism that is capable of changing the value of the system variable.
**negative feedback** A process whereby the effect produced by an action serves to diminish or terminate that action; a characteristic of regulatory systems.

**satiety mechanism** A brain mechanism that causes cessation of hunger or thirst, produced by adequate and available supplies of nutrients or water.

**intracellular fluid** The fluid contained within cells.

**extracellular fluid** All body fluids outside cells: interstitial fluid, blood plasma, and cerebrospinal fluid.

**intravascular fluid** The fluid found within the blood vessels.

**interstitial fluid** The fluid that bathes the cells, filling the space between the cells of the body (the "interstices").

on the correctional mechanism—the coils of the heater. (See Figure 11.1.) If the room cools below the set point of the thermostat, the thermostat turns the heater on, and the heater warms the room. The rise in room temperature causes the thermostat to turn the heater off. Because the activity of the correctional mechanism (heat production) feeds back to the thermostat and causes it to turn the heater off, this process is called negative feedback. Negative feedback is an essential characteristic of all regulatory systems.

This chapter considers regulatory systems that involve ingestive behaviors: drinking and eating. These behaviors are correctional mechanisms that replenish the body’s depleted stores of water or nutrients. Because of the delay between ingestion and replenishment of the depleted stores, ingestive behaviors are controlled by satiety mechanisms as well as by detectors that monitor the system variables. Satiety mechanisms are required because of the physiology of our digestive system. For example, suppose you spend some time in a hot, dry environment and lose body water. The loss of water causes internal detectors to initiate the correctional mechanism: drinking. You quickly drink a glass or two of water and then stop. What stops your ingestive behavior? The water is still in your digestive system, not yet in the fluid surrounding your cells, where it is needed. Therefore, although drinking was initiated by detectors that measure your body’s need for water, it was stopped by other means. There must be a satiety mechanism that says, in effect, "Stop—this water, when absorbed by the digestive system into the blood, will eventually replenish the body’s need." Satiety mechanisms monitor the activity of the correctional mechanism (in this case, drinking), not the system variables themselves. When a sufficient amount of drinking occurs, the satiety mechanisms stop further drinking in anticipation of the replenishment that will occur later. (See Figure 11.2.)

**Drinking**

To maintain our internal milieu at its optimal state, we have to drink some water from time to time. This section describes the control of this form of ingestive behavior.

**Some Facts About Fluid Balance**

Before you can understand the physiological control of drinking, you must know something about the fluid compartments of the body and their relationships with each other. The body contains four major fluid compartments: one compartment of intracellular fluid and three compartments of extracellular fluid. Approximately two-thirds of the body’s water is contained in the intracellular fluid, the fluid portion of the cytoplasm of cells. The rest is extracellular fluid, which includes the intravascular fluid (the blood plasma), the cerebrospinal fluid, and the interstitial fluid. Interstitial means "standing between"; indeed, the interstitial fluid stands between our cells—it is the "seawater" that bathes them. For the purposes of this chapter we will ignore the cerebrospinal fluid and concentrate on the other three compartments. (See Figure 11.3.)

![An Outline of the System that Controls Drinking](image-url)
Two of the body's fluid compartments must be kept within precise limits: the intracellular fluid and the intravascular fluid. The intracellular fluid is controlled by the concentration of solutes in the interstitial fluid. (Solutes are the substances dissolved in a solution.) Normally, the interstitial fluid is isotonic (from isos, "equal," and tonsos, "tension") with the intracellular fluid. That is, the concentration of solutes in the cells and in the interstitial fluid that bathes them is balanced, so that water does not tend to move into or out of the cells. If the interstitial fluid loses water (becomes more concentrated, or hypertonic), water will be pulled out of the cells. On the other hand, if the interstitial fluid gains water (becomes more dilute, or hypotonic), water will move into the cells. Either condition endangers cells; a loss of water deprives them of the ability to perform many chemical reactions, and a gain of water can cause their membranes to rupture. Therefore, the concentration of the interstitial fluid must be closely regulated. (See Figure 11.4.)

The volume of the blood plasma must be closely regulated because of the mechanics of the heart's operation. If the blood volume falls too low, the heart can no longer pump the blood effectively; if the volume is not restored, heart failure will result. This condition is called hypovolemia, literally "low volume of the blood" (emia comes from the Greek haima, "blood"). The body's vascular system can make some adjustments for loss of blood volume by contracting the muscles in smaller veins and arteries, thereby presenting a smaller space for the blood to fill, but this correctional mechanism has definite limits.

The two important characteristics of the body fluids—the solute concentration of the intracellular fluid and the volume of the blood—are monitored by two different sets of receptors. A single set of receptors would not work because it is possible for one of these fluid compartments to be changed without affecting the other. For example, a loss of blood obviously reduces the volume of the intravascular fluid, but it has no effect on the volume of the intracellular fluid. On the other hand, a salty meal will increase the solute concentration of the interstitial fluid, drawing water out of the cells, but it will not cause hypovolemia. Thus, the body needs two sets of receptors, one measuring blood volume and another measuring cell volume.

Two Types of Thirst

As we just saw, for our bodies to function properly, the volume of two fluid compartments—intracellular and intravascular—must be regulated. Most of the time, we ingest more water and sodium than we need, and the kidneys excrete the excess. However, if the levels of water or sodium fall too low, correctional mechanisms—drinking water or ingesting sodium—are activated. Everyone is familiar with the sensation of thirst, which occurs when we need to ingest water. However, a salt appetite is much more rare because it is difficult for people not to get enough sodium in their diet, even if they do not put extra salt on their food. Nevertheless, the mechanisms to increase sodium intake exist, even though they are seldom called upon in members of our species.

Because loss of water from either the intracellular or intravascular fluid compartments stimulates drinking, researchers have adopted the terms osmometric thirst and volumetric thirst to describe them. The term volumetric is clear; it refers to the metering (measuring) of the volume of the blood plasma. The term osmometric requires more explanation, which will be provided in

isotonic Equal in osmotic pressure to the contents of a cell. A cell placed in an isotonic solution neither gains nor loses water.

hypertonic The characteristic of a solution that contains enough solute that it will draw water out of a cell placed in it, through the process of osmosis.

hypotonic The characteristic of a solution that contains so little solute that a cell placed in it will absorb water, through the process of osmosis.

hypovolemia (hy poh voh lee mee a) Reduction in the volume of the intravascular fluid.