9.1 Maintaining an Internal Balance

You learned in the unit opener that Ray Zahab endured great physical strain as he raced across the extreme environment of the Sahara Desert. However, there are many animals native to the Sahara Desert that thrive in these conditions using special adaptations. One example is the fennec fox (*Vulpes zerda*) (**Figure 1**). Its enormous ears serve two important functions that enable it to live in such a hostile habitat. First, the large ears enhance its hearing. This allows it to hear predators coming from far away, as well as hear prey, even when underground. The large ears also act as "radiators." As you learned in the Mini Investigation in the chapter opener, the greater the surface area is, the faster and more easily the temperature can be regulated downward. The fennec fox's radiator ears give it a large surface area to dissipate thermal energy faster. Maintaining an optimal internal temperature helps the fennec fox thrive in temperatures that range from below 0 °C to above 50 °C. The maintenance of the body's internal conditions is called homeostasis. In this unit, you will be examining homeostasis in animals.

Figure 1 The large ears of a fennec fox act as "radiators" to dissipate thermal energy in the hot Sahara Desert.

homeostasis the physiological state of the body in which internal physical and chemical conditions are kept within a range that is suitable for life processes

Homeostasis is the physiological state of the body in which the internal physical and chemical conditions are maintained within an acceptable or tolerable range that is suitable for essential biological processes. Homeostasis is not a "steady state" or a constant condition, but rather a dynamic process that is continuously adjusted in response to changes in the internal or external environment. For example, the body must maintain its optimal range of conditions during exercise, fatigue, and extremes of temperature.

Imagine the body's internal conditions as a car engine that can never be turned off. The engine must be constantly fuelled to run properly. It may need to have coolant and oil added occasionally to maintain its proper operating conditions. Sometimes, parts such as the alternator need to be replaced to recharge the batteries. Like the human body, a car engine also has several built-in diagnostic tools. These tools, such as the thermostat and computer, are used to address any issues that may impede proper operations. When the negative issues are addressed, proper operations can be restored.

Similarly, the body has several key parts, fluids, and conditions that must be monitored and adjusted for the body's homeostasis, or proper operations, to be maintained. These include internal temperature; hormone levels; and the pressure, pH, flow, and concentration of glucose and other solutes in the blood. For some factors, such as the blood pH and internal temperature, the tolerable range is fairly narrow. In others, such as blood flow, glucose levels, and hormone levels, the tolerable range is broader and there can be considerable variation without harmful consequences.

In this section, you will explore answers to the following questions: What is homeostasis? What does "internal balance" really mean? What body systems are involved in maintaining this balance?

The Internal Environment

The purpose of homeostasis is to maintain internal physical and chemical conditions that are appropriate for the cells to function properly. The **internal environment** refers to the extracellular fluid, which consists of the **interstitial fluid** that fills the spaces between our cells and tissues, and the plasma or fluid portion of our blood. A typical adult has 15 L of extracellular fluid, which constitutes approximately 20 % of our body's mass. When discussing homeostasis, we do not include the intracellular fluid (the fluid inside of the cells). Instead, we focus on the fluid outside of the cells.

internal environment the extracellular fluid, which consists of the fluid that surrounds the cells and tissues in the body and the plasma portion of the blood

interstitial fluid the fluid that surrounds the body cells

Every cell in the body is surrounded by the extracellular fluid, which acts as a medium for delivering energy, transporting chemicals, and eliminating waste. The regulated flow of energy, chemicals, and waste into and out of the extracellular fluid allows the cells to function properly. When the cells function properly, the tissues, organs, and organ systems, and thus the whole organism, can thrive.

The volume, temperature, and chemical composition of our internal environment can change quickly. Rigorous physical activity, other extreme conditions, and even infection can tip the balance that is maintained in the extracellular fluid. These changes can have a dramatic (often negative) effect on cellular functions, so the body uses many systems to maintain and regulate its internal conditions. CAREER LINK

Organ Systems Involved in Homeostasis

Establishing and maintaining homeostasis requires the work of a complex set of activities and processes. There are numerous organs and organ systems that are directly involved in homeostasis (**Figure 2**).

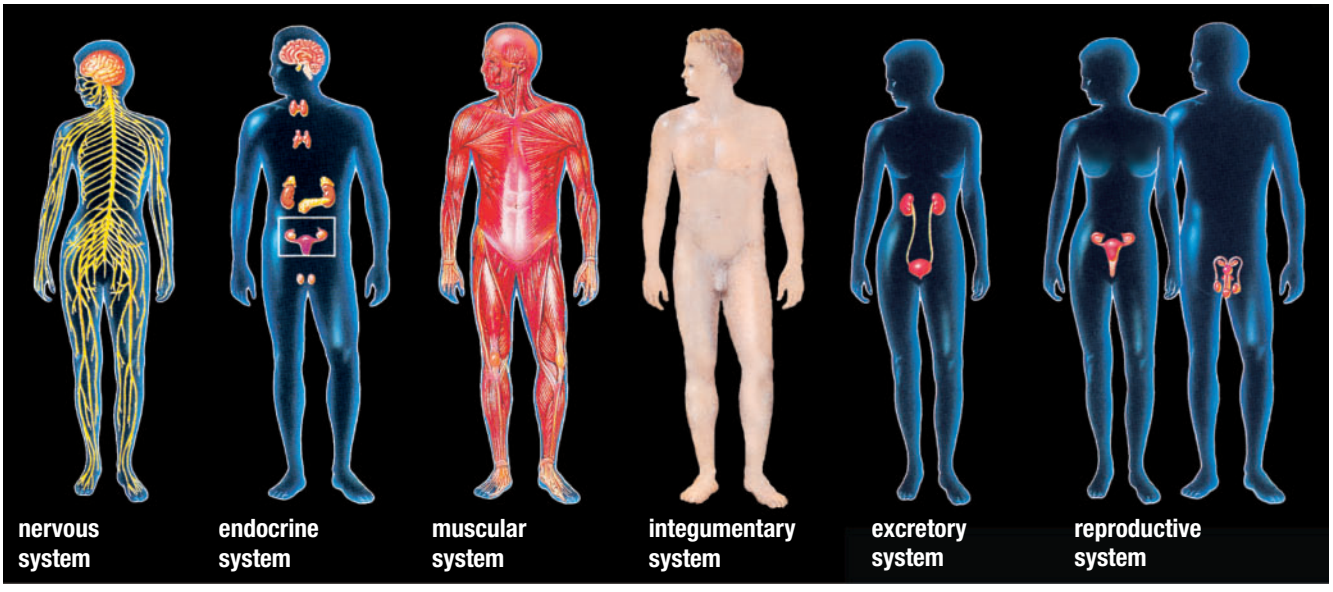

Figure 2 This diagram shows some of the organ systems in the human body. All of the organ systems play a role in maintaining homeostasis in the internal environment.

The nervous system (Chapter 11) receives sensory data from the environment, which informs the body of external conditions and transmits signals throughout the body to regulate homeostasis. The excretory system (Section 9.5) works to rid the body of waste and maintain a clean internal environment. The endocrine system (Chapter 10) regulates the levels of various hormones that are essential to life processes, and the circulatory system carries these hormones and other chemicals throughout the body and distributes thermal energy. The immune system protects the body from infection and also fights infection. The liver—an organ that is part of the digestive system—has several roles in maintaining homeostasis. For example, the liver controls amino acid levels by breaking down any amino acids that are not used, detoxifying harmful chemicals (such as alcohol), and manufacturing important blood proteins. The integumentary system, or skin, is important for maintaining a constant body temperature, since it is in constant contact with the external environment.

The cells within these tissues and organs carry out basic metabolic activities that contribute to the function of each organ system as a whole. All of the organ systems are coordinated to carry out the tasks necessary for the survival of the organism. No matter how simple or complex the animal, these functions include

- taking in nutrients and other required chemicals (such as oxygen) from the environment, processing and distributing them throughout the body, and disposing of the waste
- synthesizing proteins, fats, carbohydrates, and other molecules that are essential for cellular function and structure
- sensing and responding to changes in the external environment, such as temperature, physical sensations, and pH
- protecting the body from injury and from infection by viruses, bacteria, and other disease-causing agents
- reproducing, and protecting and feeding offspring

Together these tasks maintain homeostasis within the body. Their functions and activities make up most of an animal's actions during its life, because maintaining an internal dynamic equilibrium is the only way that life can continue.

The endocrine and nervous systems are the most important systems for maintaining homeostasis. (You will study these systems in detail in Chapters 10 and 11.) For example, oxygen and carbon dioxide concentrations are regulated by the nervous system, blood glucose is mainly regulated by the endocrine system, and blood pH and internal temperature are regulated by both systems. These are only a few of the many **homeostatic mechanisms** that are responsible for maintaining homeostasis by responding to changes in either the internal environment or the external environment. To understand how homeostatic mechanisms work, consider the regulation of body temperature. When the body's internal temperature is too high, we sweat; the evaporation of sweat from our skin is an endothermic process, so the body experiences a net loss of thermal energy absorbed by the water during this change of state. When we are cold, we shiver; these tiny muscle contractions generate thermal energy and raise the internal temperature. Even the sensations of hunger and thirst are mechanisms that trigger behavioural responses to ensure the adequate nutrition and hydration of an animal.

homeostatic mechanism a system that monitors internal and external conditions and changes bodily functions to maintain homeostasis

Since homeostatic mechanisms respond to internal and external conditions, they are described as detection-correction or feedback systems. In the next section, you will take a closer look at how the elements of homeostatic mechanisms use information about internal or external conditions to maintain homeostasis.

9.1 Review

Summary

- Homeostasis is the process by which animals and plants maintain an internal environment that promotes proper cellular function.
- Homeostasis is an ongoing dynamic process that acts in response to both internal and external conditions.
- The body's internal environment consists of the interstitial fluid that surrounds cells and tissues, and the plasma in the blood.
- Numerous organs and organ systems coordinate their activities to maintain homeostasis; however, the nervous and endocrine systems are the most important systems.

Questions

1. Explain the meaning of homeostasis, and give an example of how homeostasis occurs in the body. K/U
2. Why is homeostasis not considered to be a "constant" condition? Be specific in your response. K/U
3. List the body's responses to being too hot or too cold. What are some of the organ systems that may be involved in these responses? K/U
4. Suggest some situations in which it may be better if the body does not maintain homeostasis. (Think of specific chemicals or conditions within the body.) A
5. Diabetes, a disease that disrupts the blood glucose homeostasis, can be lethal if not monitored and maintained. Research and describe how humans artificially maintain their blood glucose levels. T/I
6. In the car analogy, there were several examples of diagnostic tools that the car uses to maintain homeostasis (**Figure 3**). What are some examples of diagnostic tools in the body? K/U

Figure 3

7. Explain how cruise control on a vehicle is a good metaphor for homeostasis. K/U A
8. The fennec fox is a member of the dog family (*Canidae*) (Figure 1, page 428). K/U T/I
   (a) Using the Internet and other resources, research how other members of the dog family maintain temperature homeostasis.
   (b) Does what you have learned about the fennec fox provide you with any insights about the size and shape of an elephant's ears? Explain.
9. Why does the body sometimes go outside normal homeostasis ranges? T/I
10. Certain molecules in the muscular system must be maintained in a homeostatic range for the muscles to operate properly. What symptoms might indicate that these molecules are outside of the normal range? T/I
11. Explain the relationship of the terms "regulation" and "feedback" to the concept of homeostasis. K/U
12. Every year some deaths are linked to vigorous exercise or exertion in hot, humid conditions. What are the body's homeostatic mechanisms for heat and humidity? Why do you think these mechanisms do not always work? K/U T/I

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