A SYSTEM IS A NETWORK of relationships among parts, elements, or components that interact with and influence one another through the exchange of energy, matter, or information. Systems receive inputs of energy, matter, or information; process these inputs; and produce outputs of energy, matter, or information.

Earth’s environment consists of complex, interlinked systems. Earth’s systems include the complex webs of relationships among species and the interactions of living organisms with the nonliving objects around them. Earth’s systems also include cycles that shape landscapes and guide the flow of chemical elements and compounds that support life and regulate climate.

Interacting Systems

An output of one of Earth’s systems is often also an input to that or another system.

Systems seldom have well-defined boundaries, so deciding where one system ends and another begins can be difficult. Consider a desktop computer system. What are its boundaries? Is the system made up of just what arrives in the shipping box and sits on your desk? Or does it also include the network you connect it to? What about the energy grid you plug it into, with its distant power plants and transmission lines—is that part of the system, too? Does the system include the Internet?

Whenever we try to define a system, we run into connections to other systems. Systems may exchange energy, matter, and information with other systems, and they may contain or be contained within other systems. So the boundaries we draw for a system usually depend on our focus at the moment. In our discussions of Earth’s systems then, you may infer connections to other systems that are not being discussed at the moment. Don’t worry—we’ll get to them.
Earth’s Systems Inputs into Earth’s systems include energy, information, and matter. Energy inputs to Earth’s environmental systems include solar energy as well as energy released by geothermal activity, the life processes of organisms, and human activities such as fossil fuel combustion. Information inputs can come in the form of sensory cues or genes. Inputs of matter occur when chemicals or physical materials move among systems, such as when seeds are dispersed long distances or when plants convert carbon in the air to living tissue via photosynthesis.

For example, as a system, the Gulf of Mexico receives inputs of fresh water, sediments, nutrients, and pollutants from the Mississippi and other rivers. Shrimpers and fishers harvest some of the Gulf system’s output: matter and energy in the form of shrimp and fish (Figure 11). This output then becomes input to the global economic system and to the digestive systems of the many people who consume the shrimp and fish.

Feedback Loops Sometimes an event is both a cause, or input, and an effect, or output, in the same system, a cyclical process called a feedback loop. A feedback loop can be either negative or positive.

▶ Negative Feedback Loops In a negative feedback loop (Figure 12), the output of a system moving in one direction acts as input that causes the system to move in the other direction. Input and output respond to each other’s effects, canceling them out and stabilizing the system.

A thermostat, for example, stabilizes a room’s temperature by turning the furnace on when the room gets cold and shutting it off when the room gets hot. One environmental example of negative feedback is a system in which predator and prey populations—wolves and moose, for example—rise and fall in response to each other. Most systems in nature involve negative feedback loops. Negative feedback loops enhance stability, and in the long run, only stable systems persist.

ANSWERS

Reading Checkpoint What would you call a process in which an event is both an input and output of the same system?

FIGURE 11 Earth’s Systems The shrimp caught by this shrimper are an output of the Gulf of Mexico system. The shrimp will become inputs for several human systems.

FIGURE 12 Negative Feedback Loop Negative feedback loops stabilize systems and are common in nature. The human body’s responses to heat and cold involve a negative feedback loop.

**FIGURE 13 Positive Feedback Loop**
Positive feedback loops destabilize systems and push them toward extremes. For example, the clearing of plants from land can lead to uncontrolled soil erosion. Water flowing through an eroded ditch may expand it and lead to further erosion. Positive feedback loops are rare in natural systems, but common in systems altered by humans, such as on land that has been grazed too much by livestock.

**Positive Feedback Loops** Positive feedback loops have the opposite effect of negative feedback loops. Rather than stabilizing a system, they drive it toward an extreme. Erosion, the removal of soil by water, wind, ice, or gravity, can lead to a positive feedback loop. Once plants have been cleared from an area and soil is exposed, erosion may increase if the effects of water or wind surpass the rate of plant regrowth (Figure 13). (You will learn more about erosion in a later chapter.) Because positive feedback destabilizes a system and drives it toward an extreme, it can alter a system drastically. This may be the reason that positive feedback loops are relatively rare in natural environmental systems. They are, however, common in environmental systems changed by people.

**Earth’s “Spheres”**
Earth’s geosphere, lithosphere, biosphere, atmosphere, and hydrosphere are defined according to their functions in Earth’s systems.

Despite the challenges discussed earlier, categorizing Earth’s environmental systems can help make Earth’s complexity and environmental issues easier to understand. So scientists often divide Earth into spheres, some of which are described more by their makeup than by their location (Figure 14). Earth’s **geosphere** is made of all the rock at and below Earth’s surface. The **lithosphere** is the hard rock on and just below Earth’s surface—the outermost layer of the geosphere. The **biosphere** consists of all the planet’s living or once-living things and the nonliving parts of the environment with which they interact. The **atmosphere** consists of the layers of gases surrounding our planet. The **hydrosphere** encompasses all water—salt, fresh, liquid, ice, and vapor—on Earth’s surface, underground, and in the atmosphere. You will learn more about Earth’s spheres in the next lesson.

**ANSWERS**

**Reading Checkpoint** All living and once-living things as well as the nonliving parts of the environment with which they interact.

**What are the components of the biosphere?**

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Although these spheres are useful models, keep in mind that they both overlap and interact. For example: Picture a robin plucking an earthworm from the ground after a rainstorm and then flying to a tree. You are witnessing the robin (an organism) eating the earthworm (another organism) that has been tunneling through the soil (the lithosphere)—all made possible because rain (from the hydrosphere) has dampened the ground. The robin might then fly through the air (the atmosphere) and land in a tree (another organism), in the process respiring (combining oxygen from the atmosphere with glucose from the organism, and adding water to the hydrosphere and carbon dioxide and heat to the atmosphere). Finally, the bird might release waste, adding nutrients to the soil (the lithosphere). And it all takes place in the biosphere. The study of the complex interactions in such apparently simple events is typical of environmental science.

ANSWERS
Lesson 2 Assessment
1. Negative and positive. Similar: inputs of the cycle are also outputs of the cycle; different: negative feedback loops stabilize a system and are common in natural systems, while positive feedback loops destabilize a system and are rare in natural systems.
2. Mud contains components from the lithosphere (soil), the hydrosphere (water), and the biosphere (living things).
3. Yes; positive feedback. As snow melts, more dark surface becomes exposed and absorbs more heat. The more heat it absorbs, the more the snow melts, exposing more of the dark surface.

LESSON 2 Assessment

1. **Compare and Contrast** What are the two types of feedback loops? How are they similar? How are they different?
2. **Classify** Suppose your lab partner were to empty a beaker of mud onto your lab table and ask you which of Earth’s spheres it was part of. How would you answer? Explain.
3. **THINK IT THROUGH** As snow melts on a city street, it exposes some darker-colored pavement. Dark-colored surfaces absorb more sunlight and heat than light-colored surfaces. Would you expect a feedback process to result from this situation? If so, which type? Explain your answer.