Name **Hour**

Energy in the Earth System

Earth System Science

1. What is a system?

2. What is matter?

3. What is energy?

Open Systems

4. What is an open system?

5. Give an example of an open system

Closed Systems

6. What is an closed system?

7. Give an example of an closed system

Earth's Energy Budget

8. What does the First Law of Thermodynamics state?

9. What does the Second Law of Thermodynamics state?

Traditionally, different fields of Earth science have been studied separately. Geologists studied Earth's rocks and interior, oceanographers studied the oceans, and meteorologists studied the atmosphere. But now, some scientists are combining knowledge of several fields of Earth science in order to study Earth as a system.

Earth-System Science

An organized group of related objects or components that interact to create a whole is a **system.** Systems vary in size from subatomic to the size of the universe. All systems have boundaries, and many systems have matter and energy that flow through them. Even though each system can be described separately, all systems are linked. A large and complex system, such as the Earth system, operates as a result of the combination of smaller, interrelated systems, as shown in **Figure 1.**

system a set of particles or interacting components considered to be a distinct physical entity for the purpose of study

The operation of the Earth system is a result of interaction between the two most basic components of the universe: matter and energy. *Matter* is anything that has mass and takes up space. Matter can be atoms or molecules, such as oxygen atoms or water molecules, and matter can be larger objects, such as rocks, living organisms, or planets. *Energy* is defined as the ability to do work. Energy can be transferred in a variety of forms, including heat, light, vibrations, or electromagnetic waves. A system can be described by the way that matter and energy are transferred within the system or to and from other systems. Transfers of matter and energy are commonly accompanied by changes in the physical or chemical properties of the matter.

Figure 1 This threadfin butterflyfish is part of a system that includes other living organisms, such as coral. Together, the organisms are part of a larger system, a coral reef system in Micronesia.

in both the open system (left) and the closed system (right). In the open system, matter is also exchanged.

Open Systems

An *open system* is a system in which both energy and matter are exchanged with the surroundings. The open jar in **Figure 2** is an open system. A lake is also an open system. Water molecules enter a lake through rainfall and streams. Water exits a lake through streams, evaporation, and absorption by the ground. Sunlight and air exchange heat with the lake. Wind's energy is transferred to the lake as waves.

Closed Systems

A *closed system* is a system in which energy, but not matter, is exchanged with the surroundings. The sealed jar in **Figure 2** is a closed system. Energy in the form of light and heat can be exchanged through the jar's sides. But because the jar is sealed, matter cannot exit or enter the system. Most aquariums are open systems because oxygen and food must be added to them, but some are closed systems. Closed-system aquariums contain a variety of organisms: plants, which produce oxygen, and aquatic animals, some of which are food for others. Some of the animals feed on the plants. Animal wastes and organic matter nourish the plants. Only sunlight enters from the surroundings.

The Earth System

Technically, all systems that make up the Earth system are open. But the Earth system is almost a closed system because matter exchange is limited. Energy enters the system in the form of sunlight and is released into space as heat. Only a small amount of dust and rock from space enters the system, and only a fraction of the hydrogen atoms in the atmosphere escape into space.

Reading Check **What types of matter and energy are exchanged between Earth and space?**

Earth's Four Spheres

Matter on Earth is in solid, liquid, and gaseous states. The Earth system is composed of four "spheres" that are storehouses of all of the planet's matter. These four spheres are shown in **Figure 3**.

The Atmosphere

The blanket of gases that surrounds Earth's surface is called the **atmosphere**. The atmosphere provides the air that you breathe and shields Earth from the sun's harmful radiation. Earth's atmosphere is made up of 78% nitrogen and 21% oxygen. The remaining 1% includes other gases, such as argon, carbon dioxide, and helium.

The Hydrosphere

Water covers much of Earth's surface, and 97% of this water is contained in the salty oceans. The remaining 3% is fresh water. Fresh water can be found in lakes, rivers, and streams, frozen in glaciers and the polar ice sheets, and underground in soil and bedrock. All of Earth's water makes up the **hydrosphere**.

The Geosphere

The mostly solid part of Earth is known as the **geosphere**. This sphere includes all of the rock and soil on the surface of the continents and on the ocean floor. The geosphere also includes the solid and molten interior of Earth, which makes up the largest volume of matter on Earth. Natural processes, such as volcanism, bring matter from deep inside Earth's interior to the surface. Other processes move surface matter back into Earth's interior.

atmosphere a mixture of gases that surrounds a planet, moon, or other celestial body

hydrosphere the portion of the Earth that is water

geosphere the mostly solid, rocky part of the Earth; extends from the center of the core to the surface of the crust

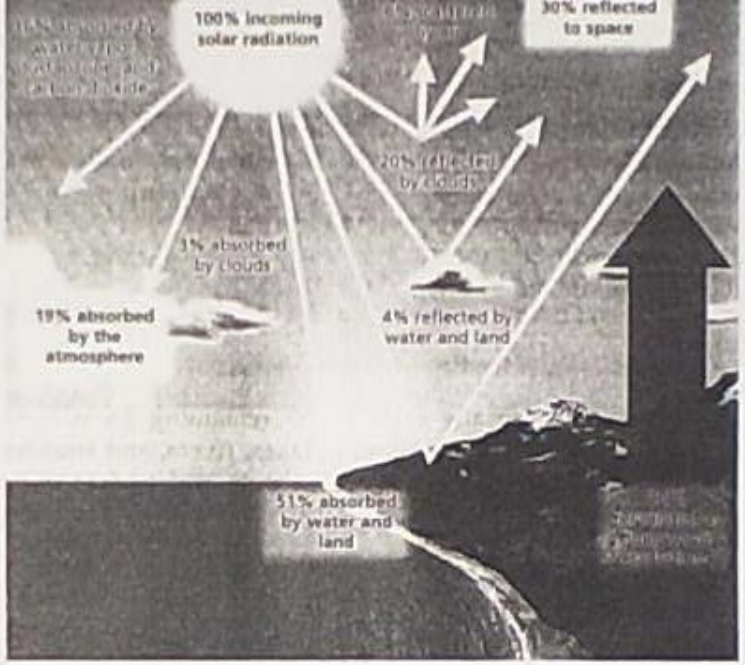
biosphere the part of Earth where life exists; includes all of the living organisms on Earth

Figure 3 The Earth system is composed of the atmosphere, hydrosphere, geosphere, and biosphere. *Can you identify elements of the four spheres in this photo?*

The Biosphere

Another one of the four subdivisions of the Earth system is the biosphere. The **biosphere** is composed of all of the forms of life in the geosphere, in the hydrosphere, and in the atmosphere. The biosphere also contains any organic matter that has not decomposed. Once organic matter has completely decomposed, it becomes a part of the other three spheres. The biosphere extends from the deepest parts of the ocean to the atmosphere a few kilometers above Earth's surface.

systems.



Earth's Energy Budget

Exchanges and flow of energy on Earth happen in predictable ways. According to the *first law of thermodynamics*, energy is transferred between systems, but it cannot be created or destroyed. The transfers of energy between Earth's spheres can be thought of as parts of an *energy budget*, in which additions in energy are balanced by subtractions. This concept is shown in **Figure 4**, which shows how solar energy is transferred through Earth's systems. Solar energy is absorbed and reflected in such a way that the solar energy input is balanced by the solar energy output. Like energy, matter can be transferred but cannot be created or destroyed.

The *second law of thermodynamics* states that when energy transfer takes place, matter becomes less organized with time. The overall effect of this natural law is that the universe's energy is spread out more and more uniformly over time.

Earth's four main spheres are open systems that can be thought of as huge storehouses of matter and energy. Matter and energy are constantly being exchanged between the spheres. This constant exchange happens through chemical reactions, radioactive decay, the radiation of energy (including light and heat), and the growth and decay of organisms.

Reading Check **Define *energy budget*.**