

Earth's Four "Spheres" Earth's surface is a vast area of 500 million km² (193 million mi²) where four immense open systems interact. The three **abiotic**, or nonliving, systems overlap as the framework for the realm of the **biotic**, or living, system. The abiotic spheres are the *atmosphere*, *hydrosphere*, and *lithosphere*. The biotic sphere is the *biosphere*. Together, these spheres form a simplified model of Earth systems.

- **Atmosphere (Part I, Chapters 2–4)** The **atmosphere** is a thin, gaseous veil surrounding Earth, held to the planet by the force of gravity. Formed by gases arising from within Earth's crust and interior and the exhalations of all life over time, the lower atmosphere is unique in the Solar System. It is a combination of nitrogen, oxygen, argon, carbon dioxide, water vapor, and trace gases.
- **Hydrosphere (Part II, Chapters 5–8)** Earth's waters exist in the atmosphere, on the surface, and in the crust near the surface. Collectively, these waters form the **hydrosphere**. That portion of the hydrosphere that is frozen is the **cryosphere**—ice sheets, ice caps and fields, glaciers, ice shelves, sea ice, and subsurface ground ice. Water of the hydrosphere exists in three states: liquid, solid (the frozen cryosphere), and gaseous (water vapor). Water occurs in two general chemical conditions, fresh and saline (salty).
- **Lithosphere (Part III, Chapters 9–14)** Earth's crust and a portion of the upper mantle directly below the crust form the **lithosphere**. The crust is quite brittle compared with the layers deep beneath the surface, which move slowly in response to an uneven distribution of heat energy and pressure. In a broad sense, the term *lithosphere* sometimes refers to the entire solid planet. The soil layer is the *edaphosphere* and generally covers Earth's land surfaces. In this text, soils represent the bridge between the lithosphere (Part III) and biosphere (Part IV).
- **Biosphere (Part IV, Chapters 15–17)** The intricate, interconnected web that links all organisms with their physical environment is the **biosphere**, or **ecosphere**. The biosphere is the area in which physical and chemical factors form the context of life. The biosphere exists in the overlap of the three abiotic, or nonliving, spheres, extending from the seafloor, the upper layers of the crustal rock, to about 8 km (5 mi) into the atmosphere. Life is sustainable within these natural limits. The biosphere evolves, reorganizes itself at times, undergoes extinctions, and manages to flourish.

Within each part, the sequence of chapters generally follows a systems flow of energy and materials.

Each of the four part-opening page spreads summarizes the main system linkages; these diagrams are presented together in Geosystems in Action 1. As an example of our systems organization, Part I, "The Energy–Atmosphere System," begins with the Sun (Chapter 2). The Sun's energy flows across space to the top of the atmosphere and through the atmosphere to Earth's surface, where it is balanced by outgoing energy from Earth (Chapters 2 and 3). Then we look at system outputs of temperature (Chapter 3) and winds and ocean currents (Chapter 4). Note the same logical systems flow in the other three parts of this text.

Mount Pinatubo—Global System Impact A dramatic example of interactions between Earth systems in response to a volcanic eruption illustrates the strength of the systems approach used throughout this textbook. Mount Pinatubo in the Philippines erupted violently in 1991, injecting 15–20 million tons of ash and sulfuric acid mist into the upper atmosphere (see photos in GIA 1). This was the second greatest eruption during the 20th century; Mount Katmai in Alaska in 1912 was the only one greater. The eruption materials from Mount Pinatubo affected Earth systems in several ways, as noted on the map. For comparison, the 2010 eruption of Eyjafjallajökull in Iceland was about 100 times smaller in terms of the volume of material ejected, with debris reaching only the lower atmosphere.

As you progress through this book, you see the story of Mount Pinatubo and its implications woven through six chapters: Chapter 1 (discussion of systems theory), Chapter 3 (effects on energy budgets in the atmosphere), Chapter 4 (satellite images of the spread of debris by atmospheric winds), Chapter 8 (temporary effect on global atmospheric temperatures), Chapter 10 (volcanic processes), and Chapter 16 (effects on net photosynthesis). These discussions help us see the linkages and global impacts of such a volcanic explosion.

Location and Time on Earth

Earth's *sphericity*, or roundness, was first determined more than two millennia ago by the Greek mathematician and philosopher Pythagoras (ca. 580–500 B.C.). The idea of a spherical rather than a flat Earth was generally accepted by the educated populace as early as the first century A.D. Christopher Columbus, for example, knew he was sailing around a sphere in 1492; this is one reason why he thought he had arrived in the East Indies.

Until 1687, the spherical-perfection model was a basic assumption of **geodesy**, the science that determines

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GEOREPORT 1.2 Earth's unique hydrosphere

The hydrosphere on Earth is unique among the planets in the Solar System: Only Earth possesses surface water in such quantity, some 1.36 billion km³ (0.33 billion mi³). Subsurface water exists on other planets and their satellites—on the Moon and on the planets Mercury and Mars, on Jupiter's moon Europa, and on Saturn's moons Enceladus and Titan. The Curiosity rover in 2012 landed in an area of Mars that billions of years ago was flooded with waist-deep water.