Chapter 1 Introduction to Earth Science

The chapter *Introduction to Earth Science* opens by listing and describing what sciences comprise the encompassing heading of Earth science. These include geology, oceanography, meteorology, astronomy, and environmental science. It goes on to introduce the concept of scales of space and time. The nature of scientific inquiry is discussed. The chapter explains the origins and creation of the Earth and solar system while noting the differences in how the inner and outer planets formed. Earth's four major spheres are addressed. These spheres are the hydrosphere, atmosphere, biosphere, and geosphere. The chapter looks at Earth's internal structure from both a physical properties and a chemical composition point of view. This leads to the concept of plate tectonics and a brief introduction to plate boundary types. A quick overview of the difference between major continental features and major oceanic features follows. The chapter wraps up by discussing how and why Earth is a system, citing examples of feedback loops and how people interact with the Earth system.

FOCUS ON CONCEPTS

After reading, studying, and discussing the chapter, students should be able to:

1.1 List and describe the sciences that collectively make up Earth science. Discuss the scales of space and time in Earth science.
1.2 Discuss the nature of scientific inquiry and distinguish between a hypothesis and a theory.
1.3 Outline the stages in the formation of our solar system.
1.4 List and describe Earth's four major spheres.
1.5 Label a diagram that shows Earth's internal structure. Briefly explain why the geosphere can be described as being mobile.
1.6 List and describe the major features of the continents and ocean basins.
1.7 Define *system* and explain why Earth is considered to be a system.

STRATEGIES FOR TEACHING EARTH SCIENCE

Chapter 1 is meant to be an introductory chapter. Use this chapter to highlight topics in which you have particular expertise or that you expect to cover in more detail throughout the course. Since it is meant to be an overview of Earth science, avoid the pitfall of going into great detail about each topic at the beginning of your course when students are reading this chapter. Give students the general idea of what they will encounter during the course. It may be useful to point out which chapters explore particular topics in more detail for the coming weeks.

- Pose the question, "What is Earth science?" Consider having students discuss this question with others seated near them and asking for collective answers. This is also a good icebreaker for the start of a course, so that students may meet others in the class.
- Have students brainstorm, either individually or in small groups, ways that Earth science affects them. Have them think of how they impact the Earth.
- Use a visual aid to help students grasp the concept of geologic time. Construct a toilet paper geologic time scale prior to class (see Additional Resources). This generates student interest and shows the

vastness of geologic time in a concrete way. Alternatively, have students construct their own calculator tape time scale (also in Additional Resources) for a more interactive experience.

- Make a list of statements where some are hypotheses and some are theories but don't tell the students which are which. Present these to the class and have students make their own decisions about which statements are hypotheses and which are theories. Reveal the correct answers and discuss what makes a statement a hypothesis or a theory. Students retain the information better if they've tried to figure it out before you've actually presented it.
- When discussing the origins of the solar system, stress the differences between the inner and outer planets; the inner planets are terrestrial whereas the outer planets are gaseous.
- Before introducing Earth's spheres, have students come up with lists of features that are naturally a part of Earth. They may be surprised at the things they did not think of (or did think of) as part of the study of Earth science.
- Save the detailed discussion of Earth's interior structure for later when it is covered in more detail in the book. However, it may be useful to bring a hardboiled egg and slice it in half. Use the analogy that the shell of the egg approximates the thickness of Earth's crust, so that students see how thin a layer it is.
- Introduce students to the idea that continental crust and oceanic crust are two different rock types. Ask students to describe some of the more notable features of continents and ocean basins.
- Be sure to use visuals when describing introductory plate tectonics. At this stage illustrations and diagrams from the text should suffice. Video clips and animations will be useful later.
- When introducing the concept that Earth is a system, have students come up with their own ideas of what constitutes a system. Relate a few of those ideas back to the Earth system, stressing the interconnectedness of everything.

Teaching Strategy Summary for Chapter 1
Keep it basic and introductory. Give students a glimpse at the course ahead of them. Get students involved in thinking about concepts rather than just presenting the ideas as slides or notes. Students will feel more ownership over the course material if you give them opportunities to think about a topic before you lecture on it.

CONCEPT CHECK ANSWERS

Concept Check 1.1

1. List and briefly describe the sciences that collectively make up Earth science.

- Geology – this is the study of the solid Earth. Physical geology examines the materials that comprise the Earth and historical geology aims to understand the origins and development of the planet.
- Oceanography – examines the composition and dynamics of the world's oceans. It also involves the study of coastal processes and seafloor topography as well as marine life.
- Meteorology – this is the study of Earth's atmosphere. It includes weather and climate.
- Astronomy – this examines Earth as a body in space, both as part of the solar system and as part of a larger universe.
- Environmental science – includes the study of natural resources, environmental hazards, and how people influence their environments and Earth processes.

2. **Name the two broad subdivisions of geology and distinguish between them.**
    - Physical geology – this is the study of the materials and processes that define the planet Earth. It includes the study of Earth's composition, events such as volcanism, and the dynamics of Earth processes such as plate tectonics.
    - Historical geology – this is the study of the origins and evolution of Earth. It pieces together a chronological history of Earth based on clues in the rock record. These clues can include evidence of physical and biological changes throughout Earth's 4.6 billion year history.

3. **List at least four different natural hazards.**
    - Earthquakes
    - Volcanoes
    - Floods
    - Tsunami
    - Hurricanes
    - Landslides

4. **Aside from natural hazards, describe another important connection between people and Earth science.**
    Humans influence Earth by altering its surface. People build cities and roads, and engineer projects that alter river flooding patterns. People pollute the air, the land, and the water, changing Earth from what is its natural state.

5. **List two examples of size/place scales in Earth science that are at opposite ends of the spectrum.**
    - A lightning flash happens within a fraction of a second but can instantly alter the immediate landscape.
    - Uplift of mountain ranges takes tens to hundreds of millions of years to occur.

6. **How old is Earth?**
    4.6 billion years old.

7. **If you compress geologic time into a single year, how much time has elapsed since Columbus arrived in the New World?**
    3 seconds.

<u>Concept Check 1.2</u>

1. **How is a scientific hypothesis different from a scientific theory?**
    A hypothesis is an untested explanation for an observed phenomenon. It requires further observation or testing to see if it is valid. A theory is generally accepted by the scientific community as the best explanation for observable facts, as it has been subjected to rigorous scrutiny and tested repeatedly.

2. **Summarize the basic steps followed in many scientific investigations.**
    - An observation is made about the natural world.
    - Data surrounding that observation are collected.
    - A working hypothesis is developed.
    - More observations and/or experiments are performed to test the hypothesis.
    - The hypothesis is accepted, rejected, or modified.
    - Data and results are shared with the scientific community for critical analysis and further testing.

Concept Check 1.3

1. **Name and briefly outline the theory that describes the formation of our solar system.**
   The nebular theory states that the early solar system originated as a cloud of dust and gas about 5 billion years ago as a star gravitationally collapsed. This rotating nebular cloud eventually contracted into a flattened, rotating disk. The cloud cooled and heavier metallic and rocky material condensed and accreted into the inner planets. The outer planets formed from residual gases and ices in the outer nebular cloud.

2. **List the inner planets and the outer planets. Describe basic differences in size and composition**.
   Inner planets: Mercury, Venus, Earth, and Mars. These planets are relatively small and rocky; they are made up largely of metals and silicate minerals.
   Outer planets: Jupiter, Saturn, Uranus, and Neptune. These planets are much larger than the inner planets and are composed of ices and gases.

Concept Check 1.4

1. **List Earth's four spheres.**
   - Atmosphere
   - Hydrosphere
   - Biosphere
   - Geosphere

2. **Compare the height of the atmosphere to the thickness of the geosphere.**
   The atmosphere is a very thin layer compared to the planet itself. The radius of the solid Earth is about 6400 km (4000 mi) whereas the entire atmosphere is roughly 160 km (100 mi) thick.

3. **How much of Earth's surface do oceans cover? How much of the planet's total water supply do oceans represent?**
   Oceans cover 70% of the planet. They account for 97% of Earth's water supply.

4. **To which sphere does soil belong?**
   Geosphere

Concept Check 1.5

1. **List and briefly describe Earth's compositional layers.**
   - Crust – this is the outermost layer of Earth. It is very thin and made up of oceanic and continental types of crust.
   - Mantle – this is a semi-molten, relatively thick layer of Earth. It is divided into the upper and lower mantle and its semi-fluid state allows for plate tectonics.
   - Core – this is at the center of Earth. The inner core is solid nickel and iron, whereas the outer core is liquid. It is the thickest of all Earth's structural layers.

2. **Contrast the lithosphere and the asthenosphere.**
   The lithosphere is the relatively cool, hard, outer shell of Earth's crust. The asthenosphere is relatively soft and has some melting in its upper layer. The different natures of these two layers, which are in contact with each other, is what allows for plate tectonics, where the hard lithosphere moves on the semi-fluid upper portion of the asthenosphere.

3. **What are lithospheric plates? List the three types of boundaries that separate plates.**
   Lithospheric plates are the broken up slabs of Earth's rigid outer shell, the lithosphere. The three types of plate boundaries are divergent, convergent, and transform fault.

Concept Check 1.6

1. **Contrast continents and ocean basins.**
   Continents are made of granitic rocks whereas oceans are made of basaltic rocks. Continents are less dense and thicker than ocean basins.

2. **Describe the general distribution of Earth's youngest mountains.**
   They are at the margins of continents.

3. **What is the difference between shields and stable platforms?**
   A shield is a large stable area of very old crystalline rock. A stable platform is a shield covered by sedimentary rock.

4. **What are the three major regions of the ocean floor and some features associated with each region?**
   - Continental margins – contains the continental shelf, the continental slope, and the continental rise. It is the boundary between continents and oceans.
   - Deep-ocean basins – these include the vast, flat abyssal plains of the ocean bottom. They also contain deep ocean trenches and seamounts in varied stages of erosion.
   - Oceanic ridges – these are divergent plate boundaries where new igneous rock is formed. These are vast winding ridges of underwater volcanic mountains that wind around the Earth.

Concept Check 1.7

1. **What is a system? List three examples of systems.**
   A system is a group of interacting, independent parts that make up a complex whole. Examples of systems include a city transportation system, a weather system, or an automotive cooling system.

2. **What are the two sources of energy for the Earth system?**
   The Sun and Earth's interior.

3. **Predict how a change in the hydrologic cycle, such as increased rainfall in an area, might influence the biosphere and geosphere in that area.**
   An increase in rainfall might affect the biosphere by changing the amount and types of vegetation found in that area. In turn, the vegetation change could alter the types of animals that inhabit the region. Increasing the rainfall could affect the geosphere by increasing erosion. Conversely, if vegetation increases also, the plants could be a stabilizing factor that decreases erosion.

GIVE IT SOME THOUGHT ANSWERS

1. **After entering a dark room, you turn on a wall switch, but the light does not come on. Suggest at least three hypotheses that might explain this observation. How would you determine which one of your hypotheses (if any) is correct?**
   - There is a local power outage.
   - The light source (bulbs, tubes, etc.) is "burned out" and no longer working.
   - The electricity to the room is not turned on or has been disconnected.

You can determine which of these is correct by testing the hypothesis. For example, you can replace the light bulb with a new one to see if it works. You can look at the circuit breakers and see if any of them are not on. You can call the electric company to see if service has been discontinued or if there are general power outages in your area.

2. **Each of the following statements may either be a hypothesis (H), a theory (T), or an observation (O). Use one of these letters to identify each statement. Briefly explain each choice.**
   a. **A scientist proposes that a recently discovered large ring-shaped structure on the Canadian Shield is the remains of an ancient meteorite crater.**
   b. **The Redwall Formation in the Grand Canyon is composed primarily of limestone.**
   c. **The outer part of Earth consists of several large plates that move and interact with each other.**
   d. **Since 1885, the terminus of Canada's Athabasca Glacier has receded 1.5 kilometers.**

   a. Hypothesis – it is a tentative explanation
   b. Observation
   c. Theory – well tested and widely accepted by the scientific community
   d. Observation – direct measurement of how far the glacier has moved

3. **Making accurate measurements and observations is a basic part of scientific inquiry. The accompanying radar image, showing the distribution and intensity of precipitation associated with a storm, provides one example. Identify another image in this chapter that illustrates a way in which scientific data are gathered. Suggest an advantage that might be associated with the example you select.**
   Figure 1.7 shows a paleontologist collecting fossils. An advantage of fossil data is that it is concrete and observable. Fossils can be used to tell about the past climate of an area and they can be used to help determine the age of the rocks in which it was found, and the ages of surrounding rocks.

4. **The length of recorded history for humankind is about 5000 years. Clearly, most people view this span as being very long. How does it compare to the length of geologic time? Calculate the percentage or fraction of geologic time that is represented by recorded history. To make calculations easier, round the age of Earth to the nearest billion.**
   5000/5,000,000,000= 0.000001%

5. **Refer to the graph in Figure 1.13 to answer the following questions.**
   a. **If you were to climb to the top of Mount Everest, how many breaths of air would you have to take at that altitude to equal one breath at sea level?**
      Air pressure at the top of Mount Everest is about 1/3 that at sea level, so you would need to take 3 breaths relative to sea level.
   b. **If you are flying in a commercial jet at an altitude of 12 kilometers (about 39,000 feet), about what percentage of the atmosphere's mass is below you?**
      About 75% of the atmosphere's mass is below you.

6. **Examine Figure 1.12 to answer these questions.**
   a. **Where is most of Earth's freshwater stored?**
      Glaciers
   b. **Where is most of Earth's liquid freshwater found?**
      Groundwater

7. **Jupiter, the largest planet in our solar system, is 5.2 astronomical units (AU) from the Sun. How long would it take to go from Earth to Jupiter if you traveled as fast as a jet (1000 kilometers/hour)? Do the same calculation for Neptune, which is 30 AU from the Sun. Referring to the GEOgraphics feature on page 15 will be helpful.**
   1 AU = 150 million km. 5.2 AU × 150,000,000 km = 780,000,000 km
   780,000,000 km × hour/1000 km = 780,000 hrs = 32,500 days = 89 years

   Neptune: 30 AU × 150 million km = 4.5 billion km
   4.5 billion km × hour/1000 km = 4,500,000 hours = 187,500 days = 513.7 years

8. **These rock layers consist of materials such as sand, mud, and gravel that, over a span of millions of years, were deposited by rivers, waves, wind, and glaciers. Each layer was buried by subsequent deposits and eventually compacted and cemented into solid rock. Later, the region was uplifted, and erosion exposed the layers seen here.**
   a. **Can you establish a relative time scale for these rocks? That is, can you determine which one of the layers shown here is likely oldest and which is probably youngest?**
   b. **Explain the logic you used.**
   The oldest rock is on the bottom and the youngest is on the top. Each layer was put down successively; therefore newer rock kept building upon the rock already in place.

EXAMINING THE EARTH SYSTEM ANSWERS

1. **This scene is in British Columbia's Mount Robson Provincial Park. The park is named for the highest peak in the Canadian Rockies.**
   a. **List as many examples as possible of features associated with each of Earth's four spheres.**
   Geosphere – mountains, rock
   Biosphere – trees, vegetation on slopes
   Hydrosphere – lake, ice on mountain slope
   Atmosphere – sky, clouds

   b. **Which, if any, of these features was created by internal processes? Describe the role of external processes in this scene.**
   The mountains were created by internal processes. Earth's internal heat engine is responsible for plate tectonics. Plate tectonics drives mountain building.
   External processes in this scene would include precipitation to create the lake and the water for the ice. Erosion would generate the soil for the trees to grow in. Erosion would also shape the rock features and mountains. Atmospheric temperature determines the state of matter of the water.

2. **Humans are a part of the Earth system. List at least three examples of how you, in particular, influence one or more of Earth's major spheres.**
   Answers will vary. Examples could include driving a car and putting pollution in the atmosphere, living in a home heated by natural gas taken from the Earth, eating food that requires clearing of forests to create cropland.

3. **The accompanying photo provides an example of interactions among different parts of the Earth system. It is a view of a debris flow (popularly called a mudslide) that was triggered by extraordinary rains. Which of Earth's four spheres were involved in this natural disaster, which buried a small town on the Philippine island of Leyte? Describe how each contributed to or was influenced by the event.**
   Geosphere – contains the soil that became mud flowing down the mountain. The geosphere is also part of the topography that created the mountain.

Atmosphere – heavy rains fell during an atmospheric event.
Biosphere – any vegetation growing on the slope or in the path of the mudslide will have been uprooted or destroyed.
Hydrosphere – water that fell to the earth saturated the soil and became part of the hydrosphere. The hydrosphere also contained the water that was evaporated and eventually became the rainfall that triggered this event.

4. **Examine the accompanying concept map that links the four spheres of the Earth system. All of the spheres are linked by arrows that represent processes by which the spheres interact and influence each other. For each arrow list at least one process.**
Atmosphere – Hydrosphere – Water evaporates from the hydrosphere into the atmosphere and water precipitates from the atmosphere to become part of the hydrosphere.
Hydrosphere – Geosphere – The geosphere creates the topography in which lakes, rivers, and ocean basins can form.
Geosphere – Biosphere – The geosphere contains the soil in which vegetation may grow.
Biosphere – Atmosphere – Plants transpire moisture into the atmosphere and they respire oxygen into the atmosphere.
Atmosphere – Geosphere – The atmosphere generates precipitation that can trigger erosion.
Hydrosphere – Biosphere – The hydrosphere contains ground water that allows growth of vegetation.

DISCUSSION TOPICS

- Why study Earth science?
- Do you think the scientific method is an exact recipe that scientists follow or more of a set of guidelines for investigation? Explain your reasoning.
- Why do we make a distinction between the different "spheres" of Earth?
- What do Earth scientists mean when they speak of change as a constant?
- Why is it important to recognize Earth as a system? When can it be more relevant to study individual parts of the system?

ADDITIONAL RESOURCES

DVDs or Movies

- *How the Earth Was Made* (2008) Narrated by Alec Baldwin. History Channel, 1 hour 34 minutes
- *Inside Planet Earth* (2008) Narrated by Patrick Stewart. Discovery Channel, 2 hours.
- *Earth Revealed, Episode 1: Down to Earth* (1992) Annenberg Media, 30 minutes. Available on DVD or for free streaming video on demand from http://www.learner.org/resources/series78.html

Websites

- Evolution of Our Solar System – Framework for an interactive classroom activity where students learn the order of events that created the solar system. http://www.lpi.usra.edu/education/timeline/activity/
- Earth Science Picture of the Day – Various pictures that can open up discussion in the classroom. http://epod.usra.edu
- Toilet Paper Geologic Time Scale – Directions for creating a visual time scale analogy for a class demonstration.
http://serc.carleton.edu/quantskills/activities/TPGeoTime.html
- Calculator Tape Time Scale – Similar to the toilet paper time scale except students do the calculations and create the time scale themselves.
http://serc.carleton.edu/quantskills/activities/calculatortape.html