Answers to Critical Thinking and Review End of Chapter Questions:

1. Briefly describe some of the long-term ecological research conducted at Hubbard Brook Experimental Forest (HBEF). What are some of the environmental effects observed in the deforestation study at HBEF?

Ans: HBEF has conducted long-term studies that have addressed hydrology, biology, geology, and chemistry of forests and associated aquatic life. The effects of deforestation have also been studied. Deforestation studies have shown that there is an increase in soil erosion and leaching of essential minerals which results in decreased soil fertility.

2. What is a biogeochemical cycle? Why is the cycling of matter essential to the continuance of life?

Ans: Biogeochemical cycles move matter from one organism to another and from living organisms to the abiotic environment and back again. The cycles of matter- carbon, nitrogen, phosphorus, sulfur and hydrologic- involve biological, geologic and chemical interactions. These five cycles are particularly important to organisms, because these materials make up the chemical compounds of cells.

3. Describe how organisms participate in each of these biogeochemical cycles: carbon, nitrogen, phosphorus, and sulfur.

Ans: In the carbon cycle organisms fix, or incorporate, carbon from the atmosphere into chemical compounds through photosynthesis. Organisms also release carbon during cellular respiration. Other biological molecules that are not release during cellular respiration can be stored as fossil fuels for millions of years. Aquatic organisms incorporate Ca^{2+} and HCO_3^- into their shells. When these organisms die, their shells sink to the ocean floor and become part of the sedimentary rock layer. The CO_2 in these rock layers will later be released due to weathering or subduction.

Atmospheric nitrogen is very stable and must be broken apart in order to combine with other elements. Bacteria are exclusively involved in all five steps of the nitrogen cycle, except assimilation. Nitrogen-fixing bacteria carry out biological nitrogen fixation in soil and aquatic environments. Soil bacteria perform nitrification, a two step process. First soil bacteria convert ammonia or ammonia to nitrite. Then other soil bacteria oxidize nitrite to nitrate. The process of nitrification furnishes these bacteria with energy. Ammonification begins when organisms produce nitrogen-containing waste products such as urea and uric acid. These substances, as well as the nitrogen compounds that occur in dead organisms, are decomposed, releasing nitrogen into the abiotic environment. Finally, denitrifying bacteria reverse the action of nitrogen-fixing and nitrifying bacteria by returning nitrogen to the atmosphere.

In the phosphorus cycle, plants roots absorb inorganic phosphates. Animals obtain most of their required phosphate from the foods they eat. Phosphorus is then released back into the soil when organisms die and decompose. In aquatic environments, phosphorus is

absorbed and assimilated by algae and plants, which are then consumed by plankton and larger organisms. A small portion of phosphate in the aquatic food web finds its way back to the land in the manure of sea birds.

A tiny fraction of the global sulfur is present in living organisms. Plant roots absorb sulfate and assimilate it by incorporating the sulfur into plant proteins. Animals assimilate sulfur when they consume plant proteins and convert it to animal proteins. Sulfur is returned to the atmosphere by bacteria which converts sulfates to hydrogen sulfide gas.

4. What is the basic flow path of the nitrogen cycle?

Ans: There are five steps to the nitrogen cycle, in which nitrogen cycles between the abiotic environment and organisms: nitrogen fixation, nitrification, assimilation, ammonification and denitrification. Bacteria are exclusively involved in all of these steps except assimilation.

5. A geologist or physical geographer would describe the phosphorus cycle as a "sedimentary pathway." Based on what you have learned about the phosphorus cycle in this chapter, what do you think that means?

Ans: Phosphorus does not form compounds in the gaseous phase and does not appreciably enter the atmosphere. In the phosphorus cycle, phosphorus cycles from the land to sediments in the ocean and back to the land. Phosphorus in plants comes from weathered sedimentary rock layers and returns to the ocean floor to be incorporated back into rock.

6. Explain why Earth's temperature changes with latitude and with the seasons.

Ans: Temperature changes with Latitude
On average the sun's rays hit vertically near the equator, making the energy more concentrated and producing higher temperatures. At higher latitudes, the sun's rays hit more obliquely, making the sun's energy to be scattered and the temperatures are lower.
Temperature with seasons
Seasons are determined primarily by Earth's inclination on its axis. During half of the year the Northern Hemisphere tilts toward the sun and the temperature is warmer. During the other half it tilts away and the temperature is colder. The orientation in the Southern Hemisphere is the opposite of the Northern.

7. What are the two lower layers of the atmosphere? Cite at least two differences between them.

Ans: The layer of the atmosphere closest to the Earth is the troposphere. The troposphere extends to a height of approximately 10km (6.2mi). The temperature of the troposphere decreases with increasing altitude about -6°C (-11°F) for every kilometer. Weather,

including turbulent wind, storms and most clouds, occur in the troposphere. The layer directly above the troposphere is the stratosphere. The stratosphere extends from 10-45 km (6.2 to 28 mi) above the Earth's surface and contains the ozone critical to life because it absorbs much of the sun's damaging ultraviolet radiation. There is a steady wind but no turbulence. There is little water, and temperature is more or less uniform (-45°C to -75°C), however, the absorption of ultraviolet radiation by the ozone layer heats the air, and so temperature increases with increasing altitude in the stratosphere.

8. Describe the general directions of atmospheric circulation.

Ans: Differences in temperature are caused by variations in the amount of solar energy reaching different locations on Earth, and drive the circulation of the atmosphere. The warm surface near the equator heats the air in contact with it, causing this air to expand and rise. As the warm air rises, it cools and then sinks again. Much of it re-circulates almost immediately to the same areas it has left, but the remainder of the heated air splits and flows in two directions, toward the poles. The air chills enough to sink to the surface at about 30 degrees north and south latitudes. This descending air splits and flows over the surface in two directions. Similar upward movements of warm air and its subsequent flow toward the poles occur at higher latitudes, farther from the equator. At the poles, the cold polar air sinks and flows toward the lower latitudes, generally beneath the sheets of warm air that simultaneously flow toward the poles. The constant motion of air transfers heat from the equator toward the poles, and as the air returns, it cools the land over which it passes. This continuous turnover moderates temperatures over Earth's surface.

9. What is a gyre, and how are gyres produced?

Ans: Gyres are large, circular ocean current systems that often encompass an entire ocean basin. Gyres are produced by persistent prevailing winds that blow over the oceans.

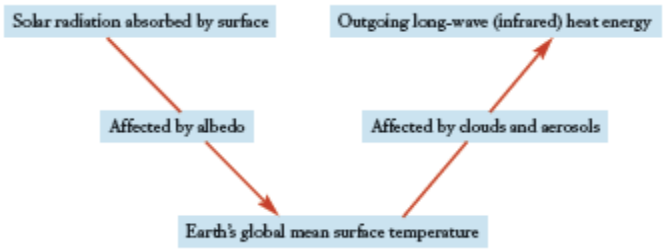
10. How does ENSO affect climate on land?

Ans: ENSO are periodic, large-scale warming of surface waters of the tropical eastern Pacific Ocean that affects both ocean and atmospheric circulation patterns. The heat from the ocean can affect atmospheric circulation. ENSO alters global air currents that can result in sometimes dangerous weather.

11. What are some of the environmental factors that produce areas of precipitation extremes, such as rain forests and deserts?

Ans: Answers will vary but should include: rain shadow and Hadley cells

12. The system encompassing Earth's global mean surface temperature can be diagrammed as follows:



Explain each part of this system.

Ans: The sun releases energy into space in the form of electromagnetic radiation. A small fraction of this energy reaches the Earth's surface and is absorbed and runs the hydrologic cycle, drives winds and ocean currents, powers photosynthesis and warms the plant. The amount of energy absorbed is affected by albedo. Albedo is the proportional reflectance of solar energy from Earth's surface, commonly expressed as a percentage. Glaciers and ice sheets have high albedo, whereas ocean and forests have low albedo. The more energy that is absorbed the greater the Earth's global mean temperature will be. Aerosols are tiny particles of air pollution consisting mostly of sulfates, nitrates, carbon, mineral dusts, and smokestack ash. Once in the atmosphere, aerosols enhance the scattering and absorption of sunlight in the atmosphere and cause brighter clouds to form. Both the clouds and the light-scattering effect in the atmosphere cause a warming of the atmosphere and a threefold reduction in the amount of solar radiation reaching Earth's surface, including the ocean. Ultimately, all of this energy is lost by the continual radiation of long-wave infrared energy into space.

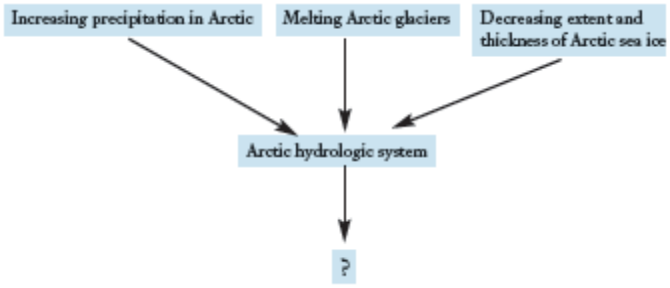
13. How are tornadoes and tropical cyclones alike? How do they differ?

Ans: A tornado is a powerful, rotating funnel of air associated with severe thunderstorms. Tornadoes form when a mass of cool, dry air collides with warm, humid air, producing a strong up-draft of spinning air. Tropical cyclones are giant, rotating tropical storms with winds of at least 118 km per hour. Tropical cyclones form as strong winds pick up moisture over warm surface waters of the tropical ocean and starts to spin as a result of the Earth's rotation.

14. Relate the locations of earthquakes and volcanoes to plate tectonics.

Ans: Most earthquakes occur along faults, fractures where rock moves forward and backward, up and down, or from side to side. Fault zones are often found at plate boundaries- any area where two plates meet. Therefore, earthquakes are very common at plate boundaries. Understanding plate tectonics has increased our knowledge of earthquakes and predicting where they may occur.

15. Examine the following changes that have been identified in the arctic hydrologic system in the past few decades. Predict the effect of these changes on the salinity in the North Atlantic Ocean.



Ans: Due to increased precipitation, melting of artic glaciers, and decreasing extent and thickness of artic sea ice the salinity in the North Atlantic Ocean is likely to decrease. Cold, salty warm is less dense than warm, less salty water. This physical property drives the deep ocean conveyor. Scientists are therefore concerned that this decrease in salinity could alter the ocean conveyor and the global climate.

16. How have global air temperatures changed in the recent past? How is this change related to the carbon cycle?

Ans: Globally average air temperatures have increased during the past century. The increase in air temperature has been accompanied by a corresponding increase in atmospheric carbon dioxide. As humans demand for fossil fuels increase the amount of carbon dioxide being released into the atmosphere has also increased.

Answers to Review Questions

The Cycling of Materials Within Ecosystems

1. What roles do photosynthesis, cellular respiration, and combustion play in the carbon cycle?

   The global movement of carbon between organisms and the abiotic environment is known as the carbon cycle. Photosynthesis incorporates carbon from the abiotic environment into the biological compounds of producers. Those compounds are then used as fuel for cellular respiration, and as a result, CO_2 is returned to the atmosphere. Similarly, carbon is also returned to the atmosphere through combustion (i.e., burning of coal, oil, natural gas, or wood).

2. What are the five steps of the nitrogen cycle?

   The five steps of the nitrogen cycle are nitrogen fixation, nitrification, assimilation, ammonification, and denitrification.

3. How does the phosphorus cycle differ from the carbon, nitrogen, and sulfur cycles?

Unlike the carbon, nitrogen, and sulfur cycles, phosphorus does not form compounds in the gaseous phase and does not appreciably enter the atmosphere (except during dust storms).

4. What sulfur-containing gases are found in the atmosphere?

   While sulfur gases comprise only a minor part of the atmosphere, they are released by many different processes. For example, sea sprays, forest fires, and dust storms deliver sulfates (SO^{2-}_4) into the air. Additionally, volcanoes release both hydrogen sulfide (H_2S) and sulfur oxides (SO_x) into the atmosphere.

Solar Radiation

1. How does the sun affect temperature at different latitudes? Why?

   Variation in Earth's temperature is produced because the sun's energy does not reach all places uniformly. More specifically, the angle at which the sun's rays strike Earth varies from one geographic location to another owing to Earth's spherical shape and its inclination on its axis. On average, the sun's rays hit vertically near the equator, making the energy more concentrated and producing higher temperatures. At higher latitudes, the sun's rays hit more obliquely. This results in the energy being spread over a larger surface area. Additionally, rays of light entering the atmosphere obliquely near the poles pass through a deeper envelope of air than does light entering near the equator. This causes more of the sun's energy to be scattered and reflected back to space, and lessens the concentration of solar energy reaching polar areas; thus, creating lower temperatures near the poles.

2. What is albedo?

   Albedo is the proportional reflectance of solar energy from Earth's surface. It is commonly expressed as a percentage. Glaciers and ice sheets tend to have high albedos, while oceans and forests exhibit low albedos.

The Atmosphere

1. What is the innermost layer of the atmosphere? Which layer of the atmosphere contains the ozone that absorbs much of the sun's ultraviolet radiation?

   The innermost layer of the Earth's atmosphere is the troposphere. The stratosphere, found directly above the troposphere, contains a layer of ozone that absorbs much of the sun's damaging ultraviolet radiation.

2. What basic forces determine the circulation of the atmosphere?

   Variations in the amount of solar energy reaching different places on Earth largely drive atmospheric circulation. Likewise, atmospheric heat transfer from the equator to the poles produces a movement of warm air toward the poles and a movement of cool air toward the equator, moderating the climate. The

atmosphere also exhibits surface winds, complex horizontal movements that result in part from differences in atmospheric pressure and from the Coriolis effect.

The Global Ocean

1. How are the sun's energy, prevailing winds, and surface-ocean currents related?

   The heat from solar energy is partly responsible for the major surface winds that blow continually across the Earth; it is these persistent prevailing winds, which blow over the ocean and produce surface-ocean water currents.

2. What is the El Niño-Southern Oscillation (ENSO)? What are some of its global effects?

   The El Niño-Southern Oscillation (ENSO) is a periodic, large-scale warming of surface water of the tropical eastern Pacific Ocean that affects both ocean and atmospheric circulation patterns. Globally, ENSO is often correlated with fishery devastation due to the lack of upwellings of colder, nutrient rich deep water during an ENSO event. ENSO also alters global air currents, directing unusual and sometimes dangerous weather to areas far from the tropical Pacific. It has been associated with torrential rains, snows, ice storms, floods, fires and droughts in parts of the world unprepared for such weather events.

Weather and Climate

1. How do you distinguish between weather and climate? What are the two most important climate factors?

   Weather refers to the conditions in the atmosphere at a given place and time, whereas climate refers to the average weather conditions that occur in a place over a period of years. Temperature and precipitation largely determine an area's climate.

2. Distinguish between tornadoes and tropical cyclones.

   A tornado is a powerful, rotating funnel of air associated with severe thunderstorms. Tornados form when a mass of cool, dry air collides with warm, humid air, producing a strong updraft of spinning air on the underside of a cloud. When this funnel makes contact with the ground it is considered a tornado. A tropical cyclone is a giant, rotating tropical storm with high winds. Tropical cyclones forms as strong winds pick up moisture over warm surface waters of the tropical ocean and start to spin as the result of Earth's rotation. Tropical cyclones are called hurricanes in the Atlantic, typhoons in the Pacific, and cyclones in the Indian Ocean.

Internal Planetary Processes

1. What are tectonic plates and plate boundaries?

Plate tectonics is the study of the processes by which the lithospheric plates move over the asthenosphere. Earth's lithosphere (outermost rock layer) consists of seven large plates and a few smaller ones. Any area where two plates meet is termed a plate boundary. Plate boundaries are sites of intense geologic activity, such as mountain building, volcanoes, and earthquakes.

2. Where are earthquakes and volcanoes commonly located, and why?

Earthquakes and volcanoes are commonly located along plate boundaries due to the events that occur when plates meet. Three types of plate boundaries exist: divergent plate boundaries (when two plates move apart); convergent plate boundaries (when two plates collide); and transform plate boundaries (when plates move horizontally in opposite but parallel directions.