45 The Global Ecosystem

Chapter Outline

We are all in this together. Because all of Earth's systems are interrelated, a change in wind patterns over the ocean can cause climate changes around the world. When a large volcano erupts, injecting gases and ash into the upper atmosphere, the effects are felt across the globe for years. A change in climate will alter the productivity of an ecosystem.

Gross primary productivity (GPP) is the amount of energy trapped by the producers in an ecosystem, but not all of this is available to consumers. Much is dissipated as heat energy during the catabolism of fuel molecules. Net primary productivity (NPP) is the amount of energy captured in the tissues of primary producers, so it is a key indicator of the amount of energy available to the next trophic level (consumers). Measurements of an ecosystem's NPP are important descriptors of productivity.

The recycling of elements and nutrients in ecosystems occurs via biogeochemical cycles. Nutrients typically move from one form to another, into and out of major pools and sinks at varying flux rates. Most studied are the water, carbon, and nitrogen cycles.

The biogeochemical cycle of carbon has direct impacts on the world's climate. The increased release of greenhouse gases from human activities is a significant contributor to warmer winters and summers, more powerful storms, and increasingly unpredictable weather. Like a pane of clear glass, the atmosphere allows the passage of most solar radiation, warming Earth's surface. Much of this energy is reradiated as heat energy, but greenhouse gases in the atmosphere prevent it from reaching space. Instead, the energy further warms our atmosphere, causing global climate change.

Climate changes cause many disruptions to ecosystems, such as evolving plant species, shifting migration patterns, and melting polar ice caps. Historically, organisms have substantially changed Earth's atmosphere, most notably resulting from the evolution of photosynthetic organisms and the subsequent release of molecular oxygen gas (O_2). Other physical changes have resulted in warming and cooling trends. But now one species, *Homo sapiens*, is single-handedly causing large-scale deviations. The challenge we face is to minimize human influence on climate change and mitigate the effects of the damage we've already done. This requires a genuine commitment to worldwide cooperation.

Chapter 45 includes **Big Idea 2** and **Big Idea 4**. The specific parts of the AP Biology curriculum covering **Big Idea 2:** Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis, include:

- **2.A.2**: Organisms capture and store energy for use in biological processes.
- **2.A.3**: Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.

The specific parts covering **Big Idea 4:** Biological systems interact, and these systems and their interactions possess complex properties, include:

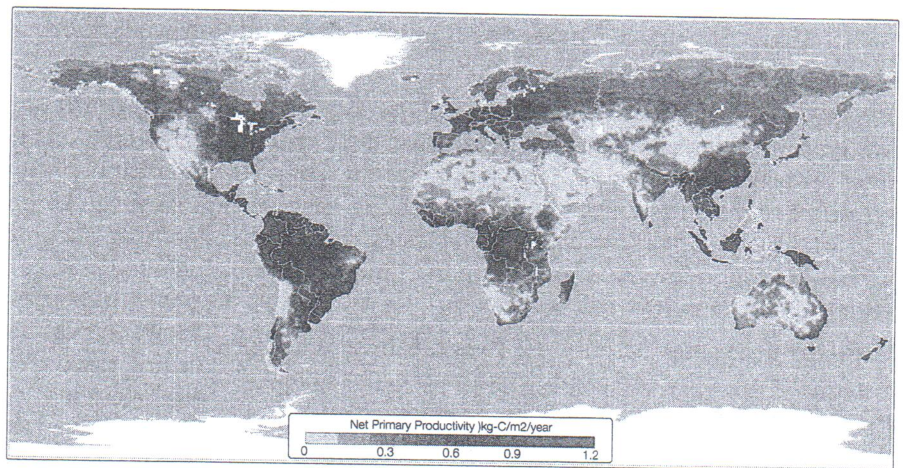
- **4.A.6**: Interactions among living systems and with their environment result in the movement of matter and energy.
- **4.B.4**: Distribution of local and global ecosystems changes over time.
- **4.C.4**: The diversity of species within an ecosystem may influence the stability of the ecosystem.

Chapter Review

Concept 45.1 *examines how net primary productivity (NPP) varies with climate change.*

1. Explain why NPP does not measure the rate of exchange between organisms and all of the nutrients they need.

Refer to the diagram at the right to answer Questions 2 and 3.



Map courtesy of the Center for Sustainability and the Global Environment, University of Wisconsin—Madison

2. Identify two reasons that NPP is higher in the equatorial regions.

3. Summarize the pattern of NPP across North America, and discuss why these patterns exist.

4. Design an experiment to determine the identity of the limiting nutrient in a grassland ecosystem.

5. Explain why the limiting nutrient in a grassland ecosystem might not be a limiting nutrient in another ecosystem.

Concept 45.2 *identifies and discusses biological, geological, and chemical processes contributing to biogeochemical cycles.*

6. Describe the primary energy source that drives the constant recycling of most matter.

7. Earth is considered an open system with regard to energy. Discuss this concept with attention to free energy and entropy.

8. Earth is considered to be a closed system with regard to matter. Discuss this concept with attention to free energy and entropy.

Concept 45.3 *considers the three most important biogeochemical cycles in ecosystems: the water, carbon, and nitrogen cycles. One result of too much nitrogen runoff from agricultural fields and animal wastes is the cultural eutrophication in bodies of water. This can result in hypoxic or anoxic zones in these ecosystems.*

9. Complete the table below for each of the three major biogeochemical cycles. Sinks are the locations where the nutrient is inaccessible for long periods.

Cycle	Fluxes	Pools	Sinks
Water			
Carbon			
Nitrogen			

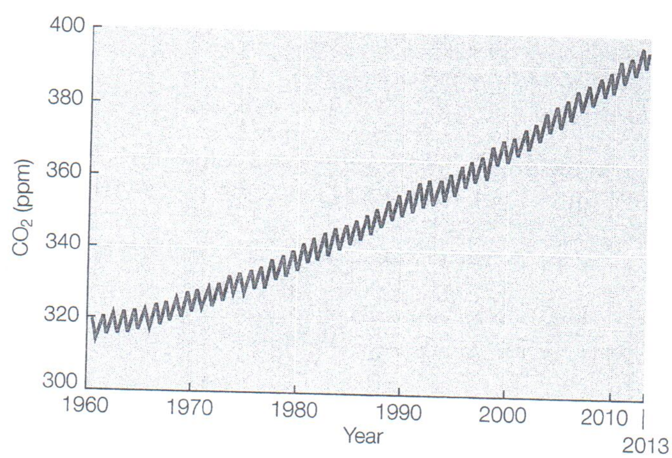
10. Draw either the nitrogen cycle or the carbon cycle, showing the major fluxes, pools, and sinks. Include examples of living organisms.

11. Excess nutrients (nitrates) entering a body of water from surface runoff can result in an algal bloom. Explain how the overabundance of algae in a body of water can lead to an anoxic zone (i.e., no dissolved O_2).

12. Though nitrogen gas (N_2) makes up approximately 78 percent of the Earth's atmosphere, it is a limiting nutrient in many ecosystems. Explain why we need to constantly apply nitrogen as fertilizer to agricultural fields, despite its abundance in air.

Concept 45.4 *relates biogeochemical cycles and global climate, with a particular focus on the greenhouse effect and the recent increases of greenhouse gases in the atmosphere.*

Refer to the graph at the right, showing the concentration of carbon dioxide (CO_2) in the atmosphere, to answer Questions 13 and 14.



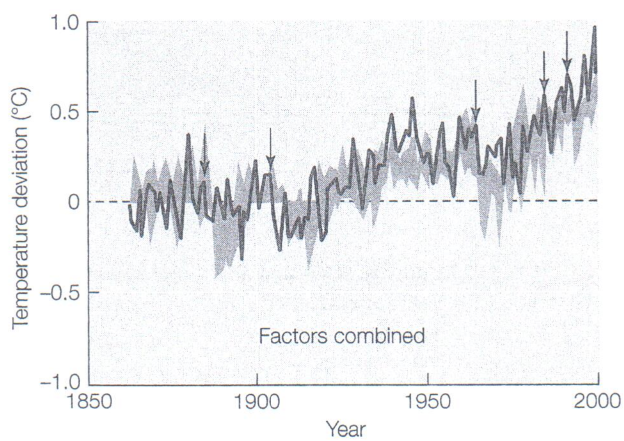
13. Draw a diagram or flow chart that represents the rise and fall of CO_2 in the atmosphere over one year. Assume that the data are from a temperate forest, and include living organisms

14. Calculate the percent increase of CO_2 in the atmosphere between 1980 and 2010.

15. Carbon dioxide is not the most potent greenhouse gas, yet it is the one that is most often discussed. Explain the reason for this.

Concept 45.5 *looks at the effects of global climate change on the Earth's ecosystems and predicts how ecological systems are changing as a result.*

Refer to the graph below, showing a computer's simulation of temperature in the atmosphere and the actual results (dark line), to answer Questions 16–19. Arrows indicate five major volcanic eruptions.

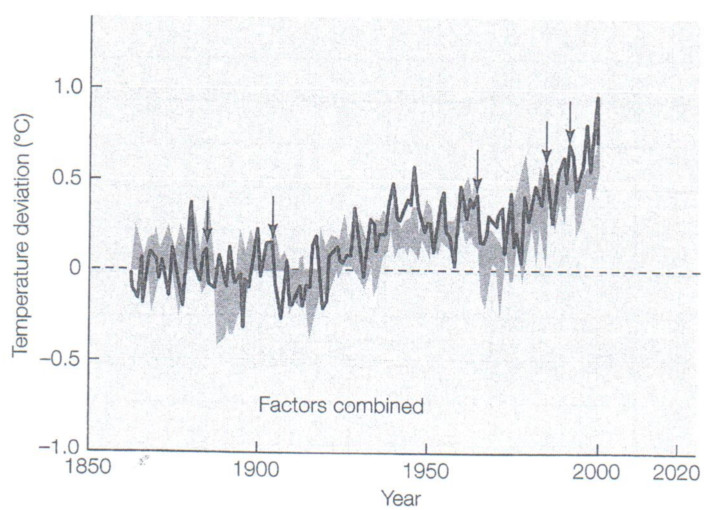


16. Explain the dashed line across the middle of the graph.

17. Discuss what the data show for the ten years following volcanic eruptions, and explain how this change occurred.

18. Discuss what likely happened to ecosystems in the ten years following the volcanic eruptions.

19. There was a major volcanic eruption in Iceland in 2011, and carbon dioxide concentrations have continued to rise. Using the graph below, expand the line to 2020 with these two factors in mind.



Concept 45.6 *focuses on humans and their impact on the environment, raising the hope that humans can mitigate the damage done.*

20. Interview one or two older members of your local community who have spent the majority of their lives nearby. How has the local climate changed over their lifetimes? Has local vegetation or animal life changed over the years?

21. Imagine that you have been elected president of the United States. What is the first major thing you would do to change how Americans affect climate change? How would you work to influence other global leaders to reduce their greenhouse gas emissions?

Science Practices & Inquiry

In the AP Biology Curriculum Framework there are seven **Science Practices**. In this chapter, we focus on **Science Practice 2:** The student can use mathematics appropriately. More specifically, we focus on **Science Practice 2.2:** The student can apply mathematical routines to quantities that describe natural phenomena.

Question 22 asks you to apply mathematical routines to quantities that describe interactions between living systems and their environment, which result in the movement of matter and energy (**Learning Objective 4.14**).

22. The chart below shows how NPP varies with different ecosystems. Using the entire NPP for terrestrial ecosystems, calculate the percent NPP of temperate forests. Express your answer to the nearest tenth, and record your answer on the grid provided. Show your work.