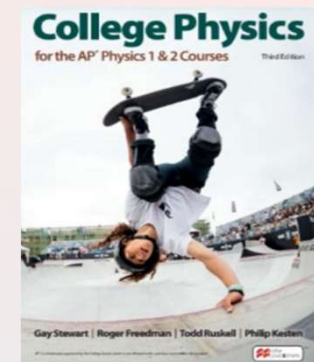


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Environmental Science for the AP[®] Course 4th edition

Andrew Friedland | Rick Relyea



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Teacher-Centered Programs. Expert authorship. Powerful digital solutions.



Let's hear from you.

Do your students struggle with math on the APES exam?

How do you currently teach math and graphing to your students?

Do you have enough AP® practice?

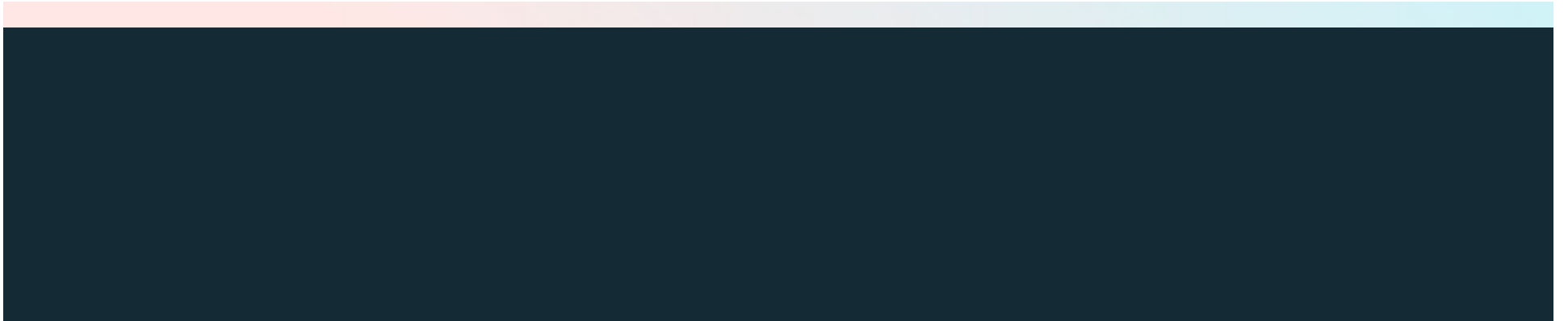
Are you happy with the pacing of your course?

What is a need you have in your APES course?



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What do you need?



What we've heard from your peers.

Students struggle with math and graphing.

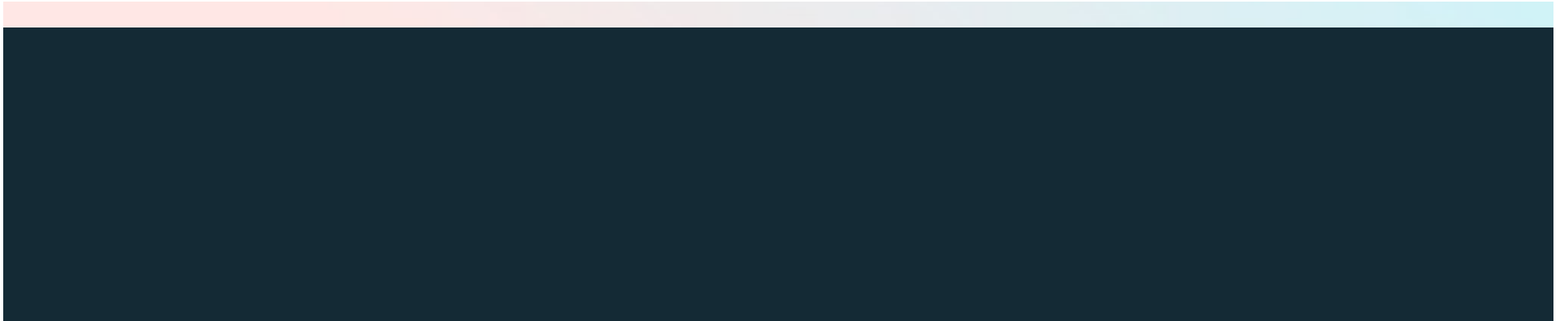
It's hard to match course pacing and unit depth to the CED.

Students struggle to interpret data and apply concepts to real-world situations.

Students don't get enough practice for the exam.



Meet our authors!



About the Authors



Andrew Friedland, Richard and Jane Pearl Professor in Environmental Studies at Dartmouth College

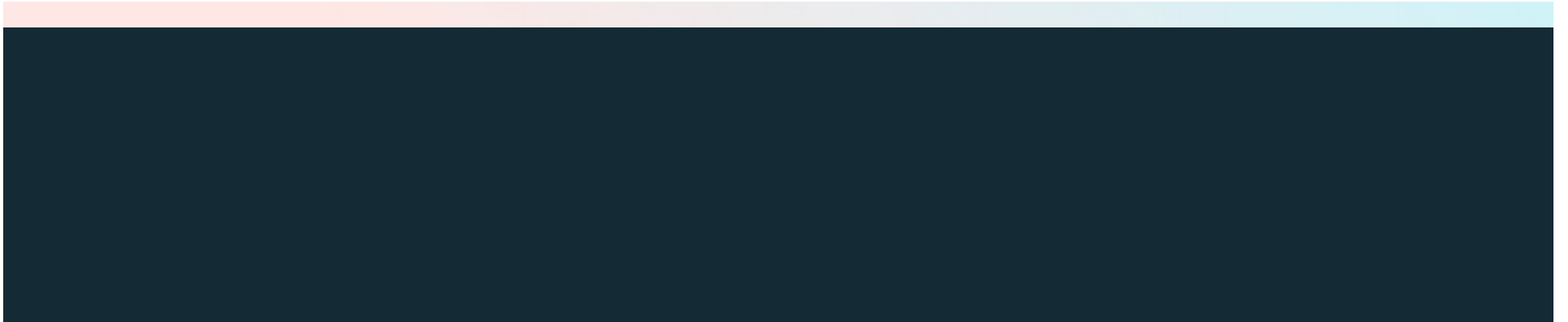
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- Co-author on 80 peer-reviewed publications
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- Published in *Ecology*, *Ecology Letters*, *American Naturalist*, *PNAS*, and other leading ecological journals

Student Edition



Precise Alignment to the CED

Materials are divided into short, bite-sized modules

Each module precisely matches the Course and Exam Description to the topic level. Feel confident you are giving your students what they need to be successful!

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College Board AP® ENVIRONMENTAL SCIENCE

Unit 1: The Living World: Ecosystems

Unit 2: The Living World: Biodiversity

Unit 3: Populations

Unit 4: Earth Systems and Resources

Unit 5: Land and Water Use

Unit 6: Energy Resources and Consumption

Unit 7: Atmospheric Pollution

Unit 8: Aquatic and Terrestrial Pollution

Unit 9: Global Change



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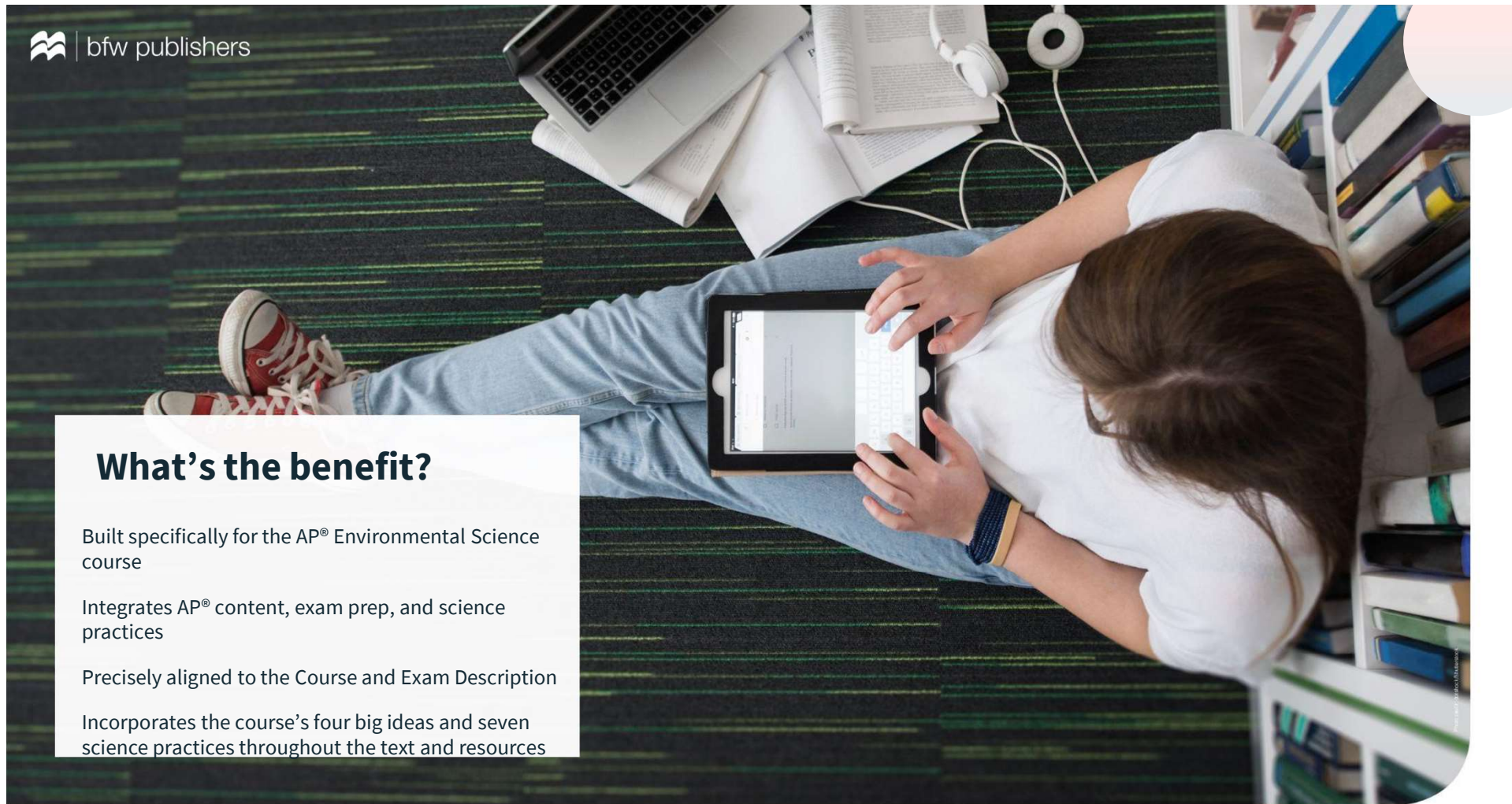
What's the benefit?

Built specifically for the AP® Environmental Science course

Integrates AP® content, exam prep, and science practices

Precisely aligned to the Course and Exam Description

Incorporates the course's four big ideas and seven science practices throughout the text and resources



NEW Module 0

Module 0 provides an introduction to Environmental Science

Give your students the foundation and background they need to grasp the material from the beginning!



Module 0

What Is Environmental Science?

0-1 What is environmental science and why is it important?

Environmental science is important if you live on this planet

Stop reading for a moment and look up to observe your surroundings. Consider the air you breathe, the heating or cooling system that keeps you at a comfortable temperature, and the natural or artificial light that helps you see. Our **environment** is the sum of all the conditions surrounding us that influence life. These conditions include living organisms as well as nonliving components such as soil, temperature, and water. The influence of humans is an important part of the environment as well. The environment we live in determines how healthy we are, how fast we grow, how easy it is to move around, and even how much food we can obtain. One environment may be strikingly different from another—a hot, dry desert versus a cool, humid tropical rainforest, or a coral reef teeming with marine life versus a crowded city street.

We are about to begin the study of **environmental science**, the field of study that looks at interactions among human systems and those found in nature. By “system” we mean any set of interacting components that influence one another by exchanging energy, materials, or information. We have already seen that a change in one part of a system—for example, a pandemic disease in the human population such as Covid-19—can cause changes elsewhere in the system, such as in the populations of wildlife returning to locations in Yosemite National Park.

An environmental system may be completely human-made, like a subway system, or it may be natural, like weather. The scope of an environmental scientist’s work can vary from looking at a small population of individuals, to multiple populations that make up a species, to a community of interacting species, or to even larger systems, such as ecosystems or the global climate system. Some environmental scientists are interested in local or regional problems, such as the impact of fewer cars on the road in a particular city during the pandemic. Other environmental scientists work on global issues, such as species extinction and climate change.

Many environmental scientists study a specific type of natural system known as an ecosystem. An **ecosystem** is

Learning Goals

After reading this module you should be able to

0-1 describe the field of environmental science and discuss its importance.

0-2 identify ways in which humans have altered and continue to alter our environment.

0-3 explain the four “Big Ideas” in environmental science.

0-4 describe the scientific method and justify how it is used to design and evaluate information in environmental science.

a particular location on Earth with interacting **biotic**, or living, and **abiotic**, or nonliving, components.

As you embark on this new field of study, you should recognize that environmental science is different from **environmentalism**, which is a social movement that seeks to protect the environment through lobbying, activism, and education. An environmentalist is a person who participates in environmentalism. In contrast, an environmental scientist, like any scientist, follows the process of observation, hypothesis testing, and field and laboratory research. We’ll learn more about the process of science later in this module and throughout this book.

So, what then does the study of environmental science actually include? As **FIGURE 0.1** shows, environmental science encompasses topics from many scientific disciplines, such as chemistry, biology, and Earth science. Environmental science is itself a subset of the broader field known as

Environment The sum of all the conditions surrounding us that influence life.

Environmental science The field of study that looks at interactions among human systems and those found in nature.

Ecosystem A particular location on Earth with interacting biotic and abiotic components.

Biotic Living.

Abiotic Nonliving.

Environmentalism A social movement that seeks to protect the environment through lobbying, activism, and education.

NEW Unit Openers

- Updated case studies and NEW“Practice Your Science Skills” questions at the beginning of every unit tie into the seven Science Practices
- The new unit openers engage students’ critical thinking skills and prompt spirited discussions!



MODULE 8 Introduction to Biodiversity
MODULE 9 Ecosystem Services
MODULE 10 Island Biogeography

MODULE 11 Ecological Tolerance
MODULE 12 Natural Disruptions to Ecosystems

MODULE 13 Adaptations
MODULE 14 Ecological Succession

CASE STUDY

The Benefits of Biodiversity

Biodiversity, a combination of the words “biological” and “diversity,” is the diversity of life forms in an environment. You may have heard people talking about the importance of biodiversity, but why should we preserve it around the world? We have long appreciated that species in nature provide benefits to humans including food, fiber, lumber, and medicines. We also know that collections of species in ecosystems provide primary productivity in the land and water, the production of clean water, and buffers

ecosystem with higher species diversity can recover more quickly when rain falls and the drought ends compared to an ecosystem that has low species diversity. While these results have been encouraging, critics have pointed out that because most experiments

species and ecosystem productivity from 600,000 sample locations around the world. Across terrestrial, freshwater, and marine biomes, they found that sites with more species did indeed have higher productivity, which was consistent with the results of the earlier experiments. In addition, when the researchers considered how variation in climatic conditions and available nutrients affected the productivity of these ecosystems, they found that biodiversity was a more important factor than climate in half of the studies and

We have learned that biodiversity is critical to the proper functioning of ecosystems.

Practice your science skills

- 1. Text Analysis:** Identify one ecological claim about the benefit of biodiversity made by the author.
- 2. Concept Explanation:** Explain why an increase in ecosystem biodiversity will also increase ecosystem resilience.
- 3. Scientific Experiments:** Identify a research method used to determine the importance of biodiversity in nature.

As we have just learned, biodiversity is an important part of any ecosystem because of the role it plays in making ecosystems productive and stable over time. In this unit, we will examine biodiversity in depth, including biodiversity from the level of genes to ecosystems. We will also see how this diversity allows ecosystems to provide us with a number of important services. Then we explore how the number of species in an ecosystem is the net result of some species colonizing places they can tolerate and other species going extinct due to unsuitable biotic or abiotic conditions. Given that many ecosystems experience various disruptions over time, we examine how short- and long-term disruptions can vary in magnitude and alter the composition of species in different ecosystems. Whether an ecosystem is frequently disrupted or not, species can evolve traits to persist in a given ecosystem as a result of natural selection. Over long periods of time, the initial species that colonize an area are eventually replaced by other species that possess traits that are better suited to the changing environmental conditions. Collectively, the modules in this unit will provide an excellent discussion of how we obtain biodiversity in different ecosystems and the consequences of doing so.

The Best APES Program for Math Support

- Do the Math | Your Turn
- Practice Math and Graphing
- Math Review

Math Review

Metric Prefixes A prefix in front of a unit of measure indicates a multiple or fraction of that unit. The table below lists the most frequently used prefixes of the metric system, which you should know for the AP[®] Environmental Science Exam.

	Prefix	Equivalence	Scientific notation	Abbreviation
Largest	mega	1,000,000	10^6	M
	kilo	1,000	10^3	k
	hecto	100	10^2	h
	deci	10	10^1	da
Base unit	n.g., meter	1	10^0	m, g, L, W

Example

Convert 6.85 km into inches (1 km = 1,000 m, 1 m = 3.28 feet, and 1 foot = 12 inches).

$$6.85 \text{ km} \times \frac{1,000 \text{ m}}{1 \text{ km}} \times \frac{3.28 \text{ feet}}{1 \text{ m}} \times \frac{12 \text{ inches}}{1 \text{ foot}} = 269,616 \text{ inches}$$

Calculating Averages (See pages 13, 515.)

To find the average, or mean, of a set of values, add all the given values and divide the total by the number of given values.

$$\text{average (mean)} = (x + y + z) \div n, \text{ where } n = \text{the number of given values}$$

Example

What is the average (mean) of 107, 53, 100, 114, and 236? $(107 + 53 + 100 + 114 + 236) \div 5 = 510 \div 5 = 102$

Percent of a Total Value (See pages 54, 62, 144, 590, 602, 698.)
To calculate the percent of a total value, divide the subset value by the total value, then multiply by 100%.

$$\% \text{ of a total value} = (\text{subset value} \div \text{total value}) \times 100\%$$

Example

A group of rabbits consists of 10 brown, 15 white, and 25 black rabbits. What is the percentage of brown rabbits? $[(10 \div (10 + 15 + 25)) \times 100\% = 20\%]$

Percent Change (See pages 62, 144, 298, 525, 683.)

To calculate percent change, take the difference between the final value and the initial value, divide this difference by the initial value, then multiply by 100%.

$$\% \text{ change} = [(\text{final value} - \text{initial value}) \div \text{initial value}] \times 100\%$$

Example

What is the percent change in US meat consumption from 1960 to 2012? $[(75 \text{ kg} - 60 \text{ kg}) \div 60 \text{ kg}] \times 100\% = (15 \div 60 \text{ kg}) \times 100\% = 0.25 \times 100 = 25\%$

Annual Rate of Change (See pages 235, 525, 677.)

To calculate the annual rate of change for a given measurement, first find the difference between the final value and the initial value. Then divide that difference by the total number of years considered, which is the difference between the final year and the initial year.

$$\text{annual rate of change} = (\text{final value} - \text{initial value}) \div (\text{final year} - \text{initial year})$$

Example

Atmospheric CO₂ = 320 ppm in 1960
Atmospheric CO₂ = 390 ppm in 2010
Average annual rate of change = $(390 \text{ ppm} - 320 \text{ ppm}) \div (2010 - 1960) = 70 \text{ ppm} \div 50 \text{ years} = 1.4 \text{ ppm/year}$

pH Scale (See page 536.)

The pH scale is logarithmic, meaning that each number on the scale changes by a factor of 10.

DO THE MATH

Building a Manure Lagoon

Preparing for the AP[®] Exam

Concentrated animal feeding operations typically use manure lagoons to hold the manure produced by cattle. If an individual animal produces 50 L of manure each day and the average concentrated animal feeding operation holds 800 cattle on any given day, how much manure is produced each day?

$$\text{Daily manure production} = 50 \text{ L/animal} \times 800 \text{ animals} = 40,000 \text{ L}$$

YOUR TURN

1. If a manure lagoon needs to hold 30 days' worth of manure production for 900 cattle, what is the minimum capacity of the lagoon a farmer would need?
2. After the manure has broken down, the manure must be spread onto farm fields. A modern manure spreader can hold 40,000 L of liquid manure. How many trips will it take for the manure spreader to remove the 30 days' worth of manure that is held in the manure lagoon?

Practice Math and Graphing

Preparing for the AP[®] Exam

Answer the following questions. Be sure to show all your work.

1. Practice Math

In the United States, there are endangered species in all of the major vertebrate groups. Given the table below, calculate the percentage of endangered species in each of the five groups of vertebrates.

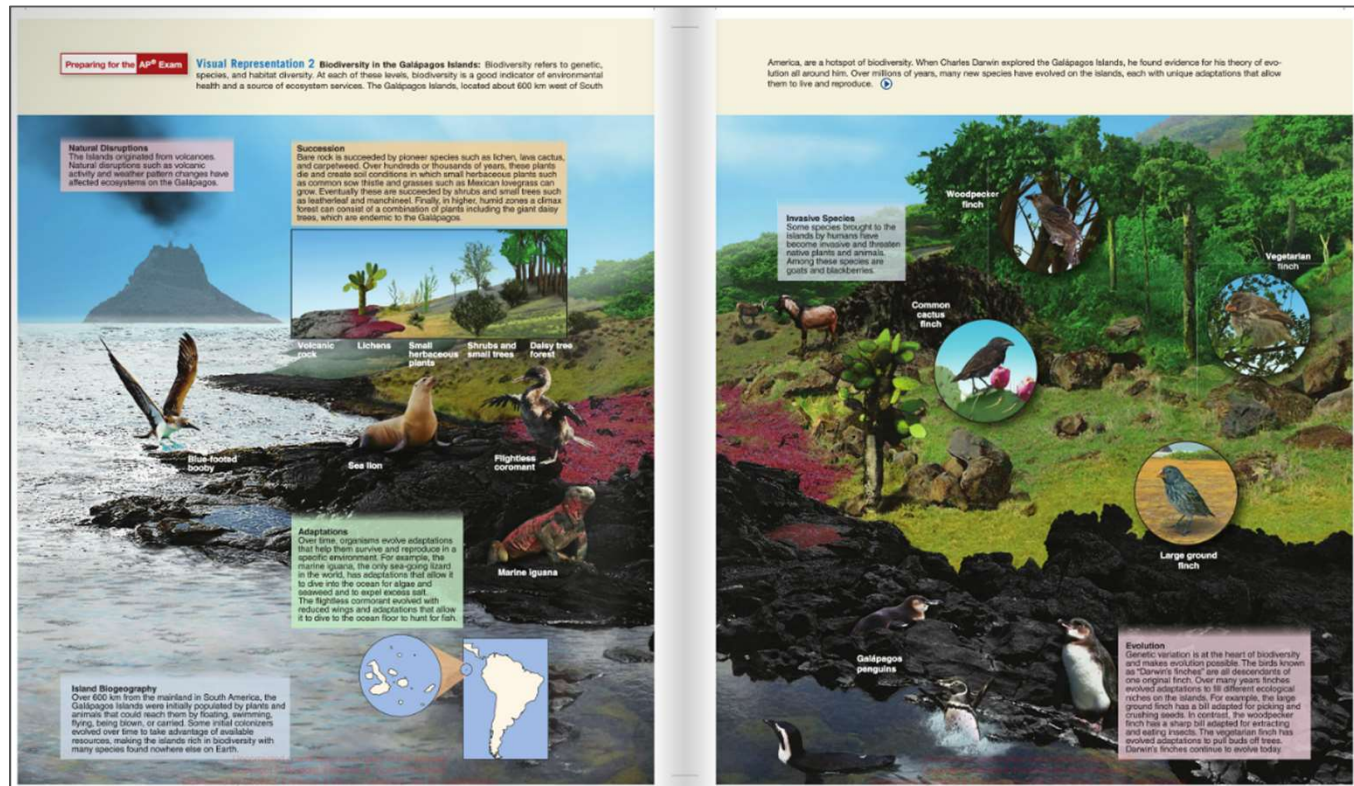
Vertebrate group	Number of endangered species	Percent of endangered species
Mammals	95	
Birds	102	
Reptiles	45	
Amphibians	36	
Fishes	164	
Total		

2. Practice Graphing

(a) Using the percentage data you calculated in "Practice Math," create a pie graph that shows the percentages of endangered species among the five groups of vertebrates in the United States.

(b) How might the total number of species in each vertebrate group affect the percentage of endangered species among the five groups?

A Closer Look: Visual Representation



Science Practices Spiral Throughout the Book

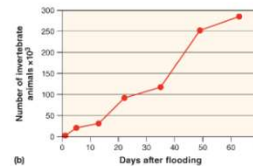
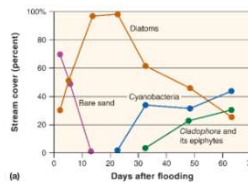
UNIT 2 Practice Your Science Skills

Preparing for the AP® Exam

Data Analysis

These graphs represent the recovery of a stream after flooding, which is a type of ecological disturbance. To answer these questions, you will need to carefully read

the graph and interpret the data, use mathematical calculations, and relate the material to your knowledge of food chains from Unit 1.



Questions

1. **Identify** how long after flooding cyanobacteria took to begin to repopulate a stream after flooding. (Hint: The AP Exam will have an acceptable range of correct answers such as ± 2 on either end.)
2. Diatoms are microscopic producers. **Describe** the pattern in the population size of diatoms from day 2 to day 60 after flooding. (Hint: When describing the pattern in a graph, use numbers in your description and be precise. The AP exam will have an acceptable range of correct numbers for each data point.)
3. **Calculate** the percent change in the number of invertebrate animals from 10 days after flooding to 30 days after flooding. (Hint: Be sure to set up your problem to earn points. You need to memorize the percentage change formula as the AP Exam does not provide a formula sheet.)
4. **Identify** the timespan (10-day timespans) that had the greatest increase in invertebrate animals. (Hint: To find the greatest increase, look for the span with the greatest slope.)
5. Cladophora is an alga that grows together in mass. Many invertebrates such as isopods and snails eat Cladophora. People often hypothesize that the increase in invertebrate animals is caused by the repopulation and increase of Cladophora. **Make a claim** about whether this hypothesis is supported or not supported by the data. (Hint: In "make a claim" questions, back up your claim with evidence. Use numbers in your evidence if the prompt, graph, or diagram has numbers.)

Pursuing Environmental Solutions

Saving Marine Biodiversity Through the Power of Partnerships

For over 70 years, The Nature Conservancy (TNC) has protected biodiversity by using a simple strategy: Buy it. The Conservancy uses grants and donations to purchase privately owned natural areas or to buy development rights to those areas. TNC has protected over 30 million hectares (125 million acres) of land by either buying land or buying the development rights of the land. As a nonprofit, nongovernmental organization, TNC has great flexibility to use innovative conservation and restoration techniques on natural areas in its possession.

TNC focuses its efforts on areas containing rare species or biodiversity hotspots, including the Florida Keys in southern Florida and Santa Cruz Island in California. Recently, it has set its sights on the oceans, including coastal marine ecosystems. Coastal ecosystems have experienced steep declines in the populations of many fish and shellfish, including oysters, clams, and mussels, due to a combination of overharvesting and pollution. By preserving these coastal ecosystems, TNC hopes to create reserves that will serve as breeding grounds for declining populations of overharvested species. In this way, preserving a relatively small area of ocean will benefit much larger unprotected areas, and even benefit the very industries that have led to the population declines.

Shellfish are particularly valuable in many coastal ecosystems because they are filter feeders. They remove tiny organisms, including algae, from large quantities of water, cleaning the water in the process and helping to prevent harmful algal blooms. However, shellfish worldwide have been harvested unsustainably, leading to a cascade of effects throughout many coastal regions. For example, oyster populations in the Chesapeake Bay were once sufficient to filter the water of the entire bay in 3 to 6 days. Now there are so few oysters that it would take a year for them to filter the same amount of water. As a result, the bay has become much murkier, and excessive algae have led to lowered oxygen levels that make the bay less hospitable to fish.

Conserving marine ecosystems is particularly challenging because private ownership is rare. State and federal governments generally do not sell areas of the ocean. Instead, they have allowed industries to lease the harvesting or exploitation rights to marine resources such as oil, shellfish, and physical space for marinas and aquaculture. So how can a conservation group protect coastal ecosystems if it cannot buy an area of the ocean to protect it? The Nature Conservancy's strategy is to purchase harvesting and exploitation rights and use them as a conservation tool. In some cases, TNC will not harvest any shellfish in order to allow the populations to rebound. In other cases, the leases require at least some harvesting, so TNC has worked to demonstrate sustainable management practices to serve as an example of how shellfish harvests can be conducted while restoring the shellfish beds.

In New York's Great South Bay, along the southern coast of Long Island, there was a long history of harvesting large

numbers of oysters and clams. Beginning in the 1930s, however, overharvesting these shellfish led to sharp declines in the shellfish and this led to the loss of thousands of jobs connected to the industry. By the 1990s, commercial shellfishing ceased and harvesting had declined to 1 percent of what it once was. Despite the reduced harvesting, the shellfish species did not rebound. In addition, with fewer shellfish to filter the algae out of the water combined with increased inputs of nutrients into the bay, the area began to experience harmful algal blooms.

From 2002 to 2004, TNC acquired the rights to 5,420 ha (13,500 acres) of oyster beds along the southern shore of Long Island. These rights, which were donated to TNC by the Blue Field Oyster Company, were valued at \$5 million. TNC worked with local governments, community members, and the shellfish industry to develop restoration strategies, including reducing the nutrient inputs, updating harvesting plans, and seeding the area with millions of



Restoring ocean populations. In areas that have declining populations of shellfish, such as this site in New Hampshire, researchers seed the area with additional individuals to help speed up the recovery of the populations. (see Appendix)

Science Applied: Concept Explanation

Science Applied 2: Concept Explanation

How Should We Prioritize the Protection of Species Diversity?

As a result of human activities, we have seen a widespread decline in biodiversity across the globe. Many people agree that we should try to slow or even stop this loss. But how do we do this? While we might want to preserve all biodiversity, preserving biodiversity requires compromises. For example, in order to preserve the biodiversity of an area, we might have to set aside land that would otherwise be used for housing, shopping malls, or strip mines. If we cannot preserve all biodiversity, how do we decide which species receive our attention? (FIGURE SA2.1)

In 1988, Oxford University professor Norman Myers noted that much of the world's biodiversity is concentrated in areas that make up a relatively small fraction of the globe. Part of the reason for this uneven pattern of biodiversity is



FIGURE SA2.1 The California tiger salamander (*Ambystoma californiense*). This salamander is endemic to the biodiversity hotspot of California and is threatened with extinction due to

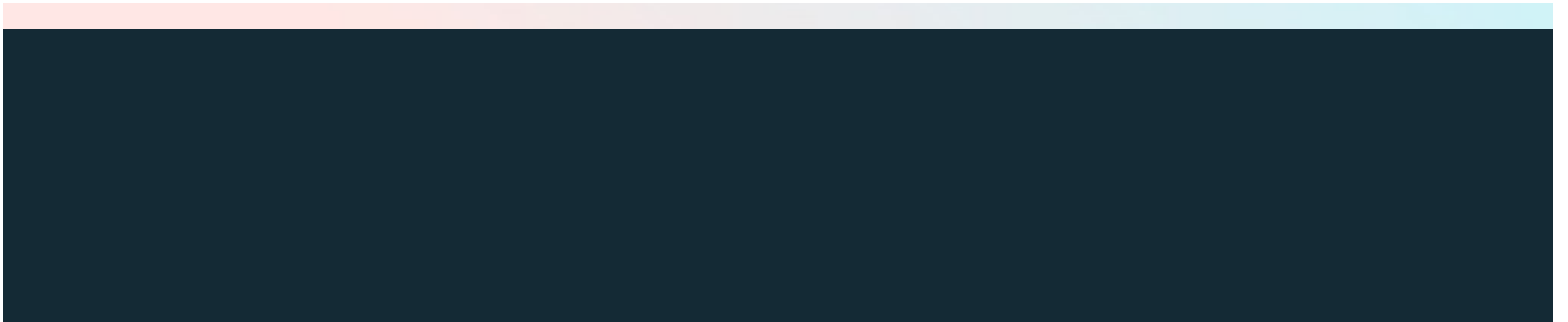
Practice AP® Free-Response Question

Write your answer to each part clearly. Support your answers with relevant information and examples. Where calculations are required, show your work.

The Florida Reef is the only living coral barrier reef in the continental United States. Like other coral reefs on the planet, Florida Reef is home to many species of coral, fish, and other aquatic life forms. Also, like other coral reefs, its health is at risk due to a number of human impacts including those associated with global warming. However, Conservation International does not list this as a biodiversity hotspot.

- Identify** two reasons why Florida Reef might not be internationally recognized as a hotspot. (3 pts.)
- Describe** two ecosystem services provided by Florida Reef. (3 pts.)
- Researchers recently found that the disturbance generated by hurricanes, which cause high winds and damaging waves, is important for maintaining the diversity of coral reef ecosystems. While a long period of no hurricanes leads to declining coral reef diversity, massive hurricanes often put many coral reef species at risk of local extinction. **Make a claim** to explain this pattern of coral reefs with occasional modest hurricanes having the greatest diversity. (4 pts.)

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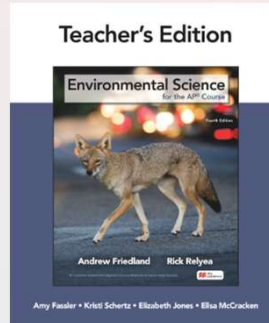
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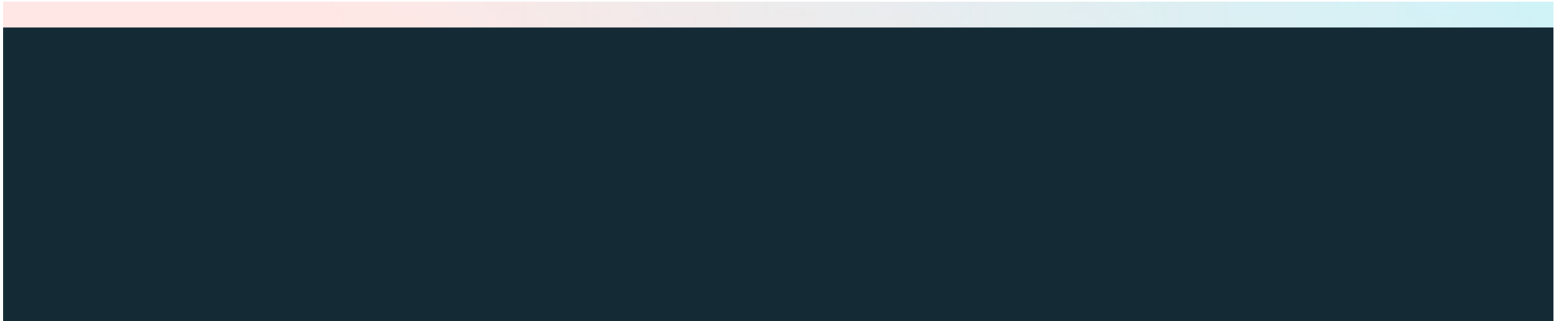


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- Instructors gain insights into student expectations and challenges
- Data suggests GRS positively impacts student course performance



Using Goal-setting and Reflection Surveys positively impacts student course performance.

*Results Based on Higher Ed Student Responses

Resources

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