

HMH SCIENCE **DIMENSIONS.**
ENGINEERED for the
NEXT GENERATION

Biology

© 2018
GRADES 9–12

Effective NGSS Instruction

Your Guide to the 5Es and
Three-Dimensional Learning



Print & Digital Curriculum

HMH Science Dimensions™ provides the richest NGSS-based 3D learning experiences available. Whether you choose print, digital, or a combination approach, students will be ready to succeed at the **Performance Expectations**.

BOTH PATHS OFFER

- Parallel Lesson Content
- Hands-on Investigations
- 5E Learning Model
- Math & ELA Connections
- Evidence Notebooking
- Engineering Activities
- Collaborative Learning
- Assessment
- Unit Performance Task
- Three-Dimensional Learning

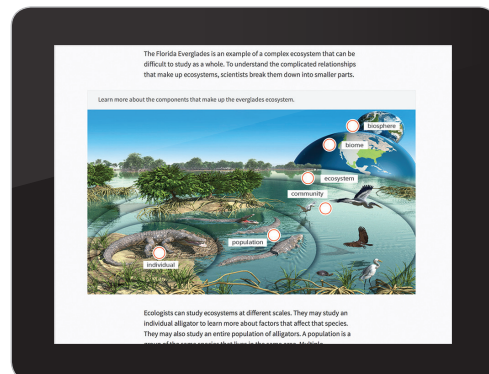
PRINT PATH

High school Biology builds interest with a hardcover text enlivened by cartoons from Randall Munroe's *Thing Explainer*.



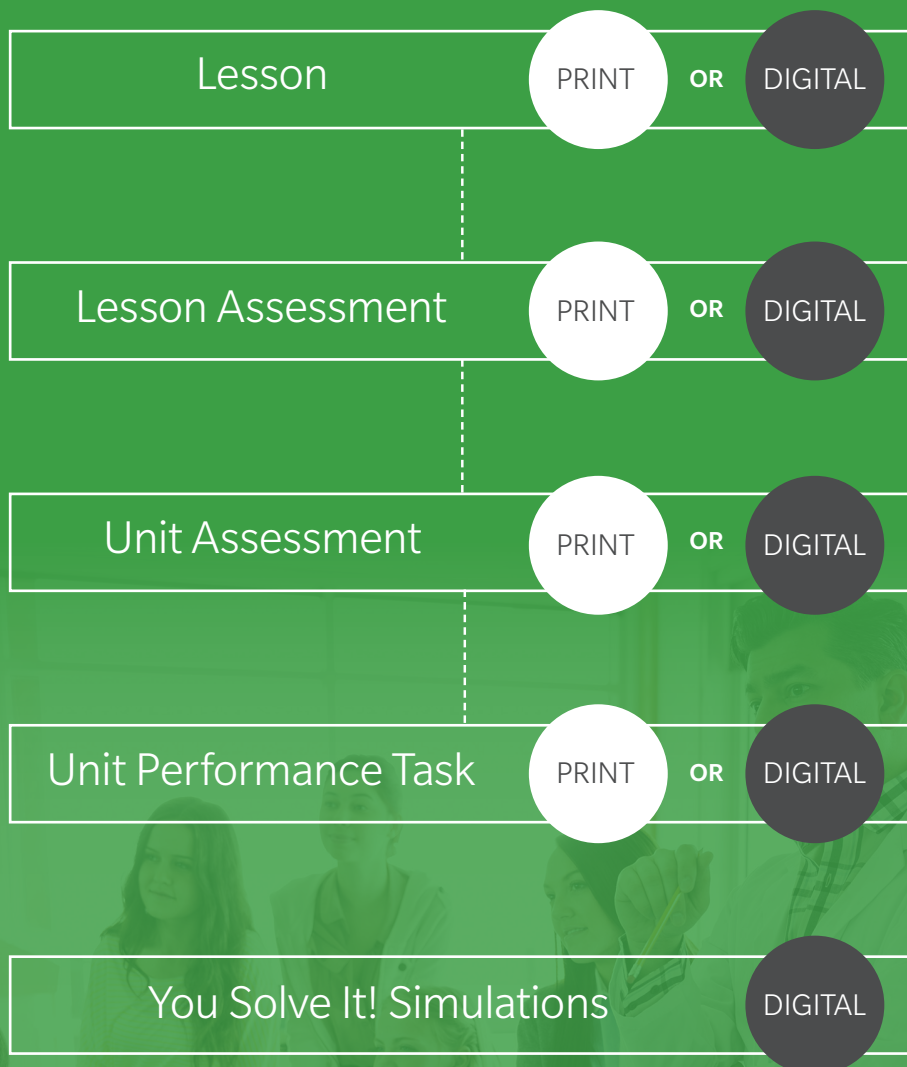
DIGITAL PATH

The robust interactive online Student Edition contains all the content from the print books, enhanced with high-interest interactive elements!



Digital? Print? It's Your Choice!

Because both the digital and print paths include the same content, your learners can follow *any* path to the Performance Expectations that you designate. Leverage digital for small-group work, flipped classrooms, learning centers, and 1:1 technology situations.



Whether you use the print book or the online interactive Student Edition, your students will encounter plenty of opportunities for **science and engineering practices, small-group work, and collaborative projects!**

HMH Science Dimensions

Designed—not aligned—for NGSS!

HMH Science Dimensions™ Biology was built for you from the ground up to authentically and effectively address both the spirit and the letter of the Next Generation Science Standards (NGSS)*.

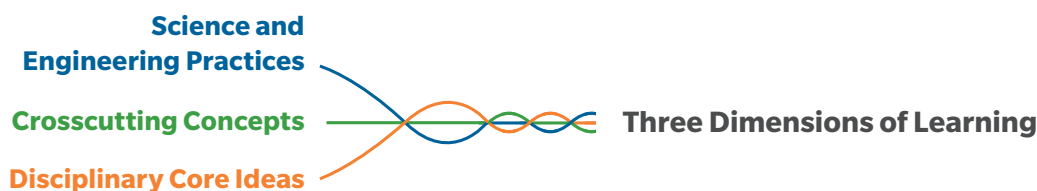
The Digital Advantage

HMH Science Dimensions Biology incorporates highly motivating interactive digital elements, like animations, videos, simulations, and more. This approach allows the program to harness the power of technology, so that students are more engaged, resulting in a more effective learning experience. Throughout this walkthrough, note the **▼ DIGITAL ADVANTAGE** sections highlighting the interactive elements designed to optimize learning.

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Three-Dimensional Learning

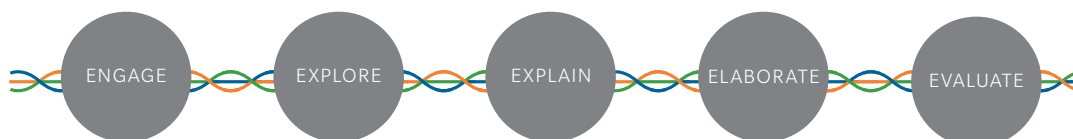
Any curriculum based on the NGSS must integrate the **Science and Engineering Practices**, **Crosscutting Concepts**, and **Disciplinary Core Ideas** (the Three Dimensions of Learning) throughout all lessons. *HMH Science Dimensions* intertwines the Three Dimensions into a cohesive, braided approach that ensures students will increase science proficiency.



Lesson Structure—the 5E Model

HMH Science Dimensions consists of units containing closely related lessons.

Each lesson is built around the familiar **5E instructional model**, endorsed by NGSS thought leaders. We've overlaid the **Claims/Evidence/Reasoning** learning model below with the 5Es to give you a better understanding of how a pedagogy driven by NGSS aligns to the 5Es.



ENGAGE **Stimulated to engage** with a discrepant phenomenon or puzzling question, students begin each lesson by making connections to the real world around them.

► **CLAIMS** Students hypothesize a model or explanation to the puzzle or problem presented. By evaluating their own mental models, students are prepared to study the phenomenon.

EXPLORE **Inspired to explore** new concepts and gather evidence, they learn actively through a variety of activities and resources.

► **EVIDENCE** Students perform experiments and pursue several methods of scientific inquiry to gather data and explore their model.

EXPLAIN **Challenged to explain** and test their ideas and claims, students become skilled at reasoning about how well their evidence supports their claims.

► **REASONING** Armed with real data related to the initial phenomenon or problem, students draw conclusions and adjust models.

ELABORATE **Motivated to extend** their new learning, students apply this knowledge in different situations to deepen understanding.

EVALUATE **Enabled to evaluate** how their understanding has changed, students are supported by a progression of formative and summative activities during the lesson.

experiences that follow.

Interactive Illustrations

also able to share their work with their teacher.



EXPLORE & EXPLAIN

In the next phases of the 5E model, a series of related Explore & Explain activities are organized as **Explorations**. During these activities, learners embark on a discovery process of gathering **evidence** to either support or challenge their **claims** through:

- hands-on activities and labs
- data analysis
- instructional diagrams
- informative videos
- immersive virtual activities

Throughout the lesson, students are prompted to record their evidence using **Evidence Notebooks** where appropriate.

Student-directed formative assessments embedded in the lesson help students assess the evidence they gather. They also share their evidence with peers and collaborate on the activities.

EXPLORATION 2

Transforming Light Energy into Chemical Energy

So far you have seen that plants transform energy from sunlight into chemical energy stored in the chemical bonds of sugar molecules. But, how does this transformation of energy happen? Chloroplasts in cells are like solar-powered chemical factories. They transfer light energy to energy-carrying molecules called **ATP** and **NADPH**. Cells use these molecules as energy currency for cell processes. In plant cells, they are used to convert carbon dioxide into sugars.

FIGURE 8: Two energy-carrying molecules are used in photosynthesis. ATP stores energy in a phosphate-phosphate bond, and NADPH carries high-energy electrons.

$$\text{ADP} + \text{P} \rightarrow \text{ATP}$$

$$\text{NADP}^+ + \text{H}^+ + 2\text{e}^- \rightarrow \text{NADPH}$$

Predict How do you think plant cells transfer energy from sunlight to the energy-carrying molecules ATP and NADPH?

Stages of Photosynthesis

Photosynthesis can be broken into two stages – the light-dependent reactions and the light-independent reactions. The light-dependent reactions take place within and across the membrane of the thylakoids, which are stacked inside the chloroplast. The light-independent reactions take place in the stroma, the area outside the thylakoids.

FIGURE 9: The two stages of photosynthesis, light-dependent reactions and light-independent reactions, occur in the chloroplast.

Analyze Identify the inputs and outputs for both stages of photosynthesis. Specify for both energy and matter.

Lesson 1: Photosynthesis 121

Print Student Edition

▼ DIGITAL ADVANTAGE

Rich Media

The audio and motion aspects of multimedia help learners visualize and see the Three Dimensions of Learning in action. Adding motion and context helps learners **relate to and internalize** the concepts portrayed.

The Light-Dependent Reactions

The light-dependent reactions are the *photo* part of photosynthesis. The main functions of the light-dependent reactions are to capture and transfer energy. Chlorophyll and other light-absorbing molecules capture energy from sunlight. The light energy is then transferred in the thylakoid membranes by two groups of molecules called photosystem II and photosystem I. They are named for the order in which they were discovered, and not the order in which they occur.

The first stage of photosynthesis is the light-dependent reactions, which include photosystem II and photosystem I. Explore the animation to learn more.

Put these steps in order to illustrate how energy is transferred from light to ATP in the light-dependent reactions of photosynthesis.

Interactive Online Student Edition

EXPLORE & EXPLAIN

Crosscutting Concepts

In each lesson, important Crosscutting Concepts are called out via a special feature and icon. Students are asked to dive deeper into the intelligent patterns of life, including:

- Energy and Matter
- Cause and Effect
- Scale, Proportion, and Quantity
- Systems and System Models
- Structure and Function
- Stability and Change

EXPLORE & EXPLAIN

Language Arts and Math Connections and Data Analysis

Being science literate requires a strong foundation in English language arts and math. So **HM Science Dimensions Biology** includes strong connections to these disciplines. These features, called **Language Arts Connection**, **Math Connection**, and **Data Analysis**, offer activities that are **integral to the core objectives** of the lesson.

EXPLORE & EXPLAIN

Hands-On Labs

Hands-On Labs are one way of addressing the Science and Engineering Practices of NGSS*.

HMH Science Dimensions Biology offers plenty of **Hands-On Labs** that encourage students to **gather their own evidence**.

Explore Online

Hands-On Lab

Investigating the Effect of Light Sources on the Rate of Photosynthesis

Imagine you wanted to optimize the rate of oxygen production by plants in a school or office building. What light source would you use? Go online to investigate how the rate of photosynthesis is affected by different wavelengths of light.

CONTINUE YOUR EXPLORATION

Hands-On Lab

Aerobic and Anaerobic Processes in Yeast

The species used in this investigation, *Saccharomyces cerevisiae*, like other species of yeast, is a facultative anaerobe. Facultative anaerobes can break down sugars using either aerobic or anaerobic processes, depending on the presence of oxygen.

OBJECTIVE

In this lab, you will construct an explanation based on evidence for how matter and energy flow in yeast under aerobic and anaerobic conditions.

SAFETY

Obtain and wear goggles for this lab. Do not eat any materials used in this lab.

PROCEDURE

1. Blow up the balloon a few times to stretch it.
2. Using the funnel, pour 150 mL of warm water into the bottle. Dry the funnel.
3. Using the dry funnel, add 1 packet of yeast to the water. Swirl the mixture gently.
4. Using the funnel, add 1 tablespoon (12 g) of sugar to the yeast solution, swirl, and quickly cover the bottle with the balloon. Allow the mixture to react for 5 minutes.
5. After 5 minutes have passed, use the string, marker, and ruler to measure the circumference of the balloon.
6. In a data table, record the circumference of the balloon, along with all of your observations of what is happening in the bottle. Continue making and recording observations every 5 minutes for the next 30 minutes.
7. Dispose of waste according to your teacher's instructions.

ANALYZE

1. Describe evidence, if any, that aerobic respiration took place in the bottle.
2. How does matter cycle during aerobic respiration? Explain how the reactants are rearranged to form the products. What is the source of energy, how is the energy transferred, and how is it used in the cell?
3. Describe evidence, if any, that fermentation took place in the bottle.
4. How does matter cycle during fermentation? Explain how the reactants are rearranged to form the products. What is the source of energy, how is the energy transferred, and how is it used in the cell?

EVIDENCE FOR ENDOSYMBIOSIS **CELLULAR RESPIRATION IN SEEDS** Go online to discover one of these other paths.

Lesson 2 Cellular Respiration 137

Hands-On Lab

Cellular Respiration and Exercise

Burning fuel through either combustion or cellular respiration requires oxygen. In each process, bonds break and new bonds form. In this lab, you will use an indicator called bromothymol blue to gather evidence to support a claim about the inputs and outputs of cellular respiration. Bromothymol blue changes color in the presence of an acid.

Predict What evidence could there be to support the claim that during cellular respiration, chemical bonds are broken and new bonds are formed?

SAFETY

Do not consume any of the materials used in this lab. Be careful not to breathe in through the straw.

PROCEDURE

1. Measure the amount of bromothymol blue solution specified by your teacher in a cup, if tube, or beaker.

2. If the timer ready, slowly blow through the straw into the bromothymol blue solution, and record how long it takes for the solution to change from blue to yellow. Be sure not to inhale when the straw is in the solution.

3. Measure the amount of bromothymol blue solution specified by your teacher in a second cup or beaker.

4. If the timer ready, slowly blow through the straw into the bromothymol blue solution, and record how long it takes for the solution to change from blue to yellow.

ANALYZE

1. After turned acidic when you blew into it because carbon dioxide in your breath reacted with water to form carbonic acid.

2. If the timer ready again, slowly blow through the straw into the bromothymol blue solution, and record how long it takes for the solution to turn yellow.

3. Do your findings support the claim that bonds were broken and new bonds were formed to produce the gas you breathed out? When you exercised, what was different about the time it took the solution to change color? Explain why this happened.

URE 4: bromothymol blue is an indicator that changes color in the presence of acid.

Image credit: Christopher Wolff/Alamy

Print Student Edition

EXPLORE & EXPLAIN

Science Notebooks and Journals

While completing the variety of data gathering activities within a lesson, students are often prompted to **Model**, **Gather Evidence**, **Explain**, and **Analyze** their findings. These writing prompts encourage students to act like scientists by handling data like a scientist.

ANALYZE

Is energy conserved in this system? In your analysis, use the amount of energy transferred to explain why the energy model is shaped like a pyramid.

MODEL

Draw a plant and label the inputs and outputs of photosynthesis. Where should the labels for enzymes and light be placed?

GATHER EVIDENCE

What information do scientists need in order to determine how much energy is converted into biomass at different trophic levels?

EXPLAIN

Summarize the evidence that you have gathered to explain how bonds are rearranged and energy is transferred in the process of cellular respiration.

1. Cite evidence to support the claim that bonds are broken and new bonds are formed in each stage of cellular respiration.
2. Explain how energy is transferred from the bonds of food molecules to cellular processes.

ELABORATE

Take It Further and Continue Your Exploration

To promote interest in science and prepare students for college and careers in engineering and science, we've added a **Take It Further** or **Continue Your Exploration** feature to EVERY lesson. These features **relate science to students' own lives and futures**, inspiring their interest in STEM. The **Guided Research** feature provides students with tips on how to consider research questions, analyze evidence, and prepare responses in the forms of presentations or papers, thus further strengthening their language arts skills.

CONTINUE YOUR EXPLORATION

Guided Research

Evaluating Solutions to Human Impacts

Scientists and engineers are working to develop solutions to human impacts on the hydrologic and biogeochemical cycles. Burning fossil fuels for energy has one of the largest impacts on these cycles. Finding alternatives to fossil fuel energy is key to decreasing human impact and making lasting changes.

Currently engineers and scientists are investigating solar, wind, water, biological, and geothermal energies as potential alternatives to fossil fuels. You may have already heard of wind and solar farms. Scientists must ask many questions when they consider implementing new energy sources such as these, including:

- **Costs** - Is the solution cost effective? Can a similar solution be reached in a less costly manner without losing quality?
- **Safety** - Is the solution safe for humans and other living things?
- **Reliability** - Is the solution going to hold up over time in the given conditions? Will it need large amounts of upkeep to be maintained over time?
- **Aesthetics** - Does the solution add to or detract from the natural visual beauty of the area?
- **Social and cultural impacts** - How does the solution impact human societies and cultures? Are there any concerns about these impacts?

Environmental impacts - How does the solution impact the environment? Are there any concerns about these impacts?

Meeting criteria - Does the solution solve the problem and meet the needs of those who will use the new energy source?

Evidence to support the solution - How well does the evidence provided support the claims that are being made about this solution and how it will work?

Language Arts Connection - Choose an alternative energy source and research how it impacts the biogeochemical and hydrologic cycles or how it reduces human impact on these cycles. Write a blog entry detailing your research. Explain how the alternative energy source will work for human populations in terms of its trade-offs, such as cost, reliability, and impact on society and the environment. Gather evidence from multiple sources and describe specific evidence from each source.

THE LUNGS OF THE PLANET **NITROGEN FIXATION** **Go online to choose one of these other paths.**

168 Unit 3 Matter and Energy in Living Systems

Print Student Edition

DIGITAL ADVANTAGE

Student's Choice: Take It Further

Digital delivery allows for more student choice than in print. Nowhere is this more evident than the **Take It Further** and Continue Your Exploration (Elaborate) portion of the lesson. Online, students have **several options to choose from**, one of which is sure to capture their interest.

TAKE IT FURTHER

Choose one of the paths below to continue your exploration.

Variation in Photosynthesis

Research how plants have adapted the process of photosynthesis to survive in different environments.

The Color of Plants on Other Planets

Investigate what the color of plants might be on two known planets, Kepler-438b and Kepler-442b.

The Color of Plants on Other Planets

In the search for life on other planets, some questions that scientists have asked are "Could plants grow on other planets?" and "Would plants on other planets look like plants on Earth?" Plants on Earth evolved to absorb wavelengths of visible light that are readily available on this planet. In this activity, your objective is to research a type of star, the Red Dwarf, and prepare a multimedia report explaining what color the plants on a planet orbiting a Red Dwarf might likely be.

Tip Use Media in a Presentation

A multimedia presentation combines text, sounds, and images. A successful multimedia presentation includes:

- a clear and consistent focus
- ideas that are presented clearly and logically
- graphics, text, music, video, and sounds that support key points
- an organization that is appropriate to its purpose and audience

EVALUATE

Lesson Self-Check

All the students' learning experiences come together in the Evaluate section. Students revisit the puzzling occurrence or intriguing problem they made a claim about in the Engage section. As students progress through the lesson, they gathered evidence throughout the Explore and Explain sections. When they reach Evaluate, students return to their **claim** and evaluate the **evidence** they gather. They **reason** how the evidence supports or challenges their claim, thereby strengthening their understanding of the science.


EVALUATE

Lesson Self-Check

CAN YOU EXPLAIN IT?

As scientists and engineers plan for the next phase of space exploration—traveling to and colonizing other planets, they must devise ways of meeting the needs of humans. Today's astronauts are studying how plants grow in space. Their results will help scientists determine the best way to keep plants alive until they arrive at the new planet. The next step in this process will be to determine how plants might grow in the new planet's environment.

FIGURE 14: Growing plants in space is important not only as a long-term food source, but also as a connection to life on our home planet, Earth.



Explain Use what you have learned to further explain how plants could be grown on other planets. Address the following in your explanation:

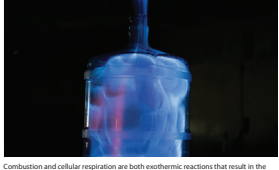
1. What inputs do plants need to carry out photosynthesis, and how might you provide these on another planet?
2. What outputs do plants produce from photosynthesis, and how do these benefit humans?
3. How do plants transfer energy from light to sugar molecules?
4. What questions would you ask about the planet to refine your list of necessary materials?

EVALUATE

Lesson Self-Check

CAN YOU EXPLAIN IT?

FIGURE 15: Because ethanol burns more cleanly than gasoline, it is added to gasoline to help reduce the emission of greenhouse gases produced by combustion engines in cars. Like gasoline, ethanol contains energy in its chemical bonds that can be released by the process of combustion.



Combustion and cellular respiration are both exothermic reactions that result in the release of energy. The energy is released when chemical bonds that store energy are broken. Combustion is a fast process that results in the production of energy in the forms of heat and light.

$$\text{CH}_3\text{CH}_2\text{OH} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{heat}$$

In contrast, cellular respiration is a slow process, with energy being released over a series of several steps. This makes energy available for use whenever cells of the body need it to carry out cellular activities.

$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{ATP}$$

Explain A scientist named Antoine Lavoisier demonstrated that cellular respiration is a combustion process. Recall that car engines use a combustion reaction to release energy. Construct an explanation for how the breakdown of fuel in a car engine compares to the breakdown of fuel in your body's cells. Answer the following questions:

1. Look carefully at the equations for both combustion and cellular respiration, and compare the inputs and outputs. How can the different inputs result in the same outputs based on what you know about chemical bonds and atoms?
2. What is missing from the process of combustion that makes it an imperfect model for cellular respiration? Explain your answer.

Print Student Edition

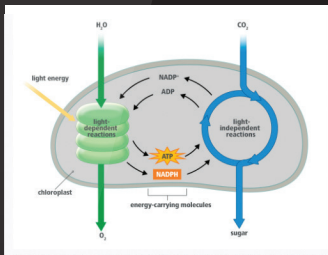
DIGITAL ADVANTAGE

Formative Assessment with Instant Feedback

Online delivery of assessments can provide **instant feedback**. This allows learners to truly take charge of their learning by monitoring their progress while actively engaging with the lesson.

Which of these effects are most likely to result if photosynthesis were no longer possible on Earth?

- ☐ A. Consumers would not have an energy source.
- ☒ B. Consumers would begin producing their own energy.
- ☐ C. The amount of oxygen produced would decrease.
- ☒ D. The amount of carbon dioxide in the atmosphere would increase.
- ☒ E. Producers would begin consuming energy instead of producing it.



The two stages of photosynthesis, light-dependent reactions and light-independent reactions, occur in the chloroplast.

Use the stages of photosynthesis model above to complete this statement:

In the light-dependent reactions, water and light energy are inputs, and is an output. In these reactions, two energy-carrying molecules, and NADPH, are produced and sent to the light-independent reactions. In the light-independent reactions, gas is an input, and is an output.

Scaffolded Formative Assessment

Online learning allows scaffolded formative assessment. By responding to questions with limited-response options, students gradually increase their understanding of concepts. In these examples, students are given a choice of answers or an example of a possible answer.

EVALUATE

Formative Assessment

Lesson Formative Assessment

The interactive nature of the lessons provides constant formative assessment, but additional formative assessment is provided in the **Self-Check** and **Checkpoints** at the end of each lesson. As is true throughout the program's lessons, the assessment **fully integrates all three dimensions** of science learning—Crosscutting Concepts, Disciplinary Core Ideas, and Science and Engineering Practices.

Unit Formative Assessment

At the end of each Unit, learners have access to the **Unit Practice and Review**. This formative assessment covers the same three dimensions of learning for the entire Unit.

UNIT PRACTICE AND REVIEW

SYNTHESIZE THE UNIT

In your Evidence Notebook, make a concept map, graphic organizer, or outline using the Study Guide you used for each lesson in this unit. Be sure your outline is supported by your data.

When synthesizing individual information, consider the following:

- Did the evidence support your claim?
- Did the evidence support your reasoning?
- Did the evidence support your evidence?
- Did the evidence support your claim?

DRIVING QUESTIONS

Look back to the Driving Questions from the opening section of this unit. In your Evidence Notebook, review and answer your previous answers to these questions. Use the evidence you gathered and other observations you made throughout the unit to support your claims.

PRACTICE AND REVIEW

FRANK & Energy transferred to electrons moves through the light-dependent reactions.

1. Solar panels capture energy from sunlight and convert it to electricity. As light hits the silicon atoms in a solar cell, the energy is transferred to electrons. The electrons are emitted from silicon atoms, and an electric field organizes the electrons into an electric current. Compare the way a solar cell works to the way a chloroplast works to capture and transfer energy.

2. The cell is a system in which processes such as photosynthesis and cellular respiration take place so that the cell can survive. Which processes are most important to the survival of other organisms, including humans?

3. Describe the relationship between cellular respiration and photosynthesis in terms of energy and matter.

4. In a general sense, the highest order organisms have the most complex number of individuals in an ecological community. What might happen if the population of this organism increased significantly? In your Evidence Notebook, develop a model explaining the effect this increase would have on other members of the community.

5. 50% of the energy is lost as heat between trophic levels. Approximately how much energy is available to the secondary consumers in the energy pyramid?

FRANK & Energy in trophic levels.

6. Make a model in your Evidence Notebook to show how a biogeochemical cycle is connected to the transfer of matter and energy through a food chain. In your model, include matter and how it moves through the cycle of matter and energy.

7. An increase in energy can change the dynamics of a system. Explain how alterations in the carbon cycle result in an increase in the amount of energy contained in the Earth system. Discuss how this addition of energy might affect the cycling of matter in other biogeochemical cycles.

8. Why does the amount of energy in an ecosystem depend on its producers?

9. The nitrogen cycle relies on various organisms carrying out very specific functions. One of the organisms in the nitrogen cycle would be disrupted if there were a sudden population explosion of nitrogen-fixing bacteria?

10. A population explosion of nitrogen-fixing bacteria would lead to a decrease in atmospheric levels in the water.

11. A population explosion of nitrogen-fixing bacteria will cause dissolved nitrogen levels in the water to increase.

12. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to increase.

13. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to decrease.

14. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to increase.

15. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to decrease.

16. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to increase.

17. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to decrease.

18. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to increase.

19. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to decrease.

20. A population explosion of nitrogen-fixing bacteria will cause atmospheric levels of nitrogen to increase.

EVALUATE

CHECKPOINTS

Check Your Understanding

1. In a prairie ecosystem, which of the following populations has the most stored energy for use by other organisms?

- herbivores
- producers
- primary consumers
- tertiary consumers

2. Which food chain correctly shows the direction that energy and matter flow through a forest ecosystem?

- herbivores → producers → tertiary consumers
- producers → herbivores → tertiary consumers
- tertiary consumers → producers → herbivores
- producers → tertiary consumers → herbivores

3. Which of the following terms are in the correct order, from smallest to largest?

- population, ecosystem, community, ecosystem, biome, Earth, biosphere
- ecosystem, community, population, ecosystem, biome, Earth, biosphere
- ecosystem, population, community, ecosystem, biome, Earth, biosphere
- ecosystem, ecosystem, population, community, biome, Earth, biosphere

4. Consider a pyramid model with a producer level, a primary consumer level, a secondary consumer level, and a tertiary consumer level. Which of the following statements are correct?

- The sun is the ultimate source of energy in an ecosystem.
- Matter cycles and is generally conserved within an ecosystem.
- Energy flows through ecosystems, but only a certain amount of energy is transferred to the next trophic level.
- Energy flows through ecosystems, but some is lost to the environment as heat.
- Matter and energy are completely conserved and transformed into biomass within an ecosystem.

5. In your Evidence Notebook, make a model to explain how energy enters a food web and how it is transferred from one organism to another.

6. Why is a desert in North America, such as Arizona's Sonoran Desert (Figure 2.15), considered to be the same biome as a desert in Africa?

7. What biotic and abiotic factors influence the flow of matter and energy in different biomes?

8. Do you think it is possible for a biome to change from one type to another due to human activities? Explain a situation in which this might happen.

Figure 2.15: Sonoran Desert

Source: National Geographic

Print Student Edition

Summative Assessment

Each Unit includes a **Unit Project** and a separate **Performance Task** so students can demonstrate the **NGSS* Performance Expectation** competency using the **Claims/Evidence/Reasoning** approach they practiced using in the lessons.

The authentic and practical application of student learning creates a full three-dimensional science learning experience, addressing Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts.

Many performance-based activities are designed around STEM applications and the Engineering Design Process.

UNIT PERFORMANCE TASK

Analyzing Water Pollution

The small town of Lakewood is located on the shores of Piper Lake. The town relies on the lake for fishing, water recreation, and recreational activities. Recently, a fertilizer plant, F.C. Fertilizers, was built upstream in Eagle River, which leads into Piper Lake. The town has noticed an increase in algae blooms in the lake. They are concerned the fertilizer plant is dumping too much nitrogen into the river and their livelihood could be affected. Is the town right? Does the plant need to control the waste they put into the river?

FIGURE 2.15: Fertilizer plant is upstream from Piper Lake.

1. DEFINE THE PROBLEM

With your team, write a statement outlining the problem you've been asked to solve. Record any questions you have on the problem and the information you need to solve it.

2. CONDUCT RESEARCH

With your team, investigate the cause-and-effect relationship between nitrogen, algae blooms, and fish populations. Could the fertilizer plant be responsible for the changes the town is experiencing?

3. ANALYZE DATA

On your own, analyze the problem you've defined along with your research. Make a model to show how excess nitrogen cycles through the aquatic ecosystem. Your model should also show any effects the nitrogen may have on the ecosystem using a food web, energy pyramid, biomass pyramid, or pyramid of numbers.

4. COMMUNICATE

Present your findings to the town and the fertilizer company explaining whether or not the runoff from the fertilizer plant is adversely affecting the lake ecosystem. Your presentation should include images and data to support your claims.

CHECK YOUR WORK

A complete presentation should include the following information:

- a clearly defined problem with supporting questions that are answered in the final presentation
- a model of the effect of the fertilizer runoff
- a recommendation that explains how to solve the problem and use evidence to support the solution
- images and data that further support your solution

Bottle Biome

How do energy and matter cycle through a closed system such as the Earth system? How do the plants and animals survive? Make your own closed biological system inside a bottle, and investigate how the plants and animals survive with no materials being added to the system. Can you explain how the bottle represents Earth?

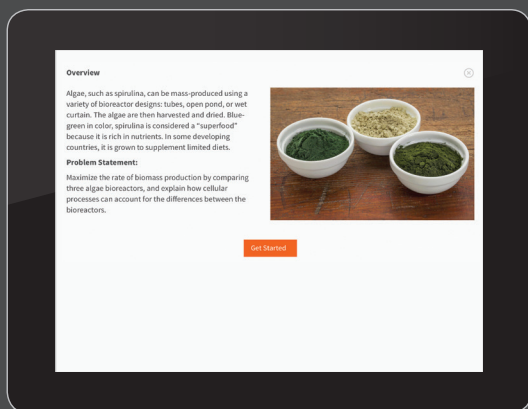
Go online to download the Unit Project Worksheet to help plan your project.

Unique Digital Simulations Reinforce Three-Dimensional Learning and Claims/Evidence/Reasoning

▼ DIGITAL ADVANTAGE

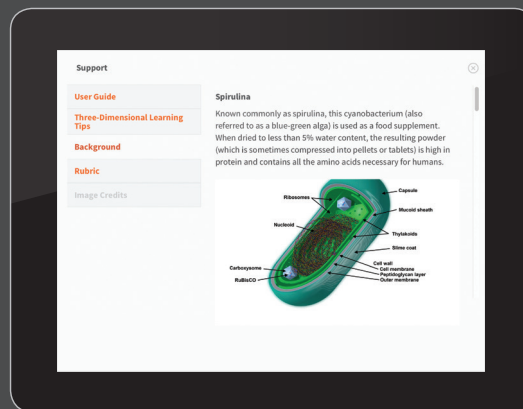
You Solve It! Open-ended Simulations

You Solve It! simulations involve a rich data-gathering or problem-solving exploration that goes far beyond requiring merely a single right answer. Available as part of the digital path, these unparalleled NGSS-centric open-ended simulations support the **Claims/Evidence/Reasoning** instructional model and allow students to answer questions and solve problems in their own way.



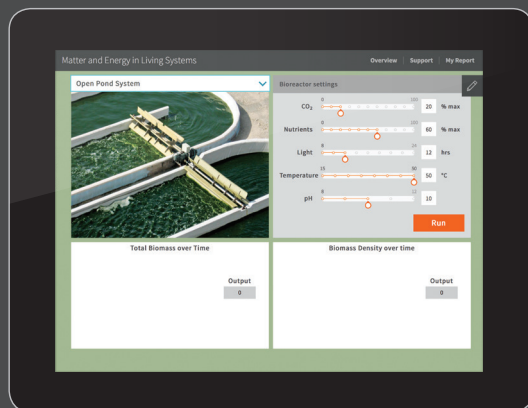
Overview

This provides context and some basic instructions on using the open-ended simulation.



Support

The Support section reminds students of the NGSS connections, such as relevant SEPs, DCIs, and CCCs. It also provides helpful background information and instruction on how to control the simulation.



Simulation

This open-ended simulation gives students FULL control. They make their own choices on how to gather evidence or achieve a solution.

Notes/Report

Students can jot notes about their evidence and reasoning for later creating a report about their claim. They can restart their work at home or on the go when they log into their online Student Edition with any compatible device.

The Teacher Edition— Your NGSS Companion

The Teacher Edition is designed to easily guide you through an NGSS* lesson organized around the 5E model.

LESSON 1

Photosynthesis

Building to the Performance Expectations

The learning experiences in this lesson prepare students for mastery of:

PE-HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

PE-HS-LS2-3 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Trace Tool to the NGSS

Go online to view the complete coverage of standards across lessons, units, and grade levels.

SEP Science & Engineering Practices

Developing and Using Models
Use a model based on evidence to illustrate the relationships between systems or between components of a system.

DCI Disciplinary Core Ideas

LS2.B Cycles of Matter and Energy Transfer in Ecosystems
Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)
LS1.C Organization for Matter and Energy Flow in Organisms
The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
PS3.D Energy in Chemical Processes
The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)

CCC Crosscutting Concepts

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-LS2-5)

Energy and Matter
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5), (HS-LS1-6)

Energy and Matter
Energy drives the cycling of matter within and between systems. (HS-LS2-3)

CONNECTION TO MATH

MP2 Reason abstractly and quantitatively

CONNECTIONS TO ENGLISH LANGUAGE ARTS

RS.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

116A Unit 3: Matter and Energy in Living Systems

LESSON 4 Explore | Explore/Explain | Evaluate | Evaluate

EXPLORATION 1 Matter Cycles Through Ecosystems

3D Learning Objective
Students learn that as matter and energy flow through an ecosystem chemical elements are recombined in different ways to form different products, and use models to illustrate relationships between components of a system. Students construct explanations of how energy drives the cycling of matter within and between systems.

Math Connection
MP2 Reason abstractly and quantitatively.
Answer: 100% - 22% = 48% = 20% reflected back into space

Collaboration
Group Discussion Have students discuss as a group the question about how Earth's ecosystems are affected by solar radiation. At the end of the discussion, students should recognize that all ecosystems on Earth would be affected. If Earth absorbed more solar radiation, the temperatures on Earth would be higher than they are now. If Earth absorbed less solar radiation, the temperatures on Earth would be lower than they are now. Organisms within ecosystems that could not adjust to the temperature changes would either move to another location where the temperatures were better suited to their needs, or they would die.

EVIDENCE NOTEBOOK
All of the matter on Earth has been here for billions of years. It travels within system cycles through the atmosphere, geosphere, hydrosphere, and biosphere.

Lesson 4 Cycling of Matter and Energy in Ecosystems 159

3D Learning Objectives

Using the program's customized 3D Learning Objective and clearly labeled Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices, educators can keep track of the specific standards that students are covering at any given point in the lesson.

3D Learning Objective

Students learn that as matter and energy flow through an ecosystem **chemical elements are recombined in different ways to form different products**, and **use models** to illustrate relationships between components of a system. Students construct explanations of how **energy drives the cycling of matter within and between systems**.

LESSON 4 Explore | Explore/Explain | Evaluate | Evaluate

EXPLORATION 1 Matter Cycles Through Ecosystems, continued

Get It Online
Hands-On Lab
Nitrogen Fixation
Students investigate the role of nitrogen-fixing bacteria in a legume root nodule.

SEP Constructing Explanations
Students look at prepared slides of cross-sections of root nodules from legumes containing nitrogen-fixing bacteria, and then explain how planting legumes in a field can help meet a crop.

SEP Student Lab Worksheet and complete Teacher Support are available online.

CCC Energy and Matter
Students should recognize that energy drives the cycling of matter within and between systems.

EVIDENCE NOTEBOOK
Bacteria and, to a lesser extent, plants in a fish tank take up the ammonium in the fish tank and restore a healthy environment for the fish. Bacteria change ammonium into nitrate through nitrification. Plants convert nitrate into useful compounds such as amino acids.
When legumes, such as alfalfa, peas, and beans, are harvested or removed from the ecosystem, they are not removed from the nitrogen cycle. The nitrogen in the legumes might be removed from the soil in that ecosystem, but the nitrogen is relocated to the bodies of the organisms that consume the legumes. The nitrogen in that organism will be returned to the environment in waste products and when the organism dies and decomposes. All of these processes are part of the nitrogen cycle.

Hands-On Lab
Manager Function Introduce the role of nitrogen-fixing bacteria in legume root nodules.

Energy and Matter
Rhizobium Bacteria
Rhizobium bacteria form symbiotic relationships with certain types of plants, particularly those in the legume family. Rhizobium bacteria live in the nodules on the roots of legumes, as shown in Figure 1. The plant provides essential nutrients to the bacteria, and in return, the bacteria fix nitrogen into ammonium, which the plant absorbs. Most of the ammonium made by the bacteria is kept by the plant and used either to synthesize amino acids and build the plant's tissues, or to produce the amino acids released into the soil for other organisms to use. Rhizobium bacteria convert the atmospheric nitrogen into an ammonium ion.

The Phosphorus Cycle
Phosphorus and nitrogen are essential to living things. It is a component of phosphate groups in ATP (204), and plays a role in cell membranes. Phosphorus occurs in the form of phosphate ions bound to oxygen, sulfide, and hydroxide. Geological processes release these ions, and water and wind break them down, making them available to plants and animals.

164 Unit 3: Matter and Energy in Living Systems

3D Item Analysis

The 3D Item Analysis in the Unit Review identifies the associated Three Dimensions of Learning for EACH review question. This helps educators assess students' knowledge of each component of the Next Generation Science Standards.

3D Item Analysis	1	2	3	4	5
SEP Developing and Using Models					•
SEP Constructing Explanations	•	•			
SEP Using Mathematics and Computational Thinking				•	•
DCI Organization for matter and Energy Flow in Organisms	•	•	•		
DCI Cycles of Matter and Energy Transfer in Ecosystems				•	•
DCI Energy in Chemical Processes	•	•	•		
CCC Energy and Matter	•	•	•	•	•
CCC Systems and System Models		•	•	•	•

UNIT 3 Practice and Review

LESSON 3.1: Matter and Energy in Living Systems

CONSTRUCTING EXPLANATIONS

Look back to the Energy Questionnaire. Remember, you are a scientist. Your job is to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered.

DEVELOPING AND USING MODELS

Look back to the Energy Questionnaire. Remember, you are a scientist. Your job is to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered.

LESSON 3.2: Matter and Energy in Living Systems

CONSTRUCTING EXPLANATIONS

Look back to the Energy Questionnaire. Remember, you are a scientist. Your job is to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered.

DEVELOPING AND USING MODELS

Look back to the Energy Questionnaire. Remember, you are a scientist. Your job is to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered. Use the evidence you gathered to explain the evidence you have gathered.

Synthesize the Unit

Encourage students to show relationships among concepts introduced in different lessons. They can do so by having students write a brief explanation of how their understanding of each Driving Question has changed since the start of the unit.

Formative Assessment

Practice and Review

1. A complete answer will compare how both processes capture light energy and how energy is transferred, transformed, and stored. Photosynthesis produces sugars that are required to fuel cellular respiration. Without these sugars, humans would not be able to produce energy for cellular functions.

2. The model predicts that photosynthesis and cellular respiration are coupled processes. Photosynthesis uses light energy to build carbon-based molecules and releases oxygen. Cellular respiration uses oxygen to break down carbon-based molecules and releases energy. The two processes are coupled because they share the same molecules and energy.

3. If a model shows a low level of photosynthesis, the amount of oxygen released would be low. If a model shows a high level of photosynthesis, the amount of oxygen released would be high. The amount of oxygen released would be directly proportional to the amount of light energy available. If there are 1000 J of energy available to the producer level, 1000 J are transferred to the primary consumer level, and 100 J are transferred to the secondary consumer level.

Unit 3 Unit Review

SEP	DCI	CCC	ETS
SEP Constructing Explanations	•	•	•
SEP Developing and Using Models	•	•	•
DCI Organization for matter and Energy Flow in Organisms	•	•	•
DCI Cycles of Matter and Energy Transfer in Ecosystems	•	•	•
DCI Energy in Chemical Processes	•	•	•
CCC Energy and Matter	•	•	•
CCC Systems and System Models	•	•	•

Common Core State Standards

For added convenience, many of the Math and ELA features in the lessons identify the Common Core State Standards that are referenced by NGSS.

Language Arts Connection

Alternative Energy In this activity, students consider some of the questions scientists and engineers must ask when exploring and developing alternative energy sources. Use this opportunity to incorporate Common Core English Language standards into the lesson. Encourage students to make strategic use of digital media in their blog entry about alternative energy to enhance understanding of findings, reasoning, and evidence. Also encourage students to cite specific textual evidence to support their analysis of science and technical texts, including noting any important distinctions that authors make and any gaps or inconsistencies in the author's analysis. Remind students to synthesize information from a range of sources into their blog entry and to write a coherent explanation of the alternative energy process that they are describing.

- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
- RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

LESSON 4 Engage • Explore/Explain • Elaborate • Evaluate

CONTINUE YOUR EXPLORATION Guided Research

Language Arts Connection

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WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Explore Online:

The Lungs of the Planet

Students analyze data to determine whether it is correct to refer to forests as "the lungs of the planet."

Nitrogen Fixation

Students investigate the role of nitrogen-fixing bacteria in a legume root nodule.

Guided Research

Evaluating Solutions to Human Impacts

Scientists and engineers are working to develop solutions to human impacts on the environment. One of the most important solutions is to develop alternative energy sources. Alternative energy sources are sources of energy that do not harm the environment. They are sources of energy that are sustainable and that do not produce greenhouse gases. They are sources of energy that are clean and that do not pollute the environment. They are sources of energy that are safe and that do not pose a risk to human health. They are sources of energy that are affordable and that do not cost too much. They are sources of energy that are easy to use and that do not require a lot of infrastructure. They are sources of energy that are reliable and that do not stop working. They are sources of energy that are efficient and that do not waste a lot of energy. They are sources of energy that are flexible and that can be used in a variety of ways. They are sources of energy that are scalable and that can be used to power a large number of people. They are sources of energy that are secure and that do not depend on a single source. They are sources of energy that are transparent and that do not involve a lot of secrecy. They are sources of energy that are inclusive and that do not exclude anyone. They are sources of energy that are resilient and that can withstand a lot of challenges. They are sources of energy that are innovative and that do not rely on old ideas. They are sources of energy that are collaborative and that do not involve a lot of competition. They are sources of energy that are ethical and that do not involve a lot of harm. They are sources of energy that are just and that do not involve a lot of inequality. They are sources of energy that are sustainable and that do not harm the environment. They are sources of energy that are clean and that do not pollute the environment. They are sources of energy that are safe and that do not pose a risk to human health. They are sources of energy that are affordable and that do not cost too much. They are sources of energy that are easy to use and that do not require a lot of infrastructure. They are sources of energy that are reliable and that do not stop working. They are sources of energy that are efficient and that do not waste a lot of energy. They are sources of energy that are flexible and that can be used in a variety of ways. They are sources of energy that are scalable and that can be used to power a large number of people. They are sources of energy that are secure and that do not depend on a single source. They are sources of energy that are transparent and that do not involve a lot of secrecy. They are sources of energy that are inclusive and that do not exclude anyone. They are sources of energy that are resilient and that can withstand a lot of challenges. They are sources of energy that are innovative and that do not rely on old ideas. They are sources of energy that are collaborative and that do not involve a lot of competition. They are sources of energy that are ethical and that do not involve a lot of harm. They are sources of energy that are just and that do not involve a lot of inequality. They are sources of energy that are sustainable and that do not harm the environment.

Trophic Levels

Trophic levels, shown in Figure 1.1, are the levels of organization in a food chain. The first trophic level is occupied by the producers. The second level is occupied by the primary consumers, usually herbivores. The third and fourth levels consist of secondary and tertiary consumers, and so on. Each level can be represented by a different organism.

Figure 1.1 Each organism in a food chain occupies a different trophic level.

1. Producer
2. Primary consumer
3. Secondary consumer
4. Tertiary consumer

Explore: This energy transfer explains how one trophic level is linked to the others. How does this energy transfer explain the flow of energy?

Collaborate: This activity explains and shows the flow of energy. How does this energy transfer explain the flow of energy?

Data Analysis

Population Size

A scientist sampled a small area of a grassland ecosystem. Her data for each trophic level are shown in the table.

Trophic Level	Producers	Primary Consumers	Secondary Consumers	Tertiary Consumers
Population Size	1,000,000	100,000	10,000	1,000

Analyze: Answer the following questions in your Science Notebook.

- How does the population size change at each trophic level in the sample?
- What is the relationship between population size and trophic level?
- What is the relationship between population size and energy transfer?

EVIDENCE NOTEBOOK

- Energy is lost at each level of a food chain as the organism uses energy for its own metabolism, and some energy is lost to the environment as heat.
- Population size decreases significantly with each trophic level.
- A tertiary consumer would probably not be supported and would not be able to survive.

Lesson 3 Modeling Matter and Energy in Ecosystems 147



Math Connection

MP.2 Reason abstractly and quantitatively.

As students work through the data analysis activity, they should be able to reason that fewer organisms can be supported at each trophic level.

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