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SCIENCE
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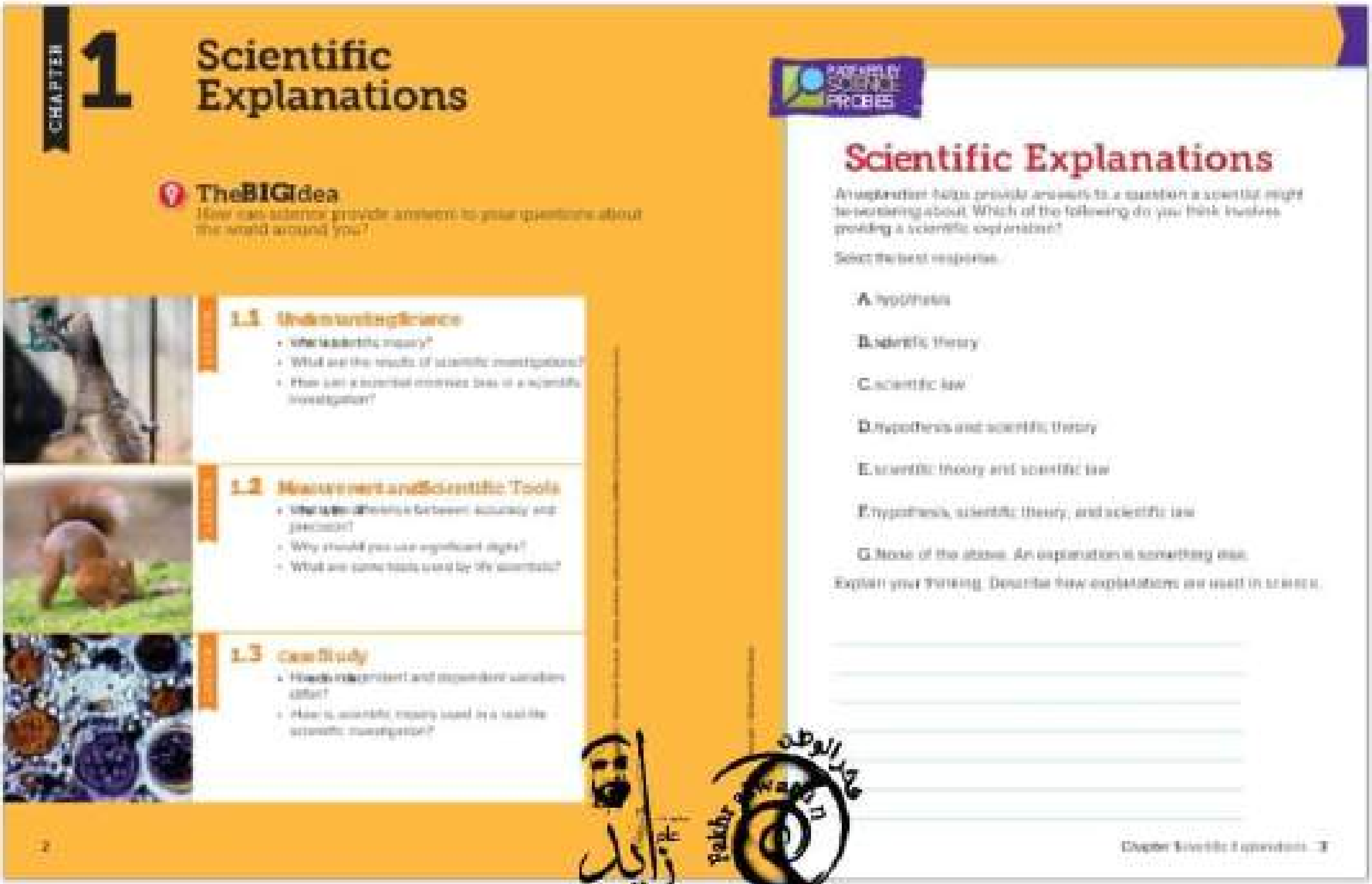
McGraw-Hill Education

Integrated Science

United Arab Emirates Edition

Mc Graw Hill Education



CHAPTER 1 Scientific Explanations

The BIG Idea How can science provide answers to your questions about the world around you?

1.1 Understanding Science

1.2 Measurement and Scientific Tools

1.3 Case Study

Scientific Explanations

Select the best response.

A. hypothesis

B. scientific theory

C. scientific law

D. hypothesis and scientific theory

E. scientific theory and scientific law

F. hypothesis, scientific theory, and scientific law

G. None of the above. An explanation is something else.

Explain your thinking. Describe how explanations are used in science.

Scientific Explanations

The BIG Idea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL	**What are some things in nature or about technology that you wonder about?**	*Accept all reasonable responses. Guide students to brainstorm ideas and put them in question form. Some examples include: Why do dogs chase cats? Why are there so many of some species of birds? How does a switch turn on a light?*
OL	**How could you find the answers to questions you have?**	*Students might propose that they read about it, look for answers on the Internet, experiment, or ask an expert.*
BL	**How do you think scientists find answers to their questions?**	*Accept all reasonable responses.*

Page Keeley Science Probes: Scientific Explanations

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook.*

This Nature of Science chapter presents information about scientific inquiry, hypotheses, observation, measurement, and other scientific procedures. A case study, led by a team of Earth, life, and physical scientists, shows students how these same inquiry techniques are used in real-world science.

Throughout this book, students will apply nature of science and inquiry skills and processes while performing **Launch Labs, MiniLabs,** and **SkillPractice** activities, and chapter **Labs**. As they read articles titled **Science and Society, Careers in Science, How Things Work, How Nature Works, Green Science,** analyze case studies, and apply scientific concepts to the world around them, they gain a better understanding of the importance of science. Completing online activities provides students with the opportunity to explore, research, and analyze the work of scientists who use these same skills and processes in their daily work.

Science Content Background

Lesson 1

Understanding Science

What is science? Science is the means by which we find out how nature works. It is a process of studying nature by collecting and analyzing the information resulting from that process.

Branches of Science There are three general fields of science: life science, Earth science, and physical science. Each branch of science includes many sub-branches.

Questions Scientists Ask Science has answered many questions about nature. In 2005, for its 125th anniversary, *Science* magazine listed 125 top questions that still await answers. They included How does Earth's interior work? and What genetic changes make us uniquely human?

Scientific Inquiry In answering questions about nature, scientists use skills called scientific methods. There is no single scientific method—rather, there is scientific inquiry. This process is shown as a graphic image for better understanding.

Research Free of Bias In conducting research, scientists must guard against being biased. To avoid bias, scientists use blind studies in which the identities of substances being tested are coded until results have been obtained. Researchers also repeat a test several times to be sure the outcome is always the same.

Scientific Theory and Scientific Law A theory in science is a detailed explanation of an event or phenomenon based on scientists' investigations. A law is a verbal or mathematical statement describing a pattern or event in nature that is always true. A theory might explain how and why an event occurs, but a law only states that it will occur.

Results of Scientific Inquiry There are many possible outcomes to scientific inquiry, including new technology and new materials. Sometimes, however, it simply explains something that previously had not been understood, adding to the store of human knowledge.

Lesson 2

Measurement and Scientific Tools

Description and Explanation In their investigations, scientists describe what they observe and then seek to explain it. The observation of nature requires a variety of tools. One tool that is used by scientists is the computer, which enables researchers to make models and record and analyze large amounts of data.

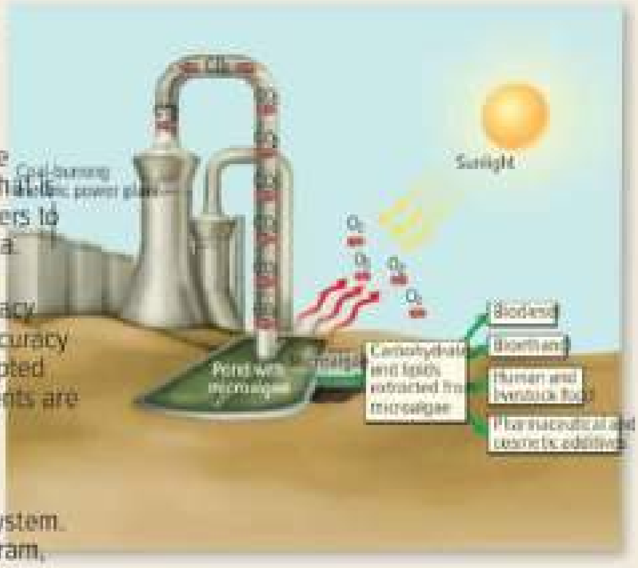
Accuracy and Precision Scientists seek to achieve both accuracy and precision in their observations and measurements. Accuracy is a description of how close a measurement is to an accepted value. Precision is a description of how similar measurements are to each other.

The International System of Units Scientists make their measurements with the International System Units, or SI system. All SI units are derived from seven base units: meter, kilogram, second, ampere, Kelvin, mole, and candela.

Lesson 3

Case Study: Biodiesel from Microalgae

The Biodiesel Revolution The by-products of the combustion of fossil fuels contribute to air pollution and are believed to [illegible] global warming. One solution could be biodiesel, diesel fuel made from plants. This would provide a limitless amount of fuel. Research seeks to obtain biodiesel from microalgae.



The Progress of Research In the 1970s, U.S. scientists experimented with species of microalgae that produce food and oils during photosynthesis. Researchers began growing microalga in outdoor ponds and, later, in closed containers called bioreactor. They were looking to maximize the amount of light provided to the algae, to maximize its oil production.

Power Plant with Biodiesel Production Research on microalgae continues. Engineers are designing power plants connected to biodiesel production facilities. These power plants most often burn coal, a fossil fuel. Carbon dioxide emissions from the combustion of the fuel are piped to the biodiesel unit, where it is used by microalgae for photosynthesis. The microalgae produce biodiesel, which is harvested and used as fuel.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

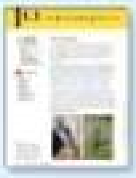
* Interactions among the senses, nerves, and brain make possible the learning that enables human beings to predict, analyze, and respond to changes in their environment.

* Human beings use technology to match or exceed many of the abilities of other species.

* Written records and photographic and electronic devices enable human beings to share, compile, and use great amounts of information.

* American Association for the Advancement of Science (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1
Understanding Science

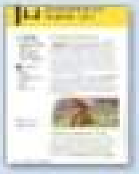


1 Scientific inquiry is a collection of skills that scientists use in different combinations to perform scientific investigations.

2 Scientific investigations often result in new technology, new materials, newly discovered objects or events, or answers to questions.

3 Scientists can help minimize bias in a scientific investigation by taking random samples, doing blind studies, repeating an experiment several times, and keeping accurate and honest records.

Lesson 2
Measurement and Scientific Tools



4 Accuracy is a description of how close a measurement is to an accepted value. Precision is a description of how similar or close measurements are to each other.

5 Significant digits communicate the precision of the tool used to make measurements.

6 Life scientists use many tools, such as science journals, microscopes, computers, magnifying lenses, slides, and dissecting tools.

Lesson 3
Case Study: Biodiesel from Microalgae

7 There are two main types of variables.

7a The independent variable is a factor in an experiment that is manipulated or changed by the investigator to observe how it affects a dependent variable.

7b The dependent variable is the factor measured or observed during an experiment.

8 Scientific inquiry is used to gain information and find solutions to real-life problems and questions.

Identifying Misconceptions

Scientific Inquiry

Find Out What Students Think

Students may think that...

... all experiments follow exactly the same method. Some students may not understand that a collection of skills is part of scientific inquiry, but that scientists may use different scientific methods or steps in their efforts to understand events or predict what might happen if certain conditions exist.

Discussion

Write the following sequence on the board or chart paper using arrows between each step: *Ask Questions* → *Hypothesize* → *Predict* → *Test Hypothesis* → *Analyze Results* → *Draw Conclusions* → *Communicate Results.* Write *scientific inquiry* over the sequence. **Ask:** Why is it important to first ask questions? **Asking what, when, where, who, why, and how helps the scientist focus on what he or she wants to know.** What is a hypothesis? **a possible explanation about an observation that can be tested by scientific investigation** Continue to help students understand the collection of skills in scientific inquiry. Switch two steps in the sequence. **Ask:** Would it be possible to predict a result before I create a hypothesis? **It might be possible, but it also might be difficult because I would not know what I was trying to predict.** Could I draw conclusions before I analyze results? **It's possible, but your conclusions could be faulty.** Explain that skills that are part of scientific inquiry involve different methods, and can change depending on the experiment, the methods, and/or sequence of steps. How a scientist decides to analyze results, for example, depends on the type of data obtained. **Ask:** What are examples of how data can be analyzed? **Compare and contrast, observing patterns, determining relationships.** Emphasize that it is essential to understand the skills that are part of scientific inquiry.

Promote Understanding

Activity Prior to the activity, place pieces of paper with different topics written on them, such as *spiders, plants, ants, school lunch, favorite color,* and *time spent playing video games* in a container. Divide the class into five groups. Each group needs chart paper and markers.

1. Explain that each group will design an experiment using scientific inquiry.
2. Have each group choose a topic by selecting a piece of paper at random from the container.
3. Each group should write several questions about the topic and decide on one question to use for designing an experiment. Remind students that they will not be conducting the experiment, so they are not limited by time, materials, or equipment.
4. Have each group share its experiment and explain how scientific inquiry was used in the experiment's design.

Controlled Experiments

Find Out What Students Think

Students may think that...

... in a controlled experiment, the scientist controls the results. Students may not understand that in an experiment a scientist establishes constants and manipulates an independent variable to determine effects on the dependent variable.

Discussion

Define *independent* and *dependent* with the students. Provide examples of something dependent on an independent factor, such as getting to school on time. Have students suggest examples of *constants,* things that do not change in regard to getting to school on time. Draw the following graphic organizer on the board or chart paper.

independent variable + constants → dependent variable

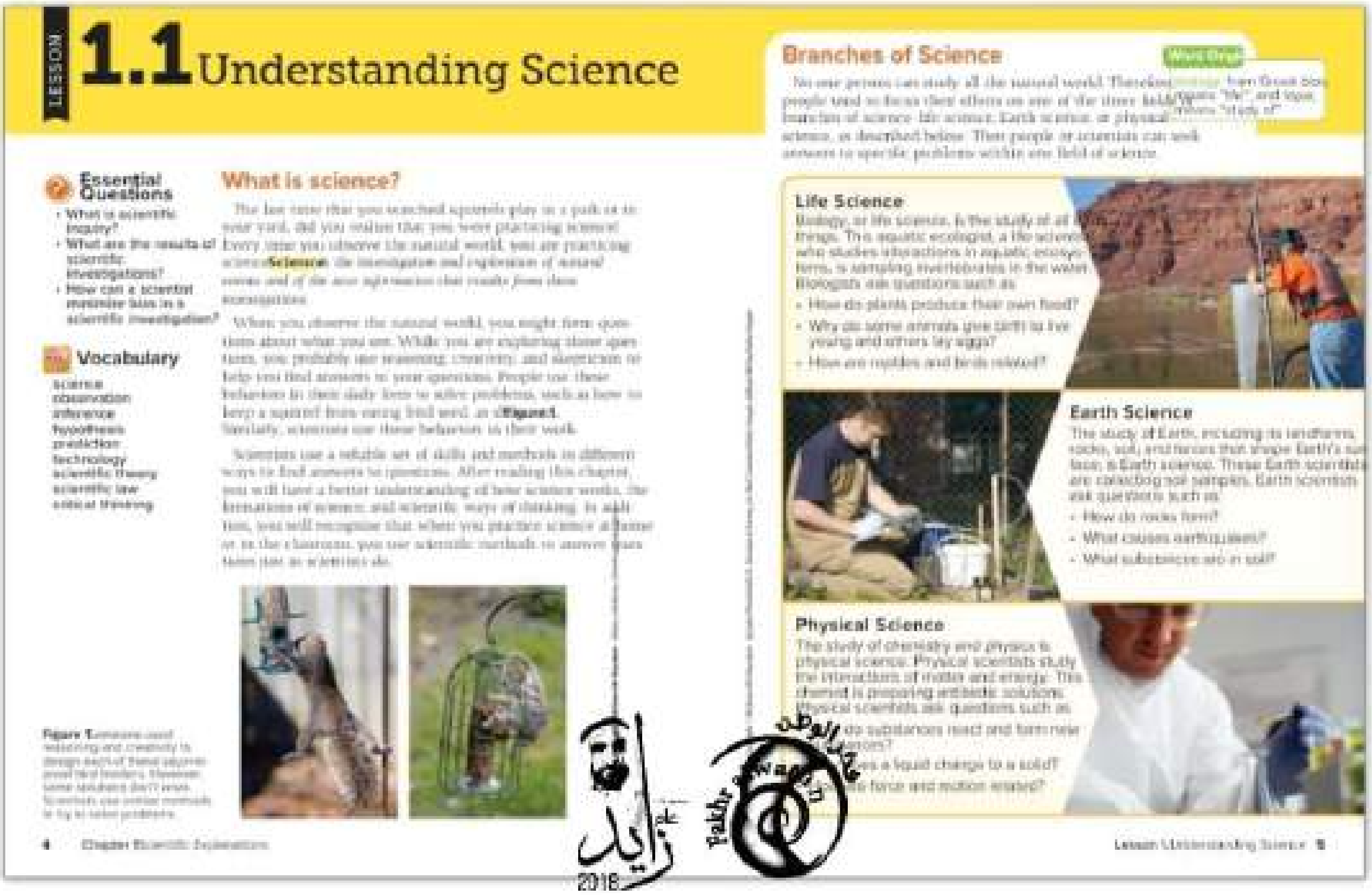
Explain that in a controlled experiment, the scientist determines *constants,* or factors in the experiment that remain the same. The independent variable is changed by the scientist, who then measures or observes what happens to the dependent variable. Explain that you want to determine if adding fertilizer to soil affects the growth of a bean plant. **Ask:** What dependent variable will I measure? **height of a bean plant** What independent variable will I manipulate or change? **fertilizer added to one plant** What constants should I establish? **same bean seeds, same soil, same growing conditions for both plants** Which plant is the control? **plant with no fertilizer added**

Promote Understanding

Activity Divide students into groups. Explain that students will design a controlled experiment to determine if offering free popcorn at football games increases attendance. Provide chart paper and markers for each group.

1. Have students in each group determine the independent variable, dependent variable, and constants. Students should create a chart noting the variables and constants.
2. Each group should brainstorm ways the experiment could be designed, discuss any difficulties with constants in the experiment, and other factors that might affect the outcome.
3. Have groups share their ideas and discuss why in experiments, many trials are needed to draw valid conclusions.

PAGE KEELEY SCIENCE PROBES



Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Discussing a Common Misperception

1. Write the terms *observation* and *hypothesis* on the board.
2. **Ask: What do you think of when you hear the words *observation* and *hypothesis*?** *Different responses will vary. Many students will connect these words to science. They may believe that making observations and hypotheses is something limited to scientists during experiments.*
3. Tell students that, in reality, we all do and experience science every day. Discuss examples of everyday science, observations, and hypotheses, such as:
   - Cookies are burned.
   - Copper is tarnished.
   - Hail forms and falls down to Earth.
   - Ice is slippery.
4. Have students build class definitions for *observation* and *hypothesis*. Students should record these definitions in their Science Journals.

Branches of Science

There are three main fields of science: life science, Earth science, and physical science.

Life Science

Life science is the study of all living things. Use the questions below to see what students already know about this field.

Guiding Questions

- **AL What is another name for life science?** *It is also called biology.*
- **OL What kind of interactions might this aquatic ecologist be studying?** *Students should conclude that the scientist is studying the interactions of the invertebrates with other aquatic organisms and the environment.*
- **BL What are examples of living things?** *Students should understand that animals, plants, and microscopic organisms all are living things.*

Earth Science

Earth scientists study our planet's landforms, rocks, soils, and interior. Astronomy is also part of Earth science.

Guiding Questions

- **OL What natural Earth science topic might these scientists be studying?** *They might be studying soil content.*
- **BL What other parts of Earth can you think of that would logically be part of Earth science?** *The oceans and atmosphere are part of Earth, so they are also part of Earth science.*

Physical Science

The two main fields of physical science are physics and chemistry.

Guiding Questions

- **OL In general terms, what do physicists and chemists study?** *They study the interactions of matter and energy.*
- **BL The chemist in the photo is preparing antibiotic solutions. How do chemistry and other sciences work together in the development of antibiotics?** *Biology, the study of life, is key to understanding how antibiotics are processed by the body. Biochemists work with biology and chemistry.*

Teacher Notes

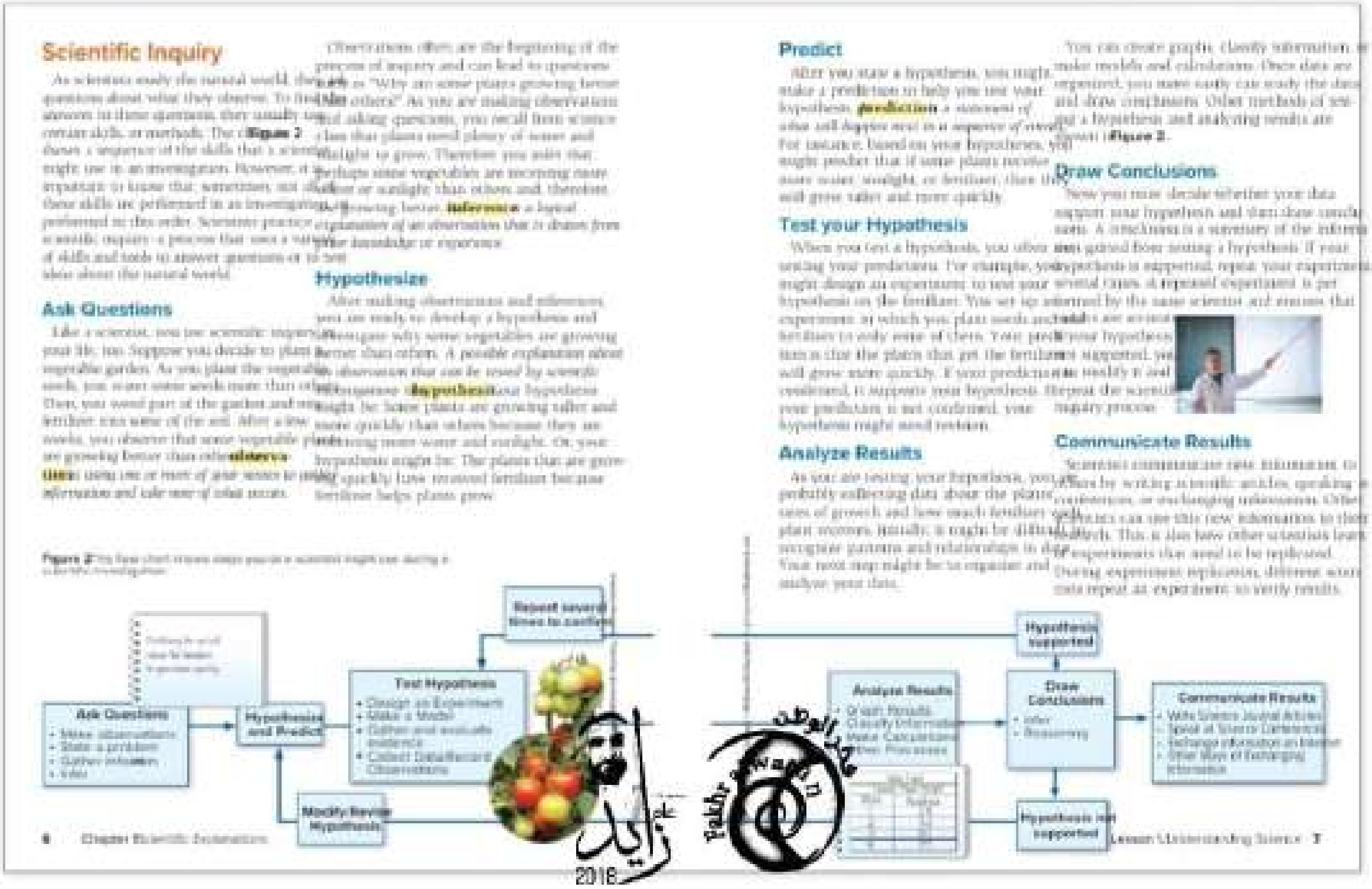
Word Origin

biology

Read aloud the derivation of the word biology and then ask the following question.

Ask: What are some other sciences with names that end in -ology?
Accept all reasonable responses. Answers may include: *zoology, geology, anthropology, entomology, archaeology, meteorology, and psychology.*

OL On Level AL Approaching Level BL Beyond Level


Scientific Inquiry
Ask Questions
Hypothesize
Predict
Test your Hypothesis
Analyze Results
Draw Conclusions
Communicate Results

Scientific Inquiry

Point out to students that there is no single scientific *method*. Rather, there is scientific *inquiry*. Scientists ask questions about nature and decide on methods that will help them find answers to each one.

Ask Questions
Hypothesize

A properly framed question is one of the first steps in scientific inquiry. The next step in an inquiry is the formation of a hypothesis.

Guiding Questions

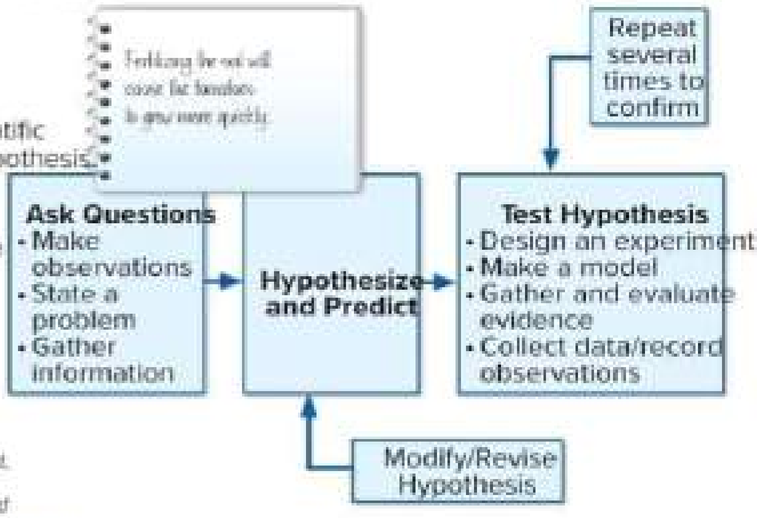
AL **What is scientific inquiry?** *Scientific inquiry is a process that uses a set of skills and methods to answer questions or to test ideas about the natural world.*

OL **What is a hypothesis?** *It is a possible explanation about an observation that can be tested by scientific investigation.*

OL **How might a hypothesis be tested?** *designing and completing an experiment, making a model, gathering and evaluating evidence, collecting data, and recording observations*

Visual Literacy: Figure 2

Have students study the flowchart. **Figure 2** shows a possible sequence of steps involved in formulating and testing a hypothesis.



Ask: What happens if a hypothesis is not supported? *You can modify your hypothesis and repeat the scientific inquiry process.*

Design an Experiment and Make a Prediction

Share with students that, after developing a hypothesis, they can design an experiment and make a prediction. The outcome of the experiment will either support the hypothesis or cast doubts on its validity.

Guiding Questions

AL How does a prediction differ from a hypothesis?	A hypothesis is a possible explanation about an observation that can be tested. Whereas, a prediction is a statement about what will happen next in a sequence of events.
OL How might the results of a scientific investigation be analyzed?	Results might be analyzed by graphing the results, classifying information, making calculations, and other processes.

The Research Hypothesis

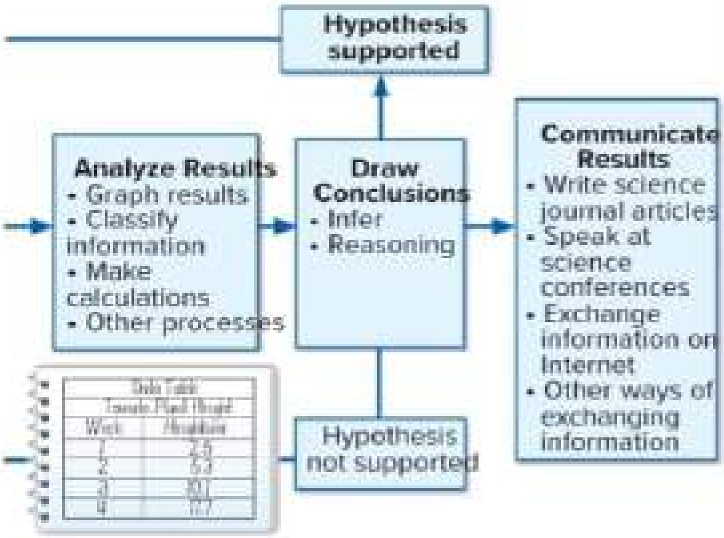
A research hypothesis can help students design an experiment and make a prediction. **Ask: What should be included in a research hypothesis?** *The original hypothesis, a method for testing it, and a prediction that supports the hypothesis*

Analyze Results / Draw Conclusions / Communicate Results

Discuss with students that, after testing the hypothesis, a scientist analyzes the data from the inquiries. From that analysis, a scientist draws conclusions about the validity of the original hypothesis. Scientists then communicate their results with others.

Guiding Questions

OL If a scientist's hypothesis predicts a certain outcome of a test and that outcome does not occur, what should the scientist do?	The scientist might revise the hypothesis, continue researching, compare results of the study with peers, and repeat the scientific inquiry process.
OL What is an inference?	An inference is a logical conclusion based on available information or evidence.
BL What are some examples of how a scientist can communicate results?	write science journal articles, speak at science conferences, exchange information, confer with colleagues



Differentiated Instruction

AL Writing Hypotheses Tell students to look for clues about what factors can affect plant growth. Have them write down all the possible factors: water, weeding, fertilizer. Then, write hypotheses by incorporating each factor into an *if-then* statement. For example, "If I give a plant more water, then it will grow taller."

BL The Flow of Scientific Inquiry Have groups create illustrations of methods of scientific inquiry to include headings from the lesson. Then, give this scenario: You walk into a room and try to turn on the lights. They don't come on. Have students draw and label beneath each heading how they try to solve this problem.

Teacher Toolbox

Teacher Demo

Observation or Inference? Review with students the definition of observation as "the act of watching something and recording what occurs." *Inference* is defined as "a logical conclusion based on available information or evidence." Display a whole red apple to the class. Ask students to classify these statements as observations or inferences.

1. The apple's covering is red.
2. The apple is edible.
3. There are seeds inside the apple.

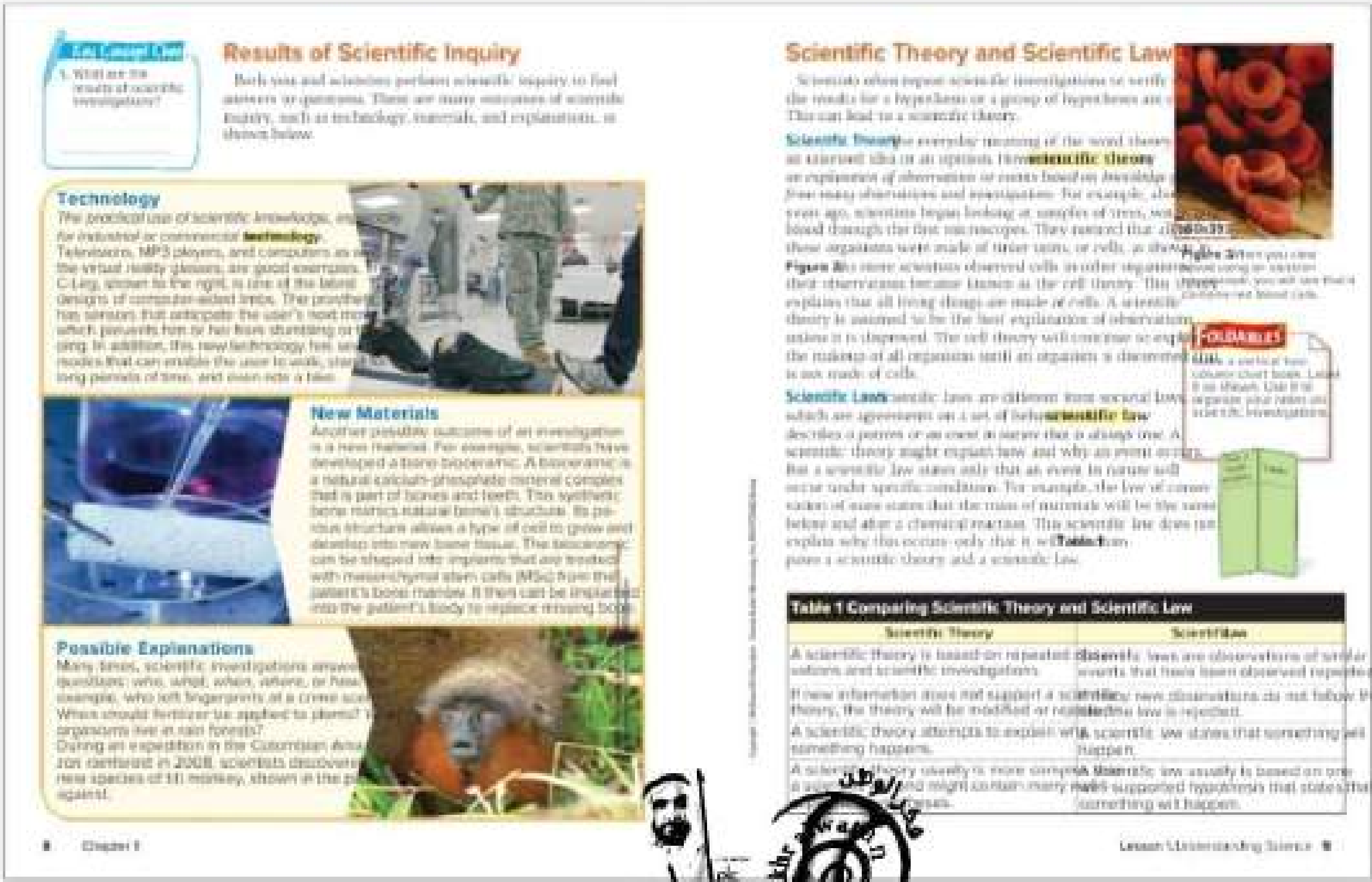
Statement 1 is an observation—it can be seen. Statements 2 and 3 are inferences made from prior knowledge of apples. Could statement 3 become an observation? Cut the apple.

Reading Strategy

Scientific Inquiry In their Science Journals, ask students to write down a difficult problem that they have recently tried to solve in everyday life. Have students compare and contrast the process of a scientific investigation with the process they used to try to solve the problem. Students should ask themselves:

- Did I narrow down my problem to a question, making observations and gathering information? (Ask Questions)
- Did I think of a possible solution and predict an outcome? (Hypothesize and Predict)
- Did I try the solution? (Test Hypothesis)
- Did the solution work? (Analyze Results)
- Did I figure out why the solution worked or failed? (Draw Conclusions)
- Did I let others know that the problem was solved or not? (Communicate Results)

OL On Level AL Approaching Level BL Beyond Level



Results of Scientific Inquiry

Technology

New Materials

Possible Explanations

Scientific Theory and Scientific Law

Table 1 Comparing Scientific Theory and Scientific Law

Chapter 1

Lesson 1 Understanding Science

Results of Scientific Inquiry

Scientific findings can lead to answers to long-standing questions. They also can result in practical applications.

Guiding Questions

AL Why might you engage in scientific inquiry?	*We do so to find answers to questions about nature.*
Key Concept Check What are the results of scientific investigations?	*new technology, new materials, and possible explanations of natural phenomena*

Technology/New Materials

New technologies and materials often result from scientific research.

Guiding Questions

OL What is technology?	*Technology is the practical use of scientific knowledge, especially for industrial or commercial use.*
BL What is an example of a new material that has resulted from scientific investigation?	*Answers will vary, but should show an understanding of how a new material can be useful to people.*

Possible Explanations

Scientific inquiry can answer important questions. Such questions can be limited, and specific to a particular time and place, such as "Who committ this crime?" In most cases, scientists' questions are of a more general nature, such as "What factors are causing global warming?"

Guiding Questions

OL What questions are asked and answered in many scientific investigations?	*Who? What? When? Where? How?*
BL What is an example of a scientific investigation that led to a possible explanation?	*Answers will vary, but should show an understanding of the purpose of scientific inquiry*

Scientific Theory and Scientific Laws

Scientific investigations can lead to the formulation of theories and laws. Use the questions below to help students contrast theories and laws.

Guiding Questions

AL What is a scientific theory?	*It is an explanation of observations or events based on knowledge gained from many observations and investigations.*
OL What is one example of a scientific theory?	*Accept all reasonable responses. The cell theory states that all living things are made of cells.*
BL Do you think it's possible to prove a scientific theory is true?	*No, a scientific theory can't be proved beyond all doubt, but it can be disproved. However, if a tested theory adequately explains observations or events and is not disproved, it is accepted as correct.*
OL What does a scientific law do?	*It describes a pattern or event in nature that is always true.*
OL What is one example of a scientific law?	*Sample answers include: Law of conservation of mass or the commonly understood law that the Sun will rise again tomorrow.*
OL How do scientific theories and scientific laws compare?	*A theory explains how and why a particular event occurs. A law simply says that it will occur.*

Visual Literacy: Comparing Scientific Theory and Scientific Law

Have students review **Table 1**. Then determine how well they have assimilated the information presented by discussing the following questions.

Table 1: Comparing Scientific Theory and Scientific Law

Scientific Theory	Scientific Law
A scientific theory is based on repeated observations and scientific investigations.	Scientific laws are observations of similar events that have been observed repeatedly.
If new information does not support a scientific theory, the theory will be modified or rejected.	If new observations do not follow the law, the law is rejected.
A scientific theory attempts to explain why something happens.	A scientific law states that something will happen.
A scientific theory usually is more complex than a scientific law and might contain many well-supported hypotheses.	A scientific law is based on one well-supported hypothesis that states that an event will occur.

Say: Compare and contrast how scientific theories and scientific laws are connected to observations. *A scientific theory is based on observations. A scientific law is an observation.*

Say: Compare and contrast how scientific theories and laws might be rejected. *A scientific theory might be rejected if new information doesn't support it. A scientific law might be rejected if new information doesn't follow it.*

Say: Compare and contrast the complexity of scientific theory to scientific law. *A theory is usually more complex than a law. This is because most theories contain many hypotheses, while laws usually contain one hypothesis.*

Differentiated Instruction

AL Retracing the Steps Have student partners write each step of the scientific inquiry process on a separate inde[x] card. Have them form a sequence using all of the cards. Next, have them form a new sequence using some or a[ll of] the cards. Ask students to describe each sequence in t[heir] own words.

BL Application of Scientific Inquiry Have student groups make poster reports on a technological advance or a n[ew] material that resulted from scientific inquiry. In their rep[orts,] students should identify the practical question research[ers] were trying to answer. They should include any relevan[t] steps of scientific inquiry. Have them present their findi[ngs] to the class.

Teacher Toolb[ox]

Teacher Demo

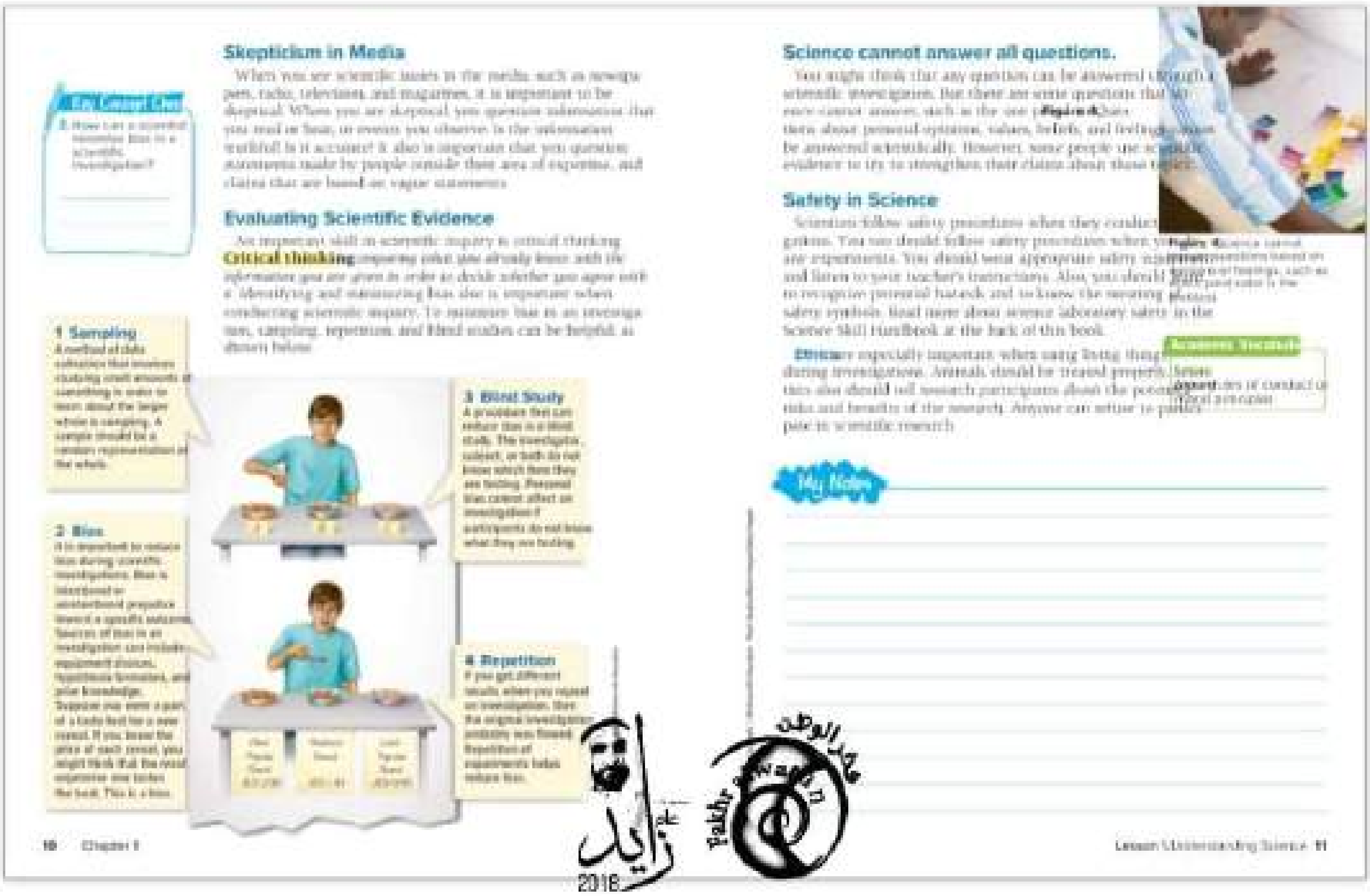
Cell Theory Evidence Demonstrate how evidence can be gathered to prove the cell theory.

1. Scrape a toothpick against the inside of your cheek, t[hen] across a clean microscope slide.
2. Add a drop of stain to the slide. Place a cover slip on slide and put the slide on the microscope stage.
3. Use the microscope to allow students to observe the cells. Project the image for the class.
4. Explain that samples taken from every human would contain cells. This is the basis of the cell theory.

Real-World Science

Thinking Like a Scientist Encourage students to pose questions about the world they see—for example, "Ho[w do] birds fly?" Student questions have probably already be[en] answered. However, they will be thinking like scientist[s by] asking questions. Have students brainstorm questions [and] design basic investigations to determine answers.

OL On Level AL Approaching Level BL Beyond Level



Skepticism in Media / Evaluating Scientific Evidence

It is important to evaluate information presented. It pays to be skeptical about news, especially because the media often reports stories to excite their readers. For research to be valid, it must be conducted in such a way that the investigator's personal biases do not influence results.

Guiding Questions

OL	What is critical thinking?	*It is comparing what you already know about something with new information and then deciding whether you agree with the new information.*
	Key Concept Check How can a scientist minimize bias in a scientific investigation?	*A blind study will help to prevent bias. Factors that contribute to bias include poor formation of hypothesis, lack of prior knowledge about the study, researcher expectations of conclusions and de-emphasis of results that do not support that conclusion.*
BL	Clinical trials of new drugs are almost always "double-blind" studies. What do you think is meant by that term?	*Neither the investigators nor the participants in the study know who is getting the drug and who is getting a placebo, or inactive substance.*

Science cannot answer all questions. Safety in Science

Briefly discuss with students why topics are testable by science. Safety precautions are important in many kinds of scientific investigations. Brainstorm some potentially dangerous situations and review the appropriate procedures.

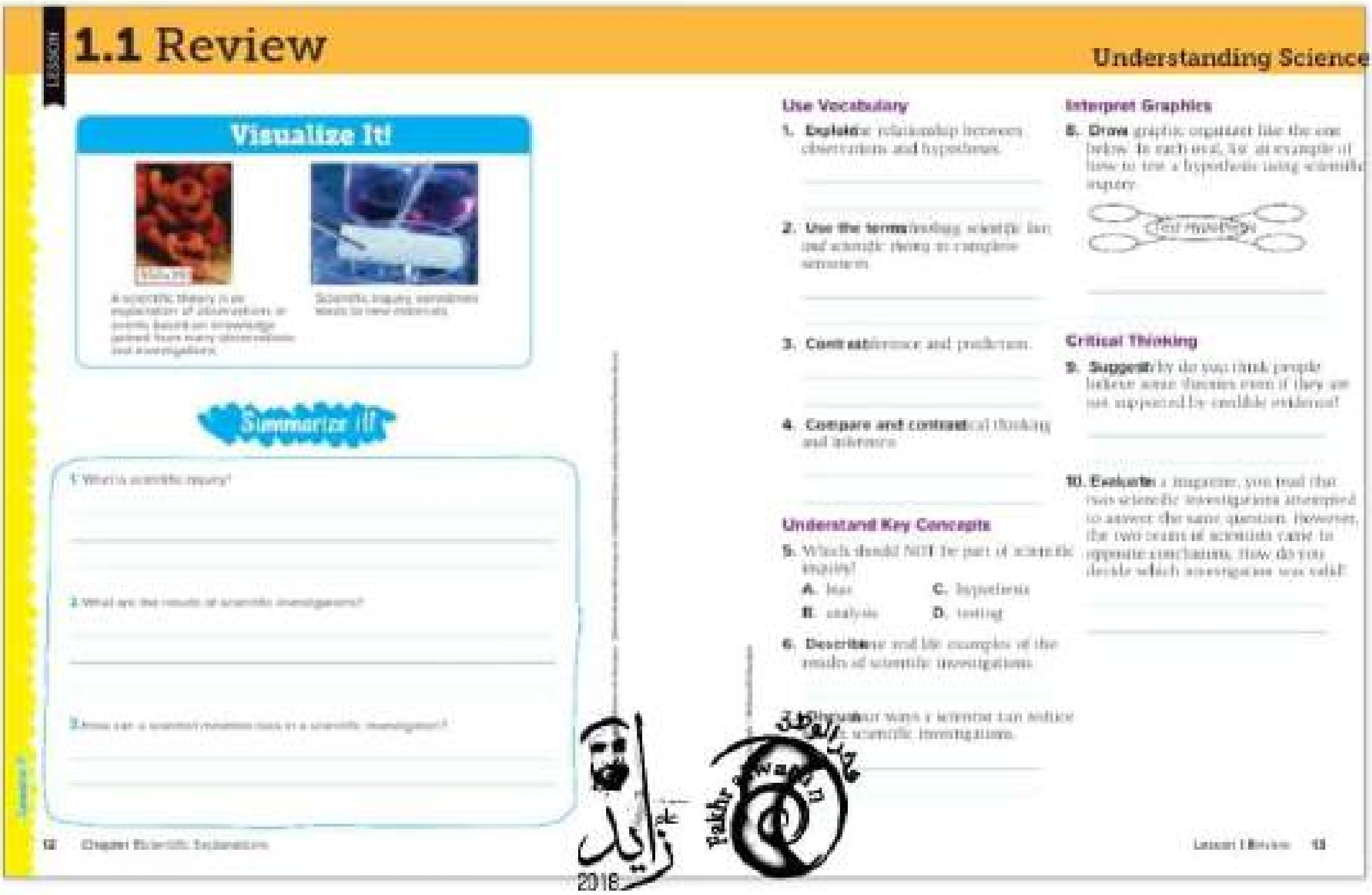
Academic Vocabulary

ethics

Use caution when discussing ethical treatment of animals as students may feel strongly, giving rise to debate and possible hurt feelings.

Guiding Questions

OL	What safety equipment is essential when working with dangerous chemicals?	*safety goggles, an apron, protective gloves, a near source of water, fire extinguisher, fire blanket, eyewash*
OL	When are ethical guidelines most often required?	*They are most often required in research involving animals or human subjects.*
BL	Why are questions about personal opinions, values, beliefs, and feelings beyond science?	*They are personal opinion. For instance, science cannot determine which color is prettier. Color preference is subjective.*


1.1 Review

Understanding Science

Visualize It!

Summarize It!

Use Vocabulary

Interpret Graphics

Critical Thinking

Understand Key Concepts

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **To which key concept does each image relate?**

Summarize It!

Answer may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Branches of Science
- Scientific Inquiry
- Results of Scientific Inquiry
- Scientific Theory and Scientific Laws

Use Vocabulary

1. An observation in nature often leads to a testable hypothesis that explains how or why the observation occurred. **DOK 1**
2. Sample answer: The new video game has the latest, most amazing technology. The change of season is an example of a scientific law in action. One basic scientific theory is that all living things are made up of cells. **DOK 2**
3. An inference is a logical conclusion based on available information or evidence. A prediction is a statement of what will happen next in a sequence of events. **DOK 1**
4. Both are decision-making skills. An inference is a logical conclusion based on available information or evidence. Critical thinking is comparing what you know to be true with new information and determining if the new information is true. **DOK 1**

Understand Key Concepts

5. A. bias **DOK 1**
6. Sample answers: artificial limbs, vaccines, pharmaceutical drugs, airplanes, spacecraft, synthetic textiles, and the discovery of all the planets and their moons **DOK 2**
7. A scientist can use a blind study, sampling, and repetition and not allow prior knowledge to influence the interpretation of test results. **DOK 1**

Interpret Graphics

8. design an experiment, make a model, gather and evaluate evidence, and collect data/ record observations **DOK 2**

Critical Thinking

9. Sample answers might include: People might not understand the process of scientific inquiry; they might think a common theory is supported by valid evidence, even though in reality it is not. They also might believe common theories because, for personal reasons, they want to believe in what the theory is saying. **DOK 3**

10. Sample answers might include: To decide which investigation is valid, you use critical thinking skills to examine the information you are given. You should be skeptical of investigations that show signs of bias. You should examine the investigations for correct use of the skills of scientific inquiry and laboratory procedure. **DOK 3**

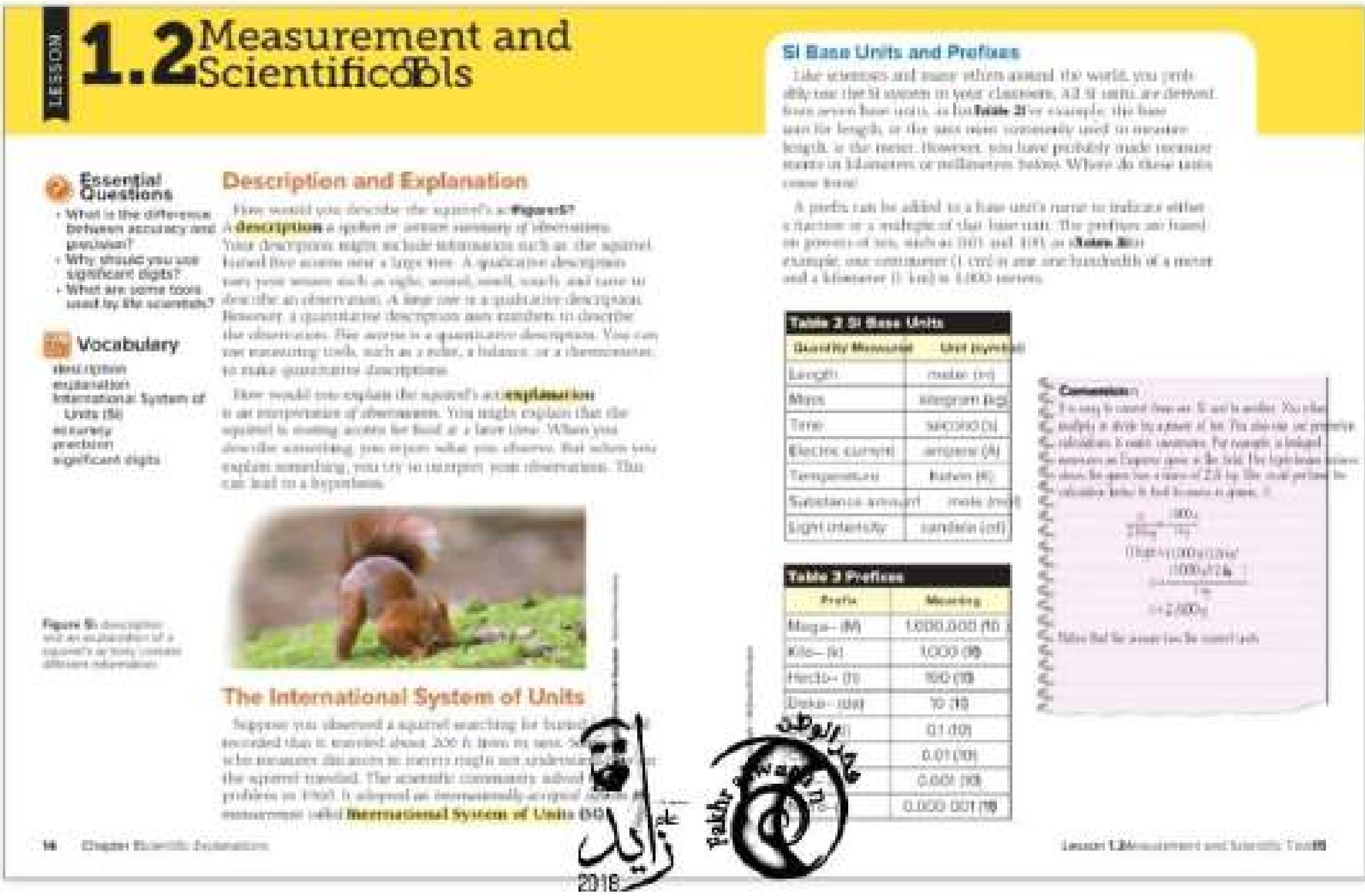
Teacher Toolb

Teacher Demo

Classroom Blind Study Conduct your own blind study. Us three varieties of a common item, such as pudding, popcorn, colored pencils, or tissues. Have students appropriately test the samples without knowing the na and price of each one. Then repeat the study with new samples whose identities are known to the students. Compare the outcome of the two tests. Did bias play a in students' selections? Try repeating this test with a p with the brand names and prices switched around in th non-blind part of the test. Will students say they prefer of the cheaper brands if they think it's actually the pre brand?

Reading Strategy

Learning Journal Have students use learning journals. As students to divide each page into three columns. In th column, record headings from the text. In the middle column, include summary notes. In the right column, ha them include page numbers of text and illustrations tha helped them understand a concept. Continue the journ throughout the course.



LESSON 1.2 Measurement and Scientific Tools

Essential Questions
- What is the difference between accuracy and precision?
- Why should you use significant digits?
- What are some tools used by life scientists?

Vocabulary
description
explanation
International System of Units (SI)
accuracy
precision
significant digits

Description and Explanation

The International System of Units

SI Base Units and Prefixes

Table 2 SI Base Units	
Quantity Measured	Unit (symbol)
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Electric current	ampere (A)
Temperature	kelvin (K)
Substance amount	mole (mol)
Light intensity	candela (cd)

Table 3 Prefixes	
Prefix	Meaning
Mega– (M)	1,000,000 (10^6)
Kilo– (k)	1,000 (10^3)
Hecto– (h)	100 (10^2)
Deka– (da)	10 (10^1)
[illegible]	0.1 (10^{-1})
[illegible]	0.01 (10^{-2})
[illegible]	0.001 (10^{-3})
[illegible]	0.000 001 (10^{-6})

Conversions

14 Chapter 1 Scientific Explorations

Lesson 1.2 Measurement and Scientific Tools 15

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Using Word Origins

1. Write *accuracy* and *precision* on the board or chart paper. Toss a wad of paper at a wastebasket. Explain that if you hit the wastebasket, your toss will be accurate. Toss a second wad of paper at the wastebasket. Explain that if both papers fell next to each other on the floor the tosses would be precise, though not accurate, because the wads of paper fell close to each other. If both fell in the wastebasket, the tosses would have both precision and accuracy.
2. **Ask:** **Why are scientists concerned about accuracy?** *need repeated results that are on target* **How can the results of an experiment be precise but not accurate?** *Results can be precise but not accurate when they are consistent, but not "on target."*
3. In this chapter students will learn about methods and tools scientists use to measure accurately and precisely.

Description and Explanation

Present the vocabulary words *description* and *explanation*. Direct student attention to Figure 5 and read the caption emphasizing the two vocabulary words. Have students read the two paragraphs.

The International System of Units

Explain the term *international*. Then have students read the paragraph. Guide their understanding by asking the following questions.

Guiding Questions

BL What is SI?	*an accepted international system for measurement*
OL How does having an international system of units help scientists communicate worldwide?	*They all use the same type of measurement, which makes sharing scientific information easier.*

SI Base Units and Prefixes

Discuss the value of having an international system of units .

Guiding Questions

AL What term is used to describe the scientific measurement of length?	*meter*
OL What do the seven base units measure?	*distance, time, and the physical properties of objects and substances*
BL How do prefixes change the value of a base unit?	*They consistently show a multiple or a fraction of a base unit.*

Visual Literacy Tables 2 and 3

Have students read the first paragraph, then direct them to **Table 2 SI Base Units**. Read through the list and comment on how each of these units is used by scientists internationally. Provide scientific tools used to measure each property—metric ruler, meterstick, triple-beam or electronic balance, stopwatch or clock with second hand, ammeter, thermometers, equation 6.02 × 10, light meter and standard candle.

Table 2 SI Base Units

Quantity Measured	Unit (symbol)
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Electric current	ampere (A)
Temperature	Kelvin (K)
Substance amount	mole (mol)
Light intensity	candela (cd)

Some students may not have had experience with base units that have prefixes added to them. Write the following terms on the board: meter, kilometer, hectometer, millimeter, micrometer. Redirect students' attention to **Table 3**.

Table 3 Prefixes

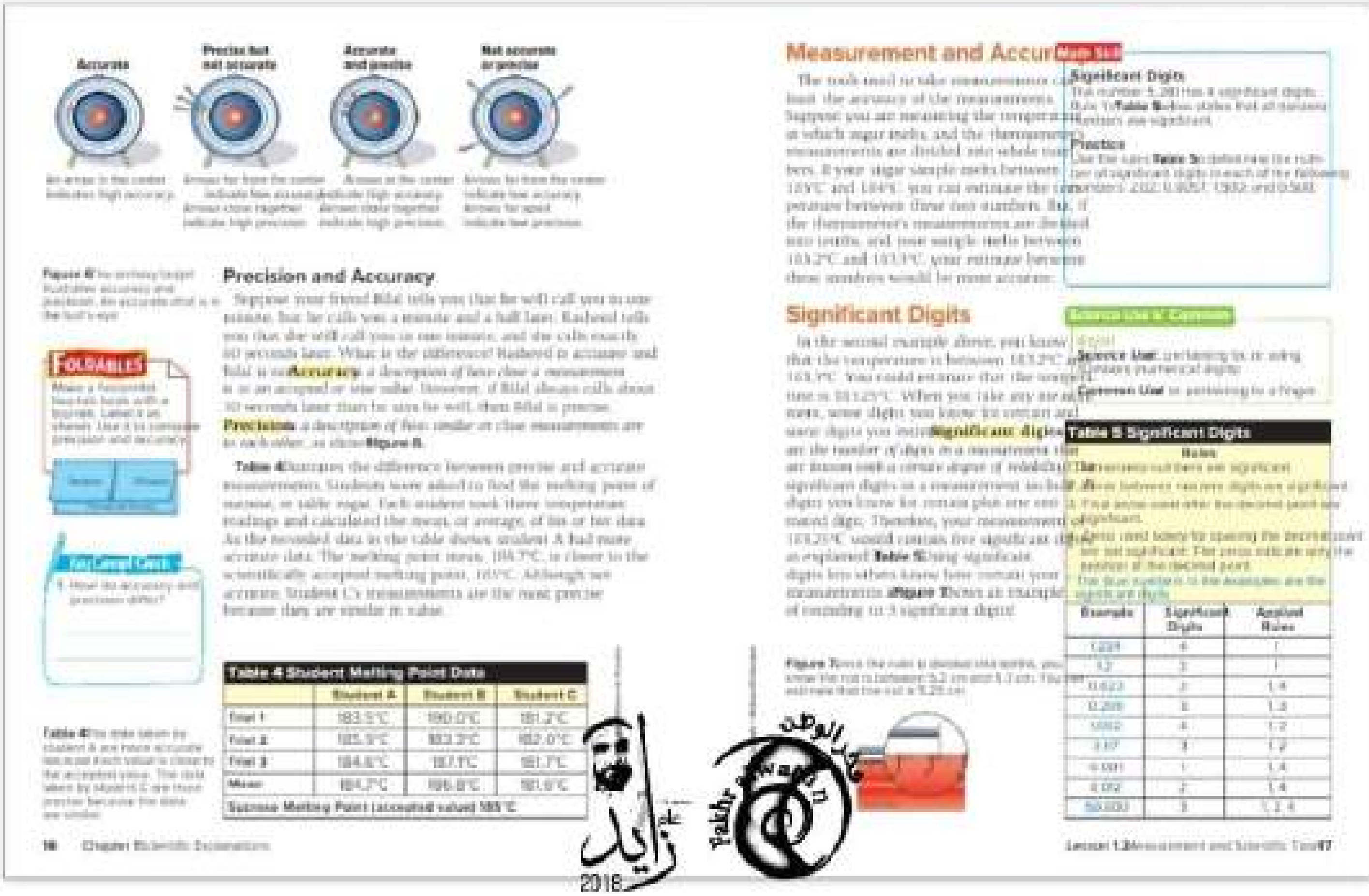
Prefix	Meaning
Mega- (M)	1,000,000
Kilo- (k)	1,000
Hecto- (h)	100
Deka- (da)	10
Base unit	1
Deci- (d)	0.1 (1/10)
Centi- (c)	0.01 (1/100)
Milli- (m)	0.001 (1/1,000)
Micro- (μ)	0.000 001 (1/1,000,000)

Ask: **Suppose you are investigating how sunlight and heat affect photosynthesis in a plant. What SI base units might you use to measure this?** *kelvin and candela*

Teacher Notes

Ask: **Suppose you are comparing elephants and hippos. What base units might you use to make measurements?** *meters and kilograms*

Ask: **Suppose you are observing the speed of a mouse moving across a table. What SI base unit might you use to measure this?** *seconds*



Precision and Accuracy

Visual Literacy: Figure 6

Have students answer the following questions and then provide examples of their own for results that are accurate, precise, or both accurate and precise.

Accurate | **Precise but not accurate** | **Accurate and precise** | **Not accurate or precise**

Ask: If the goal is to hit the center of the target, how can these arrows be described? *precise*

Ask: Why are these results both accurate and precise? *Are close together (precise) and are placed where targeted (accurate)*

Direct student attention to **Table 4** and read the caption. Discuss the data in the table and reinforce the difference between accurate data, precise data, and data that is both accurate and precise.

Guiding Questions

OL How can you tell the data taken by Student C shown in Table 4 is precise?	*data points are consistently near the same value*
Key Concept Check How do accuracy and precision differ?	*Accuracy indicates how close a measurement is to an accepted value, while precision is how close measurements are to each other.*
BL What would data look like if it were both accurate and precise?	*The values would be close to each other in value and close to the accepted value.*

Measurement and Uncertainty

Look at a clock and make a general statement about time, such as *the bell will ring soon*. Discuss when the bell will ring based on what you said. Discuss whether the time you mentioned, *soon*, can be measured. Have students provide suggestions for measuring time with more certainty.

Guiding Questions

AL Why is it important for your watch to have the accurate time?	*so I can get to places on time*
OL Why is it important for a tool that measures to be calibrated to be precise and accurate?	*so its measurement is precise and accurate*
BL How can a clock be precise, but not accurate?	*A clock that runs fast or slow gives consistently incorrect time, so is precise, but because the time is incorrect, it is not accurate.*

Science Use v. Common Use

Digital

Ask: **Do you prefer to use a digital clock or an analog clock?** *Answers will vary.*

Ask: **How many digits do you have on one foot or one hand?** *five digits on each*

Significant Digits

Remind students that the word *significant* means *important* or *essential*. Direct attention to **Figure 10** and read the caption. Have students estimate the distance from one wall to another in the room. Discuss the difference between an estimate and precision. Ask which would be best when ordering new carpet.

Direct attention to Table 5, read through the rules for determining significant digits, and discuss the questions.

Guiding Questions

OL Why should you use significant digits?	*to communicate the precision of the tool used to make a measurement*
OL How many significant digits does the number 4.01 have?	*3; all nonzero numbers are significant and zeros between nonzero digits are significant*
BL Why is it important to consider all four rules when determining significant digits?	*to be as accurate as possible*

Math Skill

Significant Digits
Explain to students that they will be determining significant digits.

Practice
Ask students to complete the practice task. The answers are: 2.02—3 significant digits; 0.0057—2 significant digits; 1,500—2 significant digits; 0.500—3 significant digits

Differentiated Instruction

AL Precision and Accuracy Working in small groups, use tape to construct a target on the floor. Be creative. Have students toss 5 wads of paper onto the target from a s distance away. Chart each student's precision, accurac and both accuracy and precision.

BL Significant Digits Give students the following examples: a school with a student population of 1500; with a population of 150,000; a country with a populati 15,000,000. Ask them to determine the number of significant digits in each example and to state which ru they used to make their determinations. (two; rules 1 a Ask them to explain how each of these numbers can h the same number of significant digits, yet represent va different quantities. (The numbers reflect the degree o precision with which you can measure each populatior example, the population of a city might be known to th nearest thousand, while the population of a country mi be known only to the nearest million.)

Teacher Toolb

Math Activity

Significant Digits Use the following activity to help students gain a better understanding of significant dig

1. Prepare the following numerals on the board or char paper: 4.05, 770.032, .0025. Discuss which numbers significant.
2. Prepare a series of numerals written on chart paper.
3. Underline each number that is a significant digit.
4. Cover each numeral with a sticky note containing th same numeral without the underlines.
5. Ask students to read the digits and determine which numerals are significant. Remove note to check ansv
6. Ask students to write three numerals each containin decimal point. Students should design an answer ke identify the significant digits for each numeral. Chec understanding and correct application. Students mig exchange numerals for added practice.

Scientific Tools

Science Journal

Balances

Thermometer

Glassware

Compound Microscope

Computers—Hardware and Software

Scientificools

Science Journal/Balances

Have students read each paragraph. Use the following questions to help students understand the purpose and use of each tool.

Guiding Questions

AL **What is the purpose of a science journal?** *to record data, observations, and other important information*

OL **Why is it important to keep a science journal?** *to have a neat, organized, clearly written, accurate, and thorough record of your procedures, questions, and results*

AL **What is the purpose of a balance?** *to measure the mass of objects*

OL **Why is it important to carefully place objects on a balance?** *so the object is not dropped onto the pan, possibly damaging the precision and accuracy of the balance*

Thermometer

After discussing the following questions, brainstorm with students to find situations when they might use thermometers.

Guiding Questions

AL **What does a thermometer measure?** *the temperature of substances*

OL **Why should a thermometer never be used as a stirring rod?** *It might break. It might give an inaccurate reading.*

OL **What safety precautions should you take when handling a glass thermometer?** *handle it carefully and do not let it roll off the table; lower it into hot substances with care so you don't get burned; report to the teacher if the thermometer breaks*

Glassware

Show students examples of glassware, such as flasks, beakers, petri dishes, test tubes, and graduated cylinders. Discuss the following questions.

Guiding Questions

AL What are graduated cylinders used to measure?	the volume of liquids
OL What unit is used for measuring volume?	usually liters and milliliters
OL What is the purpose of laboratory glassware?	to hold, pour, heat, and measure liquids
BL Why is a beaker not considered an accurate tool of measurement?	Because of their wide base, measurements can not be as accurate as with a slender graduated cylinder.

Compound Microscope

Use the Science Handbook in the back of this book to identify the parts of a compound microscope and demonstrate how to use it.

Guiding Questions

AL Why is a microscope used?	to see small objects that cannot be seen with an unaided eye
OL What precautions should be followed when moving a microscope?	Carry it carefully by holding the arm of the microscope with one hand and support the base with the other hand.
BL What is something that could be viewed with a microscope?	Accept all reasonable responses. Encourage students to think of interesting things to view that cannot be seen by using a microscope. Possible answer: bacteria, cells, dust

Computers—Hardware and Software

Many students are familiar with computers, but some students may not be aware of the vast and varied amount of data that computers can analyze. Have students read the two paragraphs. Discuss with them the guided questions. Have them suggest examples of how computers can help a scientist study an organism.

Guiding Questions

AL What is the difference between computer hardware and computer software?	hardware—the main components of the computer; software—the computer programs
BL How do computers help scientists interpret information and data?	Possible answer: Scientists can use computers to compare and analyze data, research information, and communicate with fellow scientists.

Differentiated Instruction

AL **Safety First!** Divide the class into student pairs. Using paper and markers, have students determine one safe rule for one scientific tool. Students should use their ru create a Safety First! cartoon. Display the cartoons aro the room.

BL **Scientific Tools** Pair up students and have them write Divide the class into small groups. Have each group d a game using index cards. For example, some groups design a card game, in which the name of the tool is w on one card, its purpose on a second card, and its unit a third card. Have students shuffle the cards and deal cards to each player. The object would be to create matching sets. Students may ask an opponent if he or has a particular card or may draw from the deck to loo matches. The winner could be the first student to make set, or the student who makes the most sets.

Teacher Toolb

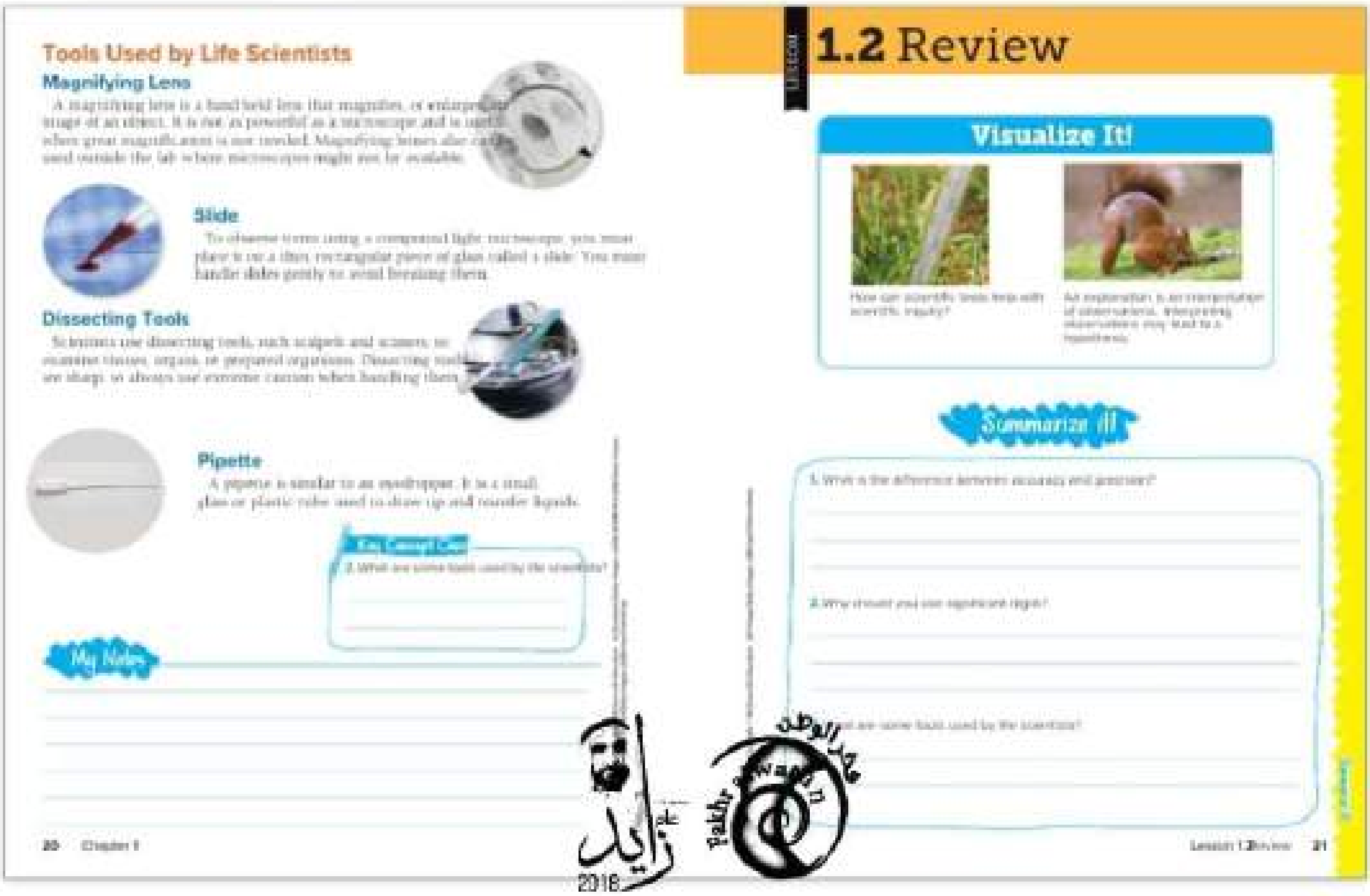
Teacher Demo

Scientific Tools

1. Gather the scientific tools described on the two pag
2. Demonstrate proper use of each tool.
3. Discuss the safety measures needed for use with each tool.
4. Provide opportunities for student to use the scientifi tools to familiarize themselves with them.

Reading Strategy

Taking Notes Write the name of one of the scientific too on the board or chart paper. Redirect students to the paragraph explaining the scientific tool in the lesson. H students reread the information about the scientific to identify the main points. Create a bulleted list under th name of the tool as students identify each main point. students practice this note taking technique using the paragraphs describing other scientific tools. You may want to divide the class into groups, have them complete th for an assigned tool, and then share their bulleted lists


Tools Used by Life Scientists

Magnifying Lens

Slide

Dissecting Tools

Pipette

Key Concept Check

My Notes

20 Chapter 1

Lesson

1.2 Review

Visualize It!

Summarize It!

Lesson 1.2 Review 21

Tools Used by Life Scientists

Magnifying Lens, Slide, Dissecting Tools, Pipette

Discuss the information in each paragraph as each one is read. Direct students to the images of the different tools as you discuss the type of tools used by life scientists. If possible, show and demonstrate use of each tool.

Guiding Questions

AL What is the purpose of a magnifying glass?	*to enlarge the image of an object*
OL Why must slides be carefully handled?	*because they are made of glass, easily broken, and could cut you*
Key Concept Check What are some tools used by life scientists?	*Accept all reasonable responses.*

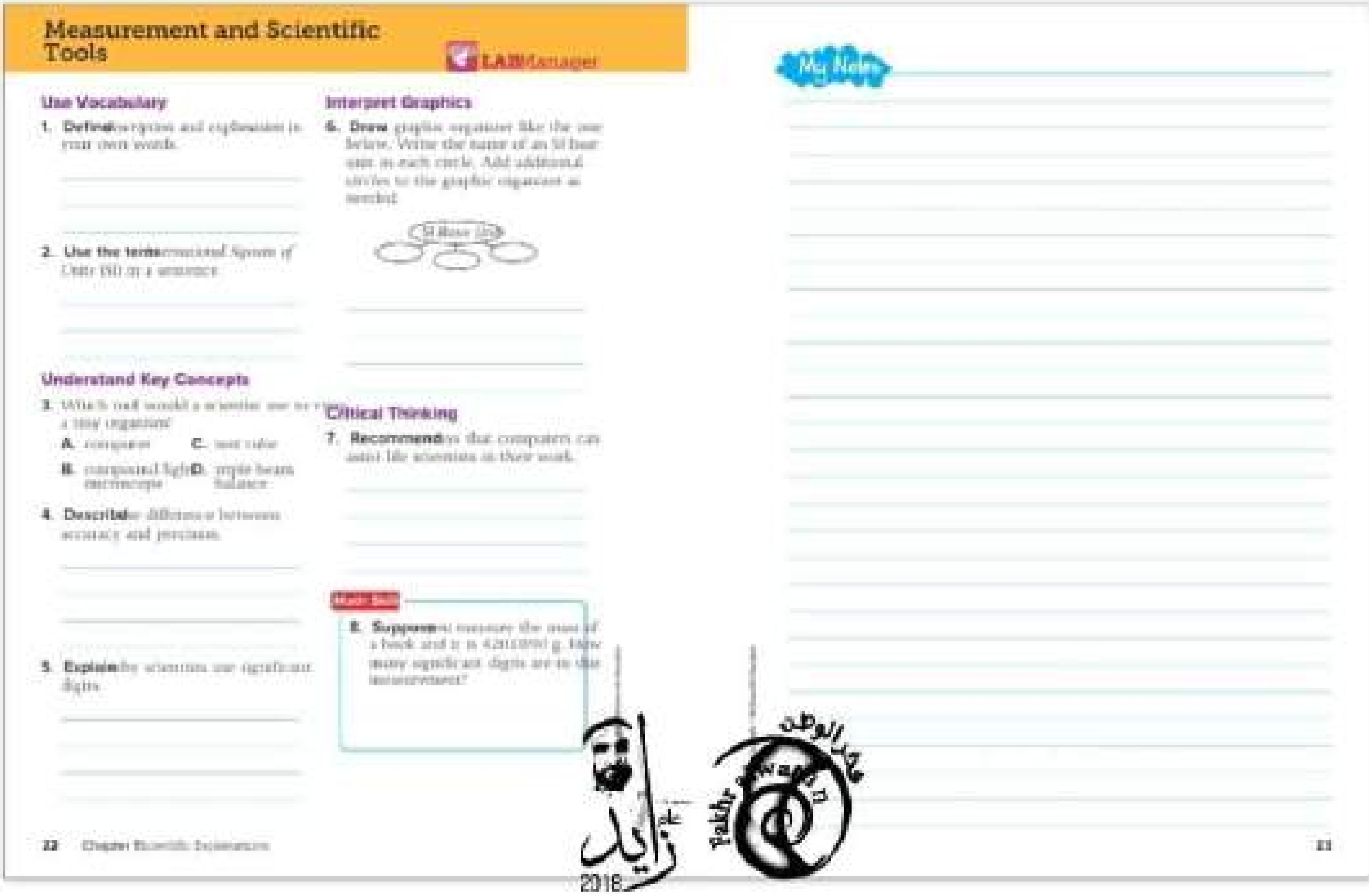
Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize It!

Answer may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Description and Explanation
- The International System of Units
- Measurement and Uncertainty
- Significant Digits
- Scientific Tools


Measurement and Scientific Tools

LABManager

Use Vocabulary

1. Define description and explanation in your own words.

2. Use the term International System of Units (SI) in a sentence.

Understand Key Concepts

3. Which tool would a scientist use to view a tiny organism?

A. computer

B. compound light microscope

C. test tube

D. triple-beam balance

4. Describe the difference between accuracy and precision.

5. Explain why scientists use significant digits.

Interpret Graphics

6. Draw a graphic organizer like the one below. Write the name of an SI base unit in each circle. Add additional circles to the graphic organizer as needed.

SI Base Units

Critical Thinking

7. Recommend ways that computers can assist life scientists in their work.

Math Skill

8. Suppose you measure the mass of a book and it is 420.03090 g. How many significant digits are in this measurement?

My Notes

22 Chapter Scientific Explanations

23

Use Vocabulary

1. Sample answer: A description is a summary of observations and an explanation is an interpretation of those observation **DOK 1**

2. Sample answer: The *International System of Units* is a system for measurement that is used and accepted by scientists worldwide **DOK 2**

Understand Key Concepts

3. B. compound microsco **DOK 1**

4. Accuracy is a description of how close a measurement is to an accepted value. Precision is a description of how similar or close measurements are to each **DOK 1**

5. Scientists use significant digits to communicate the precision their measurements to oth **DOK 1**

Interpret Graphics

6. The graphic organizer should have seven circles around the center circle. The center circle should say, SI Base Units. The following terms should be in the individual circles, in any order, surrounding the center circle: length, mass, time, electric current, temperature, substance amount, light i **DOK 2** y.

Critical Thinking

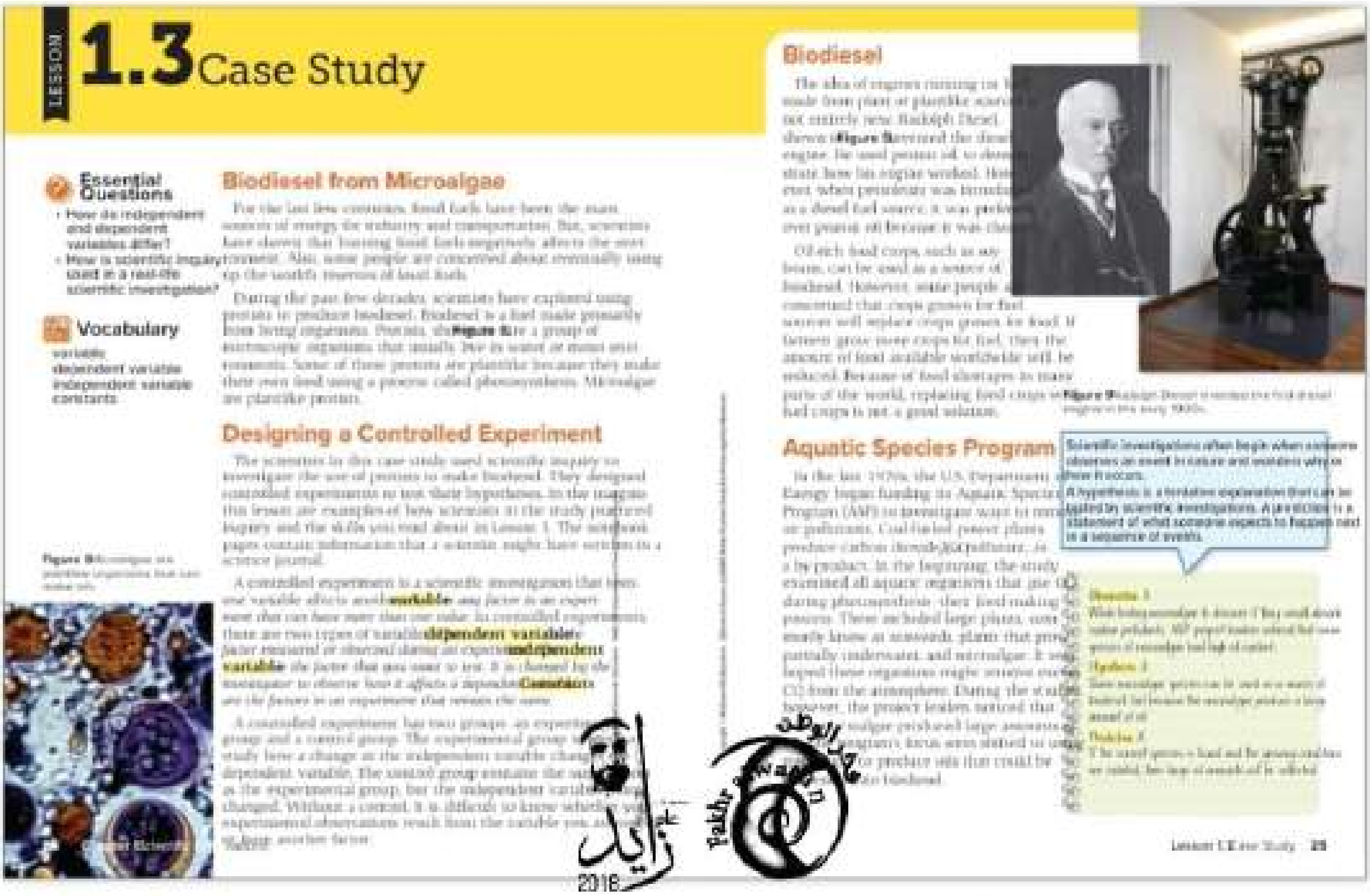
7. Answers should recommend ways in which computers can assist life scientists in their work. Sample answer: Life scientists use a computerized spreadsheet to keep track of their data, research information, graph data, and exchange ideas with scientific pe **DOK 3**

Math Skill

8. 7 significant dig **DOK 1**

LABManager

How can you build your own scientific instrument? Lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.



LESSON 1.3 Case Study

Essential Questions
- How do independent and dependent variables differ?
- How is scientific inquiry used in a real-life scientific investigation?

Vocabulary
variable
dependent variable
independent variable
constants

Biodiesel from Microalgae

Designing a Controlled Experiment

Biodiesel

Aquatic Species Program

Lesson 1.3 Case Study 25

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Connect to Prior Knowledge

Have students use their prior knowledge to understand the words *variable*, *dependent variable*, *independent variable*, and *constants*.

1. **Ask: What is the definition of *vary*? Is *vary* a noun (a thing) or a verb (an action)?** a verb
2. **Ask:** What is the noun version of vary? variable; something that can be changed in an experiment
3. Have students contrast the words *dependent* and *independent*. A dependent variable is the factor measured or observed during an experiment. The independent variable is a factor that is changed to observe how it affects the dependent variable.
4. **Ask: What is the definition of the adjective *constant*?** means "always the same, not changing." The noun version means "a thing that is always the same."

Biodiesel from Microalgae

To prepare students to recognize the value of creating biodiesel from algae, use the scaffolded questions below.

Guiding Questions

OL	**What have people used for several centuries as the main source of energy for industry and transportation?**	*fossil fuels*
CL	**What will likely happen to fossil fuels if they continue to be used at a great rate?**	*They will be depleted and will no longer exist.*
BL	**What are some negative effects of the use of fossil fuels?**	*Students should be aware of effects such as global warming, pollution, cost, or safety.*

Designing a Controlled Experiment

Use the scaffolded questions below to guide students in recognizing components of a controlled experiment.

Guiding Questions

AL What are constants?	*Constants are the factors in an experiment that remain the same.*
OL How do dependent and independent variables differ?	*A dependent variable is a factor measured or observed during an experiment. An independent variable is changed by the investigator, and the dependent variable responds to the change in the independent variable.*

Biodiesel

The scaffolded questions below will guide students in recognizing the beginnings of biodiesel, as well as concerns relevant to utilizing crops grown for fuel.

Guiding Questions

AL Name an oil-rich crop.	*soybeans*
BL What did Rudolph Diesel use as fuel?	*peanut oil*
OL Some people are concerned that crops grown for fuel will replace crops grown for food. Do you think their concerns are valid? Explain.	*Make certain students support their opinions with evidence from the text and their own background knowledge.*

Aquatic Species Program

Students have discussed biodiesel as an energy source. Use the scaffolded questions below as you continue to deepen their knowledge of sources in nature that have been examined as positive contributors to energy resources.

Guiding Questions

OL What was the purpose of the ASP?	*to investigate ways to remove air pollutants naturally using aquatic organisms*
OL What significant observations were made about microalgae during the original ASP project?	*Some of the microalgae produced large amounts of oil.*
BL How has the purpose of the ASP program changed?	*The focus of the project shifted to microalgae producing oils for biodiesel.*
BL How are biodiesel and the ASP related?	*They are both ways to utilize items grown naturally—to aid in the energy crisis.*

Teacher Notes

Which Microalgae?

Use the scaffolded questions below, focusing on algae, as you guide students in recognizing they have been discussing a variety of methods to produce energy.

Guiding Questions

OL **What is photosynthesis?**	*Photosynthesis is the process used by many plants and plantlike organisms to make food, such as sugars and oils.*
OL **Why have scientists focused on microalgae in their biodiesel research?**	*Microalgae produce oils during photosynthesis—oils that easily can be converted into biodiesel.*
BL **Why do you think scientists predicted that algae from shallow ponds were more resistant to changes in temperature and salt content in the water?**	*Students will likely recognize that algae in shallow ponds are exposed to more changes in temperature and salt content than their deep-water counterparts—so they are better acclimated to these conditions.*

Oil Production in Algae

Students have studied the value of algae in oil production. Use the scaffolded questions below to guide them in recognizing some of the problems scientists have encountered as they have worked to increase algae oil production .

Guiding Questions

OL **Why did scientists propose to starve the microalgae?**	*They hoped the algae would produce more oil.*
OL **What was the negative result of nitrogen starvation?**	*The negative result was a decrease in size.*
BL **What do you think scientists should have tried when they discovered that the same deprivation leading to the increase in oil production led to decrease in size?**	*Use this question to launch a discussion about variables, such as deprivation of a different nutrient that scientists might have tried.*

Outdoor Testing v. Bioreactors

Use the scaffolded questions below to guide students in understanding, comparing and contrasting three methods of growing algae. Encourage students to discuss the value of the hypotheses and controlled experiments in finding a profitable, feasible method.

Guiding Questions

OL What are bioreactors?	*closed containers used for growing algae*
OL As ASP scientists grew algae in outdoor ponds in New Mexico in the 1980s, what was the result of the experiment?	*smaller plants and invasion of native algae forcing out high-oil-producing microalgae species*

Visual Literacy: Figure 11

Ask students to study the photographs and captions in **Figure 11** as you draw the diagram below on the board. Encourage students to provide additional information from the main text.

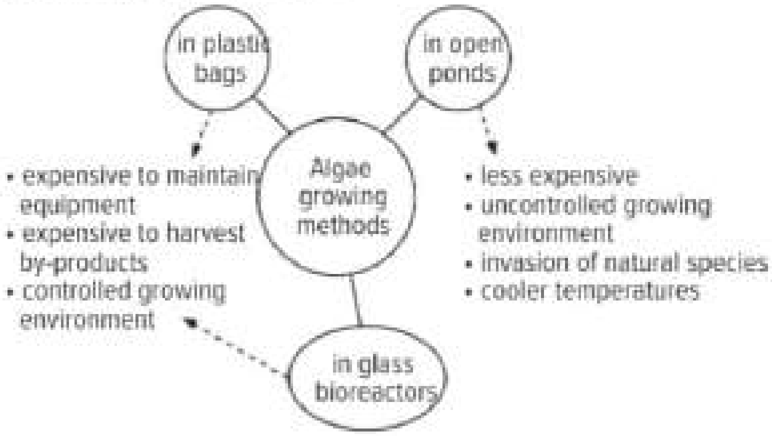
Ask: Why are open ponds used to grow algae? *They are less expensive than bioreactors.* **What is a problem with this method?** *Uncontrolled outdoor temperatures result in small microalgae. Also, native outdoor algae species can invade the ponds.*

Ask: What is the main problem with using bioreactors when growing algae? *It is expensive.*

Ask: What is a problem with using plastic bags to grow algae? *It is very expensive to collect the by-products.*

Ask: How are open ponds, plastic bags, and glass bioreactors alike? *They are examples of different hypotheses that are being tested for growing high-oilproducing microalgae in controlled experiments.*

Ask: What are some possible hypotheses that scientists might test using these three environments for growing the algae? *Accept all reasonable responses. Hypotheses might include: If we grow the algae in open ponds in a natural setting, then the algae will produce larger amounts of oil. If we grow the algae in plastic bags in a controlled setting, then the algae will produce larger amounts of oil. If we grow the algae in glass bioreactors in a controlled setting, then the algae will produce larger amounts of oil.*



Differentiated Instruction

AL **Growth Methods** Have pairs divide a large paper into three columns and label the top of the columns: *Open Ponds, Plastic Bags, Glass Bioreactors.* Have students draw an illustration, write a caption, and list advantages and disadvantages for each method.

BL **Growth Plan** Ask students to think of another method that might work for growing algae. Ask them to create a diagram with captions and callouts to explain why the method might work.

Teacher Toolbox

Teacher Demo

Method Videos Obtain videos depicting some or all of the methods: open ponds, plastic bags, glass bioreactors. After viewing the videos, discuss how bioreactors could provide enough essential fuel to fill human needs.

Real-World Science

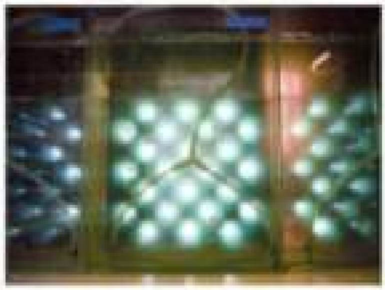
Growing Algae in Mines In November of 2009, scientists at the Missouri University of Science and Technology made plans to grow algae in abandoned mines. Their plans included use of LEDs, light-emitting diodes. The LEDs emit the red and blue parts of the light spectrum needed for algae to produce oils and oxygen. Discuss with students why scientists would possibly be interested in growing algae in mines.

Reading Strategy

Clarifying Questions Have students write five questions they would ask the scientists doing research at the facility shown in **Figure 11.**

Why So Many Hypotheses?

Increasing Oil Yield



Bringing Light to Microalgae

Experimental Group

Field Testing

28 Chapter 1 Scientific Explanations

Lesson 1 Case Study 29

Why so many hypotheses?

As students study science and scientific principles, they often form hypotheses. Use the Guiding Questions below to help them recognize they are utilizing the same types of skills utilized by seasoned scientists. Guide students in recognizing that their skill with forming hypotheses should improve as they practice.

Guiding Questions

AL **What does a scientist do after proposing a hypothesis?**	*After proposing a hypothesis, the scientist tests it.*
Reading Check **Why is it important for a scientific researcher to develop a good hypothesis?**	*A scientific researcher needs a clear and precise hypothesis that is testable by fellow scientists. Scientific research is funded by organizations that need understandable and practical information, hypotheses, and examples.*
BL **Do you think scientists grow more skilled at proposing a new hypothesis after testing many hypotheses? Explain.**	*Use this question to launch a class discussion that illustrates recognition of improving skills through repeatedly using them.*

Increasing Oil Yield

Visual Literacy: Figure 12

Have students read the caption and study the photograph in **Figure 12**. Discuss the photo using the following questions.

Ask: What kind of energy do algae use to convert water and carbon dioxide into food? *light energy*

Ask: What was the purpose of the acrylic rods shown in Figure 12? What was the purpose of the experiment? *Purpose of the rods was to distribute more light below the water's surface. Scientists thought they might be able to increase algae yields by distributing the light deeper into the water to reach more algae.*

Ask: Suppose there was a malfunction in the rods shown in Figure 12 resulting in the lights going out. What would be the impact? Explain. *Without light, algae are not productive, so the algae would not be able to photosynthesize and produce oil.*

Bringing Light to Microalgae

Experimental Group

Students are continuing to learn about scientific hypotheses and the tests of these hypotheses. Use the scaffolded questions below to establish continuity from the earlier lesson content and emphasize the importance of scientific methods and scientific inquiry to solve real-life problems.

Guiding Questions

AL Where do scientists plan to use the light-rod growing method?	*outdoor ponds*
Reading Check In the experimental group, what variables are controlled in the bioreactor?	*temperature, nutrient levels, carbon dioxide level, and airflow. The variables are controlled to help insure the only factor that changes is the independent variable which causes the affects on the dependent variable—oil production.*
BL Do you think it is a good idea for scientists to combine methods they have been working with? Support your reasoning.	*Students should support their comments with evidence from the text and their own background. They should recognize that scientists have hypothesized, tested their hypotheses, collected data, analyzed the data, and drawn conclusions— and then used these conclusions to create new hypotheses. Students should be aware that this is an integral part of scientific research.*

Field Testing

Use the Guiding Questions below to deepen students' knowledge of scientists' work with algae.

Guiding Questions

AL Why do the scientists plan to change the level of light during field testing?	*Because the light is only able to penetrate a few centimeters into the pond, the algae that is below the surface cannot receive the light to make food and oils. Scientists are working to take more light down to the algae in the hopes of producing more oil.*
Reading Check What is the benefit of the light-distribution system?	*Light is distributed throughout the depth of the pond so the whole pond—not just the top 5 cm— will be more productive.*
BL What is the advantage of many scientists spending time on real-life scientific inquiry?	*It allows for many hypotheses to be tested. Much information is gathered and allows for a thorough understanding of the problem studied and its possible solutions.*

Differentiated Instruction

AL **Illustrating Acrylic Rods** Have students create an informative illustration that shows how acrylic rods distribute light below the surface of the water. Call outs should include: sunlight, pond surface microalgae populations, deep-water algae, light rods, and oil production.

BL **Field Testing** Have students create graphic stories with at least six frames to illustrate different hypotheses for testing light rods in algae ponds. In each frame, have students diagram a pond cross section. In frame one, students could show the light system at 5 cm. Successive frames could show the light system placed at different depths. Students may list controlled variables, including temperature, nutrients, carbon dioxide, and airflow.

Teacher Toolbox

Teacher Demo

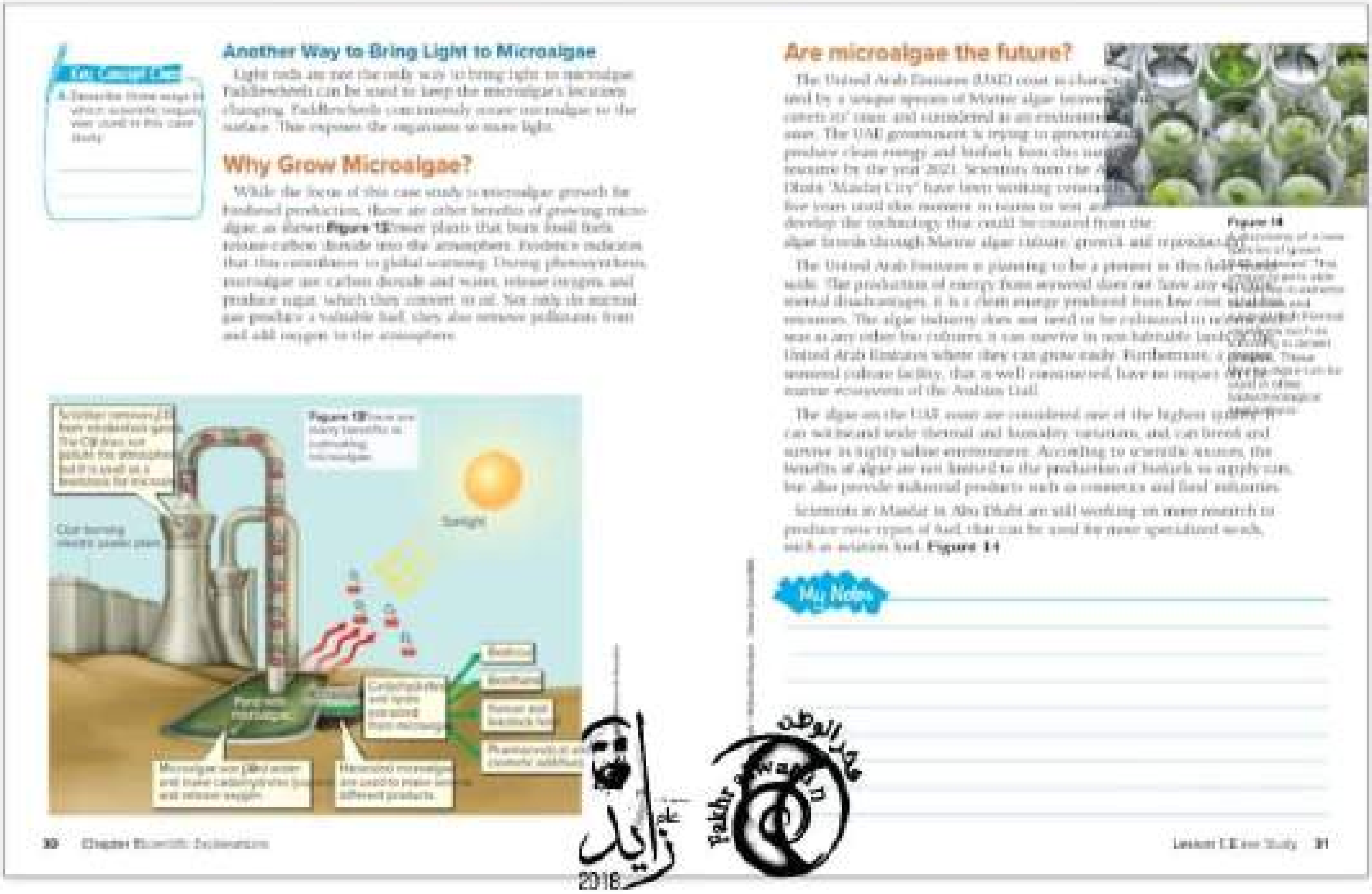
Grow Algae Demonstrate the effect light energy has on microalgae by modeling it. Obtain algae from a science supply company. Divide the algae into two samples. Place one of the samples under a plant light that is constantly on. Place the other sample in a closet. Have the class compare the results in a week.

Real-World Science

Vehicles Powered by Algae Biodiesel In January of 2008, a documentary film about biodiesel fuels was featured at the Sundance Film Festival. Cars powered by algae biodiesel were also available for public viewing.

Reading Strategy

Flowchart Have student pairs create flowcharts showing the steps researchers used to develop a "biodiesel from microalgae" process. Have students start with the Aquatic Species Program. The flowcharts can be continued and completed as students work through **Lesson 3.**



Another Way to Bring Light to Microalgae

Discuss how paddlewheels distribute microalgae to the water surface.

Guiding Questions

A1 **Describe how the use of paddlewheels are beneficial to bring microalgae to the light.** *Paddlewheels bring the algae from deep in the pond to the surface allowing more microalgae to reach the sunlight.*

Key Concept Check **Describe three ways scientific inquiry was used in this case study.** *Accept all reasonable responses. Scientists generated testable hypotheses, tested their hypotheses, refined their hypotheses, and tested them again.*

Why Grow Microalgae?

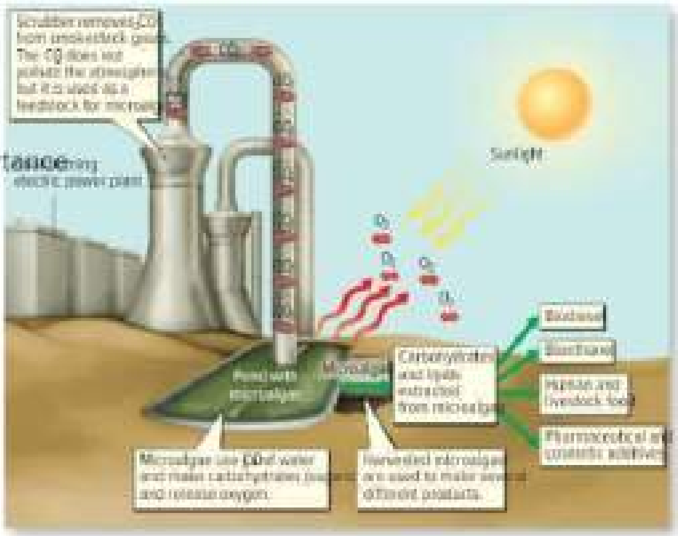
Discuss the scaffolded question below to reinforce the importance of algae growth for biodiesel production.

Guiding Questions

C1 **How is burning fossil fuels a problem? How can tiny algae be a part of the solution?** *Power plants release carbon dioxide into the atmosphere. Algae use photosynthesis to produce their food and oxygen. Sugars produced are converted to oil. Algae use carbon dioxide in the process of photosynthesis, converting it to food and oxygen.*

Visual Literacy: Figure 14

Have students study the diagram in **Figure 14**. **Ask:** **Explain why a community should establish methods to move forward with algae cultivation.** *Sample answer: The CO_2 in the process is used as feedstock for microalgae instead of polluting the air. Algae harvested from the process can be used to make several different products, including biodiesel, bioethanol, human and livestock food, and pharmaceutical and cosmetic additives.*



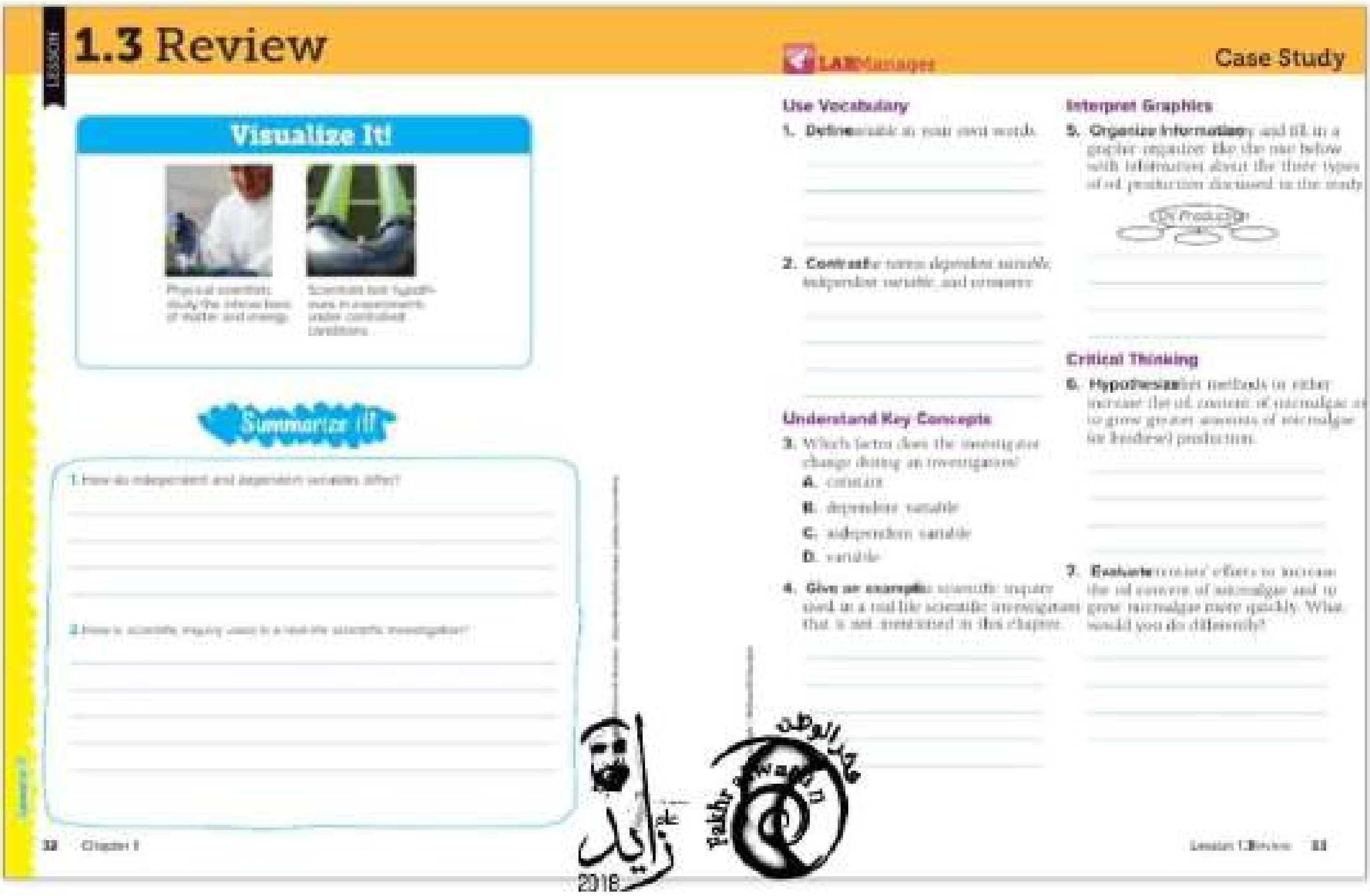
Are microalgae the future?

Use the scaffolded questions below to guide students in considering the future of algae-based biodiesel.

Teacher Notes

Guiding Questions

AL **How have scientists designed a partnership between a coalpowered electrical plant and a microalgae bioreactor?**	*The power plant produces carbon dioxide which is captured and then used by the microalgae to produce oil. This less expensive fuel can then be used in the production of electricity, saving fossil fuels, and helping to eliminate pollution and carbon dioxide in the atmosphere.*
OL **Why is algae-based biodiesel currently unable to compete with petroleum-based biodiesel?**	*…gae-based biodiesel is too expensive to compete with less expensive petroleum-based biodiesel at this time.*



Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Which Key Concept does each image relate to?**

Summarize It!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- The Biodiesel Revolution
- Designing a Controlled Experiment
- Biodiesel
- Aquatic Species Program
- Which Microalgae?
- Oil Production in Algae
- Outdoor Testing v. Bioreactors
- Why so many hypotheses?
- Increasing Oil Yield
- Bringing Light to Microalgae
- Why Grow Microalgae?

Use Vocabulary

1. Sample answer: A variable is a factor measured or observed during an experiment. **DOK 1**
2. An independent variable is the factor that you manipulate in an investigation. However, a dependent variable is a factor that responds to a change in the independent variable. The constants are all the factors in an experiment that are not allowed to change. **DOK 1**

Understand Key Concepts

3. C. independent variable **DOK 1**
4. Sample answer: Scientists use scientific inquiry when they test new medicines before these medicines are released to the public. **DOK 3**

Interpret Graphics

5. open ponds, plastic bags, glass tubes (in any order) **DOK 1**

Critical Thinking

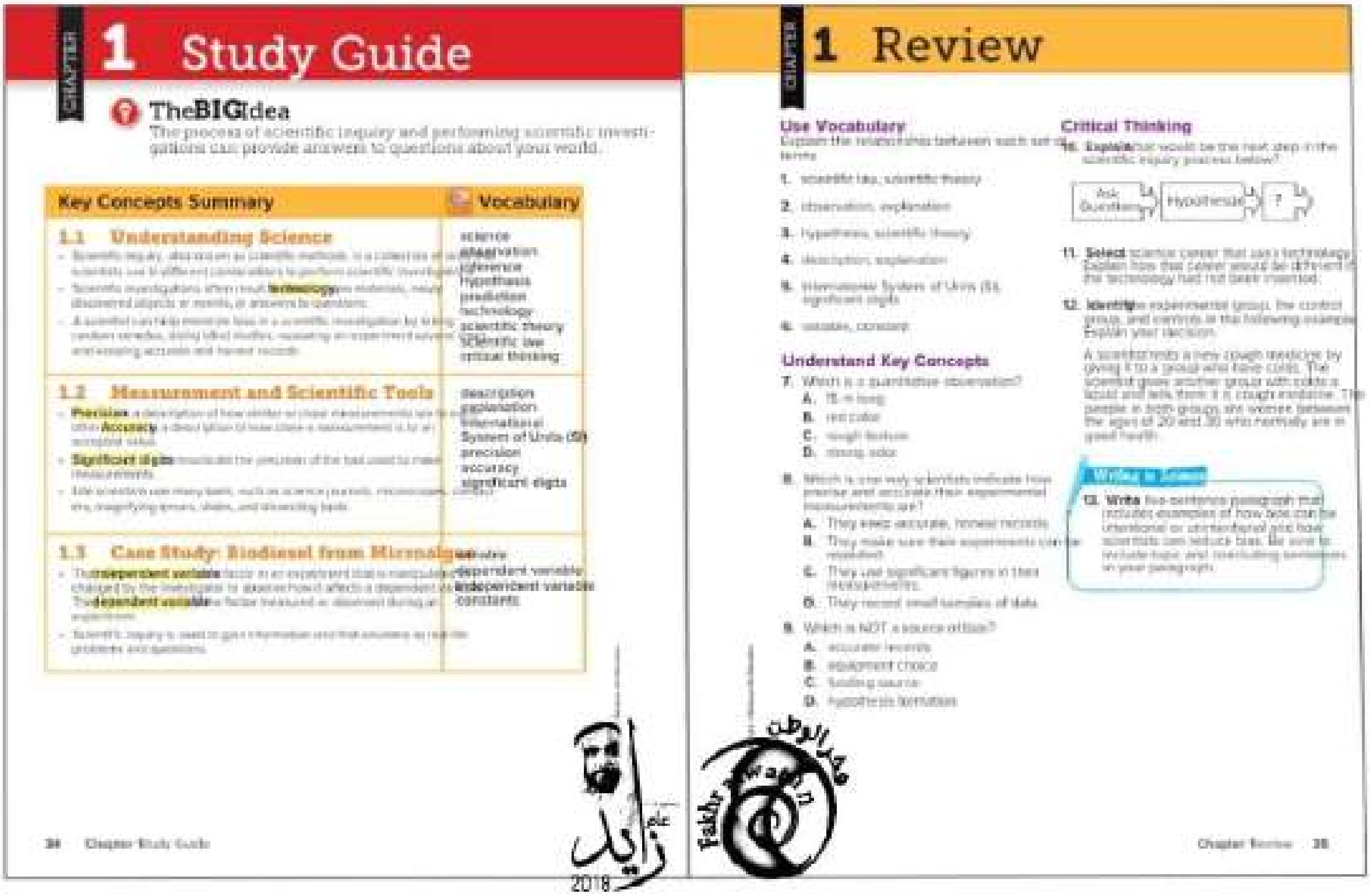
6. Accept all reasonable answers. Sample answer: If specific growing conditions were used in a pond with a top over it to control variables, then the algae growth and oil production should increase. **DOK 2**

7. Accept all reasonable responses. Sample answer: We could conduct the studies in a less expensive way, so that we could use the technology and reduce our dependency on petroleum production. **DOK 1**

Teacher Notes

LABManager

How can you design a bioreactor? This lab can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.



Key Concepts Summary

Study Strategy: Self-Assessment

Self-assessment helps students increase their awareness of their understanding.

1. Ask students to create a chart similar to the one below.
2. Have students list the Key Concept questions found on the first page of each lesson in the first column.
3. Have students write their own answer to each Key Concept question in the second column. Prompt them to use complete sentences.
4. Then have them read the Key Concept Summaries. Prompt students to self assess their answers in the third column.

Example:

Lesson Key Concept Questions	My Answers	My Self-Assessment
What is scientific inquiry?	Scientific inquiry is using different skills to do investigations in science.	I could have included it is also called the scientific method.

Use Vocabulary

1 Answers will vary. Sample answer: A scientific theory might contain many well-supported hypotheses that explain why something happens. A scientific law usually contains one well-supported hypothesis that states that something will happen.

2 Answers will vary. Sample answer: An observation is the act of watching something and recording what occurs. An explanation is an interpretation of observations.

3 Answers will vary. Sample answer: A hypothesis is a possib explanation about an observation that can be tested by scientific investigations. A scientific theory is an explanatio based on repeated observations and scientific investigatio It might contain many wellsupported hypotheses.

4 Answers will vary. Sample answer: A description is a spoke or written summary of observations. An explanation is an interpretation of observations.

5 Answers will vary. Sample answer: The International System of Units is the internationally accepted system for

measurement. Significant digits are the number of digits in a measurement that are with a certain degree of reliability.

6 Answers will vary. Sample answer: A variable is any factor in an experiment that can have more than one value. A constant is a factor in an experiment that remains the same. There can be many constants in an experiment.

Understand Key Concepts

7 A. 15 m long

8 C. They use significant figures in their measurements.

9 A. accurate records

Critical Thinking

10 Test hypothesis, which includes design an experiment, make a model, gather and evaluate evidence, and collect data/record observations.

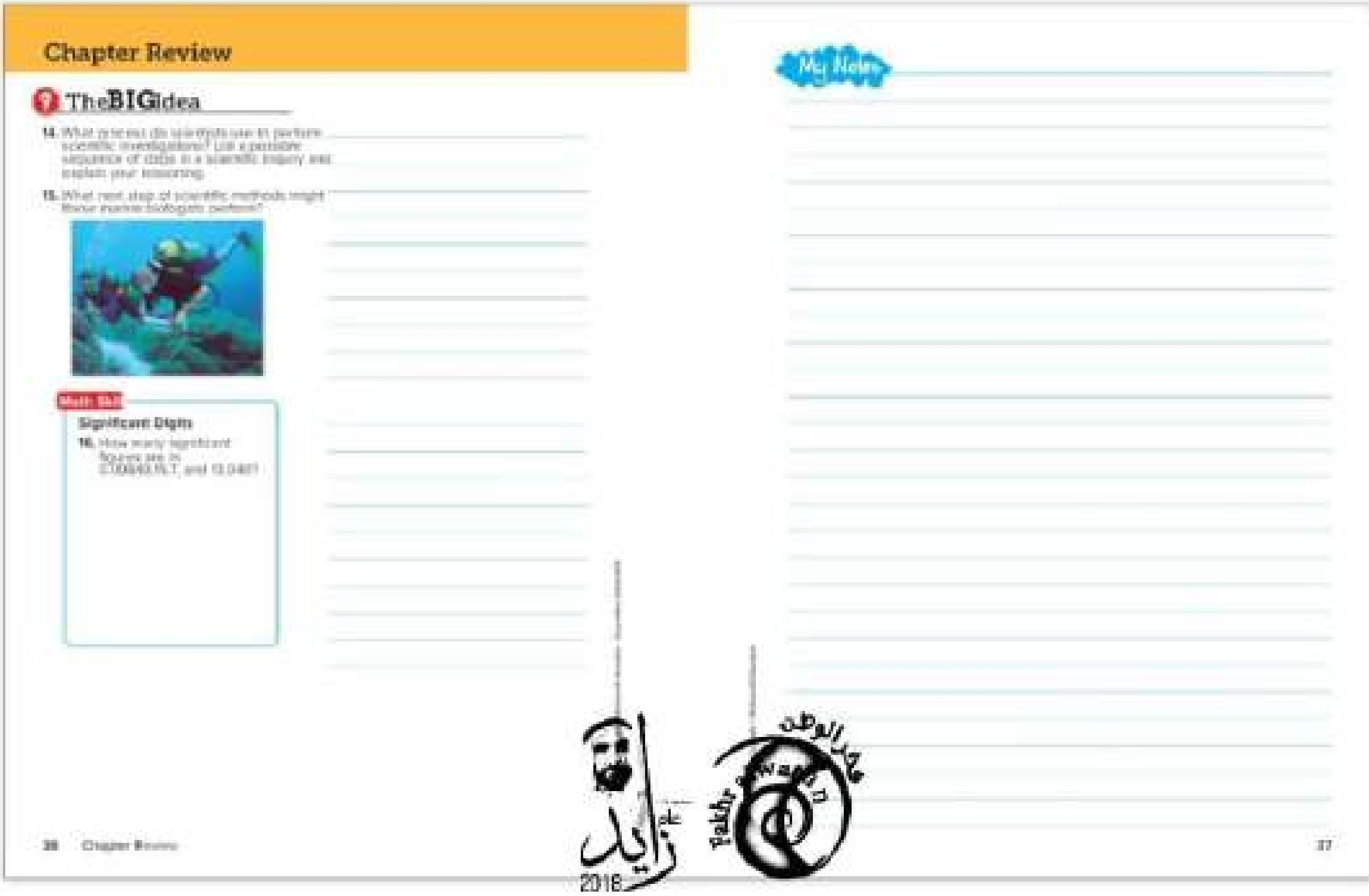
11 Accept all reasonable answers. Sample answer: A computer programmer uses technology and writes programs to make technology usable and available to more people. If computers did not exist, computer programmers would not exist. All processes and systems that use computers would not exist or would be manual processes.

12 The experimental group is the one that got the real cough medicine because they got the medicine that was being tested. The people that got the inert liquid were the control group because they were given a liquid that did not have active ingredients in it. Constants were that all participants were women ages 20–30 and normally healthy.

Writing In Science

13 Students' paragraphs should contain facts from the chapter and they should include a topic sentence and a concluding sentence.

Teacher Notes


Chapter Review

TheBIGIdea

Math Skill

Significant Digits

My Notes

TheBIGIdea

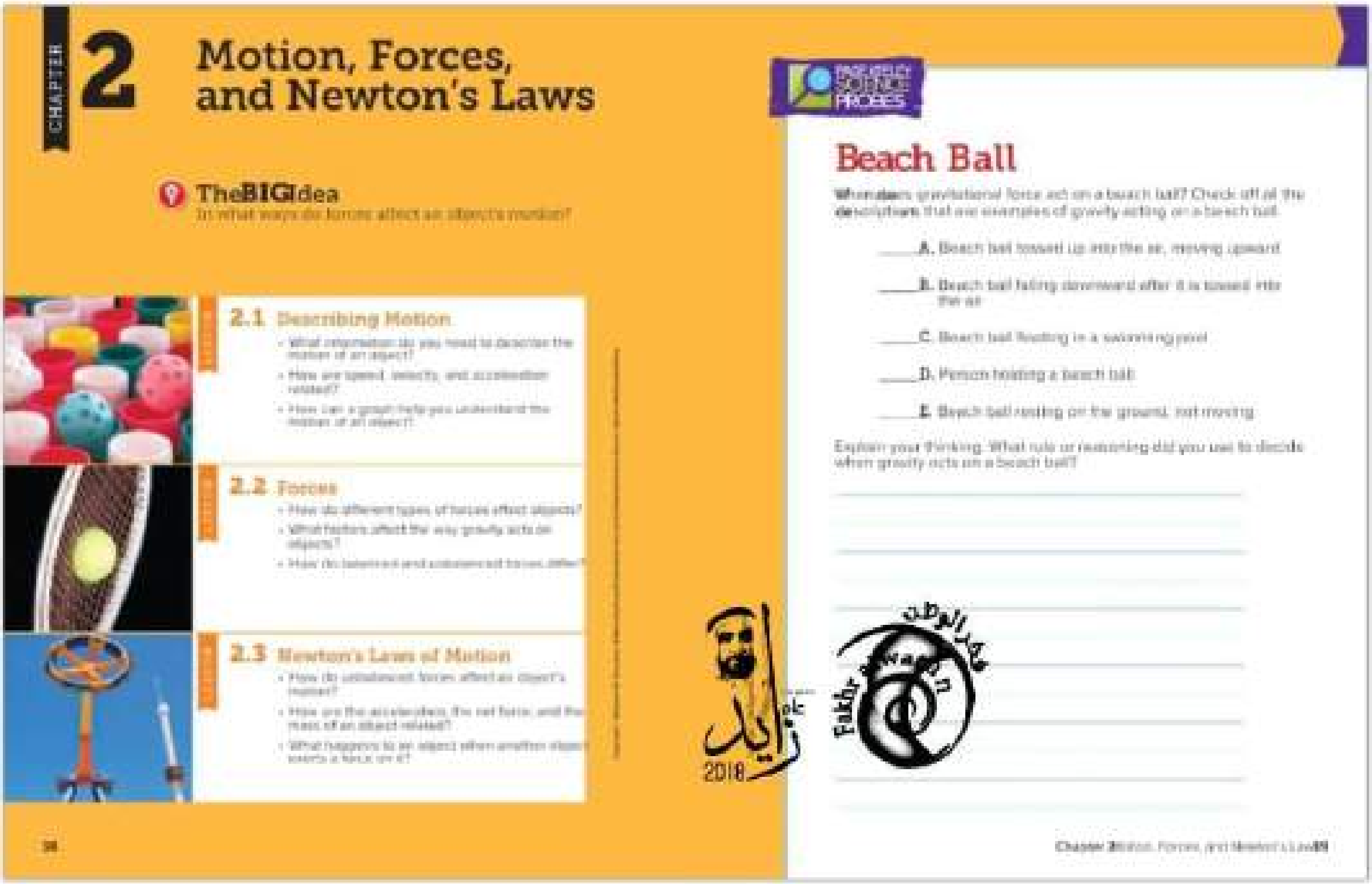
14 Scientists use a process called the scientific method. Steps include: gather information, hypothesize and predict, test hypothesis, analyze results, draw conclusions, communicate results

15 The biologists might continue to collect more data or might begin to organize and analyze their data.

Math Skill

Significant Digits

16 3; 3; 5



Motion, Forces, and Newton's Laws

TheBIGIdea

There are no right or wrong answers to these questions. Write student generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL **Describe an object that is moving.**	*Students may describe how an object travels from one location to another or its speed as an example of an object in motion. This question encourages students to reflect on ways to observe movement.*
OL **How can you tell when something is in motion?**	*Students may explain that an object in motion can often be observed as it moves, such as a car that drives past. Or you can tell that an object has moved because it started in one location and is now in another, such as the hand of a clock.*
BL **Describe one way to set an object in motion. Describe one way to stop a moving object.**	*Students may describe a push or pull that sets an object in motion, such as a push to open a door, and a push or pull that stops a moving object, such as catching a frisbee or a ball.*

PAGE KEELEY SCIENCE PROBES Beach Ball

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook.*

Get Ready to Read

What do you think?
Use this anticipation guide to gauge students' background knowledge and preconceptions about motion, forces, and Newton's laws. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. **You must use a reference point to describe an object's motion.**

   Agree. A reference point is the position that is used to describe the motion of an object.

2. **An object that is accelerating must be speeding up.**

   Disagree. An object accelerates when it changes velocity, which can include a change in speed, a change in direction, or both.

Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

- * Things change in steady, repetitive, or irregular ways—or sometimes in more than one way at the same time.
- * Changes in speed or direction of motion are caused by forces.
- * How fast things move differs greatly.
- * Earth's gravity pulls any object on or near Earth toward it without touching it.
- * The greater the force is, the greater the change in motion will be.
- * An unbalanced force acting on an object changes its speed or direction of motion, or both.

* American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1 Describing Motion

1. An object's motion depends on how it changes position. Motion can be described using speed, velocity, or acceleration.
2. Speed is how fast an object moves. Velocity describes an object's speed and the direction it moves. Acceleration describes the rate at which an object's velocity changes.
3. A graph can show you how either the distance or the speed of an object changes over time.

Lesson 2 Forces

4. A force is a push or pull on an object. Contact and noncontact forces can change the motion of an object.
5. Gravity is a force of attraction between any two objects. Gravitational force increases as the masses of the objects increase and decreases as the distance between the objects increases.
6. Balanced forces acting on an object cause no change in the motion of the object. When unbalanced forces act on an object, the sum of the forces is not equal to zero.

Lesson 3 Newton's Laws of Motion

7. An unbalanced force on an object will cause the object to accelerate.
8. Newton's second law of motion states that the acceleration of an object increases as the force acting on it increases and decreases as the mass of the object increases.
9. Newton's third law of motion states that for every action force, there is an equal but opposite reaction force. The action-reaction forces are called a force pair.

Identifying Misconcepti

Changes in Velocity

Find Out What Students Think

Students may think that...

... speed and velocity mean exactly the same thing. They may not realize that velocity also includes the direction of a moving object. They may believe that changing the direction of an object does not affect its velocity.

Discussion

Remind students that speed and velocity have different meanings. Speed is simply how fast an object is traveling. Velocity is how fast an object is traveling as well as the direction in which it is moving. The velocity of a moving object changes when its speed changes. The velocity of a moving object also changes when its direction changes. This is true even if its speed remains the same. **Ask:** Picture a roller coaster traveling 50 kilometers per hour in a straight line. It curves around a loop without slowing down. Does the speed of the roller coaster change? **No, it is still traveling 50 kilometers an hour.** **Ask:** Does the direction of the roller coaster change? **Yes, it changes from a straight line to a curving loop.** **Ask:** Does the velocity of the roller coaster change? Why or why not? **Yes, the velocity changes because the direction changes.**

Promote Understanding

Activity Use visuals to check and correct students' understanding:

1. Have students find a photograph of an amusement park ride, such as a roller coaster, Ferris wheel, chair swing ride, or water slide, from a magazine, newspaper, or the Internet.
2. Have them use the photo to create a poster advertising the ride.
3. Their posters should describe the changes in velocity that a rider will experience on the ride. One of these changes should describe a change in direction; the speed remains constant.
4. Ask students to include arrows with the photo to indicate how the ride can change direction. If students need help with this, refer them to the three diagrams in **Figure 5** in **Lesson 1**.

Newton's First Law

Find Out What Students Think

Students may think that...

... a force is needed to keep an object in motion. They may think that an object in motion will naturally come to a stop when the force that set it in motion is no longer applied. They may not realize that another unbalanced force must act on the object before it will stop.

Discussion

Remind students that Newton's first law of motion states that if the net force on an object is zero, an object at rest will remain at rest and an object in motion will remain in motion. A moving object will only come to a stop if an unbalanced force acts on it. Have students predict what will happen when you slide a book across the floor. **Ask:** When I slide this book across the floor will it keep moving or will it eventually come to a stop? **The book will eventually come to a stop.** Then have them observe as you slide the book across the floor of the classroom. **Ask:** Why did the book come to a stop? **Friction acted on the book and caused it to stop moving.** **Ask:** Without friction or some other outside force, would the book have kept moving? **Yes.** A force is not required to keep the book in motion. It is the action of another unbalanced force (in this case, friction) that brings the book to rest.

Promote Understanding

Activity In this activity, students will engage with the contact and noncontact forces that put a ball in motion and then stop it.

1. Have students work in pairs with a rubber ball. Have them predict what will happen when they hold out the rubber ball and drop it.
2. Then have them take turns dropping the ball and observe as it bounces on the floor and eventually comes to a stop.
3. Ask them to explain why the ball came to a stop. The floor exerted a force on the ball, the ball reacted, and that, along with friction, eventually caused it to stop.
4. Ask them to create a diagram that shows how unbalanced forces caused the moving ball to stop moving.

Anticipation Set for Lesson 2

3. **Objects must be in contact with one another to exert a force.**

   Disagree. Noncontact forces include electricity, magnetism, and gravity.

4. **Gravity is a force that depends on the masses of two objects and the distance between them.**

   Agree. Gravity is a noncontact force of attraction between two objects. It is dependent upon mass and distance.

Anticipation Set for Lesson 3

5. **All forces change the motion of objects.**

   Disagree. Only unbalanced forces change an object's motion.

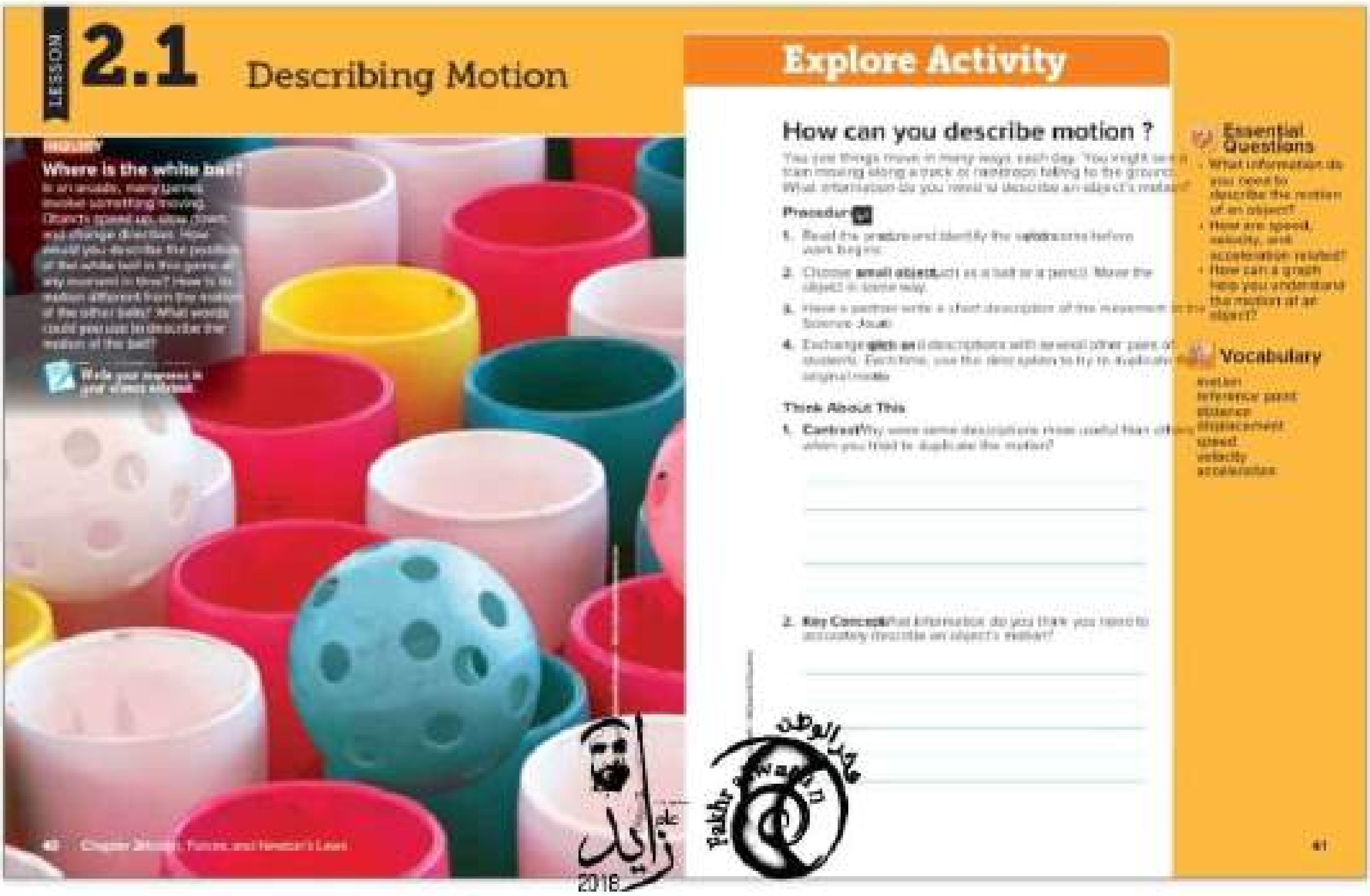
6. **The net force on an object is equal to the mass of the object times the acceleration of the object.**

   Agree. Net force equals mass times acceleration. It is expressed in units known as Newtons.

Options for Pre-Assessment

1. **What do you think?** Use the exercise on this page to determine your students' existing knowledge.
2. **Concept Mapping** Have students complete the concept map in the Chapter Study Guide. Use the result to determine students' existing knowledge and areas of need.

Teacher Notes



INQUIRY

About the Photo Where is the white ball? Carnival games are often found at arcades, movie theaters, amusement parks, and other locations. In this game, a player tosses a ball and tries to get it to bounce or land in a cup. If the ball successfully lands in a cup the player gets a prize. The ball begins moving upward and horizontally because the player exerts a force on it. The ball moves downward due to gravity and will eventually stop when it comes into contact with another object, such as the cup.

Guiding Questions

AL Describe the motion of the white ball. *Sample answer: The ball moves up, down, and away from the thrower.*

OL What sets the white ball in motion? *Sample answer: The player exerts a force on the ball, moving it in the direction of the toss.*

BL Describe the position of the white ball compared to the other balls. *The white ball is in front of the other balls and closer to the top of the cups.*

LABManager

All the labs for this lesson can be found in the *Student Lab Handbook* and the *Activity Lab Workbook.*

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Create Motion Trading Cards

1. Have each student create a set of three trading cards related to motion. The front of each card should include an illustration or diagram that shows an example of motion, such as a perso[n] riding a bike, an airplane taking off, an athlete throwing a ball, and so on. The back of the card should remain blank.
2. After students complete the lesson, ask them to write a sentence on the back of each of their trading cards to describe the illustration or diagram that appears on the front. Each sentence should include one of the vocabulary terms from the lesson. For example, a student could use the term reference point to describe an airplane traveling down a runway, or velocity to describe the speed and direction of a ball thrown during a baseball game.
3. After students complete their sentences, ask them to share o[r] exchange their cards with other members of the class.

Explore Activity

How can you describe motion?

Prep 5 min **Class** 15 min

Purpose
To explore what information is needed to accurately describe motion.

Materials
Student Pairs small object, such as a marble, pencil, or a wooden block

Before You Begin
Distribute one object to each student pair and establish a place where they will work. One student will need a place to freely move a small object; the other will need a place to write.

Guide the Investigation
Avoid leading students by telling them how to describe the motion of the object. For example, do not tell students that they need to say where the object starts or how fast it moves. Part of the learning process is having students discover how many of these details are needed. Ask them to create a simple chart in their Science Journal with all the objects they move.

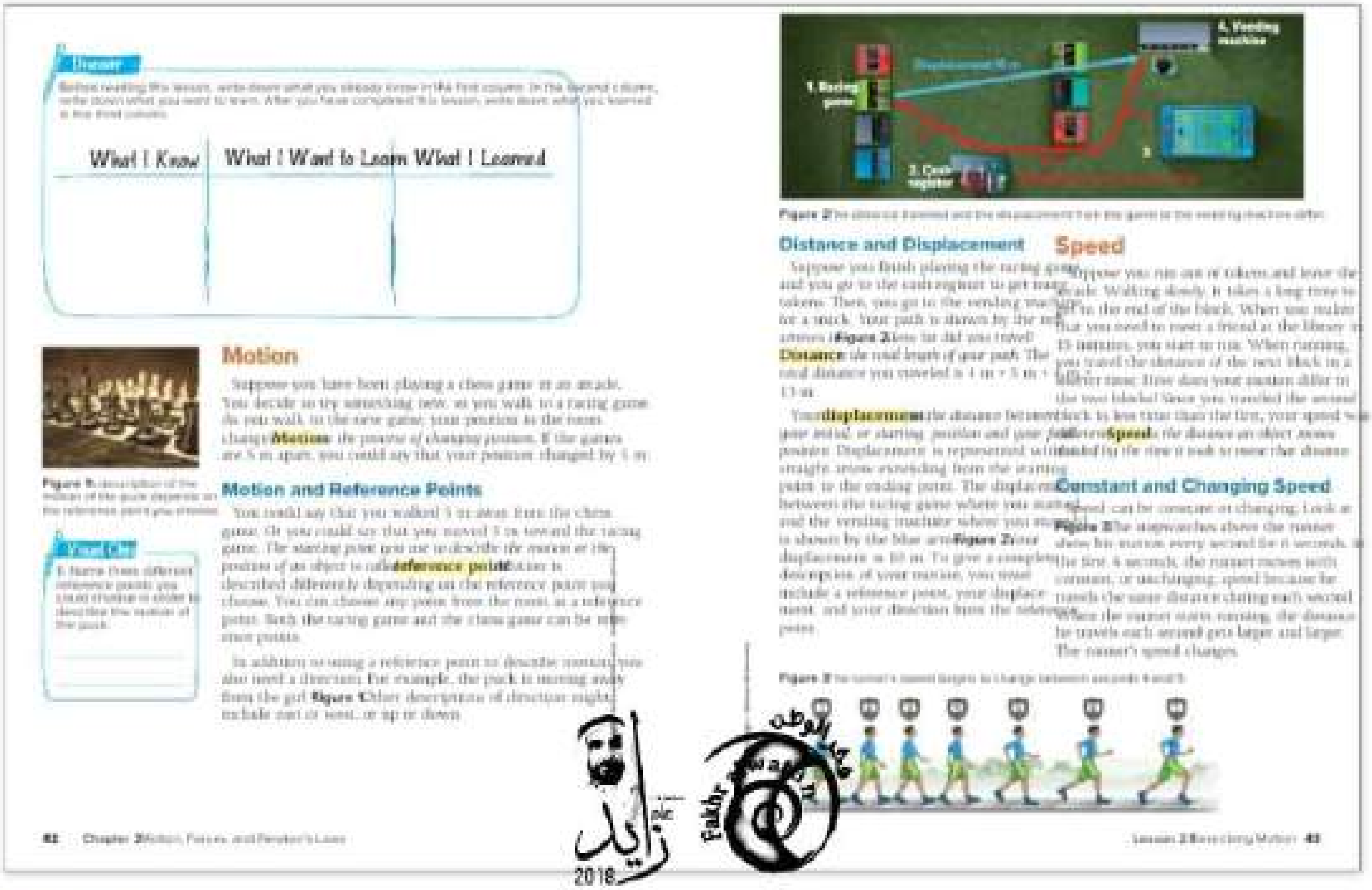
Object	Description of Movement
Marble	Flicked marble with forefingers from corner of carpet in direction of class door
Wooden block	
Pencil	

Think About This

1. Sample answer: Descriptions that told where an object began and how fast it moved were more useful than those that didn't provide this information.

2. **Key Concept** Accept any reasonable answer. Sample answer: An accurate description of an object's motion includes details about where the object started, how fast it moved, which direction it moved, any changes in its speed and direction, and where it stopped.

Teacher Notes



Motion

Have students read the paragraph and **Figure 1**. Ask them to describe the objects in motion in the photo. Have them brainstorm games they might see in an arcade, such as video games, air hockey, or bumper cars.

Motion and Reference Points

Have students read the paragraphs. Ask a volunteer to raise her hand and describe how the position of the hand changed using a reference point. Then ask the following questions to their comprehension.

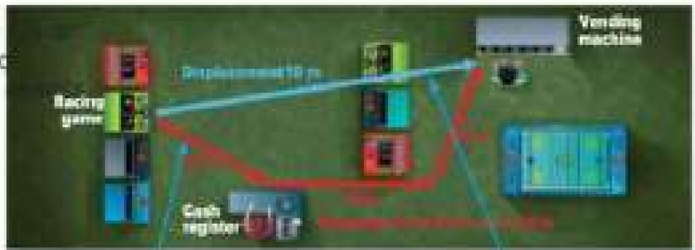
Guiding Questions

AL What is a reference point?	*A reference point is the position you use to describe the motion of an object.*
OL Describe your motion as you walk from your desk to the door. Use a reference point and a direction.	*Answers will vary, but should include a reference point, a distance, and a direction.*
OL Name three different reference points you could choose in order to describe the motion of the puck.	*Sample answers include the person's hand, the dotted line, the edge of the table, and so on.*

Distance and Displacement

Encourage students to think critically about using reference points to describe the motion of an object. Have students read the paragraphs and refer to **Figure 2**. Then ask the questions below.

Visual Literacy: Figure 2



Ask: What is the difference between the distance and the displacement as you move from the racing game to the cash register to the vending machine? *7 meters*

Ask: If you traveled back to the racing game, what would your displacement be? *0 meters*

Ask: What information do you need to describe an object's motion? *You need a reference point, a direction, and a distance.*

Speed

Ask students to discuss their experiences with the Launch Lab. Have them explain some of the ways they described the motion of the small objects they used in the lab. Have students examine the diagram of the runner in Figure 3 as they read this paragraph.

Constant and Changing Speed

Students may think that words describing motion involve only action verbs, such as run, reach, stretch, and throw. Explain that knowing the speed of an object can be helpful. Give the common example of speed limit signs on streets and highways.

Guiding Questions

AL **What is speed?**	*Speed is the distance an object moves in a unit of time.*
OL **Figure 3 shows changing speed. How would the illustration change if it showed constant speed for all seven seconds?**	*The runner's speed would remain the same. To show this, the runner would continue to look as if he were walking from seconds 4 to 7, and the distance between the illustrations of the runner would remain the same, as in seconds 1 to 4.*
BL **How does the distance an object moves per unit of time change as its speed changes?**	*The distance increases as the object speeds up or decreases as the object slows down.*

Average Speed

Have students read the paragraph. Explain that average speed does not describe the speed an object moves from one point to the next or how the speed changes over the distance traveled. Instead, it gives the average speed traveled during the course of the whole trip. Then ask the following scaffolded questions to informally assess their understanding of this concept.

Guiding Questions

AL **Name one unit of distance and one unit of time that could be used to describe average speed.**	*Sample answers include meters, kilometers, miles and seconds, minutes, hours, and so on.*
OL **Which is greater, your average speed when you ride a bike or your average speed when you walk?**	*The average speed when you ride a bike is much greater.*

Velocity

Remind students that speed includes distance and time. However, it does not include direction, which is also used to describe motion. When you measure the speed of an object, you do not need to know if it is traveling east or west, left or right, and so on. The measurement 40 km/h only tells you how far and how fast a vehicle can travel in an hour's time, not which way it is moving.

Word Origin

velocity

Have students compare the Latin origin of velocity to the scientific definition of the term.

Ask: **What element does the scientific definition of *velocity* include that the Latin origin does not?** *direction*

Ask: **How would you explain velocity in your own words?** *Sample answer: Velocity is the speed and direction that an object moves.*

Differentiated Instruction

AL **Motion, May I?** Divide students into groups to play a game of "Motion, May I?" that reviews the terms they learned in the **Motion** section of this lesson: reference poi distance, and displacement. Draw a version of **Figure 2** on the board. Have students stand a sufficient distance fr the front of the classroom. Call on students and give a statement such as "I walked 9 meters from the cash re to the vending machine." Ask students to reply with th answer, "That is distance," and ask "May I?" If they are correct, allow them to move one step forward. The firs group to advance to the front of the classroom wins.

OL **Calculate Average Speed Equations** Have students reread the section entitled **Average Speed**. Ask them to create three average speed problems. For example, w the average speed in kilometers per hour, if it took 30 minutes to bike 8 kilometers? *16 km/h* Have students exchange their problems with another student's to solv

LA **Make a Map** Put students in a group and ask them to make a map of the classroom with several different locations, such as the teacher's desk, board, door, and closet. Then have them locate three points on their ma and use a tape measure to find the difference betwee distance when walking around items to get from one t other and the displacement. Ask them to annotate the and present the difference between distance and displacement to the class.

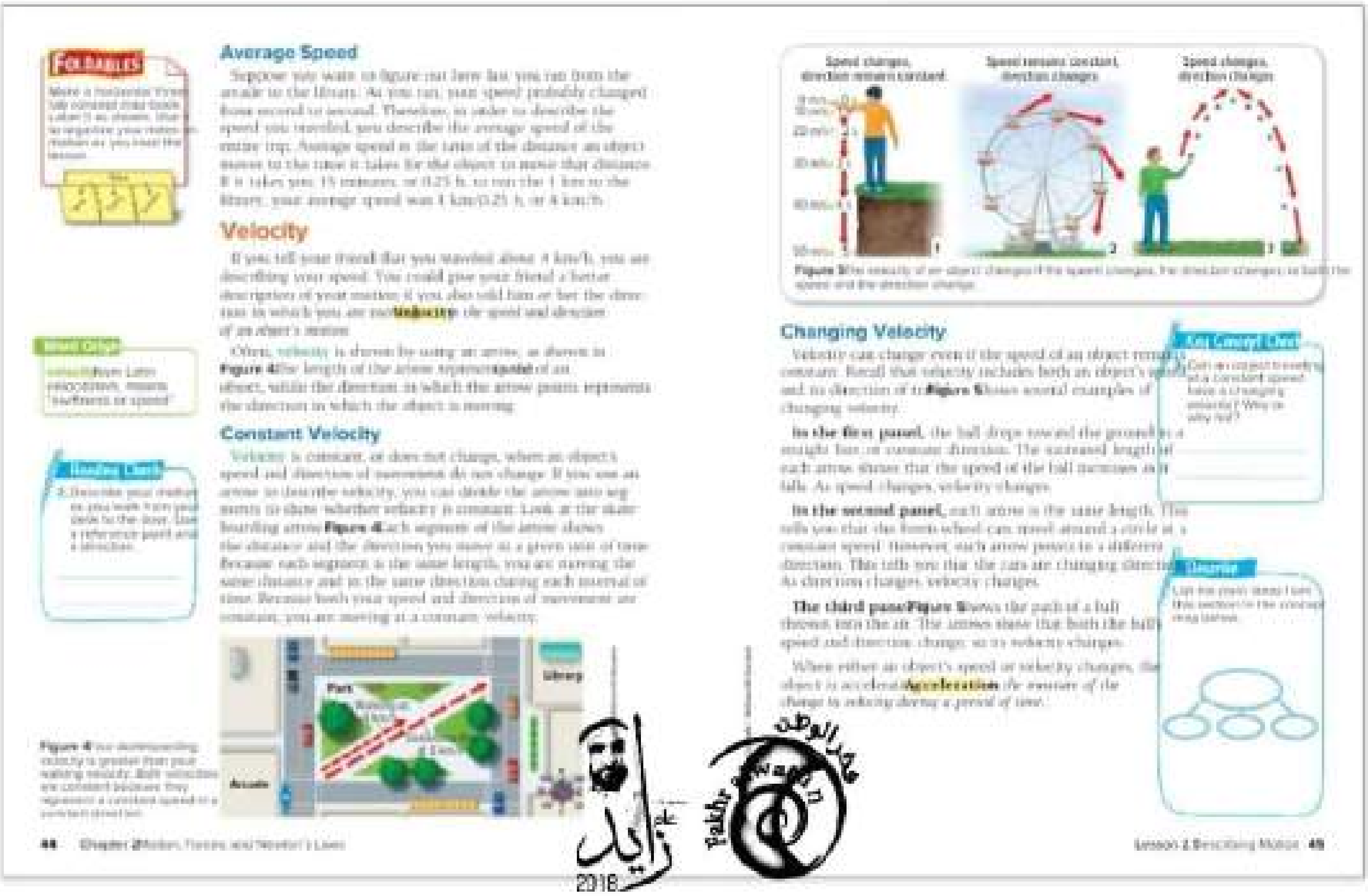
Teacher Toolbox

Reading Strategy

Summarize Have students reread the sections about **Speed**. Ask them to write a short summary to explain w the term *speed* means and the difference between co and changing speed. Remind students that summaries should primarily include the main ideas of a topic and few supporting details.

Teacher Demo

Longitude and Latitude Use a projector to display a map the emirate. Have students help you find the location several towns or attractions in the area. Write the latitu and longitude for each place on chart paper or the bo Explain that latitude and longitude are used to describ location using reference points that most people know understand.


Average Speed

Velocity

Constant Velocity

Changing Velocity

Figure 5

44 Chapter 2

Lesson 2 Describing Motion 45

Constant Velocity

Have students read the paragraph and examine the diagram in **Figure 4**. Then ask the following questions to assess their understanding.

Guiding Questions

AL If an object moves at a constant velocity, does its speed or direction change?	*No; constant velocity means keeping the same speed and direction.*
AL Why is one of the arrows in Figure 4 longer than the other?	*The person on the skateboard is moving faster than the person walking, so he or she has traveled a longer distance in the same amount of time.*
OL What is the difference between the velocity of the person walking and the person skateboarding in Figure 4?	*The difference between the two velocities is speed. The person walking and the person skateboarding are both traveling in the same direction, but the person on the skateboard moves at a faster speed.*
BL If an object's direction changes but its speed doesn't, does its velocity change? Why or why not?	*Yes, because velocity includes both speed and direction. So, if one of those changes, the velocity changes.*

Changing Velocity

Explain to students that moving objects usually do not travel at a constant speed or in the same direction. Have students imagine a girl walking down a street. She might turn a corner or slow down if the sidewalk becomes crowded, or turn around and walk back the way she came. Tell students that it is important to understand how velocity can change in order to describe how an object moves. Have them read the paragraphs and compare the three images in **Figure 5.**

Guiding Questions

AL What is acceleration?	*Acceleration is the change in the velocity of a moving object during a period of time.*
OL Can an object traveling at a constant speed have a changing velocity? Why or why not?	*Yes, if it is changing direction.*
OL How do you know the speed is constant in the second panel in Figure 5?	*The arrows are the same length.*
BL How would the arrows in the third panel of Figure 5 appear if the ball bounced back up after it fell to the ground?	*The arrows would point down as the ball falls to the ground and then up as it bounces back up. They would be different lengths to show the changes in the ball's speed.*

Calculating Acceleration

Have students read the paragraphs and study the equation. Ask volunteers to identify each element in the equation. Explain that initial velocity occurs when an object starts to move and final velocity occurs when it stops moving. Then ask the following questions.

Guiding Questions

AL Why are there two velocities in the equation for acceleration?	*v represents the velocity at the beginning of the time period. v represents the velocity at the end of the time period.*
OL How does acceleration differ from velocity?	*Velocity is speed in a given direction. Acceleration is the rate at which the velocity changes.*
BL Why is it important to include the difference between final velocity and initial velocity to calculate acceleration?	*Acceleration is a change in velocity, so it important to know the difference between the velocity when an object started moving and when it stopped to find the acceleration.*

Positive and Negative Acceleration

Discuss students' experiences with **MiniLab**. Ask them to describe how the velocity changed when they tossed the stopper to their partners. Review that acceleration is a change in velocity. Have students read both paragraphs to compare positive acceleration to negative acceleration. Then ask the following to assess their understanding.

Guiding Questions

AL During positive acceleration, how does the speed of an object change? During negative acceleration, how does the speed of an object change?	*It increases during positive acceleration and decreases during negative acceleration.*
OL If a train slows down as it pulls into a station, is that positive acceleration or negative acceleration?	*It is negative acceleration.*
BL Is direction important when calculating acceleration? Explain your answer.	*Yes, because direction is represented as one of the two velocity variables in the acceleration equation.*

Differentiated Instruction

AL **Everyday Changes in Velocity** Have students work as a group to create a poster that shows two or three examples of an everyday change in velocity, such as a changing direction or a jogger picking up speed or an airplane taking off, and so on. Ask students to label the show positive and negative acceleration.

BL **Vehicles and Velocity** Have students work in pairs to create a rider information brochure for the Ferris wheel **Figure 5.** The brochure should explain how the rider will feel when the velocity of the vehicle is constant and wh changes. They should include pictures or diagrams wit brochure that show examples of the vehicle changing i velocity.

LA **Changing Velocity** Have students clear an area on a table or the floor to experiment with toy cars. They pus cars across the surface at different speeds and note wh the cars increase or decrease speed. Ask them to set u two demonstrations for the class. Each demonstration should come with an index card that explains if acceler will decrease or increase during the demonstration and

Teacher Toolbox

Reading Strategy

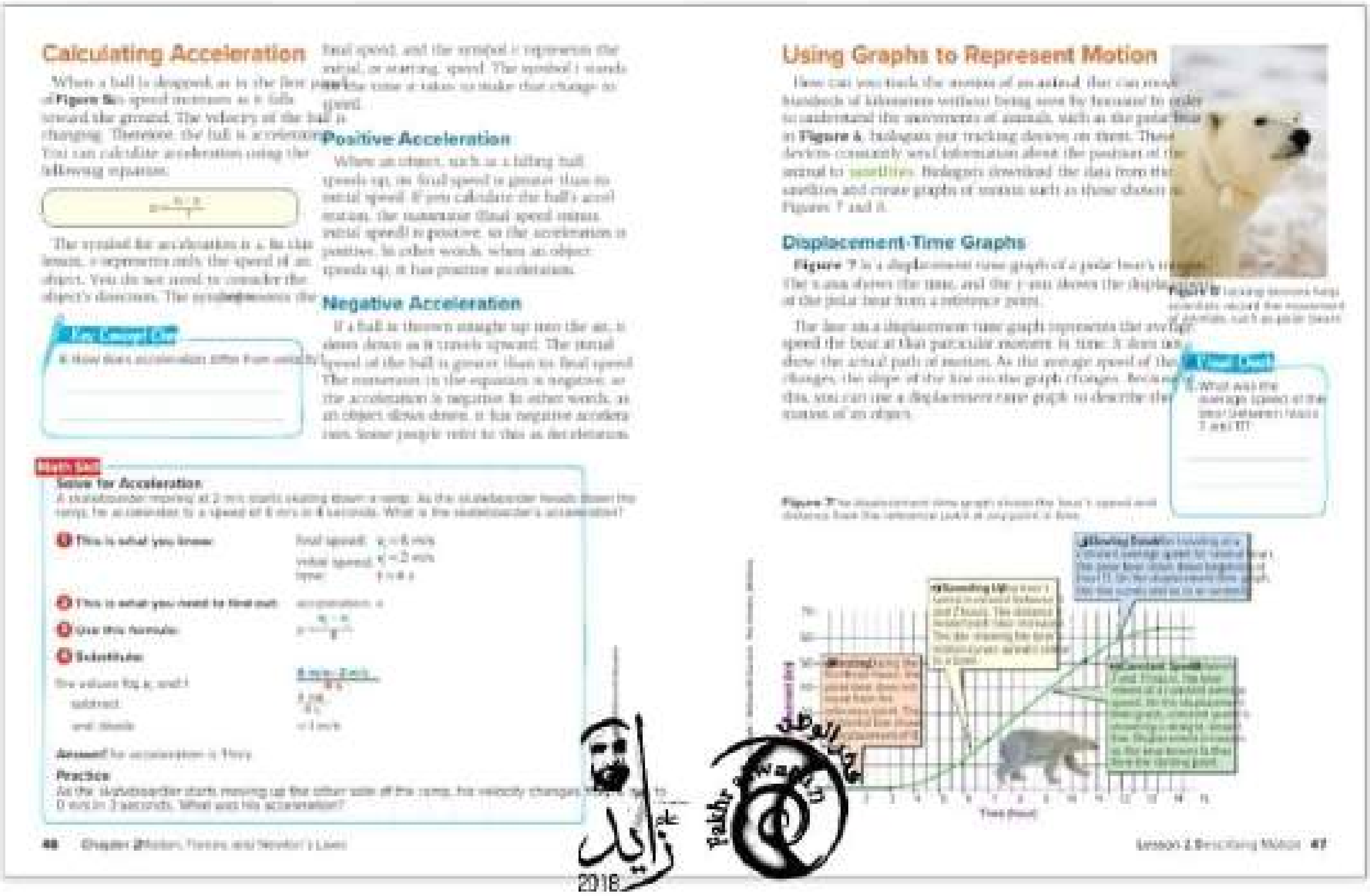
Compare and Contrast Have students complete a Venn diagram that lists one similarity and one difference bet the terms *positive acceleration* and *negative accelera* For example, both involve a change in velocity. Howev positive acceleration is an increase in speed, while ne acceleration is a decrease in speed.

Math Skills

What is the average acceleration? Present the following problem to students to solve. What is the acceleration car that increases from 15 m/s to 30 m/s in 15 seconds pulls onto a highway? *$2 m/s^2$* What is the acceleration car decreases to 10 m/s as it drives off a highway exit seconds? *$-4 m/s^2$*

Fun Fact

Formula One Racing Formula One racers drive single-se cars that are the most technologically advanced in car racing. Their design creates air flow over and under th that creates a downward force that keeps the vehicle to the ground, even at high speeds. This enables the c brake and accelerate very quickly.



Calculating Acceleration

Positive Acceleration

Negative Acceleration

Math Skill

Solve for Acceleration

Using Graphs to Represent Motion

Displacement-Time Graphs

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Lesson 2 Describing Motion 47

Math Skill

Solve One-Step Equation

On chart paper or the board, write a list of some of the distance measurements that can be used to calculate acceleration, including meters, kilometers, and miles. Then list some of the units of time that can be used, such as seconds, minutes, and hours. Have students read the Math Skills box to learn how to calculate acceleration. Remind them that during positive acceleration, speed increases, and an acceleration equation will result in a positive number. During negative acceleration, speed decreases, and an acceleration equation will result in a negative number.

Practice

Have students solve the practice question. Then ask a volunteer to write the steps he or she used to find the answer on chart paper or the board.

−2 m/s²

Using Graphs to Represent Motion

Have students read the paragraph and study the **Figure 6**. Explain to students that the polar bears must be tranquilized so that the scientists can safely attach the radio collar. At the same time, the scientist may also examine the bear to determine how healthy it is. Tell students that once the tranquilizer wears off, the bear recovers and returns to its normal activities.

Displacement-Time Graphs

Explain to students that we can graph the motion of objects to better understand how they move and how they accelerate and change velocity. Have students read the paragraph and study the graph in **Figure 7**. Tell students that this is a line graph, which shows how a variable changes over time. A displacement-time graph shows how far an object travels from a reference point during a period of time.

Academic Vocabulary

satellite

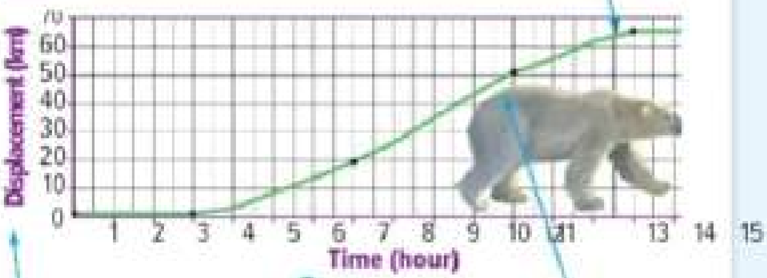
Have students read the academic definition of *satellite*.

Ask: **What might be another use of a satellite?** *Answers may vary. Sample answers include: to provide information to GPS devices, transmit satellite phone and television signals, and so on.*

Visual Literacy: Figure 7

Ask the following questions to informally assess your students' understanding of the graph in **Figure 7.**

Ask: **Between the hours of 14 and 15 does the bear continue to move?** *no* **How can you tell?** *The line is horizontal and does not move from the new reference point.*



Ask: **What does the x-axis of a displacement-time graph show? What does the y-axis show?** *The x-axis shows increments of time and the y-axis shows increments of displacement.*

Ask: **What was the average speed of the bear between hours 7 and 11?** *7.5 km/hr*

Speed-Time Graphs

Explain to students that other kinds of graphs can also help understand how an object moves. The graphs differ in the information that are shown on the x-axis and the y-axis. Have students read the paragraph and study the **Figure 8**. Explain that a speed-time graph can show how fast an object moved during a period of time and how its speed changed.

Guiding Questions

AL **What does the x-axis of a speed-time graph show? What does the y-axis show?** *The x-axis shows increments of time and the y-axis shows increments of speed.*

OL **How can a graph help you understand an object's motion?** *It helps by showing you how either the distance or the speed changes over a period of time.*

BL **What element of velocity is not shown on a displacement-time graph or a speed-time graph?** *direction*

Differentiated Instruction

AL **Plotting a Graph** Distribute graph paper to students and a table of data that includes distances (in kilometer and times (in hours) for the motion of a bike rider one afternoon. Guide students in drawing the x-axis and y-a on their graphs. Then have them use the data in the tab plot a displacement-time graph.

BL **Create a Graph** Have students use the diagram of the runner in **Figure 3** to create a displacement-time graph. They should measure the distance between each imag the runner in the diagram and use that information to p the displacement on the y-axis and use the seconds on stopwatch for the x-axis. Their completed graphs shoul show a curving line that at first moves upward at an eve slope and then becomes steeper as the speed increase

LA **Combining Vocabulary with a Graph** Have students copy the speed-time graph in **Figure 8** onto graph paper. Ask them to write sentences to describe the graph, usi many vocabulary words from the lesson as possible, including speed, velocity, acceleration, and so on.

Teacher Toolbox

Careers in Science

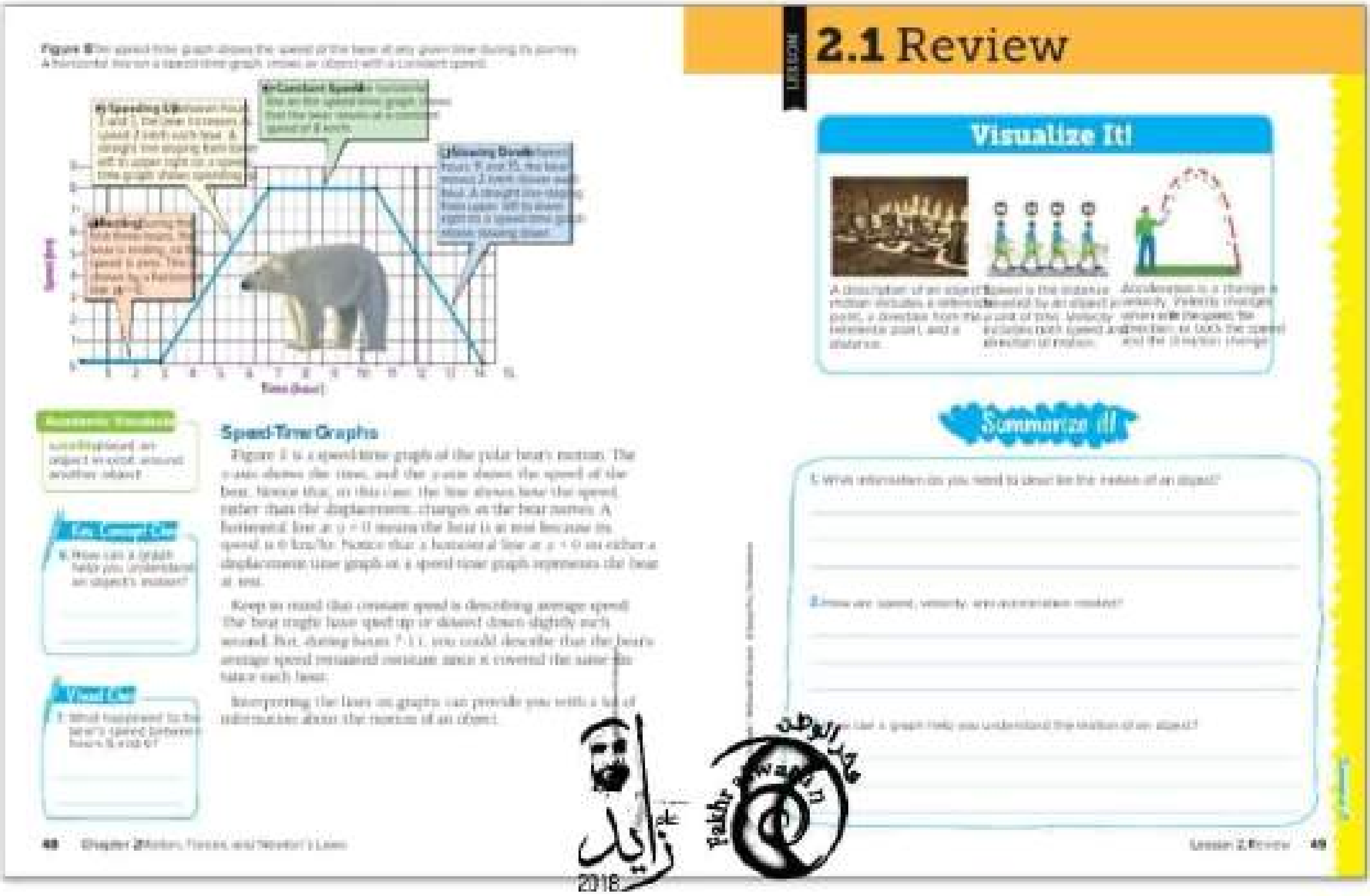
Preparing for Takeoff Engineers at NASA have to take many different calculations into account to determine space shuttle will launch into space. They have to grap potential speed and displacement of the shuttle as it t off to make sure that it launches safely.

Reading Strategy

Compare and Contrast Have students write a short paragraph to compare and contrast displacement-time speed-time graphs. They should list similarities and differences between the two. For example, both show changes in speed, but only the displacement-time grap shows a change in distance from a reference point.

Real-World Science

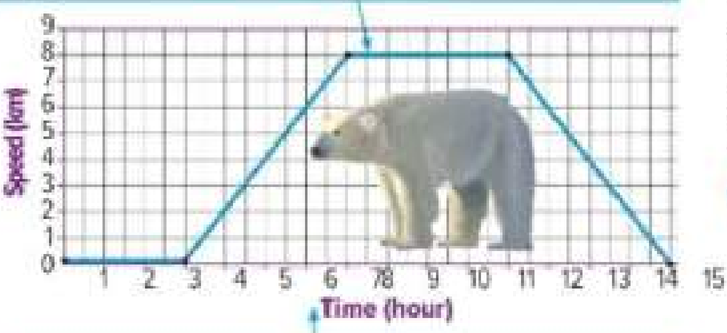
Radar Guns Police officers often use radar guns to measure the distance a car travels during a period of t The radar gun emits a pulse of electromagnetic radiati passing vehicle reflects the pulse and sends it back. T speed of the reflection helps an officer know how fast vehicle is moving.



Visual Literacy: Figure 8

Students may have difficulty distinguishing between a displacement-time graph and a speed-time graph. Have students study the graph Figure 8 and answer the following questions.

Ask: **How can you tell that the bear moved at a constant speed between hours 7 and 11?** *The line is straight and doesn't slope upward or downward.*



Ask: **What happened to the bear's speed between hours 3 and 6?** *The bear's speed increased.*

Ask: **What is the difference between the line when the bear speeds up and when it slows down?** *When the bear speeds up, the line slopes upward; when the bear slows down, the line slopes downward.*

Ask: **How are the time periods between hours 14 through 15 in Figure 7 and hours 7 through 11 in Figure 8 similar?** *A horizontal line shows there is no change in either displacement or speed during those periods.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask:** **Which Key Concept does each image relate to?**

Summarize It!

- Motion
- Speed
- Velocity
- Calculating Acceleration
- Using a Graph to Represent Motion

Intervention Planner

Based on the results of the Lesson Review, use the chart below to address individual needs.

Use Vocabulary (1–2)

- Guiding Questions, Motion and Reference Points
  Visual Literacy: Figure 2
- Quick Vocabulary
  Content Vocabulary

Understand Key Concepts (3–5)

- Key Concept Checks
  Visual Literacy: Figure 8
- Key Concept Builder

Interpret Graphics (6)

- Visual Literacy: Figure 7

Critical Thinking (7)

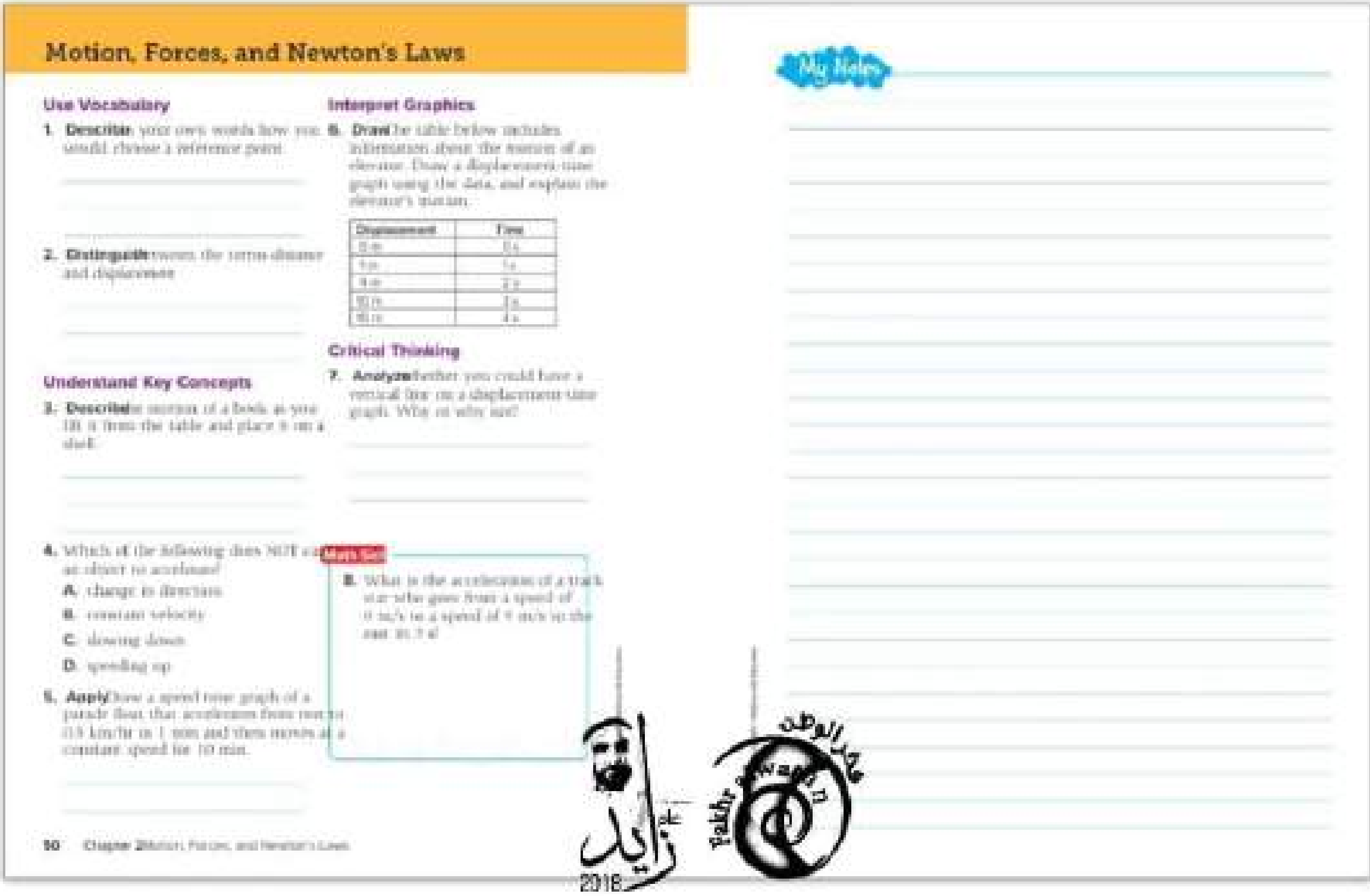
- Visual Literacy : Displacement-Time Graph
  Guiding Questions, Speed-Time Graphs
- Enrichment
  Challenge

Math Skills (8)

- Math Practice
- Math Skills

Teacher Notes

AL Approaching Level OL OnLevel BL Beyond Level LA Language Acquisition


Motion, Forces, and Newton's Laws

Use Vocabulary

Interpret Graphics

Critical Thinking

Understand Key Concepts

Math Skill

My Notes

50 Chapter 2 Motion, Forces, and Newton's Laws

Use Vocabulary

1. A reference point is the place you pick to describe the motion of an object.

2. Distance is the total length of an object's path as it moves. Displacement is the distance between where the object started and where it finished.

Understand Key Concepts

3. Students should describe the motion of the book based on a reference point, such as the table or shelf, and its direction. Example: The book moved away from the table and toward the shelf.

4. B. constant velocity

5. The line should start at the origin (0,0), move up and to the right to point 0.5 (*y*), 1 min (*x*). The line should then be horizontal at 0.5 (*y*) to *x*= 11.

Interpret Graphics

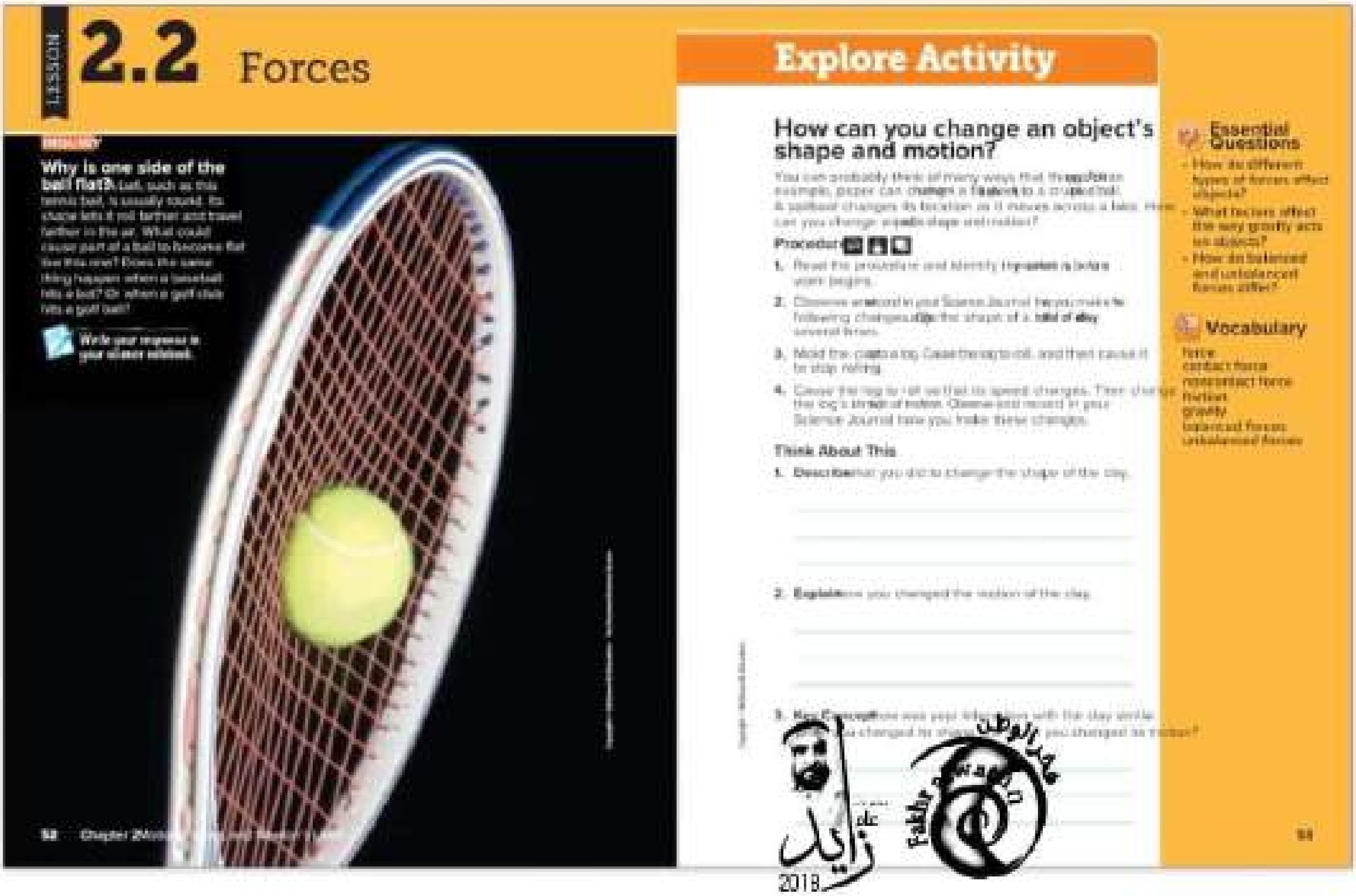
6. The elevator accelerated during the first three seconds. It started at ground level and accelerated for three seconds until it was 4 m above the ground. Then it stopped 10 m above the ground for one second.

Critical Thinking

7. No, because it would mean that the object traveled some distance in zero time.

Math Skill

8. 3 m/s2 to the east



INQUIRY

About the Photo **Why is one side of the ball flat?** When a ball hits a tennis racket, the strings of the racket exert a force that impacts the shape of the ball. You can demonstrate this to students by having them press their hands together to observe how their palms subtly change shape.

Guiding Questions

AL How has the shape of this tennis ball changed? *It has slightly flattened on the side that makes contact with the tennis racket.*

OL Do you think a baseball changes its shape when a bat hits it? Why or why not? *Yes, although a baseball is less flexible than a tennis ball, so the change in shape is probably smaller and harder to see.*

BL How might the tennis ball look after the racket has hit it? *As the ball bounces off the racket and flies back into the air, it regains its shape.*

LABManager

All the labs for this lesson can be found in the *Student Lab Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Compare Dictionary Definitions

1. Write the word *force* on chart paper three times.
2. Have students look up the word in a dictionary and write three definitions on the chart paper.
3. Compare and contrast the different definitions.
4. Ask: **What are the various meanings of the word *force*?** Students should see that meanings vary considerably but most relate to the ability to move something or change something.
5. Have students reflect on which of these definitions they have used or have heard others use in everyday speech. Ask: **What moved or changed in your example?**
6. Encourage students to spend the next week noting when they, their friends, their parents, the news media, or others use the word force. Augment the class definition by adding examples to the chart paper.

Explore Activity

How can you change an object's shape and motion?

Prep 5 min **Class** 10 min

Purpose
To explore how a force can change the shape or motion of an object.

Materials
Student modeling clay

Before You Begin
Check to be sure the modeling clay you plan to use is not so sticky that students will be unable to roll it across a table or a piece of cardboard on the table.

Guide the Investigation
Encourage students to think about what they have to do in order to change the shape of the clay. Suggest that they ask themselves about cause-and-effect relationships when observing changes in the clay. *What caused this change? What was the effect of my action?*

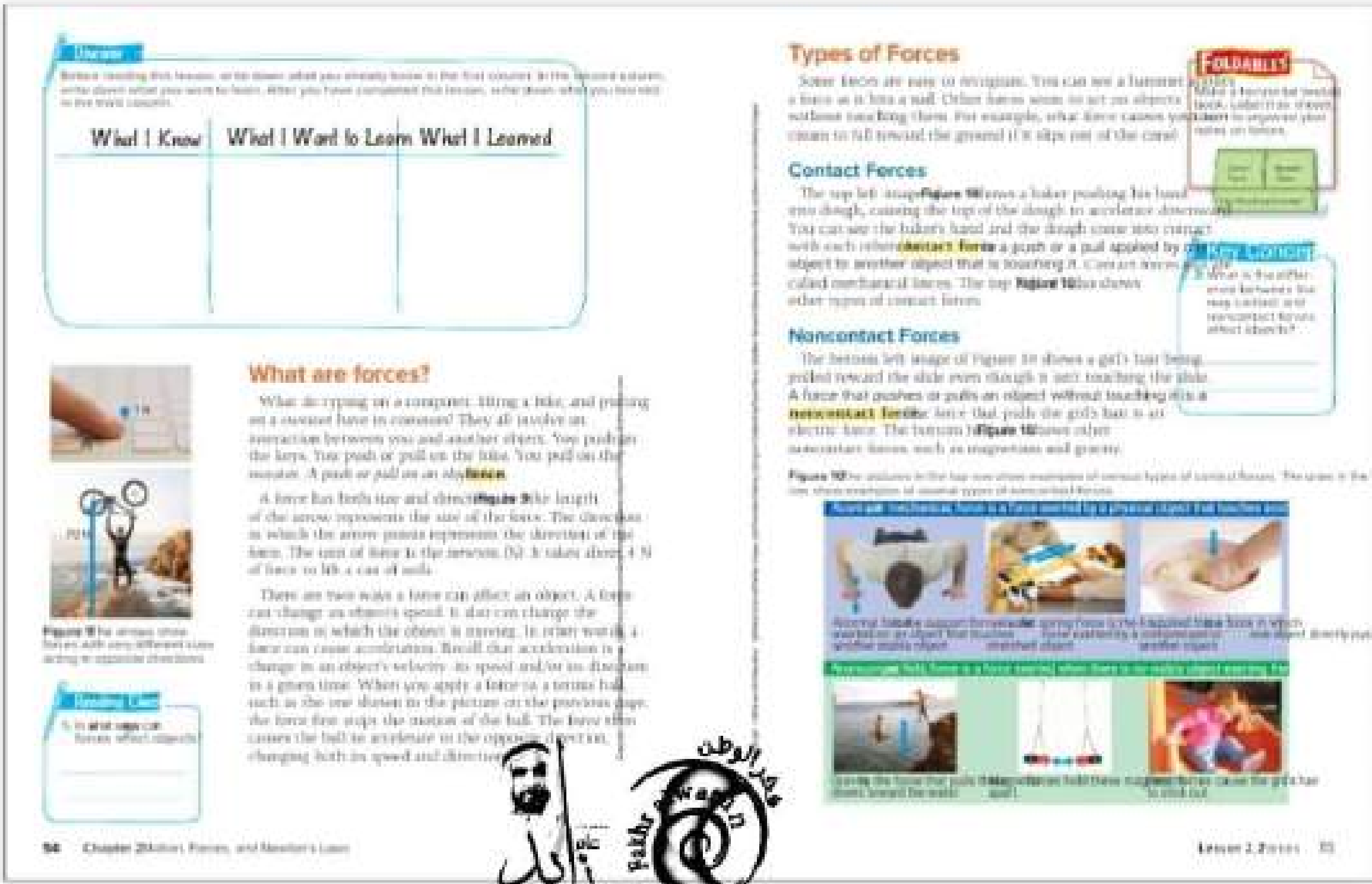
Changing shape	Shape 1	Shape 2	Shape 3	Shape 4
Shapes	stick of modeling clay	round ball	flat disc	log
Done by	received like this	rolling between hands	pounding against the table	shaped with hands

Motion	Roll	Stop	Change speed	Change direction of motion
Done by	pushing down board with hands	blocking roll with an object	push again midway across table	tilt board

Think About This

1. Students should indicate that they pushed on the clay in different directions.
2. Answers should include that the speed and/or direction of the motion changed.
3. **Key Concept** Students will indicate that they had to push or pull the clay to change its shape and to change its motion.

Teacher Notes



What are forces?

Have students describe the objects in Figure 9. Ask students what has set these objects in motion. In the top image, a finger pushes down on the button. In the bottom image, the person pulls the bicycle up. Then have students read the paragraph to learn more about forces and what happens when they push or pull on objects. Ask these questions to assess students' understanding.

Guiding Questions

AL	What is a force?	*A force is a push or pull from one thing to another.*
OL	In what ways can forces affect objects?	*Forces can change the speed or direction of objects.*
BL	Describe how a force sets a ball in motion. Is this positive or negative acceleration?	*Sample answer: A person's hand throws the ball, pushing it into the air. This is an example of positive acceleration.*

Types of Forces

Before reading the paragraph ask students to identify which objects exert a force on other objects in the photo on the lesson opener. The racket causes the ball to stop, then fly outward. The ball also pushes back against the racket and makes the strings curve backward. The hand presses against the handle to make the racket move.

Contact and Noncontact Forces

Ask students to discuss some of the ways they changed the shape or the motion of the objects in Launch Lab. Brainstorm ways to change the shape or motion of an object without touching it. Have students read the paragraph; then ask the following questions.

Guiding Questions

OL	What is the difference between the way contact and noncontact forces affect objects?	*With contact forces, the objects must touch one another. Noncontact forces can act between two objects that are not touching.*
BL	Use the terms contact and noncontact to describe the difference between the forces when a baseball is thrown into the air and when it falls to the ground.	*A thrown baseball moves because of a contact force: a person throws the ball with his or her hand. A baseball falls to the ground because of a noncontact force: gravity pulls the ball down without touching it.*

Visual Literacy: Figure 10

Have students compare the six ima**Figure 10**Clarify that the blue arrows represent forces at work. Ask the first two questions to assess their understanding of the contact and noncontact forces in the figure. Ask the last two questions to assess how well they apply their understanding to different situations.

Ask: Why is the applied force in the first image an example of a contact force? *The hand has to touch the dough to apply force and flatten it out.*

Ask: Why is magnetism an example of a noncontact force? *Magnetism repels the bar magnets and keeps them apart without the magnets touching each other.*

Ask: When you pull a notebook from your bookbag, is that an example of a contact force or a noncontact force? Why? *an example of a contact force because you have to touch the notebook to pull it out.*

Ask: Does a compass work with contact force or noncontact force? *A compass works with magnetic forces; these are non contact.*

Differentiated Instruction

Sir Isaac Newton's Famous Discovery students use the internet or school library to research the story of Sir Newton's "discovery" of gravity. According to the famou tale, ideas about gravity came to Newton while he was in his orchard. When an apple fell from a tree, he realize had been pulled to the ground by an unseen force. Ask to use what they learn to complete the following activiti Explain that they will learn more about Newton and his discoveries in the next lesson.

AL **Sing a Song** Have students work in pairs to write the lyrics for a song or a rap about Newton's discovery.

BL **Write a News Report** Have students work in pairs to write the script for a TV news report as though they w there when Newton began to piece together his ideas about gravity.

LA **Perform a Skit** Have students work in small teams to put on a skit that shows Newton making his famous discovery. They may choose to write down the skit in s form or ad-lib it for those who are just learning to read English.

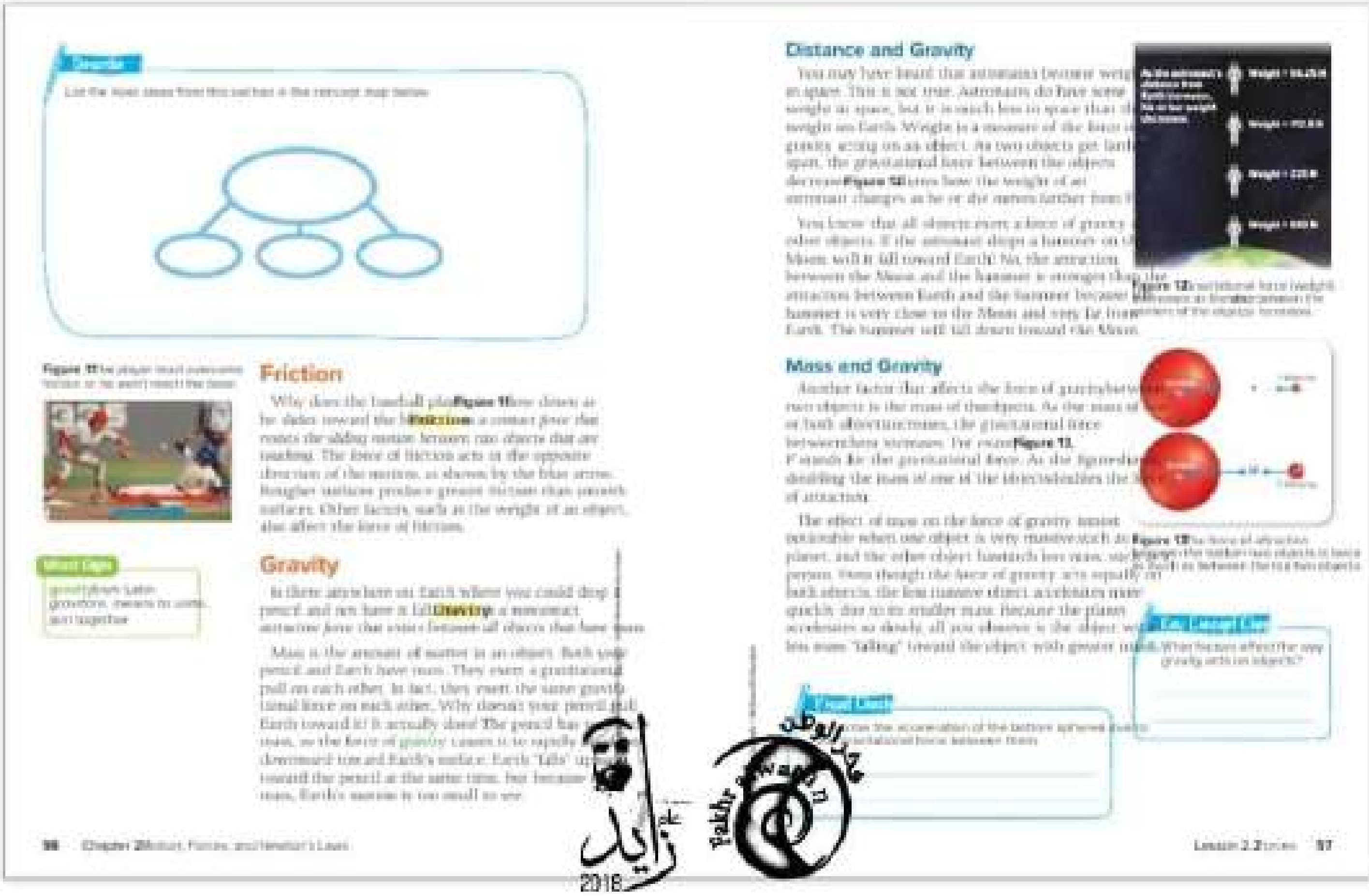
Teacher Toolbox

Reading Strategy

Main Idea and Supporting Details Have students reread the sections on friction and gravity. Ask them to comp two "main idea and supporting details" charts to expla each type of force. Their charts should provide definiti *friction* and *gravity* and include supporting details, suc the fact that friction is a contact force and gravity is a noncontact force.

Real-World Science

Gravity and Gs When you jump in the air, you fall back down at a fixed acceleration. This is acceleration due t gravity, which measures 9.8 m/s and is commonly kn as G. Most roller coasters run at a maximum accelerat between 3 and 4 Gs, which is three or four times as fa a free fall to Earth. No wonder they are so thrilling!


Friction

Gravity

Distance and Gravity

Mass and Gravity

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Lesson 2.2 57

Friction and Gravity

Have students read the two paragraphs and study the photo in **Figure 11** to learn about friction and gravity. Then ask the following questions.

Guiding Questions

OL **What would happen if the blue arrow were longer than the red arrow?**	*The player would slow down and stop sliding before he reached the base.*
OL **Which types of forces are there between Earth and the Moon: contact, noncontact, or both?**	*There are only noncontact forces because Earth and the Moon do not touch.*

Distance, Mass, and Gravity

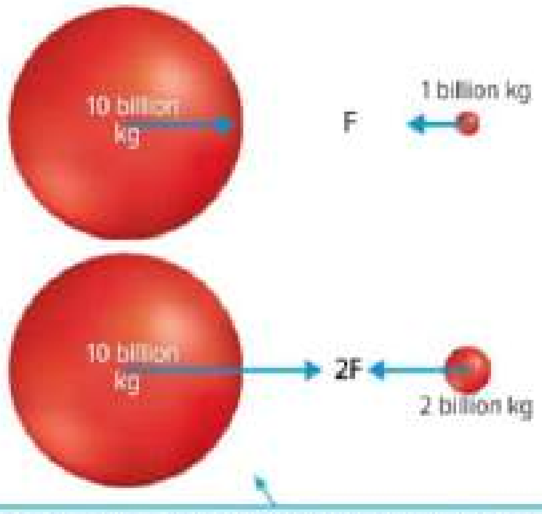
Explain to students that the strength of the noncontact force of gravity is affected by distance and mass. Review the terms *distance, mass,* and *gravity*. Distance affects the strength of the force of gravity. Have students read the paragraphs and study the diagram in **Figure 12**. Ask the following questions to assess their understanding.

Guiding Questions

AL **What is weight?**	*Weight is the measure of the force of gravity that acts on an object.*
AL **What effect does mass have on gravity?**	*They provide the major site of photosynthesis for the plant.*
OL **In the diagram in Figure 12, what is the astronaut's weight on Earth and in space? What is the difference between the two?**	*550 N; 56.25 N; 493.75 N*
OL **What factors affect the way gravity acts on objects?**	*As the mass of the objects increases, the force between them increases. As the distance between the objects increases, the force between them decreases.*

Visual Literacy: Figure 13

Have students compare the force of attraction between the two sets of spheres shown in **Figure 13**. Then ask the following.



Ask: **Describe the acceleration of the bottom spheres due to the gravitational force between them.** *The bottom spheres accelerate toward each other with twice the gravitational force as the top spheres because the mass of the spheres on the right has been doubled.*

Combining Forces

Ask students to imagine a tug-of-war game. Have them predict how a two-person team could beat a three-person team and if a five-person team could beat a fourperson team. Then have students read the paragraph. Return to the imagined team configurations. Have students use the words *forces* and *combined forces* to explain their predictions.

Forces in the Same Direction and in Opposite Directions

Have students read the paragraphs and study the images in **Figure 14** and **Figure 15.**

Guiding Questions

OL **What would the total force be if the boy on the far right in Figure 14 stopped pulling?**	*200 N*
OL **Why is the net force of the top image in Figure 15 0 N?**	*The total force of the team on the right is −300 N and the total force of the team on the left is 300 N. When you add them together, the sum is 0 N.*
BL **How could you explain the change from balanced to unbalanced forces in the two versions of Figure 15?**	*One of the individuals exerted more force in the second version of the image. That caused the net force on the left to be greater than the net force on the right.*

Differentiated Instruction

AL **Play a Game of Concentration** Have students work in pairs to write the following terms on separate index ca[rds:] *contact force, noncontact force, balanced force, unbalanced force, net force, gravity,* and *friction*. Ask t[hem] to use what they have learned from the lesson to write definitions for each term on another set of index cards. Then have them play a game of concentration by turni[ng] the cards face down on a table. They should take turn[s] turning the cards over, two at a time, to match a term t[o its] definition. After all the matches have been made, the p[layer] with the highest number of cards wins.

BL **Forces and Rubber Balls** Have partners play with rubber balls on the floor or a smooth surface while analyzing forces. Ask them to write a brief report to id[entify] when the forces acting on the balls were balanced or unbalanced. For example, if a ball is resting on a table, [the] sum of the forces between the ball and the table and [...] are balanced, so the ball does not move.

LA **Create a Picture Book** Have students create a picture book to compare how gravity affects different objects [on] Earth and on the Moon. The pictures in their books sh[ould] illustrate their understanding of how distance and mas[s] affect gravity.

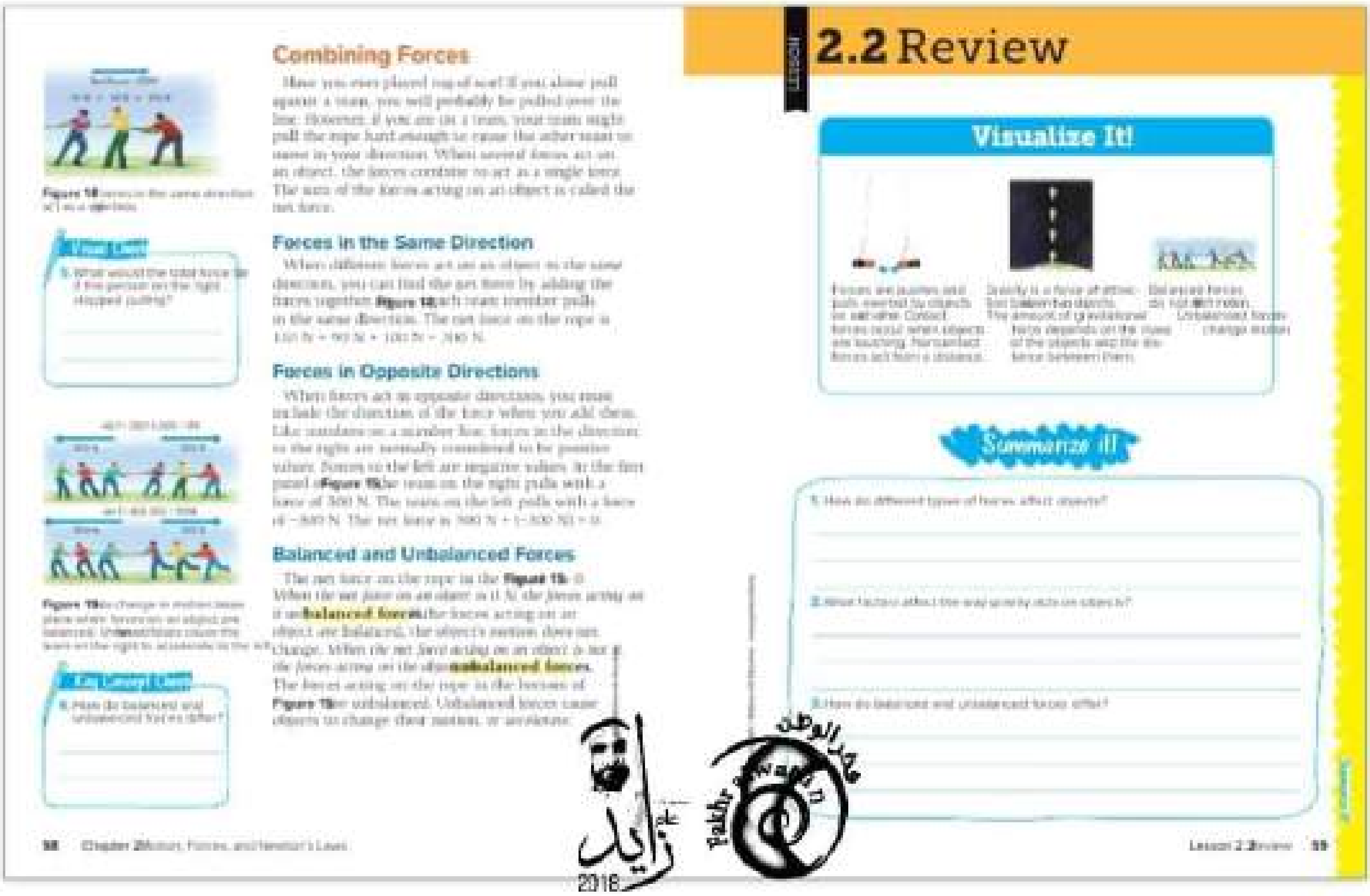
Teacher Toolbox

Teacher Demo

Balanced or Unbalanced? Bring in a two-pan balance scale. Place a 20-g mass on the right pan and a 40-g [mass] on the left pan. **Ask:** **Is the scale balanced? How do you know?** *No, it is unbalanced because one pan is lower [than] the other.* **Ask:** **How could you balance the scale?** *Add a 20-g mass to the right pan. Add the additional 20-g m[ass].* **Ask:** **How do you know the scale is now balanced?** *Both pans are now the same height.* Explain that when the [scale] is balanced the pans are level; neither one is lower th[an the] other. Something similar happens when balanced forc[es act] on an object. Its motion does not change.

Real-World Science

Gravity Around the Solar System Gravity isn't just different on the Moon than it is on Earth. It's different on other planets because each planet has a different mass. Of t[he] four terrestrial planets, gravity is weaker on Mercury a[nd] Mars, but it's about the same on Venus as it is on Eart[h].



Balanced and Unbalanced Forces

Have students read the paragraphs and study the image in **Figure 15**. To explain the difference between balanced and unbalanced forces, have them imagine a book resting on a classroom desk. Gravity exerts a downward force on the book while the desk exerts an upward force. The sum of these forces 0 N. That means the forces are balanced and the book does not move. However, if the book rested on the back of a chair that exerted a much smaller upward force, the forces would become unbalanced; the book would fall off the chair and to the floor.

Guiding Questions

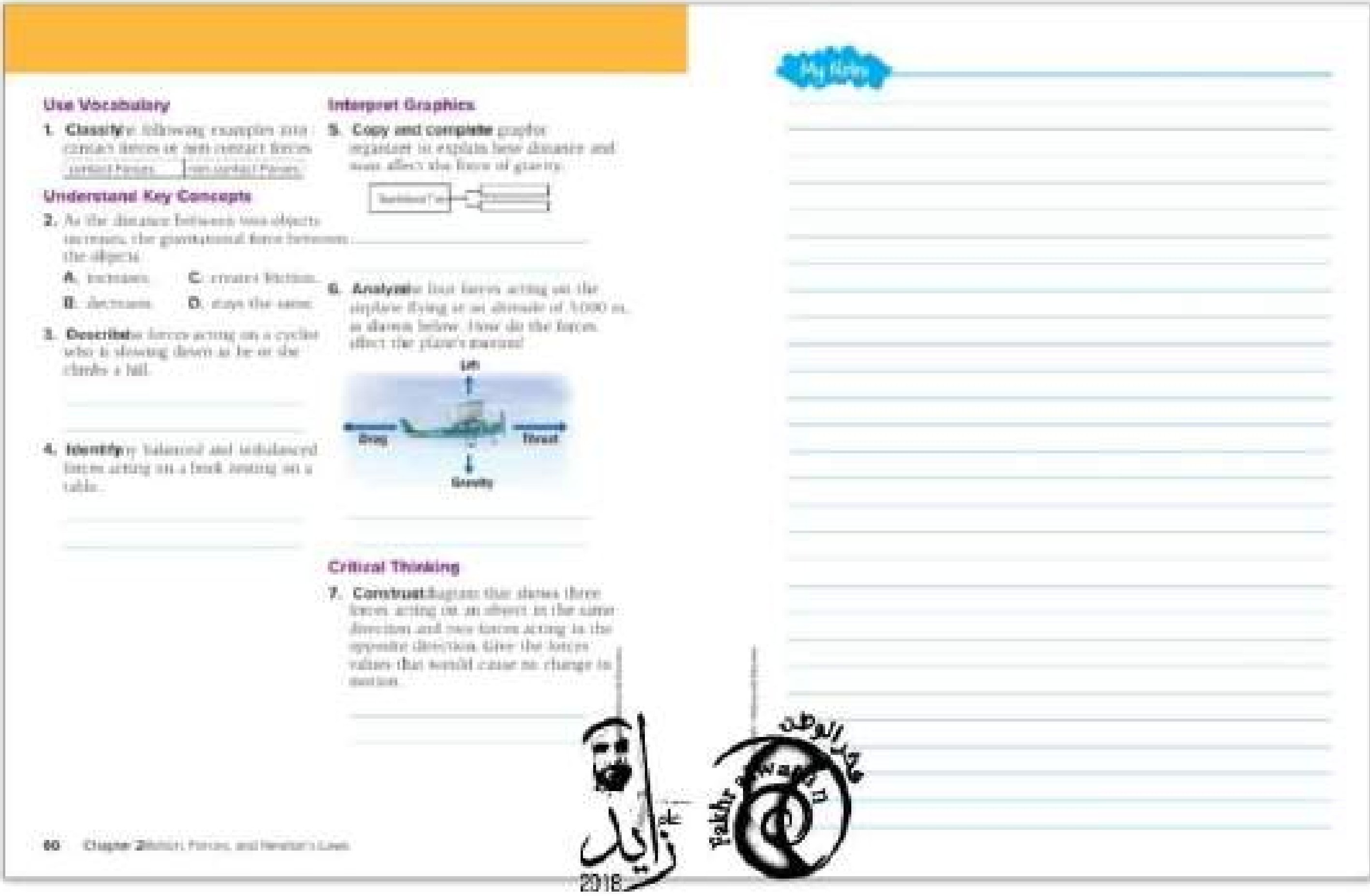
AL	If an object begins to move faster, are balanced forces or unbalanced forces acting on it?	*unbalanced forces*
OL	How do balanced and unbalanced forces differ?	*Unbalanced forces affect the motion of an object. Balanced forces do not.*
BL	How can you tell that an unbalanced force is acting on an object?	*The motion of the object changes. It could change direction or change speed, or both.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize It!

- What are Forces?
- Friction and Gravity
- Combining Forces


Use Vocabulary

1. Classify the following examples into contact forces or non-contact forces.

Understand Key Concepts

2. As the distance between two objects increases, the gravitational force between the objects

A. increases.
C. creates friction.
B. decreases.
D. stays the same.

3. Describe the forces acting on a cyclist who is slowing down as he or she climbs a hill.

4. Identify the balanced and unbalanced forces acting on a book resting on a table.

Interpret Graphics

5. Copy and complete graphic organizer to explain how distance and mass affect the force of gravity.

6. Analyze the four forces acting on the airplane flying at an altitude of 3,000 m, as shown below. How do the forces affect the plane's motion?

Critical Thinking

7. Construct a diagram that shows three forces acting on an object in the same direction and two forces acting in the opposite direction. Give the forces values that would cause no change in motion.

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Use Vocabulary

1. Friction is a contact force that slows down the sliding motion between two objects that are touching.

2. noncontact forces

Understand Key Concepts

3. B. decreases.

4. Gravity is pulling him down. The seat of the bike is pushing him up. The force produced by his feet pushing on the pedals is less than the force of friction on the bike, so the forces are unbalanced and he slows down.

5. There are no unbalanced forces. The upward force of the table balances the downward force of gravity.

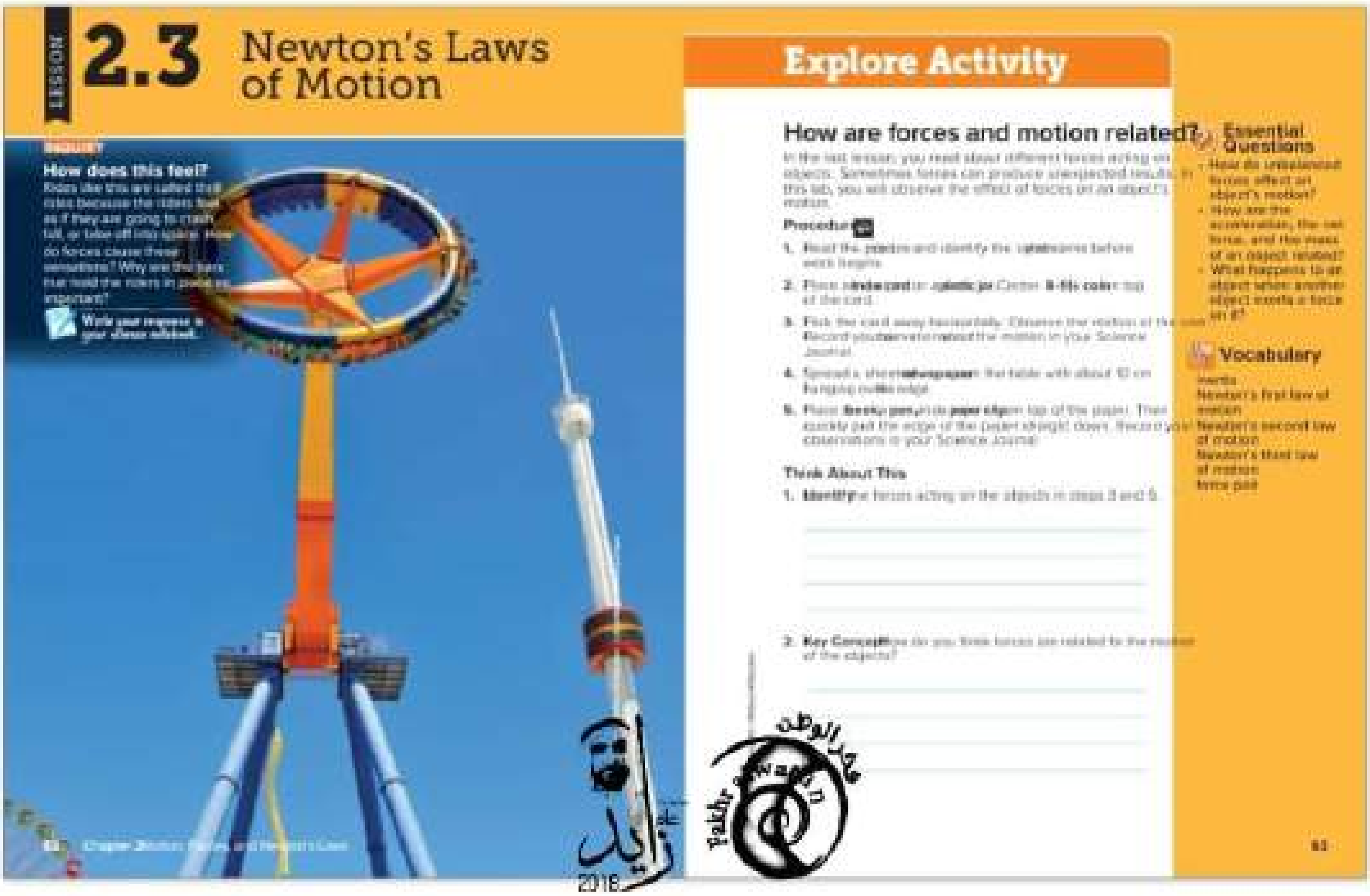
Interpret Graphics

6. As two objects get farther apart, the gravitational force betwee them decreases. As the mass of one or both objects increases the gravitational force between them increases.

7. The arrows indicate that the up and down forces (lift and gravity) are balanced. The front and back forces (thrust and drag) are also balanced. Therefore, the plane must be flying a a constant speed.

Critical Thinking

8. The diagram should show the sum of the three forces acting i one direction but equal the sum of the two forces acting in the opposite direction.



INQUIRY

About the Photo How does this feel? Thrill rides at amusement parks must undergo rigorous tests to make sure they are safe. Bars, harnesses, helmets and other safety measures counteract the forces of gravity and the pushes and pulls exerted by the ride itself to protect the people who ride them.

Guiding Questions

AL Describe what it might feel like to go on this ride.	*Sample answer: As the ride pushes and pulls the cars forward and back, up and down, it feels like you are flying and zigzagging through the air.*
OL How do the bars affect the motion of the riders?	*The bars prevent the riders from flying off the ride and into the air. They keep the riders safe while the ride is in motion.*
BL How do the bars impact the force of gravity?	*The bars counteract the force of gravity and prevent the riders from falling off the ride and toward the ground.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Build on Prior Knowledge

1. Have students discuss the meaning of the term *law*, and the ways we use it in everyday speech. For example, a law can be a rule, a practice, a custom, a way of organizing something, and so on.
2. Explain that, in science, a law is a fact or a rule that is based on evidence and observation. Scientific laws can be demonstrated and understood by using experiments.
3. Ask students to name a scientific law they may already know or have studied. For example, the Law of Conservation of Energy states that energy cannot be created or destroyed, only converted into another form. Students may also be familiar with the Law of Conservation of Mass, which states that mass cannot be created or destroyed, only changed into other forms.
4. Explain that in this lesson they will learn about three laws of motion that were revealed by English scientist I. Newton in the 1600s.

Explore Activity

Teacher Notes

How are forces and motion related?

Prep: 5 *min* **Class:** 15 *min*

Purpose
To observe what happens to an object at rest when an unbalanced force acts on it and when balanced forces act on it.

Materials
Student: index card, plastic jar, 5-fils coin, newspaper, book, paper clip, pen or pencil

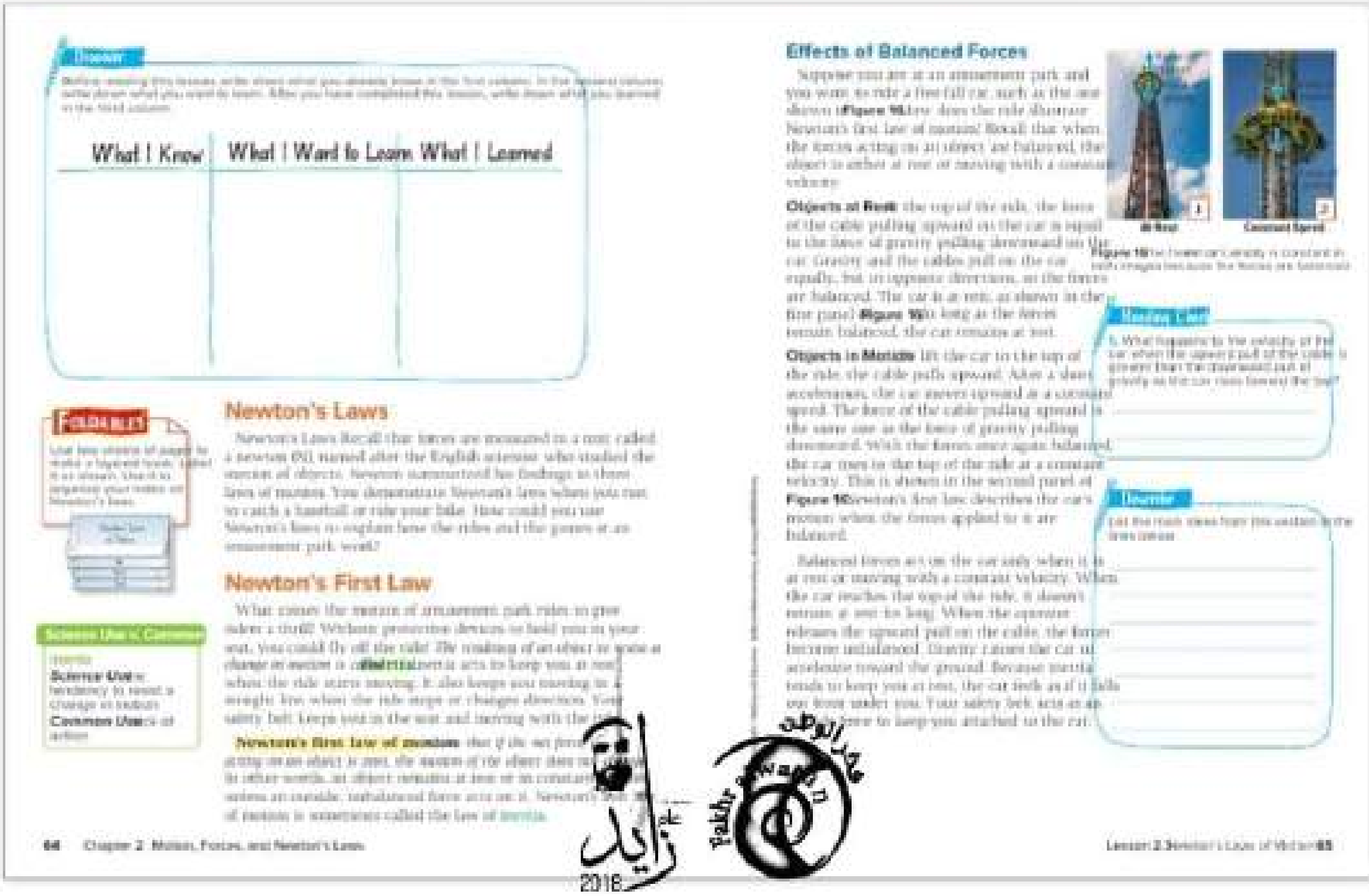
Before You Begin
Ask students if they have ever seen a magician pull a tablecloth out from under dishes. Discuss how this is possible. Suggest that they think about the forces acting on the dishes and the tablecloth. Draw a data table on the board that students can copy into their Science Journals.

	Book	Pen	Paper clip	Nickel
Describe motion when force was applied				coin fell straight into the jar

Guide the Investigation
- Students should be able to describe motion and to explain what affects contact forces and noncontact forces.
- Have students practice flicking the card off the glass without anything on top. Demonstrate how to pull the edge of the newspaper straight down quickly. Ask students to consider the different motion in each experiment.
- **Troubleshooting:** If students push on the card or pull the paper too slowly, the activity will not work.

Think About This

1. In each step, gravity pulls the object(s) down.
2. **Key Concept** Sample answer: The card moved sideways because I pushed it. Gravity pulled the coin into the jar. The paper moved because I pulled it. Maybe gravity held the book down. The paper clip and pen were lighter so maybe gravity didn't pull as hard and they moved easier.



Newton's Laws

Have students discuss their experiences with the Launch Lab. Remind students that a force is a push or pull that sets objects in motion. Ask: **Would the book, pen, or paper clip have moved if you hadn't pulled on the paper?**

Newton's First Law

Discuss how the Launch Lab relates to Newton's first law of motion. Ask students to name the parts of Newton's first law that relate to the lab. Objects such as the coin, book, pen, or paper clip remain at rest until a force sets them in motion. Once the index card was pulled, the coin was in motion until it was stopped by the bottom of the jar.

Science Use v. Common Use

inertia

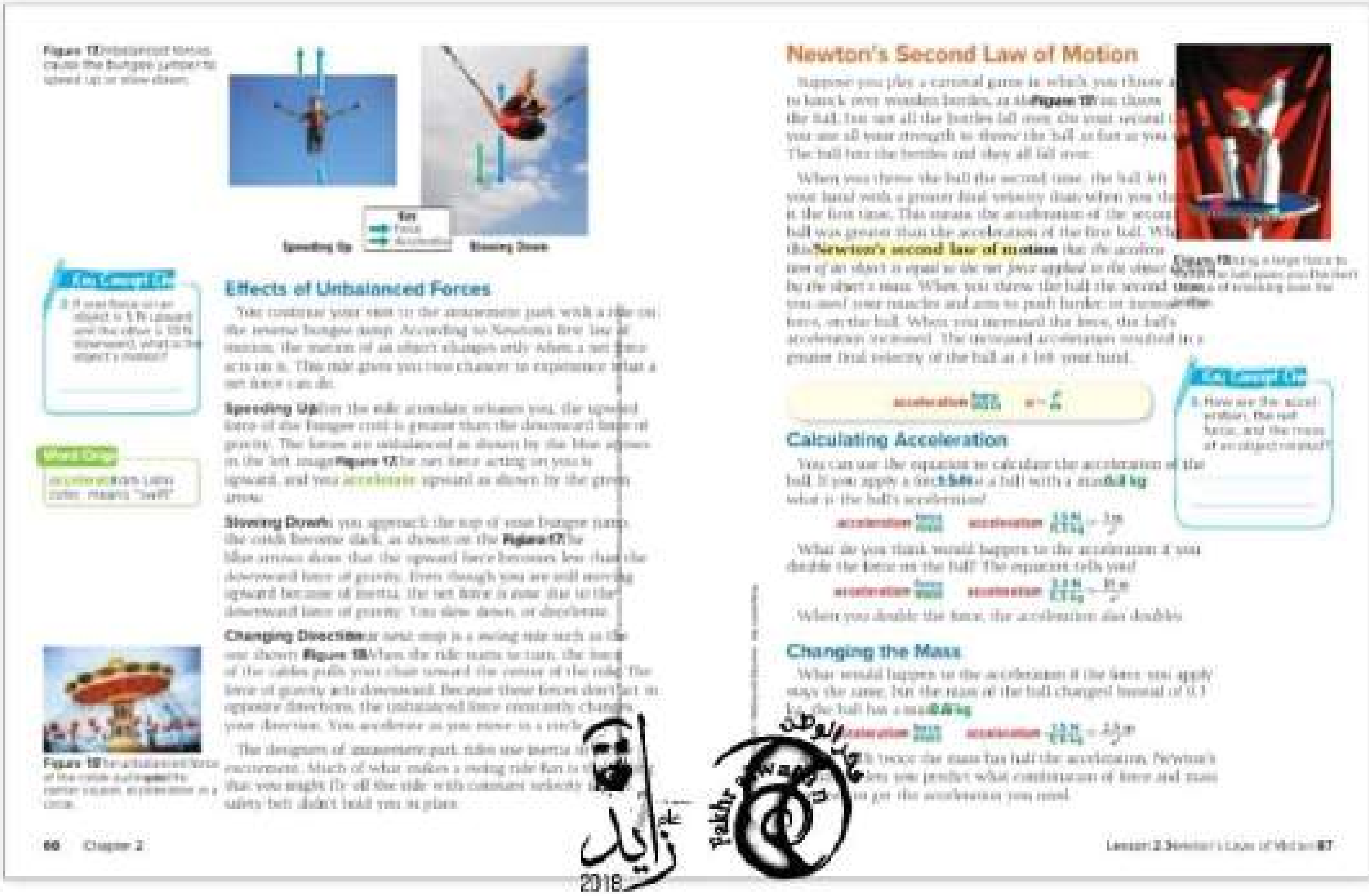
Have students compare the science definition of inertia to the everyday use of the word, for which *inactivity* and *motionless* are synonyms. Ask: **How do all three terms relate to the science use of inertia?** *All three terms describe something that resists a change in motion. The science use of inertia relates to an object that is moving, as well as one that is still.*

Effects of Unbalanced Forces

Remind students that the definition of acceleration is the change in an object's velocity during a period of time. Have students read the paragraphs and study the diagram in **Figure 17** and the photo in **Figure 18**. Then ask the following questions to informally assess their understanding.

Guiding Questions

AL	**If the downward force on an object is greater than the upward force, are the forces balanced or unbalanced?**	*They are unbalanced.*
OL	**If one force on an object is 5 N upward and the other is 10 N downward, what is the object's motion?**	*The object is accelerating downward.*
BL	**How might wind add to the forces acting on the people on the chair swing ride?**	*Wind might push against the swings and make the ride bumpy as the people spin around.*



Newton's Second Law of Motion

Have students read the paragraph and study **Figure 19** to learn how this relates to Newton's second law of motion. Then have them consider what new information they have learned about the **Launch Lab** question.

Ask: What is the acceleration of the book or the pen? *It is the net force exerted on it divided by the mass of the object. The bigger the mass, the smaller the acceleration.*

Calculating Acceleration

Tell students that another way to express this concept is $F = ma$. Multiplying kilograms by meters/seconds squared results in Newtons, which is the unit of force. Newton is the "shorthand" version of kg × m/s². Write the equation $F = ma$ on chart paper or the board to help students understand that force equals mass multiplied by acceleration.

Guiding Questions

OL **How fast would a 0.3-kg ball accelerate if the net force were 6 N?** *The acceleration would be 20 m/s².*

BL **How does increasing the force affect the acceleration? How does decreasing the force affect it?** *Increasing the force increases the acceleration. Decreasing the force decreases the acceleration.*

Visual Literacy: Calculating Acceleration and Changing the Mass

Students might find learning two equations for acceleration confusing. Explain the logical steps:

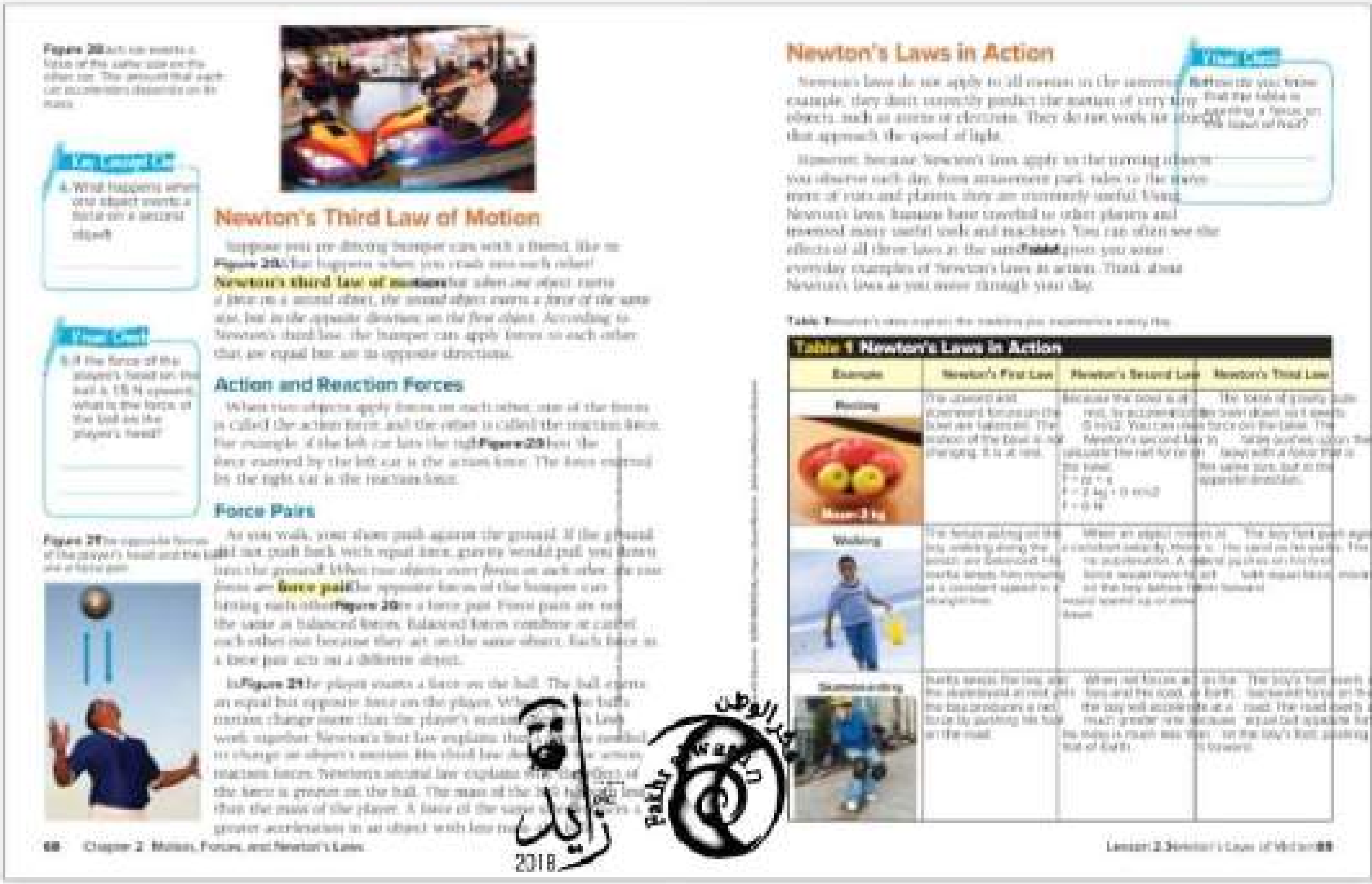
If $a = \frac{F}{m}$

and $a = \frac{(v_f - v_i)}{t}$

then $\frac{F}{m} = \frac{(v_f - v_i)}{t}$

These equations can be written on the board.

The final equation shows that if a larger force is applied to an object (left numerator), then a greater change in velocity will occur (right numerator). In addition, if the mass of an object increases (left denominator), then the time to make a given change in velocity must also increase (right denominator). **Ask: How are the acceleration, the net force, and the mass of an object related?** *They are related using Newton's second law: F = ma. As either mass or acceleration increase, force increases.*


Newton's Third Law of Motion

Action and Reaction Forces

Force Pairs

Newton's Laws in Action

Table 1 Newton's Laws in Action

Force Pairs

Have students read the paragraphs and study the photo of the soccer players in **Figure 21**. Clarify that you never combine forces in force pairs because the forces are acting on different objects. Review this in terms of the objects in **Figures 20** and **21** and compare it to the tug-of-war example. Then ask the following questions.

Guiding Questions

AL When two objects exert forces on each other, what are those forces called? *force pair*

OL If the force of the girl's head on the ball in Figure 21 is 1.5 N upward, what is the force of the ball on the girl's head? *1.5 N downward*

BL Picture two students pushing a wagon loaded with books. Do the forces exerted by the students on the wagon make a force pair? Why or why not? *No, the two forces are not a force pair. Instead, they are combined forces, because they act on a single object—the wagon—and not on each other.*

Newton's Laws in Action

Have students review Newton's three laws of motion by restating them in their own words. Then ask them to read the paragraph and study **Table 1**.

Guiding Questions

AL Do Newton's three laws apply to all motion in the universe? Explain your answer. *No; they do not apply to very small or very fast-moving objects.*

OL Which kinds of motion do not necessarily follow Newton's three laws? *the motion of very tiny objects, such as atoms and electrons, and the motion of very fast objects that approach the speed of light*

BL Newton did not realize that his laws of motion did not apply to very small or very fast-moving objects. What might be one reason for this? *Sample answer: Newton did not have any way to study very small or very fast-moving objects, so he was not able to determine whether his laws applied to them.*

Visual Literacy: Newton's Laws in Action

Have students compare the examples in **Table 1**. Then ask the following questions to assess their understanding.

Ask: **How do you know that the table is exerting a force on the bowl of fruit?** *If it weren't, the bowl would move downward.*

Ask: **How is the woman walking on the sand an example of a force pair?** *The woman is producing a net force by pushing on the sand. The sand pushes back with equal force.*

Newton's First Law	Newton's Second Law	Newton's Third Law
The upward and downward forces on the bowl are balanced. The motion of the bowl is not changing. It is at rest.	Because the bowl is at rest, its acceleration is 0 m/s². You can use Newton's second law to calculate the net force on the bowl: $F = m \times a$; $F = 2\ kg \times 0\ m/s^2$; $F = 0\ N$	The force of gravity pulls the bowl down so it exerts a force on the table. The table pushes up on the bowl with a force that is the same size, but in the opposite direction.
The forces acting on the woman are balanced. Their inertia keeps her moving at a constant speed in a straight line.	When an object moves at a constant velocity, there is no acceleration. A net force would have to act on her before she would speed up or slow down.	The woman's feet push against the sand as she walks. The sand pushes on the woman's feet with equal force, moving her forward.

Teacher Toolbox

Reading Strategy

Active Reading Have each student write down three sentences in this lesson that they believe most clearly represent the main ideas. Read key sentences in the te and have students raise their hands if they have written down the same sentence. Ask students to defend their choices.

Real-World Science

Seat Belts and Newton's First Law When a car moves forward, passengers inside the car also move forward a same speed. But, if the car stops suddenly, the passeng would remain in motion unless an outside force caused them to stop. That's why seat belts are so important. W a car suddenly stops in an accident, the motion of the passengers would hurtle them against the car or out of altogether if they weren't wearing seat belts. Seat belts protect passengers and prevent injury by providing an unbalanced force that affects motion.

Intervention Plann

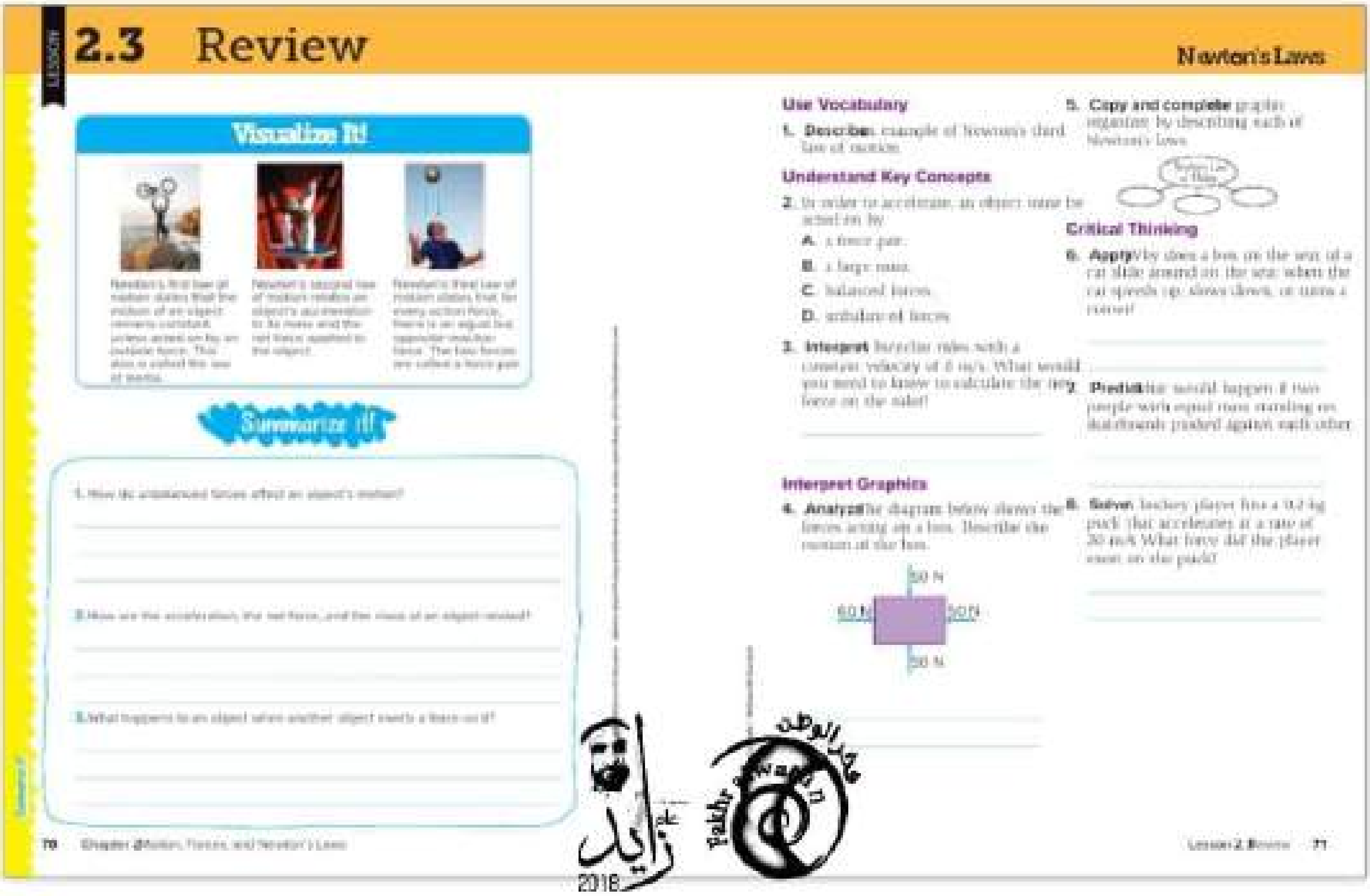
Based on the results of the Lesson Review, use the chart below to address individual needs.

Use Vocabulary (1–2)
- TE Science Use v. Common Use, inertia
- Visual Literacy: Newton's Laws in Action
- RR Content Vocabulary

Understand Key Concepts (3–4)
- TE Key Concept Checks
- RR Key Concept Builder

Interpret Graphics (5–6)
- TE Visual Literacy: Changing the Mass; Figures 17, 20

Critical Thinking (7–9)
- TE Visual Literacy: Newton's Laws in Action
- RR Enrichment
- Challenge


2.3 Review

Newton's Laws

Visualize It!

Summarize It!

Use Vocabulary

Understand Key Concepts

Interpret Graphics

Critical Thinking

Visual Summary

Concepts and terms are easier to remember when they are associated with an image: **Which Key Concept does each image relate to?**

Summarize It!

- Newton's First Law
- Newton's Second Law
- Newton's Third Law
- Newton's Laws in Action

Use Vocabulary

1. Sample answer: When my feet press on the floor, the floor presses back on my feet with equal force, but in the opposite direction. When I press the keys on the computer, the keys push back with equal force, but in the opposite direction.

2. Newton's first law relates forces to objects that are at rest or in constant motion. Newton's second law relates forces to objects that are accelerating.

Understand Key Concepts

3. D. unbalanced forces.

4. There is no net force because the rider is moving at a constant velocity.

Interpret Graphics

5. The box will move to the right, with a net force of 10

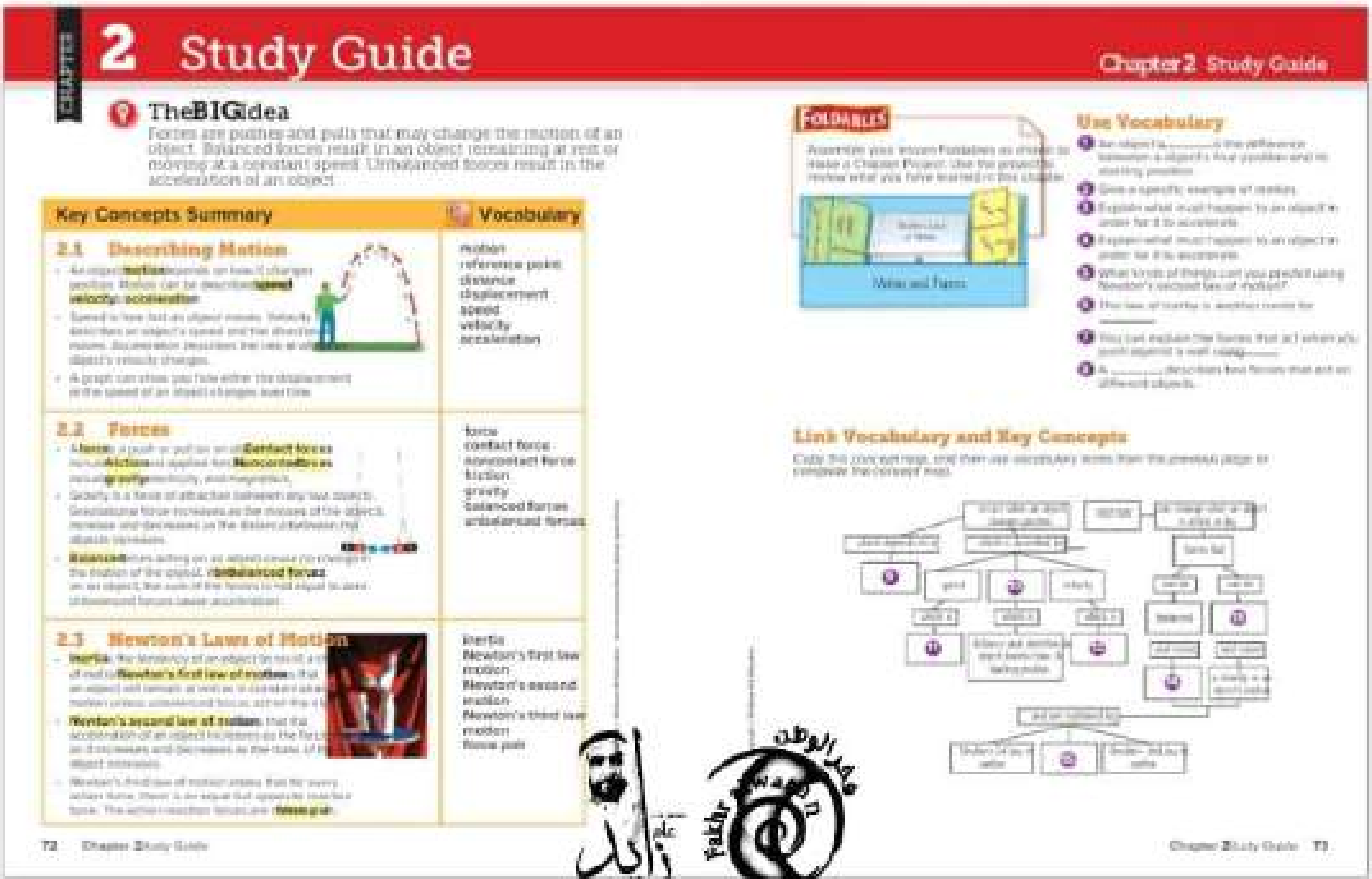
6. Newton's first law states that if the net force acting on an object is zero, the motion of the object does not change. The second law states that the acceleration of an object is equal to the net force exerted on the object divided by the object's mass. Newton's third laws says that when one object exerts a force on a second object, the second object exerts a force of the same size, but in the opposite direction, on the first object.

Critical Thinking

7. The inertia of the box keeps it moving in whatever direction the car was moving before it changes its speed or direction.

8. Both people would move backward with the same acceleration

9. 4 N


2 Study Guide

Chapter 2 Study Guide

The BIG Idea

Forces are pushes and pulls that may change the motion of an object. Balanced forces result in an object remaining at rest or moving at a constant speed. Unbalanced forces result in the acceleration of an object.

Key Concepts Summary

2.1 Describing Motion

2.2 Forces

2.3 Newton's Laws of Motion

Vocabulary

motion
reference point
distance
displacement
speed
velocity
acceleration

force
contact force
noncontact force
friction
gravity
balanced forces
unbalanced forces

inertia
Newton's first law of motion
Newton's second law of motion
Newton's third law of motion
force pair

FOLDABLES

Use Vocabulary

Link Vocabulary and Key Concepts

Key Concepts Summary

Study Strategy: Match Pictures to Captions

Students sometimes remember what they have studied without developing a true understanding of the concepts.

1. To help students better understand what they have read in this chapter, ask them to rewrite the key concepts in their own words in their Science Journals.
2. Then ask them to locate photographs in magazines, newspapers, or on the Internet that illustrate those ideas. For example, for the key concept that explains speed they might clip a photo of a race car. For the key concept that relates to gravity, they might clip a photo of a football falling from the air in the middle of a game.
3. After finding photos to match each concept, have students put them together on a poster, using their key concept sentences as captions for the different images.

The motion of an object can be described using a position or reference point.

Vocabulary

Study Strategy: Write a Quiz

When students write possible test questions based on the vocabulary terms and definitions they have learned, it takes some of the mystery out of assessment.

1. Divide students into groups of four.
2. Have each student develop a ten-question quiz based on the vocabulary words. Encourage students to include a variety of question types including true-false, matching, fill-in-the-blank, multiple choice, and short answer.
3. Have each student exchange papers with another group member, who will take the quiz. Then, that student passes the completed quiz to another group member, who will grade it.
4. Encourage groups to discuss how writing questions helped them complete a quiz.

Example:

A ______________ is a push or a pull from one object to another when the two are touching each other.

FOLDABLES

Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

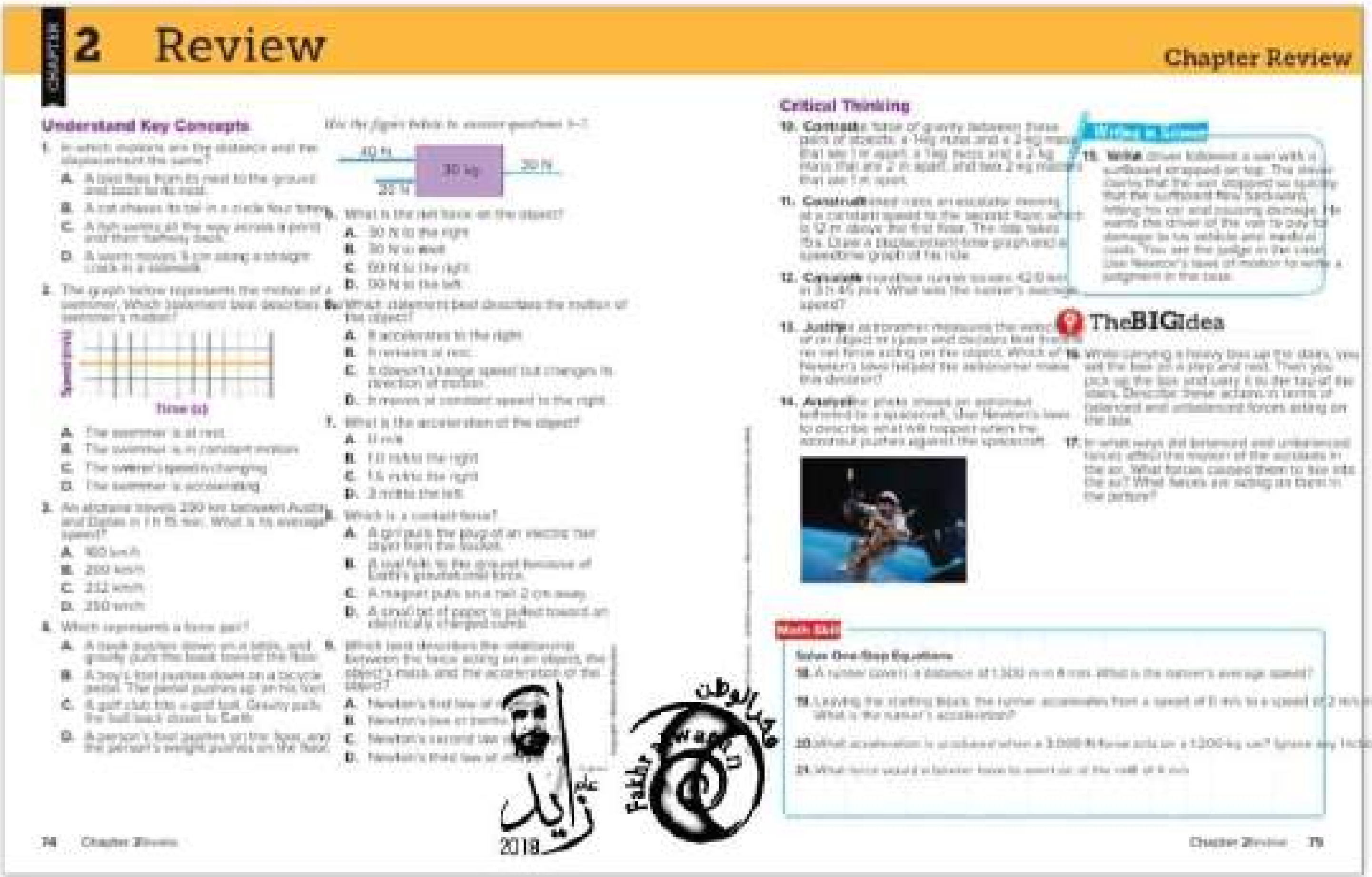
Use Vocabulary

1. displacement
2. Motion takes place when a increases the distance between her and the starting line.
3. gravity, magnetism, electricity (any two)
4. Its speed or direction must change.
5. Newton's 2nd law can predict the mass of an object, an object's acceleration, or the force acting on an object.
6. Newton's first law of motion
7. Newton's third law of motion
8. force pair

Link Vocabulary and Key Concepts

9. reference point
10. displacement
11. how fast an object changes position
12. speed in a given direction
13. unbalanced
14. no change in an object's motion
15. Newton's second law of motion

Teacher Notes


CHAPTER 2 Review

Chapter Review

Understand Key Concepts

Critical Thinking

TheBIGIdea

74 Chapter 2 Review

Chapter 2 Review 75

Understand Key Concepts

1. D. A worm moves 5 cm along a straight crack in the sidewalk.
2. B. The swimmer is in constant motion.
3. C. 232 km/h
4. B. A boy's foot pushes down on a bicycle pedal. The pedal pushes up on his foot.
5. A. 30 N to the right
6. A. It accelerates to the right.
7. B. 1.0 m/s² to the right
8. A. A girl pulls the plug of an electric hair dryer from the socket
9. C. Newton's second law of motion

Critical Thinking

10. The force of gravity is the least between the 1 kg and 2 kg masses that are 2 m apart. It is greatest between the 2 2-kg masses that are 1 meter apart.
11. The displacement-time graph should show a straight line with an upward slope extending from (0,0) to (15,12). The speed-time graph should show a horizontal line from (0,12) to (15,12).
12. 11.2 km/hr
13. She must have observed the object moving at a constant velocity, which would mean that the forces acting on it were balanced. Newton's first law
14. When the astronaut pushes against the spacecraft, the spacecraft will exert an equal but opposite force on the astronaut, causing him to accelerate away from the spacecraft (Newton's third law) until he reaches the end of the tether and an outside force acts on him (Newton's first law). Because his mass is less than that of the spacecraft, the astronaut will accelerate away from the spacecraft at a greater rate than the spacecraft will move away from him (Newton's second law).

Writing in Science

15. Students should dismiss the claim of the man because, if the van had been moving forward and suddenly stopped, the surfboard would have continued moving forward, not backward (Newton's first law).

The BIG Idea

16. As you carry the box up the stairs at a constant speed, the upward force you exert on yourself and the box is equal to the force of gravity. The forces are balanced. When you set the box down, the force of gravity downward equals the force of the step upward, so the forces are balanced. When you lift the box again, you must apply a net upward force to overcome inertia and get the box accelerating upward.

17. When the acrobats were standing on the bars, the forces on them were balanced. The men holding the bars caused the bars to exert an upward, unbalanced force that pushed the acrobats into the air. At present, their upward motion has stopped and the force of gravity is an unbalanced force that will start them falling back toward the bar.

Math Skill

Solve One-Step Equations

18. 375 m/min, or 6.25 m/s

19. 0.7 m/s²

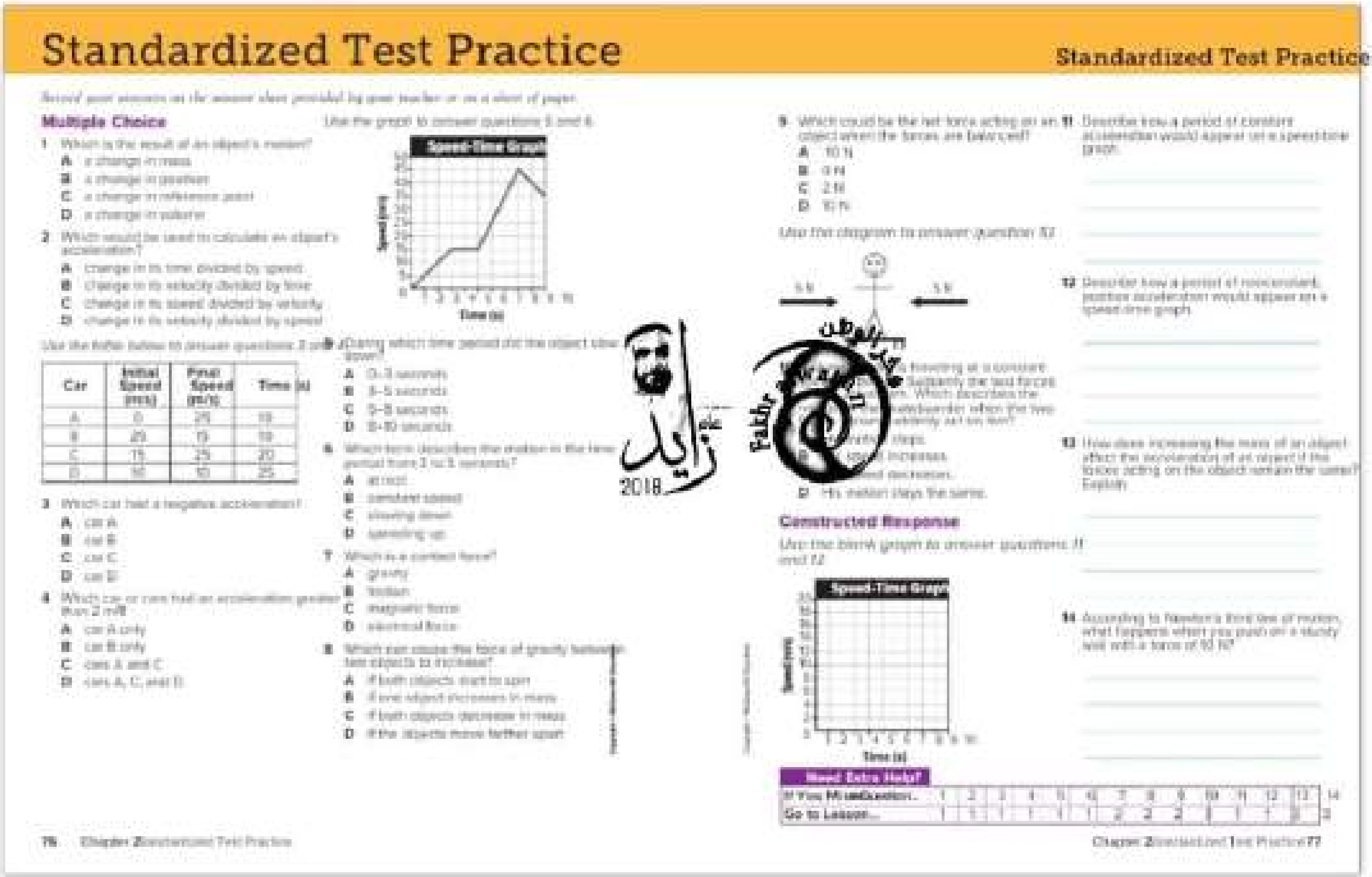
20. 2.5 m/s²

21. 24 N

Intervention Plann

Based on the results of the Chapter Review, use the char below to address individual needs.

Lesson	Questions	Intervention Options
Understand Key Concepts		
1	1–3	Key Concept Builders, Content Practice
2	5–6, 8	
3	4, 6–7, 9	
Critical Thinking		
1	11–12	Enrichment, Challenge
2	10	
3	13–14	
Writing in Science		
3	15	Language Arts, Enrichment
Review the Big Idea		
2	16	Content Practice, Enrichment, Challenge
3	17	
Math Skills		
	18–21	Math Skills, Math Practice: Solve for Average Acceleration



Multiple Choice

1 **B—Correct**A, D: Incorrect. Both describe properties unaffected by motion. C: Incorrect. A change in reference point involves a change in the description of motion.

2 **B—Correct**: Incorrect. This formula does not include direction. C, D: Incorrect. These formulas do not include time.

3 **B—Correct**, C: Incorrect. These cars show a positive acceleration. D: Incorrect. This car shows no acceleration.

4 **A—Correct**: Incorrect. This car has an acceleration of -1 m/s². C: Incorrect. This answer includes car C, which has an acceleration of 0.5 m/s . D: Incorrect. This answer includes car D, which has an acceleration of 0 m/s .

5 **D—Correct**, B, C —At 0–3 seconds the object is speeding up. At 3–5 seconds the object is at constant speed. At 5–8 seconds the object is speeding up.

6 **B—Correct**, B, C —Incorrect. From 3–5 seconds, the horizontal (zero slope) line of the speed-time graph indicates that the speed of the object was unchanging.

7 **B—Correct**, C, D—All are noncontact forces.

8 **B—Correct**: Incorrect. Both objects starting to spin does not describe a change in distance or mass. C, D: Incorrect. Both objects decreasing in mass or moving farther apart would reduce the force of gravity between the objects.

9 **B—Correct**, C, D—These show non-zero net forces, which means the forces are unbalanced.

10 **D—Correct**the forces acting on the skateboarder are balanced. A, B, C— Stopped motion, increased speed, or decreased speed describe what could happen if the forces acting on the skateboarder were unbalanced.

Constructed Response

11 A period of constant acceleration would appear as a straight line: positive slope indicates positive acceleration, zero slope (horizontal) indicates zero acceleration, negative slope indicates negative acceleration.

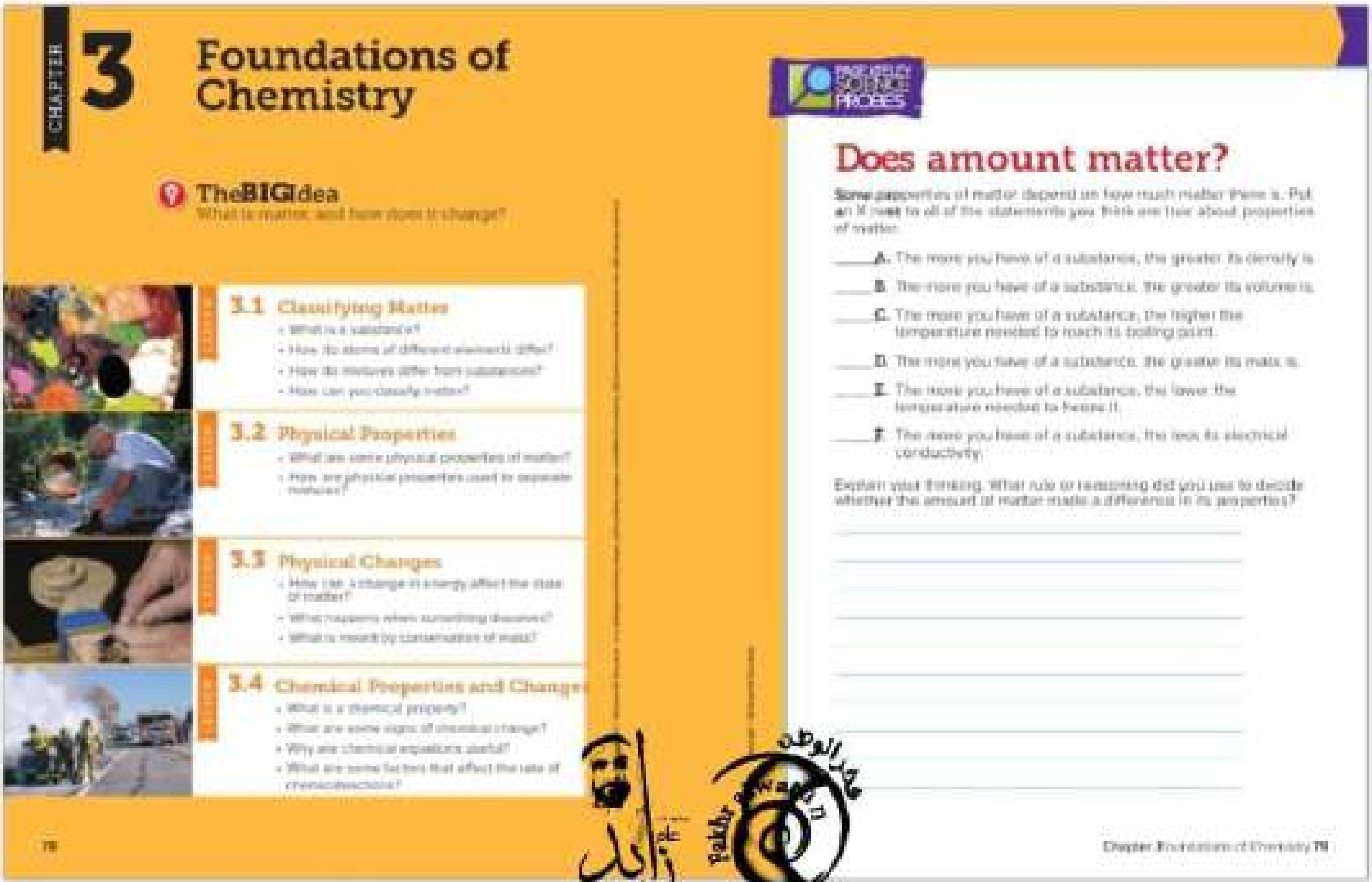
12 A period of nonconstant, positive acceleration would appear as a curved line sloping upward.

13 Acceleration is force divided by mass. Thus, a constant force divided by an increased mass would give a decreased acceleration.

14 The wall pushes with an equal force of 10 N in the opposite direction, which is back on you.

Answer Key

Question	Answer
1	B
2	B
3	B
4	A
5	D
6	A
7	B
8	B
9	B
10	D
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answer.



Foundations of Chemistry

TheBIGIdea

Accept all reasonable responses. Write student-generated questions on chart paper and return to them as you study the chapter.

Guiding Questions

BL Identify something that contains matter.	*Encourage students to think about what matter is. They might name examples of solids and liquids. Guide them to see that air and other gases are also matter.*
OL In what ways can matter change?	*Students might make observations related to seasonal changes, such as snow falling or leaves changing color. Responses might include: objects breaking, food decaying, or soil eroding. Help students recognize changes that takes place over a period of time or change that is subtle. Promote students' thinking about a visible change by having them compare matter before, during, and after a change has occurred.*
BL Name something that does not contain matter.	*Students might be able to identify energy, thoughts, and emotions as not containing matter.*

PAGE KEELEY SCIENCE PROBES — Does amount matter?

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook.*

Get Ready to Read

What do you think?

Use this anticipation guide to gauge students' background knowledge and preconceptions about the foundations of chemistry. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. The atoms in all objects are the same.

Disagree Different substances contain different types of atoms.

2. You cannot always tell by an object's appearance whether it is made of more than one type of atom.

Agree. Tests must be performed to determine if the object is an element, a compound, or a mixture.

Strand Map

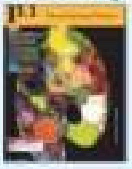
Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

- * Materials may be composed of parts that are too small to be seen without magnification.
- * Objects can be described in terms of the materials of which they are made and their physical properties.
- * Substances may move from place to place, but they never appear out of nowhere and never disappear.
- * When a new material is made by combining two or more materials, it has properties that are different from the original materials.
- * Many types of changes occur faster under warmer conditions.

* American Association for the Advancement of Science (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1 Classifying Matter



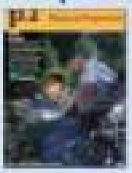
1 A substance is a type of matter that always is made of atoms in the same combinations.

2 Atoms of different elements have different numbers of protons.

4 Matter can be classified as either a substance or a mixture.

3 The composition of a substance cannot vary. The composition of a mixture can vary.

Lesson 2 Physical Properties



5 Physical properties of matter include size, shape, texture, and state.

6 Physical properties, such as density, melting point, boiling point, and size, can be used to separate mixtures.

Lesson 3 Physical Changes

7 A change in energy can change the state of matter.

8 When something dissolves, it mixes evenly in a substance.

9 The masses before and after a change in matter are equal.

Lesson 4 Chemical Properties and Changes

10 Chemical properties include the acidity, ability to burn, and the ability to rust.

11 Some signs that might indicate chemical changes are the formation of bubbles and a change in odor, color, or energy.

12 Chemical equations are useful because they show what happens during a chemical reaction.

13 Some factors that affect the rate of chemical reactions are temperature, concentration, and surface area.

Identifying Misconceptio

Believing Is More Than Seeing

Find Out What Students Think

Students may think that...

... properties don't exist unless they can be seen with our eyes. They might think that the only physical properties a substance has are those that are directly observable. Some students might not realize that some properties must be measured or calculated.

Discussion

Discuss with students different physical properties that can be determined by observation, such as luster, color, and shape. Then, discuss properties that must be measured, such as mass, volume, density, melting point, boiling point, conductivity, and solubility. Talk about some of the different ways to learn more about the physical properties of substances. **Ask:** What do all plants need to survive? **You can measure its mass and volume and calculate density by dividing mass by volume. Ask:** How can you find the melting point or boiling point of a substance? How do most plants get water and nutrients? **You can heat it and measure its temperature as it begins to melt.** Remind students that although direct observation is important, it is not the only way to learn about the properties of substances.

Promote Understanding

Activity

1. Have students work in teams to investigate the properties of three different everyday substances, such as water, baking soda, and sugar. They should note the state of each substance at room temperature, the color, texture, and so on. They should also research properties that they can't observe, including density, and melting and boiling points.
2. After completing their research and investigations, have them create a table similar to **Table 1** in **Lesson 2** to describe the properties of each substance. Encourage them to include drawings, diagrams, or images clipped from newspapers or magazines to illustrate each concept. Their tables should also identify ways to measure or observe the properties for each substance.
3. Each team should share their completed tables with other members of the class.

Heat It Up!

Find Out What Students Think

Students may think that...

... the transfer of thermal energy happens only as the result of a chemical reaction. They might not realize that the addition or removal of thermal energy can also affect physical and chemical changes.

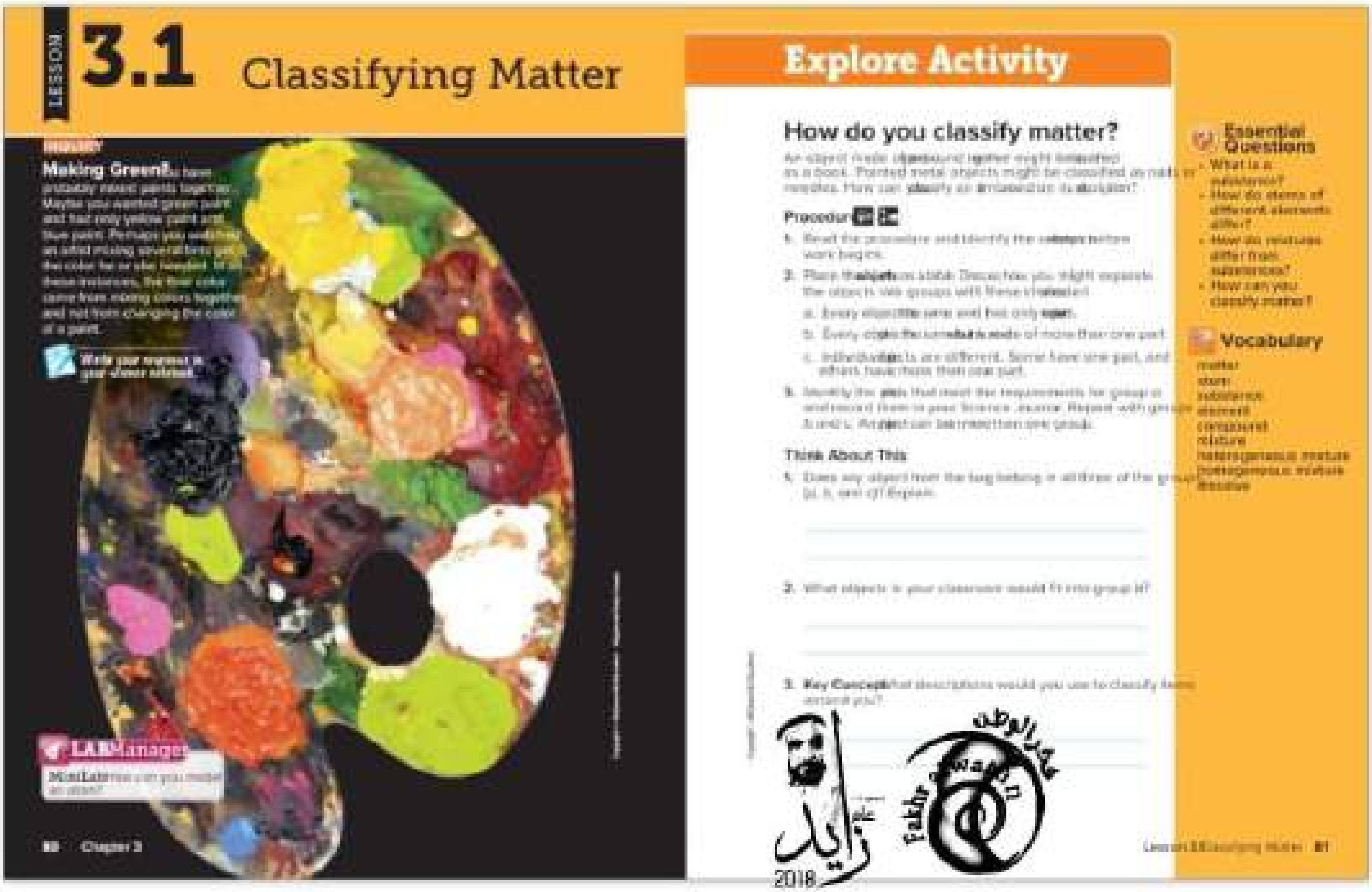
Discussion

Remind students that thermal energy can lead to a change of state, which relates to the physical properties of melting point and boiling point. **Ask:** What happens to your bare hands when you hold a snowball? **They get cold. Ask:** Where does the thermal energy from your hands go? **The thermal energy transfers from your hands to the snowball. Ask:** What happens to the snowball as a result? **It melts and changes state from a solid to a liquid.** Emphasize that the melting of the snowball was caused by the transfer of thermal energy. Explain that adding thermal energy can also increase the rate of chemical reactions, such as when you cook a meal.

Promote Understanding

Activity

1. Have students work in groups. Distribute ice cubes, paper towels, and gloves or mittens to each group. Instruct students to hold an ice cube for 1 min and note their observations. Then have them dry their hands and place them into a glove or mitten to warm up.
2. Have the group discuss what they experienced both when holding the ice cube and when wearing the glove in terms of the transfer of thermal energy.
3. Lead a discussion about what it feels like outside on a hot day versus a cold day. During the discussion, reinforce that students should describe heating processes as the transfer of thermal energy to and from substances.



INQUIRY

About the Photo **Making Green?** A painter's palette is used to mix colors to create colors and shades. Painters can combine two or more colors to create a unique color. Discuss with students the three primary colors—blue, yellow, and red—and how they can be combined in many ways.

Guiding Questions

AL	How does the artist make new colors?	*New colors of paint are made from different colors that have been combined. For example, pink is a mix of red and white.*
OL	How do you know that the wood of the palette is also made from things mixed together?	*Answers might include that you can see different components of the wood.*
BL	How might the types of matter in this photo show that most materials are made from mixing things together?	*Even the single-color paints are made from a pigment and an oil or an acrylic. Everything shown in the photo is formed from things mixed together.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Describing the World Around Us

1. Write the words *element* and *compound* on chart paper or on the board. Place each word in a separate column.
2. Ask students to describe what they think an element or a compound is. **Ask:** **What do you think these terms mean? How might they be related?** Write their responses in the appropriate column. Students should be able to relate the analogy of pure colors and mixed colors and to elements and compounds.
3. Brainstorm other relationships. Examples include numbers (10) and their divisors (5, 2; 1, 10); a car and the many parts and materials that make it; a recipe: separate ingredients and final dish.
4. After completing the lesson, have students return to their initial answers. Ask them to compare their original ideas to the definitions and concepts they learned in the lesson.

Explore Activity

How do you classify matter?

Prep: *15 min* **Class:** *15 min*

Purpose
To develop classification skills and raise questions about the composition of matter.

Materials
Student Group of 3–4: self-sealing bag containing 4 of each of the following: large paper clips, metal washers, threaded metal bolts with nuts, large paper clips hooked to metal washers, nuts threaded onto bolts, bolt/washer/nuts all connected

Before You Begin
- Assemble the materials into bags.
- Have students think about how matter differs by asking them to identify 1) objects in the room that contain only one part, such as a rubber band or a blank piece of paper; and 2) objects that contain several parts, such as a pencil (eraser, body, lead), or a chair (plastic seat, metal legs).

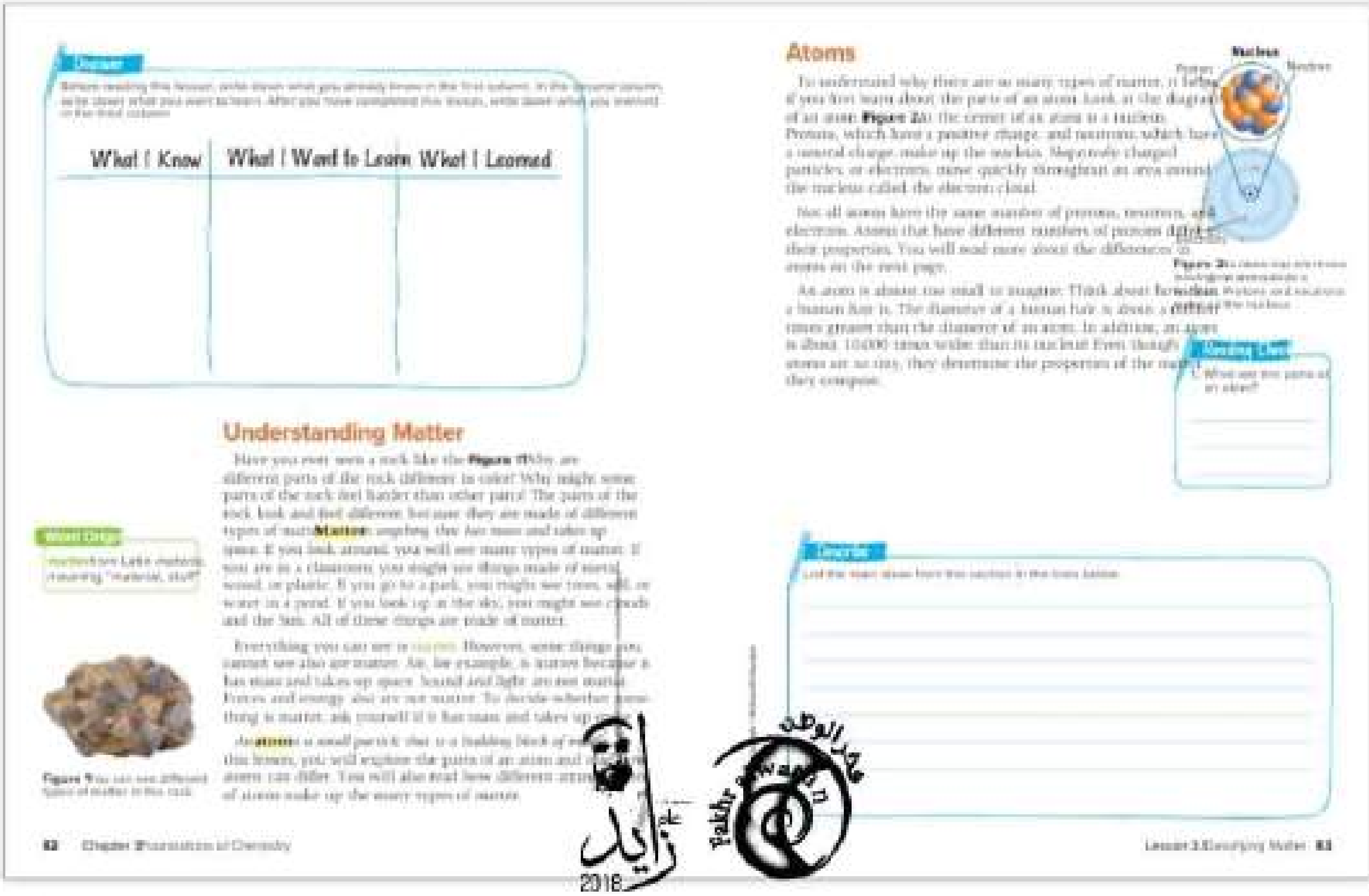
Guide the Investigation
- Point out that several different objects can be used to form the groups. There is more than one correct answer for each group.
- If students have difficulty understanding how a group can contain objects that are alike but contain several parts, point out that the chairs/desks in the room are alike, but contain parts made of different materials.

Think About This

Encourage students to hypothesize if they don't know the answer.

1. No; each object has either one part or more than one part, so the same object could not go into both Groups A and B. Objects from Groups A and B can go into Group C, so long as no objects identical to them are already in the group.
2. Sample answers: books (covers and pages), chairs (seats, legs, backs, screws)
3. **Key Concept** Sample answer: I could group things that look like one substance, such as aluminum foil, clear glass, or water, into one group, and objects made from more than one substance, such as soil or wood, in another.

Teacher Notes



Understanding Matter

Students often associate the term matter with solid objects, such as rocks in **Figure 1**, books, and tables. Help them recognize that water and air are matter.

Guiding Questions

AL What are some questions you can ask to identify matter?	*Sample questions: Does it have mass? Does it take up space?*
OL How are atoms "building blocks of matter"?	*Building blocks are used to construct different objects, just as atoms build types of matter.*
EL If light, sound, force, and energy are not matter, how do we know anything about them?	*Properties of things that are not matter have been determined by observing how they interact with matter.*

Word Origin

matter

Have students read the Latin origin of matter and ask the following questions.

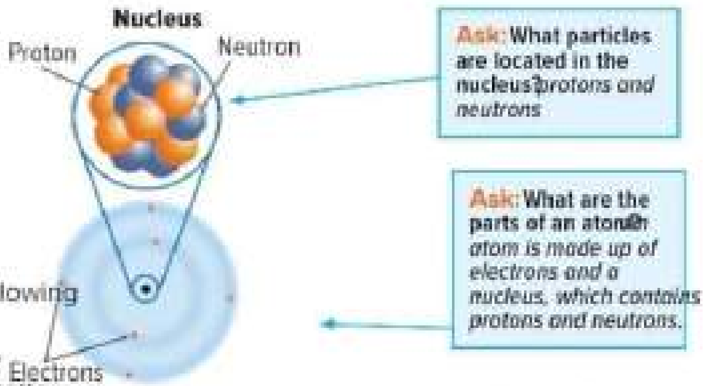
Ask: **What *stuff* do you see in Figure 1?** *Students should note that* rocks of different colors and textures are different kinds of matter.

Atoms

Explain that the atom shown in **Figure 2** is a two-dimensional simplification that makes it easier to think about a three-dimensional atom. In real life electrons move incredibly fast around a nucleus.

Visual Literacy: Figure 2

Have students examine the diagram of the atom in **Figure 2**.



Ask: **What particles are located in the nucleus?** *protons and neutrons*

Ask: **What are the parts of an atom?** *An atom is made up of electrons and a nucleus, which contains protons and neutrons.*

Ask: **Where are the positively and negatively charged particles located in the diagram?** *Protons have positive charge and are located in the nucleus, while the electrons, which move around the nucleus, have negative charge.*

Substances

Students will investigate a variety of atoms and the different ways that they can be combined. As each new term and concept is introduced, reinforce the proper use of the terms. This will help to identify whether a student is adopting a misconception. Use these questions to assess understanding.

Guiding Questions

OL What is a substance?	*A substance is a classification of matter that is made up of one or more types of atoms in the same combinations. A substance is either an element or a compound.*
AL Name one example of something that is a substance.	*Sample answers: aluminum, oxygen, water, sugar*
BL If you have a glass of pure water from a spring in Canada and a glass of pure water from a pond in California, would the arrangement of water atoms in each glass be the same or different? Explain your answer.	*They would be the same because both glasses contain the same substance (water). A substance always consists of the same kinds of atoms arranged in the same way no matter where it is found.*

Differentiated Instruction

AL **Atom-a-Go-Go** Have students work in groups to create a model of an atom using building blocks or balls of cla[y]. Students should make sure to include an equal number [of] protons and electrons in each atom.

BL **Element Detectives** Have students work in groups to brainstorm elements that they have heard of (or refer to [the] periodic table). Students should review the periodic tab[le for] some basic properties of each element, including the number of protons and electrons; whether it is a solid, liquid, or gas; whether it is a metal; what it is used for; a[nd] where it can be found naturally.

LA **Fishing for Matter** Direct students to create a chemistry card game by dividing students into groups of three or f[our]. Students can use markers and index cards. On a pair of cards, each student will draw and label an image depicti[ng] each of the following four terms: matter, atom, substance[,] element. Review their drawings. Have students mix up a[ll] cards in the group and go fishing to match terms to imag[es].

Teacher Toolbox

Fun Fact

The Fleeting Elements? Atoms with more than 92 protons [in] their nucleus aren't stable, so scientists synthesize t[hem] artificially by colliding two atoms together. These supe[r-] large atoms break down extremely quickly.

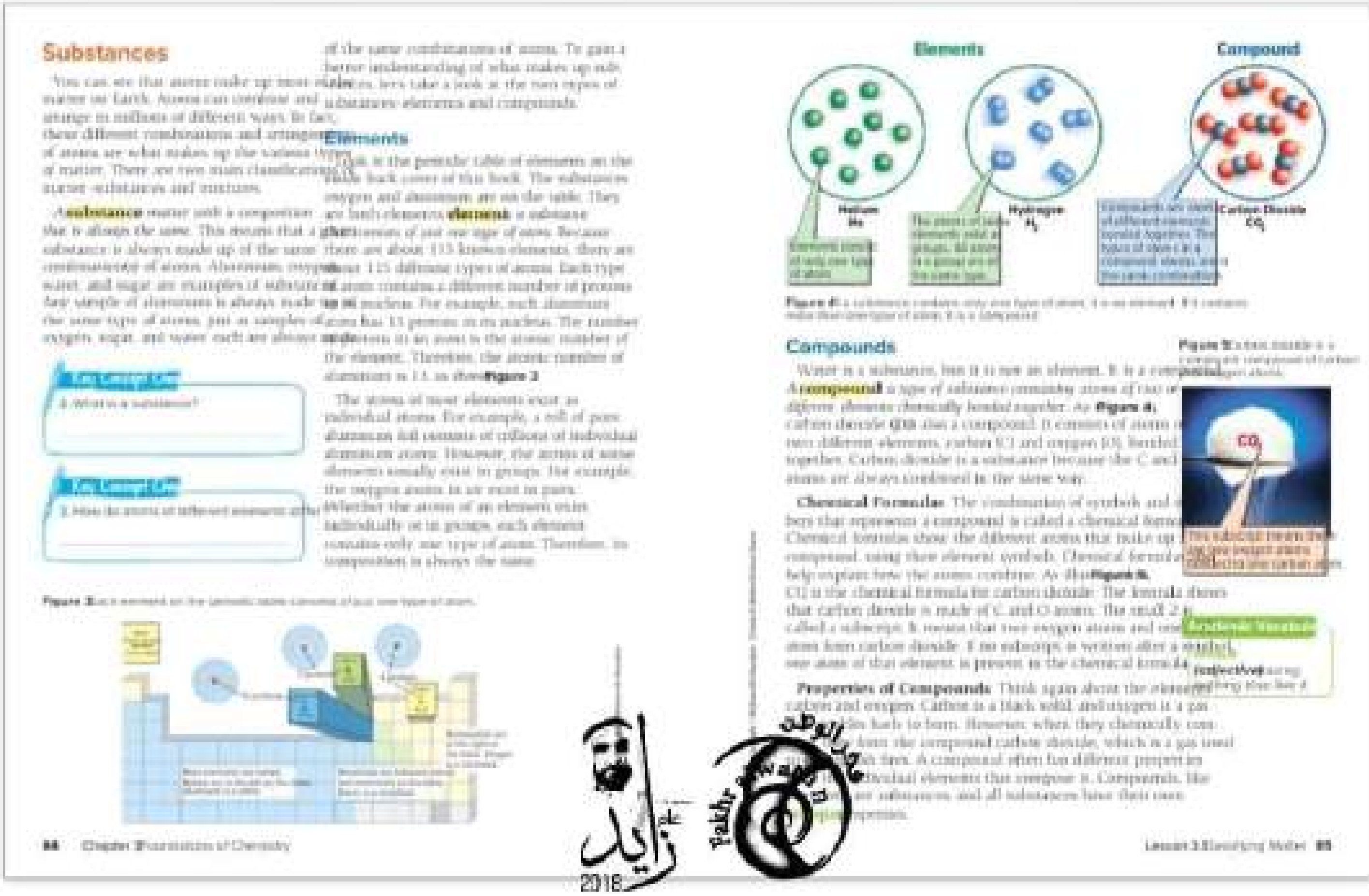
Reading Strategy

K-W-L It! Using a K-W-L worksheet and vocabulary term[s], have students complete the first two columns from the lesson. After the lesson is completed, have them fill in [the] final column on their charts.

Teacher Demo

Deconstructing Matter Make a car, a plane, or other easil[y] recognizable object out of toy building blocks.

1. Have students describe the object. Break it apart int[o] individual building blocks.
2. Brainstorm ways that the blocks are similar and way[s] they are different.
3. Discuss ways to group the blocks, such as by color, [size,] or the number of pegs on each block.
4. Organize blocks according to their suggestions. Compare and contrast the blocks to atoms.
5. Students suggest ways the toy blocks could be used [to] demonstrate vocabulary terms. For example, a single block could represent an element, other blocks joine[d] together could be a compound.


Substances

Elements

Key Concept Check

Elements

Compound

Helium He

Hydrogen H_2

Carbon Dioxide CO_2

Compounds

Chemical Formulas

Properties of Compounds

Academic Vocabulary

84 Chapter 3 Foundations of Chemistry

Lesson 3 Classifying Matter 85

Elements

Elements, organized by atom type and displayed in the periodic table, are the basic alphabet of the language of matter. It is important for students to understand how, like letters, one atom differs from another.

Have students locate the periodic table on the inside back covers of their books and find the symbols for oxygen (O) and aluminum (Al). Then have them read the paragraphs and examine the image in **Figure 3**. Explain that the unique structure of atoms determines the properties of matter. Ask the following questions to assess your students' comprehension.

Guiding Questions

OL How do atoms of different elements differ?	*Atoms of different elements contain different numbers of protons.*
AL What is the total number of protons contained in two oxygen atoms?	*16*
BL Do you think most of the materials in the world are pure elements, or are they made up of a combination of elements?	*There are more materials made up of a combination of elements, just as there are many more recipes for cake than there are cake ingredients alone.*

Compounds

Remind students that elements are always made of the same kind of atom, whereas compounds consist of different kinds of atoms that are bonded together. Writing out a compound's chemical formula is a helpful way to recognize the elements it contains.

Academic Vocabulary

unique

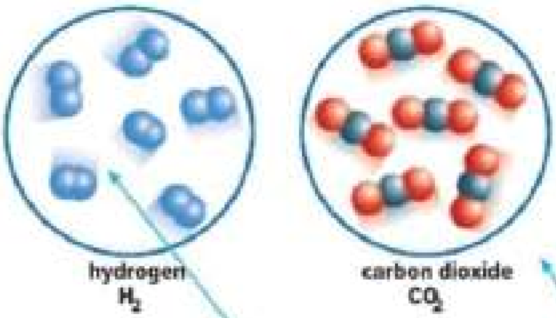
Ask: **How is the uniqueness of a compound similar to the uniqueness of a work of art, such as a painting?** *Both a compound and a painting have a set of properties or qualities that no other substance or work of art has.*

Guiding Questions

AL What does a chemical formula show?	*It shows the different kinds and numbers of atoms that make up a compound, using their chemical symbols.*
OL How do you know $NaHCO_3$ is a compound?	*$NaHCO_3$ contains more than one type of atom, so it is a compound.*
BL Are the properties of one compound always different from every other compound?	*Compounds might have some properties that are similar, but the set of all properties of a compound is unique.*

Visual Literacy: Figure 4

To understand elements and compounds, students need to be able to differentiate between the two kinds of substances. Have students examine **Figure 4** while you ask them the following questions.



Ask: Why do you think the atoms have been drawn with streaks? *The streaks show that they are in motion.*

Ask: How do you know CO_2 is a compound? *It contains two elements, carbon, and oxygen.*

Mixtures

Students might believe that you can identify a mixture by its appearance. That is, one must be able to see that two or more substances are mixed together for it to be a mixture. To address this misconception, use the following questions.

Guiding Questions

AL How do substances combine in a mixture?	*In a mixture, substances blend together physically, but do not bond chemically.*
OL Could you separate all the substances that make up mud? Why or why not?	*Yes, because mud is a mixture made up of substances that have blended together but not bonded together. So, it's possible to physically separate them.*
BL Do you think it is it possible to identify something as a mixture just by looking at it? Why or why not?	*Not necessarily. Some mixtures blend so well that you can't see the substances of which they are made. However, a microscope might help determine if a material is a mixture.*

Differentiated Instruction

AL **Social Mixing** Help students to envision the different kinds of mixtures by having them work together to mod mixtures. Assign half the students as Substance A and t rest as Substance B. For a heterogeneous mixture, brea the A group into teams of three to four students. Have t hold hands in a circle. Then instruct them to move as a group through the B group. The students in the B grou be "clumped" together or more spread out. For the homogeneous mixture, have the two groups intermingl individually with one another.

BL **How pure is your water?** Obtain the tap water test results from your local water district or research the wa your community online. Then have students research a of the substances commonly found in the tap water in y area. Lead students in a discussion of each substance, have them describe where these substances might com from and how they might be removed, based on the re of their research.

LA **Word Wizards** Have students work together in groups examine each of the vocabulary words in this lesson and for ways to simplify their sounds and meanings. Ask gro to come up with a creative way to learn the words, such rhyme, a song, hand gestures, or some other kinestheti help them understand the vocabulary terms.

Teacher Toolbox

Reading Strategy

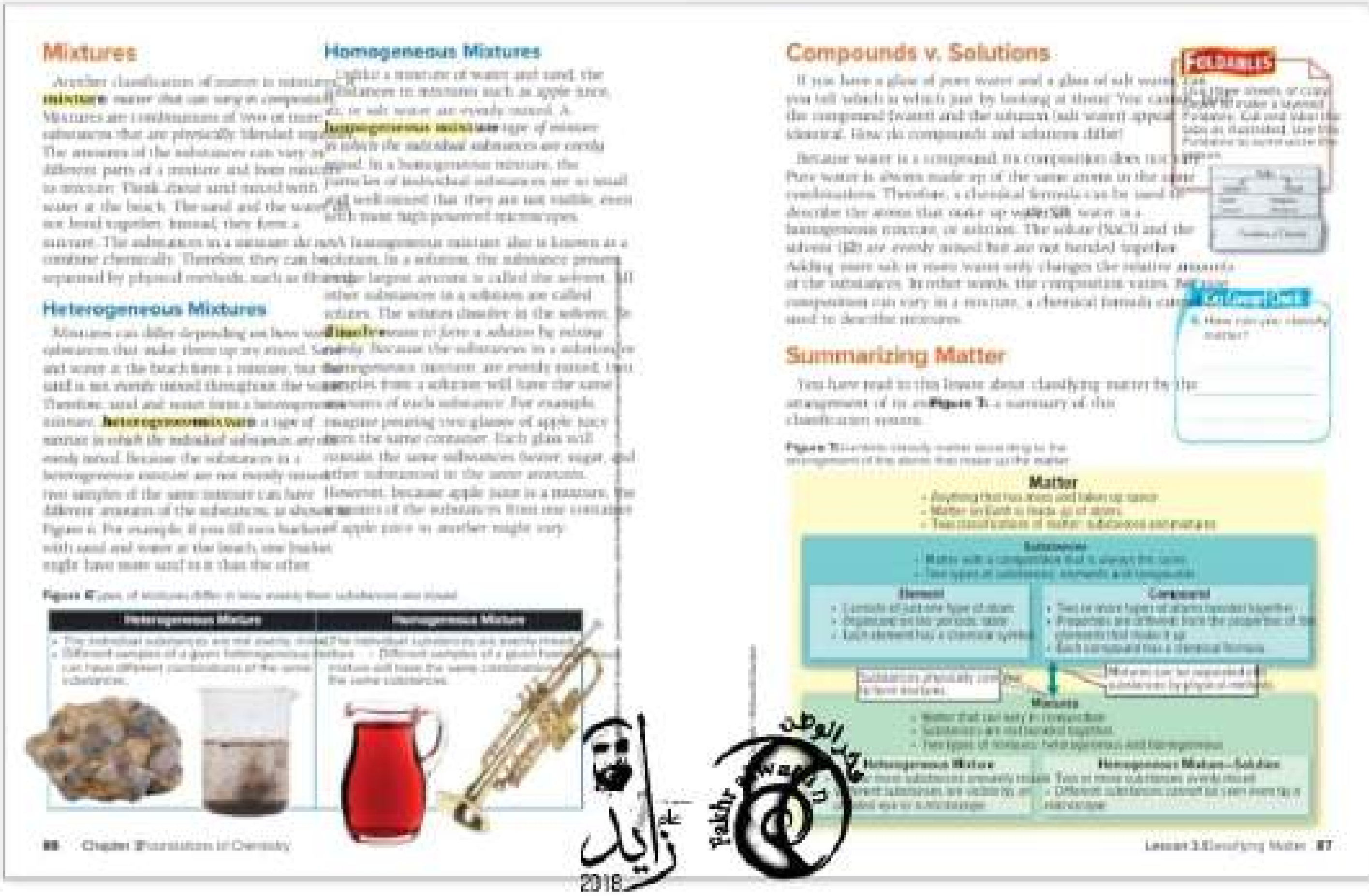
20 Questions Have students work in teams to research t properties of five common compounds, such as water, sugar, and carbon dioxide. Then have them gather into large group to play a game of 20 Questions. One pers should pick a substance while the others ask no more 20 yes-or-no questions to identify it.

Teacher Demo

Salty Solution Make a solution of Epsom salt in water in clear container, so that the class is able to observe the dissolving. Show the students that the salt has comple dissolved and is a homogeneous mixture. Pour some o solution into an aluminum pan and allow it to sit overni so that crystals can form and students can observe tha salt and water were both present in the mixture.

Reading Strategy

Compare and Contrast Have students complete a two-column chart that lists the similarities and differenc among compounds, homogeneous mixtures, and heterogeneous mixtures.



Heterogeneous Mixtures

When two substances are not mixed evenly, they are said to be heterogeneous. A common example of a heterogeneous mixture is vinaigrette, a type of salad dressing that is a mixture of vinegar and oil. When the mixture is shaken, the oil droplets seem to blend with the vinegar droplets. But in only a few moments, they begin to separate from each other. (You might opt to demonstrate this.) Help students understand these concepts with the following questions.

Guiding Questions

AL **What type of mixture is trail mix?**	*Trail mix is a heterogeneous mixture because the components of trail mix do not mix completely.*
OL **Will two portions of a heterogeneous mixture always have the same amounts of substances in them?**	*No, because the individual substances in a heterogeneous mixture do not mix completely, so composition can vary throughout the mixture.*
BL **Name one example of a heterogeneous mixture that you might eat for breakfast.**	*Answers will vary. Possible answers include cereal with fruit and milk, fruit salad, or an omelet with cheese and other ingredients.*

Homogenous Mixtures

Homogeneous mixtures appear to be a single substance to the naked eye. For instance, when sugar or salt is dissolved completely in water, there is no way to visually detect that it is a solution instead of a pure substance. This is because the substances in the mixture are mixed together at the atomic level. Students might have a difficult time recognizing matter as a mixture if it appears uniform. Guide students in thinking about homogenous v. heterogeneous mixtures by asking them the following questions.

Guiding Questions

AL **What is the difference between a homogeneous mixture and a heterogeneous one?**	*A homogeneous mixture is mixed evenly, and a heterogeneous mixture is not.*
OL **How do mixtures differ from substances?**	*If a substance contains more than one type of atom, the atoms are chemically combined. A mixture is two or more substances physically mixed together, but not chemically combined.*

Compounds v. Solutions

There are many instances in which a solution looks the same as one of the substances from which it is made. For example, if you dissolve salt in water, it looks just like water. Solutions take on the state of the solvent because it is most abundant. Demonstrate this by pouring water into two identical glasses. Then add a small amount of salt into one and have students observe as you mix it until the salt is completely dissolved. Hold them out and have students observe that they look similar.

Guiding Questions

AL What does it mean to say that a glass of water looks identical to a glass of salt water?	*It means they look the same even if they do not have the same composition.*
OL How is a compound different from a solution?	*A substance is an element or compound. Mixtures are combinations of two or more substances. Unlike substances, mixtures can have varying compositions and can be separated by ordinary physical means.*
BL What is the chemical formula for salt water?	*There is no chemical formula for salt water, because the ratios of atoms in the solution can vary depending on the sample.*

Summarizing Matter

Classifying matter is important to identifying and comparing the basic properties of matter. Have students read the paragraph and study the flowchart **Figure 7**. Assess students' understanding by asking the following questions.

Guiding Questions

AL Do substances consist of mixtures, or do mixtures consist of substances? Explain.	*Mixtures consist of substances.*
OL How can you classify matter?	*Matter can be classified according to whether it is a substance or a mixture. If it is a substance, it can be classified as to whether it is an element or a compound. If it is a mixture, it can be classified according to whether it is homogeneous or heterogeneous.*
OL Where in Figure 7 would you classify things you see each day?	*Possible answer: Most of the things I see each day are compounds or mixtures.*
BL Which methods do you think you can use to separate the substances in a mixture?	*Sample answer: You might be able to use physical methods, such as filtering, magnetism, or boiling.*

Intervention Plann

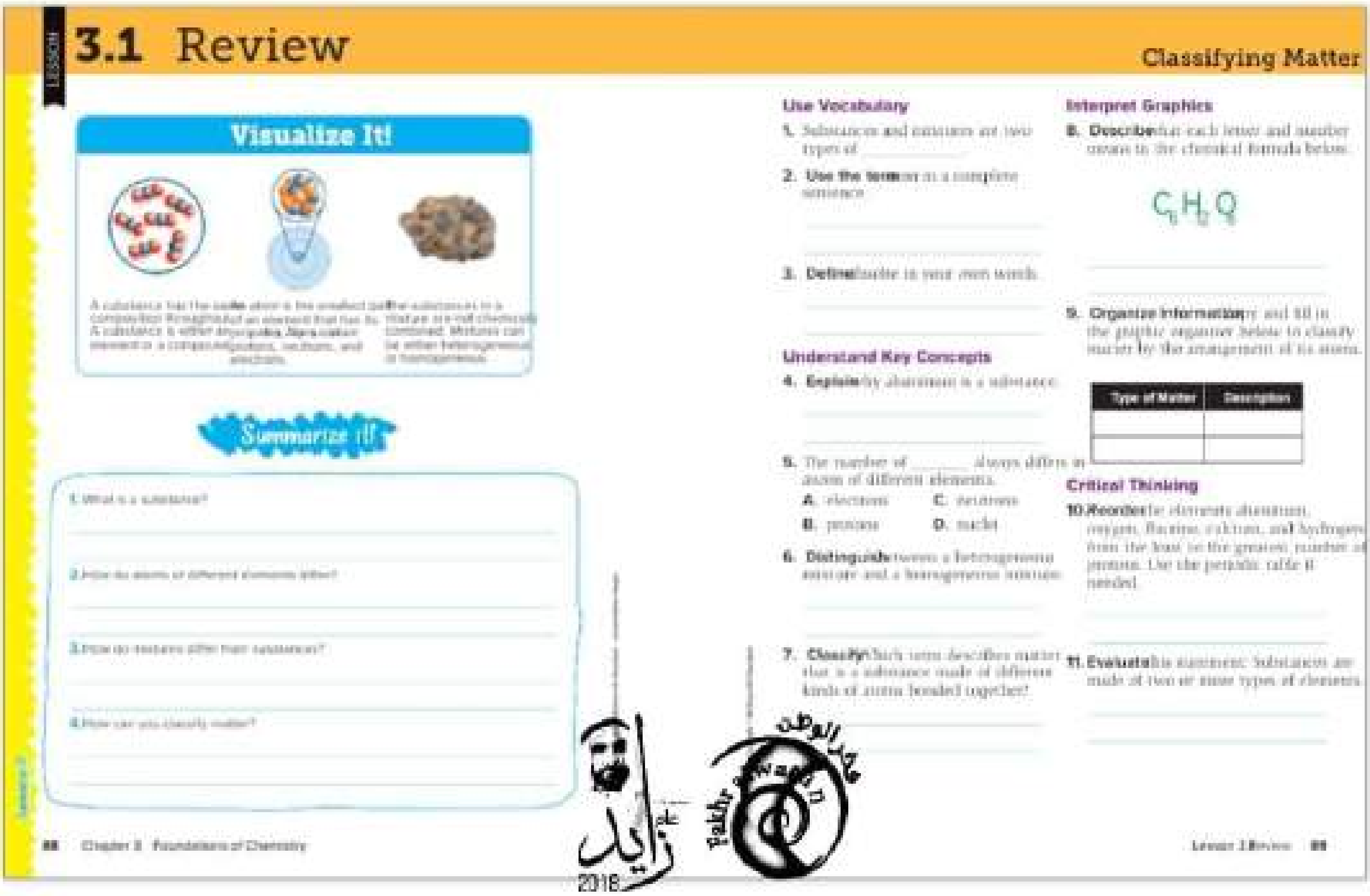
Based on the results of the Lesson Review, use the cha below to address individual needs.

Use Vocabulary (1–3)
- TE Word Origins, Understanding Matter
- Quick Vocabulary
- Content Vocabulary

Understand Key Concepts (4–7)
- TE Guiding Questions, Summarizing Matter
- Key Concept Builder

Interpret Graphics (8–9)
- TE Visual Literacy: Figure 4

Critical Thinking (10–11)
- TE Guiding Questions, Substances
- Enrichment
- Challenge


3.1 Review

Classifying Matter

Visualize It!

Summarize It!

Use Vocabulary

Understand Key Concepts

5. A. electrons C. neutrons B. protons D. nuclei

Interpret Graphics

$C_6H_{12}O_6$

Type of Matter	Description

Critical Thinking

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Which Key Concept does each image relate to?**

Summarize It!

- Understanding Matter
- Atoms
- Substances
- Mixtures
- Summarizing Matter

Use Vocabulary

1. matter.

2. Sample answer: Each oxygen atom contains eight protons.

3. Sample answer: When something dissolves, it breaks down into its simplest parts, which evenly distribute throughout another substance.

Understand Key Concepts

4. Aluminum is a substance because it is an element and contain only one type of atom.

5. B protons

6. The parts of a heterogeneous mixture are not evenly mixed. The parts of a homogeneous mixture are evenly mixed.

7. compound

Interpret Graphics

8. The C stands for carbon, the H stands for hydrogen, and the O stands for oxygen. The subscripts tell how many atoms of each element are in each unit of the compound. One unit of the compound contains 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms.

9. Sample answer:

Type of Matter	Description
Substance	has a definite makeup
Mixture	has no definite makeup

Critical Thinking

10. hydrogen, oxygen, fluorine, aluminum, calcium

11. The statement is not always true. Some substances are made of one type of element. Other substances are made of two or more types of elements.

Teacher Notes

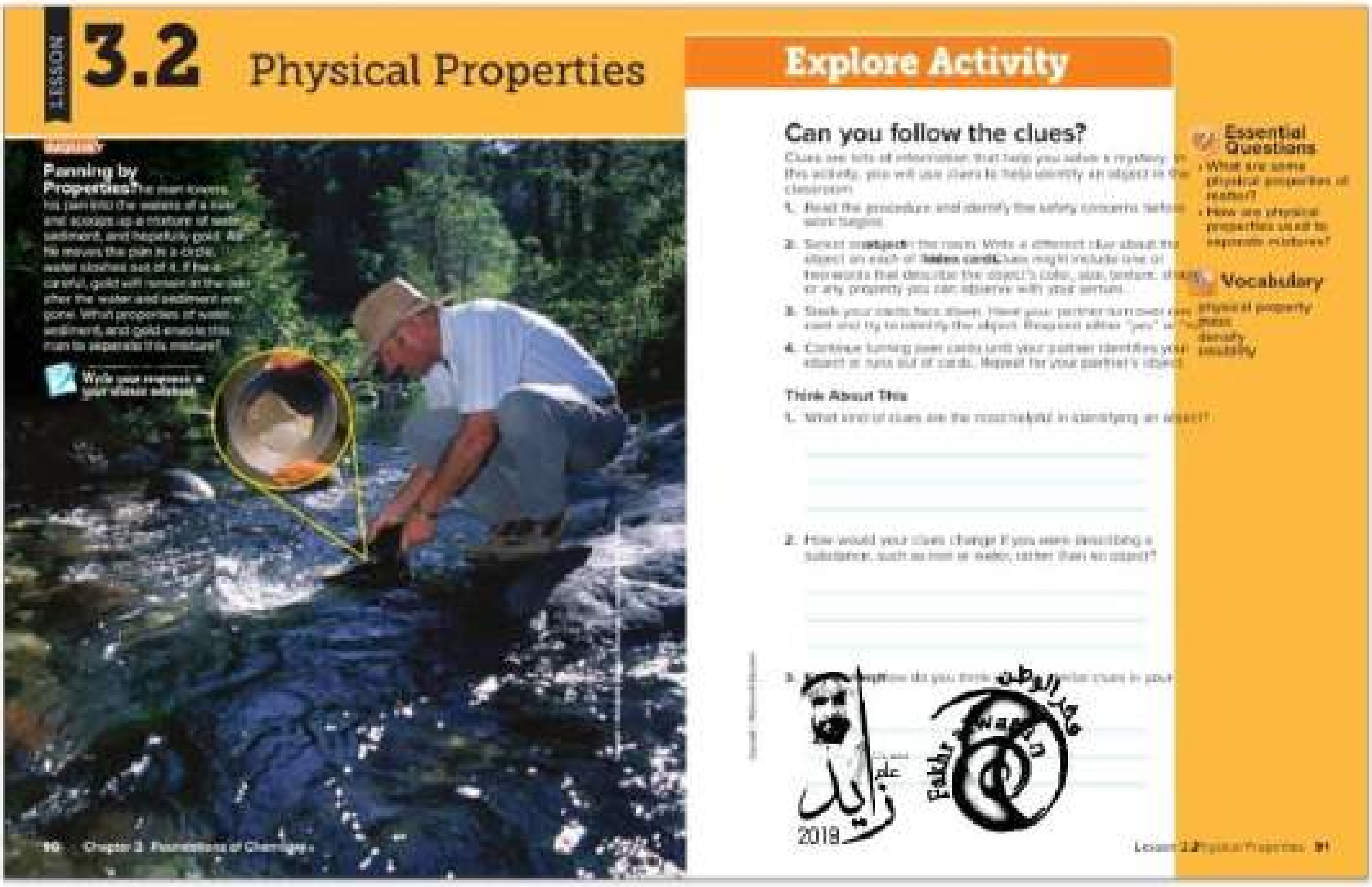
Teacher Toolbox

Real-World Science

Kinds of Steel Steel is not a substance, but a kind of mixture called an alloy, which is a solid solution of iron w about 2 percent carbon dissolved in it. The higher the carbon content, the lower the temperature required to m it. Other kinds of metal can also be dissolved in iron, su as chromium and tungsten, making different alloys with unique properties.

Careers in Science

Spectroscopist Microscopes are important in understanding the nature of matter, but they are especi important when trying to differentiate between a heterogeneous and homogeneous mixture in solids, su rock samples. A spectroscopist uses an electron micros to examine tiny portions of a sample to determine whet the substances in the mixture are mixed evenly or not.



INQUIRY

About the Photo **How does it move?** During the gold rush era of the 1800s, miners often searched for gold this way. They dipped pans into rivers and streams and sifted through the water for gold nuggets. The nuggets were heavier than sand and other materials that they scooped up in their pans, which made it easier to separate them.

Guiding Questions

AL How is gold different from water? How is gold different from rocks?	*Sample answer: Gold is a solid at room temperature while water is a liquid. Gold and rocks differ in color and texture.*
OL What is another method this miner might use to separate gold from river water?	*Sample answer: He could boil the water until it evaporates and only gold remains because gold has a different boiling point than water.*
OL How can you use the vocabulary terms learned in Lesson 1 to describe some of the matter in this photograph?	*Sample answers: water, sand, and gold are all matter made up of atoms; water is a compound; sand is a mixture; gold is an element; the sand and gold do not dissolve in the water.*
Do you think it would be possible to separate gold from a solid mixture such as the side of a cliff? Why or why not?	*Yes, but you might have to locate the gold by color or texture to distinguish it from the surrounding rock and then chip or chisel it out of the cliffside.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Thinking About Properties of Matter

1. Write the term *physical property* on chart paper or on the board.
2. Have students reflect about characteristics or qualities of matter that they have observed, such as color, size, shape, and textures.
3. Explain to students that the words characteristic and quality are often used synonymously with property.

4. Brainstorm with students a list of properties. Record their responses on the board.
5. After completing the lesson, have students reexamine the properties they listed earlier and identify which ones are physical properties.

Explore Activity

Can you follow the clues?

Prep *5 min* **Class** *15 min*

Purpose
To encourage observation of properties to recognize types of matter.

Materials
Students: index cards

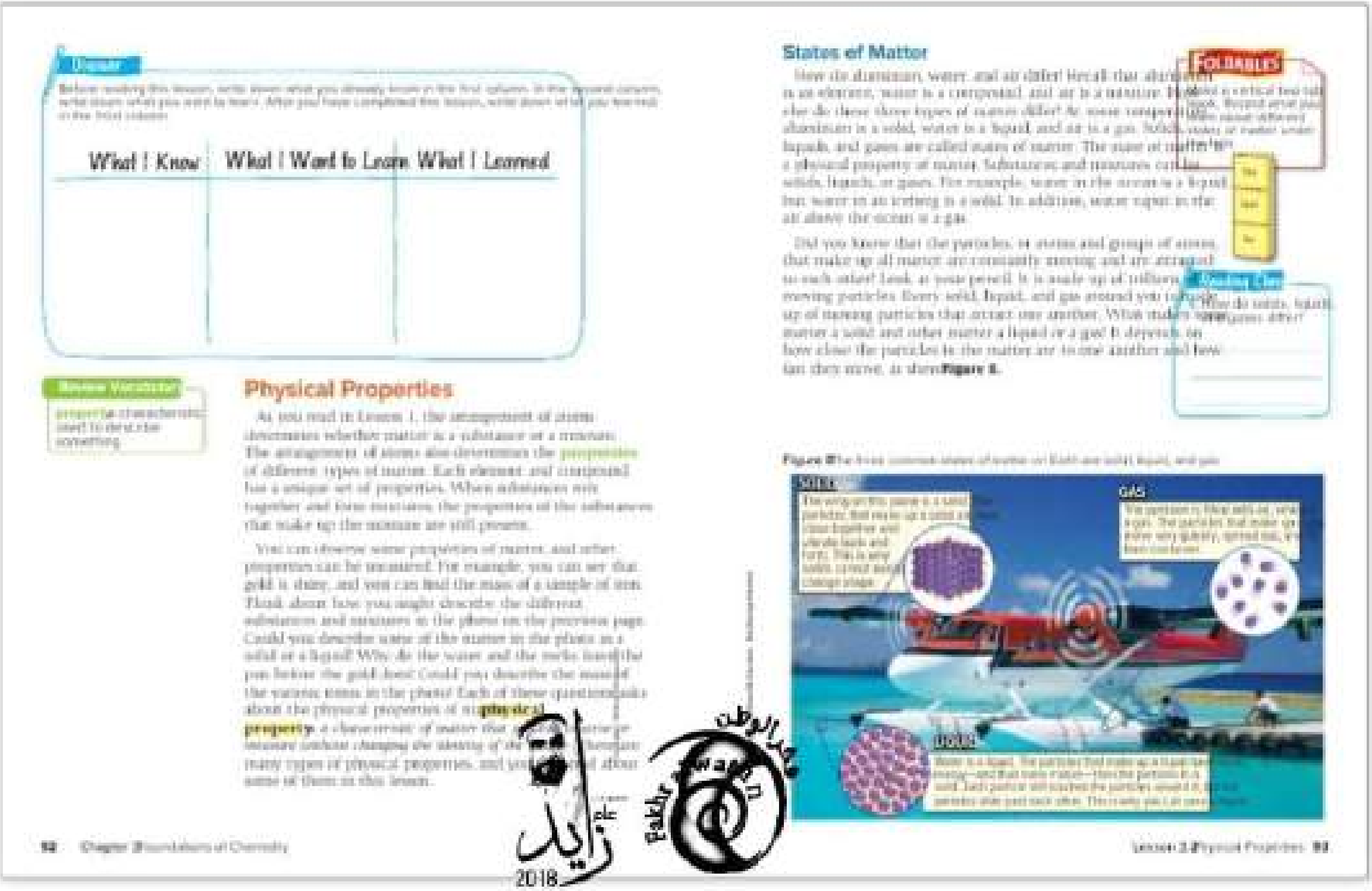
Before You Begin
Select an object in the room. Model the activity by giving one- or two-word clues that describe shape, color, physical dimensions, or texture.

Guide the Investigation
Tell students to write a set of clues that are neither too specific, such as "red" or "white," nor too general, such as "a solid."

Think About This

1. Sample answer: Clues that narrow the possibilities are the most helpful.
2. Students might realize it is easier to describe an object than a substance. An object has measurable properties, such as shape and size. Encourage them to think about properties that can be measured, such as boiling point or density.
3. **Key Concept** Sample answer: I use similar clues to recognize people, places, and things around me.

Teacher Notes



Physical Properties

To describe a physical property accurately, it must be observable or measurable. Students will recognize the importance of their senses, but they might not think about the role of measurement in describing a physical property.

Review Vocabulary

property

Explain that a characteristic is a unique trait. Rewrite the second sentence in the paragraph to read: *The arrangement of atoms also determines the unique traits of different types of matter.*

Ask: Which unique traits are physical properties? *volume, mass, density, color, velocity, shininess*

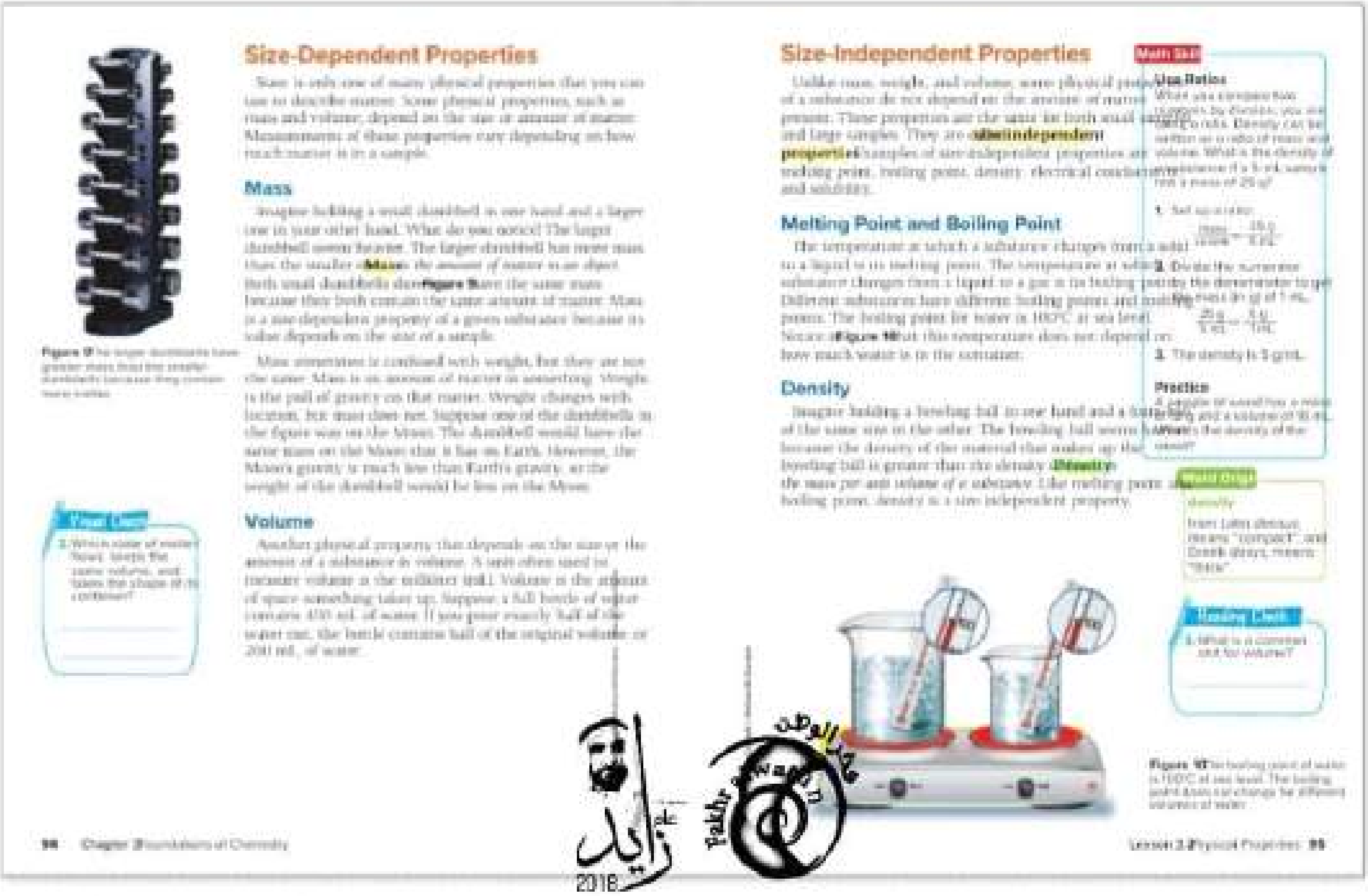
Ask: Besides mass, name one physical property that you would have to measure to describe. Explain your answer. *Possible answer: you could melt or boil a substance and use a thermometer to measure its melting point or boiling point.*

States of Matter

Have students read and study the image in **Figure 8**. Students likely have been exposed to states of matter previously, but they might not be aware of how the particles in matter behave in each state. Use the following questions to guide students through thinking about the states of matter..

Guiding Questions

AL	**Can a substance exist in more than one state of matter?**	*Yes. Water, for example, can exist as a solid (ice), a liquid (water), or a gas (water vapor).*
OL	**How do solids, liquids, and gases differ?**	*Solids, liquids, and gases differ in how close the particles are to each other and how fast the particles move (how much energy they have).*
BL	**How is the motion of particles in a book different from the motion of particles in the air around it?**	*The particles in a book are close together and vibrate slowly. The particles in the air are spread out and move more quickly.*



Size-Dependent Properties

The terms mass and weight are often confused. Explain that although mass and weight are related, they are two different measurements. Weight is dependent on gravity, while mass is not. Therefore, the weight of an object is different on the Moon than it is on Earth, but the mass does not change in either place. Have students read the paragraphs and study the **Figure 9**. Ask them to identify items in the classroom that have the greatest mass, such as the board, the desks, or a bookcase. Then use the following questions to help your students understand the concepts and to assess their comprehension.

Guiding Questions

AL **How does the mass of a person differ on Earth and on the Moon?**	*The mass of a person would be the same on Earth or on the Moon. Only the person's weight would change.*
OL **Does the mass of a solution increase if you add salt to it?**	*Yes; when the salt is added, the overall mass of the solution is the mass of the original solution plus the mass of the salt.*
BL **What happens to the mass of the water in a puddle when the water evaporates?**	*Each molecule of water has mass. The molecules still have the same mass. The only difference is that they are distributed over a wider area because the water molecules are now water vapor in the air.*

The volume of solids and liquids might be easier for students to understand because they are easier to measure and observe. A gas typically can't be seen and has no surfaces, it can be difficult to think of it as having a distinct volume. Help students think about volume by asking the following questions.

Guiding Questions

AL **Do you think it is possible for an object to have mass but not volume?**	*No. Even the lightest parts of an atom have volume.*
OL **What is a common unit for volume?**	*Sample answer: mL is a common unit for volume.*
BL **If a liquid shake is blended into foam, does its volume change? Does its mass change?**	*Yes, the volume changes because it takes up more space as foam than as a shake. However, the mass does not change because it still holds the same amount of matter, just spread out more.*

Engage | Explore | Explain | Elaborate | Evaluate

Size-Independent Properties (continued)

Have students read the paragraphs and study the image in **Figure 10**. To help them understand a little more about size- independent properties, show them an iron nail and some iron filings. Emphasize that both samples have the same density, and melt and boil at the same temperature, even though the size differs.

Guiding Questions

AL **If two objects have the same volume but one has more mass than the other, are the densities of the two objects the same or different?**	*The densities are different. Density is mass divided by volume. If volume stays the same and mass changes, density also changes.*
BL **If two objects have exactly the same melting points, are they the same substance?**	*Probably yes; point out that although such properties are unique to a substance, they might be close enough that the difference is difficult to distinguish.*

Word Origin

density

Have students compare the Greek and Latin origins of the word *density*.

Ask: **Which origin of the word *density* seems to relate to the scientific definition of the word, and why?** *The Latin origin of the word seems to relate to the scientific definition. Density is the mass per unit volume of a substance, which relates to how compact, or dense, a material is.*

Math Skill

Use Ratios

Remind students that ratios can help you compare quantities by dividing one number by another. For example, to find the density of a substance, you divide its mass by its volume. The fraction mass/volume is an example of a ratio.

Pressure and Area

Ask students to answer the practice question. Then have a student write the equation he or she used to solve the problem on chart paper or on the board. *0.75 g/mL*

Differentiated Instruction

AL **Investigating Density and Ice** Have pairs of students work together to use the density of ice and water to e[xplain] why fish can survive in a body of water when the temperature is below the freezing point of water. Explanations should include that the greater density o[f] water compared to that of ice allows for survival of aq[uatic] organisms.

BL **Investigating the Density of Ice and Water** [...] water that contains red food coloring. Then have pairs [of] students pour equal amounts of vegetable oil and wat[er into] a graduated cylinder. Ask each pair to place the ice on [the] surface of the oil (which should be the top layer) and observe the ice cube as it melts. Liquid water from the melting ice will fall through the oil to the water below. Discuss how the density changed as the ice melted.

LA **Investigating the Relationship of Mass and Volume** Have students use a graduated cylinder and a balance to measure different samples of water to show although mass and volume are size-dependent proper[ties], density is a size-independent property. **What is the density of 20 g of water? 30 g? 20 mL?** *Density of any quantity of water is always 1.0 g/mL.*

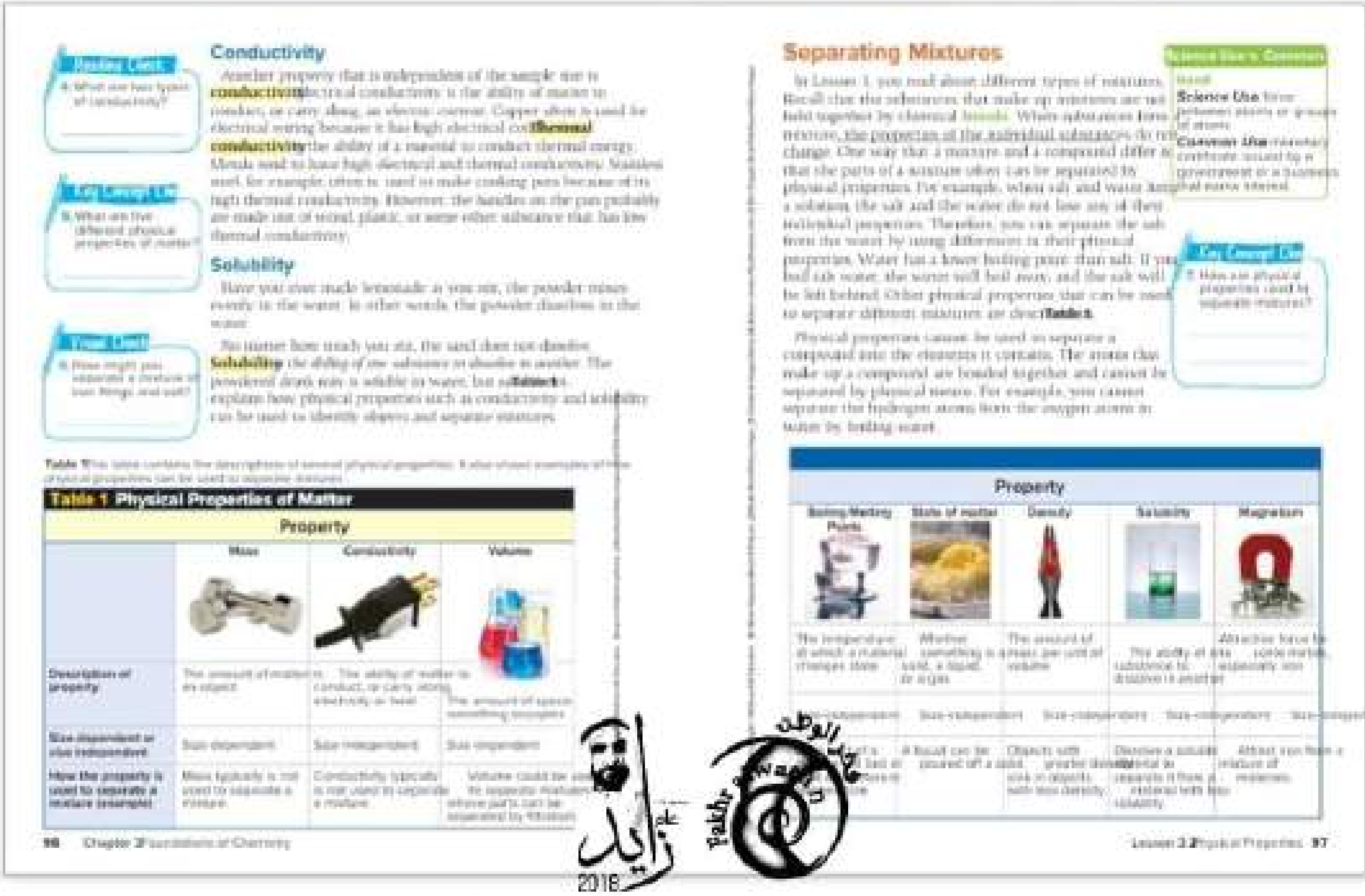
Teacher Toolbox

Teacher Demo

Ice and Water Fill a glass half full of water and place thr[ee] ice cubes in it so that they float. Have students predic[t] whether the water level will change once the ice melts. Allow the glass to sit until the ice melts. The water lev[el] should not change because the ice cube displaces the water to the same degree that the melted ice does. Ex[plain] to students that melting of icebergs or sea ice does n[ot] affect sea level because they are already displacing w[ater]. But melting of glaciers adds water and affects water le[vel].

Cultural Diversity

How the World Describes Mass Most countries use the metric system, with mass described in terms of kilogra[ms]. The Imperial System, which is used in the United State[s], England, Canada, and to a lesser extent, in Australia, I[ndia], Ireland, New Zealand, and South Africa, describes the weight of an object in pounds. The use of the pound r[eflects] the historical influence of Great Britain in this diverse s[et of] countries.


Conductivity

Solubility

Separating Mixtures

Table 1 Physical Properties of Matter

	Property		
	Mass	Conductivity	Volume
Description of property	The amount of matter in an object	The ability of matter to conduct, or carry along, electricity or heat	The amount of space something occupies
Size-dependent or size-independent	Size-dependent	Size-independent	Size-dependent
How the property is used to separate a mixture (example)	Mass typically is not used to separate a mixture.	Conductivity typically is not used to separate a mixture.	Volume could be used to separate mixtures whose parts can be separated by filtration.

Size-Independent Properties (continued)

Explain that conductivity involves the transfer of thermal and electrical energy. Some substances can conduct both types of energy well. Others are good conductors of just thermal energy or just electrical energy, while others are not good conductors of either type of energy. Explain that all metals are good conductors.

Visual Literacy: Physical Properties of Matter

Ask students to examine the first three columns of **Table 1**. Explain that organizing properties into a table can help you compare and contrast them. Ask students to name a property in the first three columns that is not size-dependent. *conductivity*

Ask: **Which property involves the movement of energy?** *conductivity*

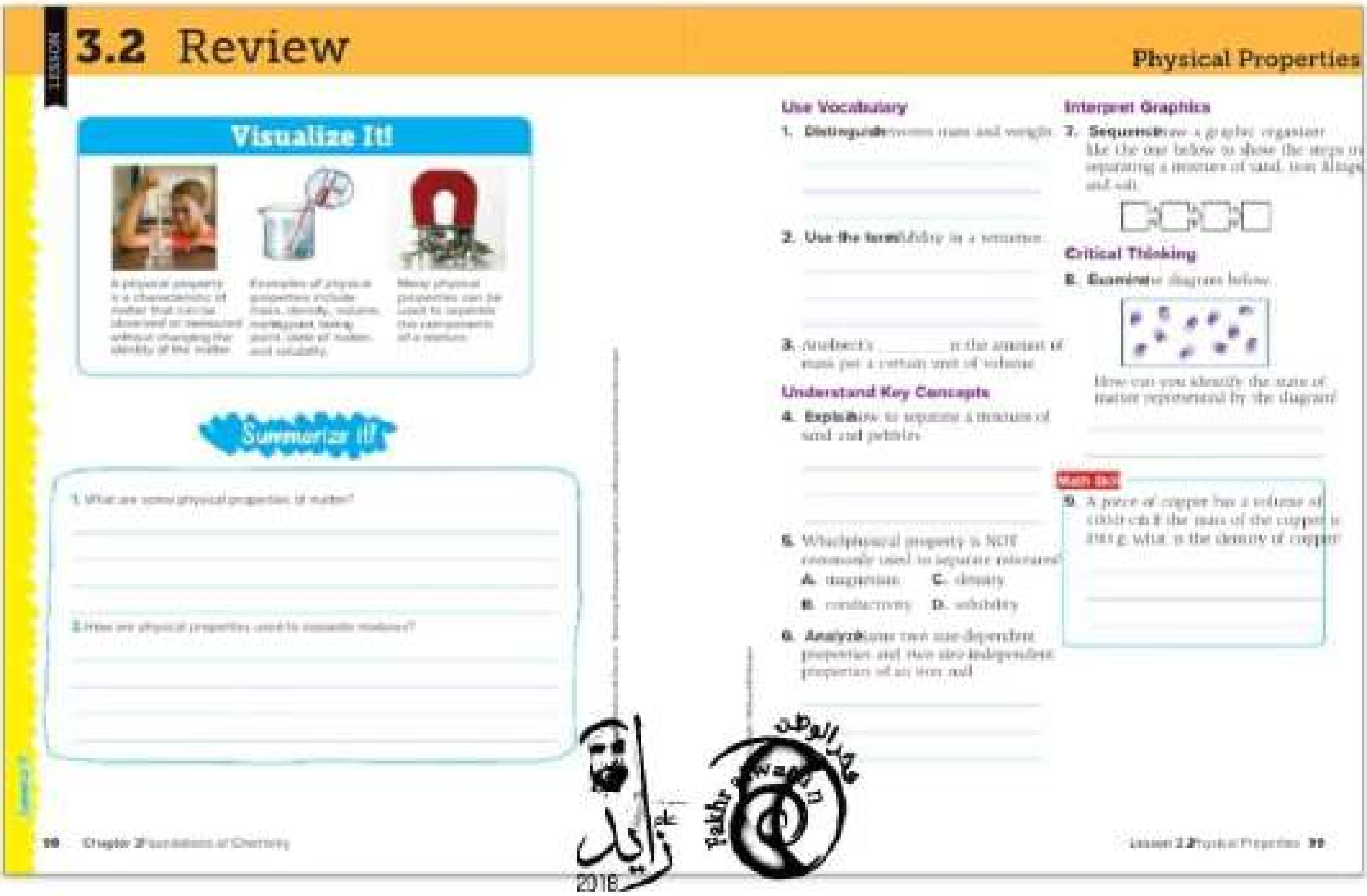
Ask: **Why use mass, rather than weight, to identify matter?** *independent of gravity and does not change.*

Size-Independent Properties

Have students read about solubility. Tell them that there is a definition of solubility that states that if one substance will dissolve in another substance, it is soluble. Solubility is also the maximum amount of a substance that will dissolve in a certain volume of another substance at a specific temperature. Ask students the following questions to assess their understanding of these concepts.

Guiding Questions

BL What is an example of a metal with high conductivity?	*Sample answer: copper*
OL What are two types of conductivity?	*Two types of conductivity are thermal and electrical.*
OL What are five different physical properties of matter?	*Sample answer: color, shape, density, melting point, electrical conductivity*
AL Which of these properties describes how one substance dissolves into another substance— conductivity, solubility, size, mass, or density?	*Solubility is the one property that describes how the substance dissolves into another substance.*


LESSON 3.2 Review

Physical Properties

Visualize It!

A physical property is a characteristic of matter that can be observed or measured without changing the identity of the matter.

Examples of physical properties include mass, density, volume, melting point, boiling point, state of matter, and solubility.

Many physical properties can be used to separate the components of a mixture.

Summarize It!

1. What are some physical properties of matter?

2. How are physical properties used to separate mixtures?

Use Vocabulary

1. Distinguish between mass and weight.

2. Use the term solubility in a sentence.

3. Archimedes' ______ is the amount of mass per a certain unit of volume.

Understand Key Concepts

4. Explain how to separate a mixture of sand and pebbles.

5. Which physical property is NOT commonly used to separate mixtures?

A. magnetism C. density

B. conductivity D. solubility

6. Analyze some two size-dependent properties and two size-independent properties of an iron nail.

Interpret Graphics

7. Sequence Draw a graphic organizer like the one below to show the steps in separating a mixture of sand, iron filings, and salt.

Critical Thinking

8. Examine the diagram below.

How can you identify the state of matter represented by the diagram?

Math Skills

9. A piece of copper has a volume of 100.0 cm³. If the mass of the copper is 893 g, what is the density of copper?

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Lesson 3.2 Physical Properties 99

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **To which Key Concept does each image relate?**

Summarize it!

Answers may vary. The information needed to complete this graphic organizer can be found in the following sections:

- Physical Properties

Use Vocabulary

1. Mass is the amount of matter in an object. Weight is the effect of gravity on mass.

2. Sample answer: The solubility of sand is low because sand does not seem to dissolve in water.

3. density

Understand Key Concepts

4. Pour the mixture through a large-holed strainer. The sand will flow through the strainer, but the pebbles will not.

5. B. conductivity

6. Sample answer: Size-dependent: mass, volume; size-independent: density, melting point

Interpret Graphics

7. Sample answer: (1) Use a magnet to remove the iron filings. (2) Stir the sand and salt into water to dissolve the salt. (3) Filter out the sand. (4) Boil the water, leaving behind the salt.

Critical Thinking

8. The matter is a gas because the particles are far apart from each other.

Math Skill

9. The density of copper is 8.90 g/cm^3.

Intervention Planner

Based on the results of the Lesson Review, use the chart below to address individual needs.

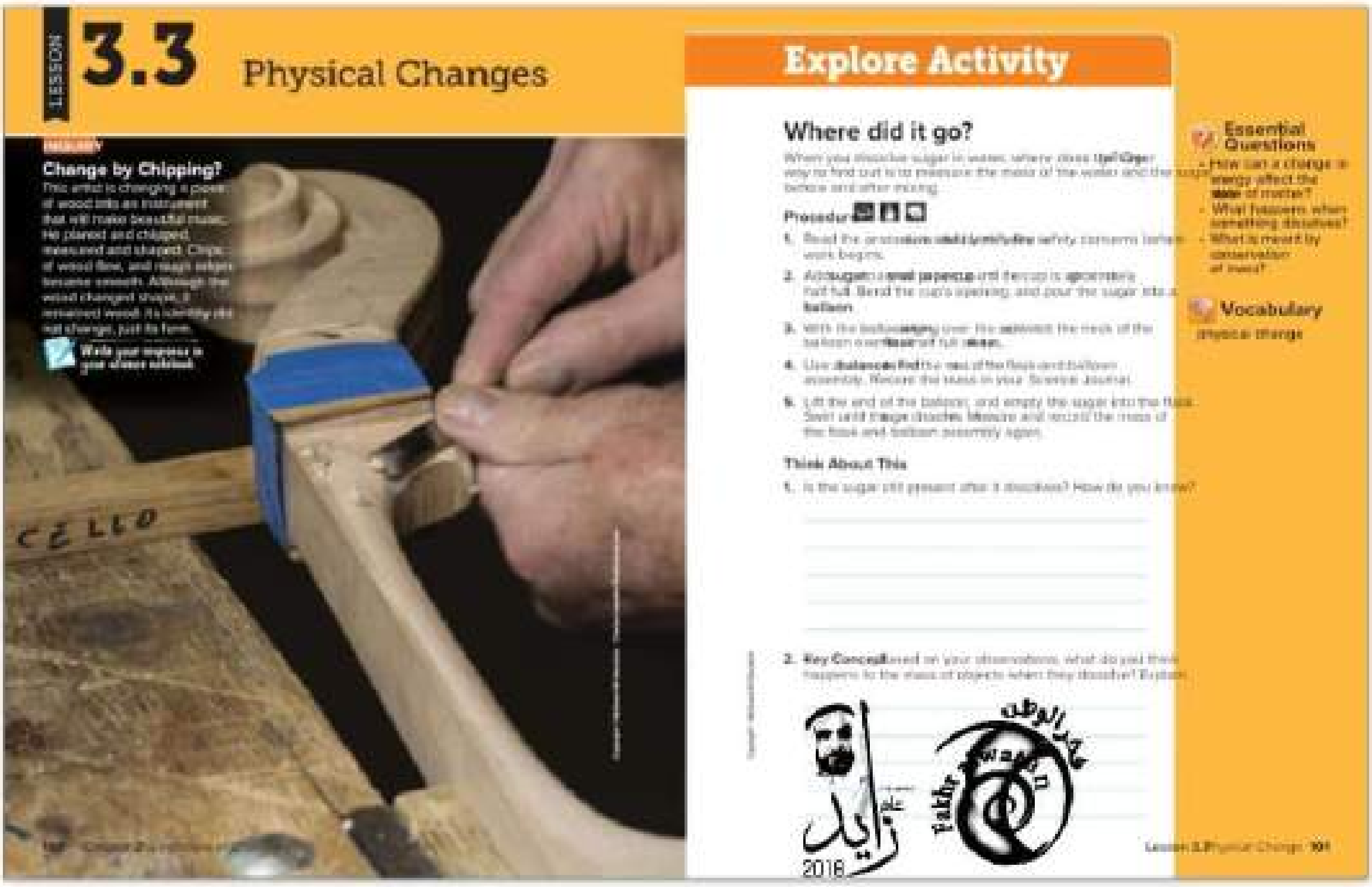
Use Vocabulary (1–3)
- TE Word Origins, Density
- DF Content Vocabulary

Understand Key Concepts (4–6)
- TE Visual Literacy: Physical Properties of Matter
- DF Key Concepts Builder

Interpret Graphics (7)
- TE Guiding Questions, Separating Mixtures

Critical Thinking (8)
- TE Visual Literacy: Solids, Liquids, and Gases
- DF Enrichment
  Challenge

Math Skills (9)
- TE Guiding Questions, Size-Independent Properties
- DF Math Skills
  Challenge
- Math Practice: Use Ratios



INQUIRY

About the Photo Change by Chipping? This photo shows an artist using a chisel to sculpt an instrument out of a piece of wood. When he is finished working, he will have made a violin. Although the shape of the wood changes, it is still wood and its properties remain the same.

Guiding Questions

AL **How would creating a picture frame from the wood differ from creating an instrument? Would it still be wood?** *It would have a different size, shape, and use, but it would still be wood.*

OL **What other changes could the artist make to the wood without changing the wood into something else?** *Sample answers: paint it, make it smaller, make other changes to its shape*

BL **Will the instrument the artist creates have the same density as wood? Why or why not?** *Yes; it is still wood and retains all of wood's properties, including its density.*

LABManager

All the labs for this lesson are indicated at point of use. Labs can be found in the Lab Manual.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Build a Class Thesaurus

1. Write the words *physical* and *change* in the middle of the board, separate from one another.
2. **Ask: What words are synonymous with *physical*?** *Sample answers:* tangible, material, concrete, natural, objective, real, visible
3. **Ask: What words are synonymous with *change*?** *Sample* answers: adjustment, alteration, conversion, difference, distortion, metamorphosis, modification, replacement, shift, substitution, transformation, and transition
4. Have students brainstorm a definition of *physical change* based on the synonyms they name. Make a record of the list and definition, and revisit them at the end of the lesson.

Explore Activity

Where did it go?

Prep 5 *min* **Class** 20 *min*

Purpose
To observe the conservation of mass during a physical change.

Materials
Student Team of 3 to 4: balance, small paper cup, sugar, round balloon, 125-mL flask (or small plastic water bottle), water

Before You Begin
To save time, prepare 10 g of sugar in the paper cup for each team. Introduce the activity by asking students what happens to sugar when it dissolves in water. Have them explain their reasoning and predict whether the mass will change.

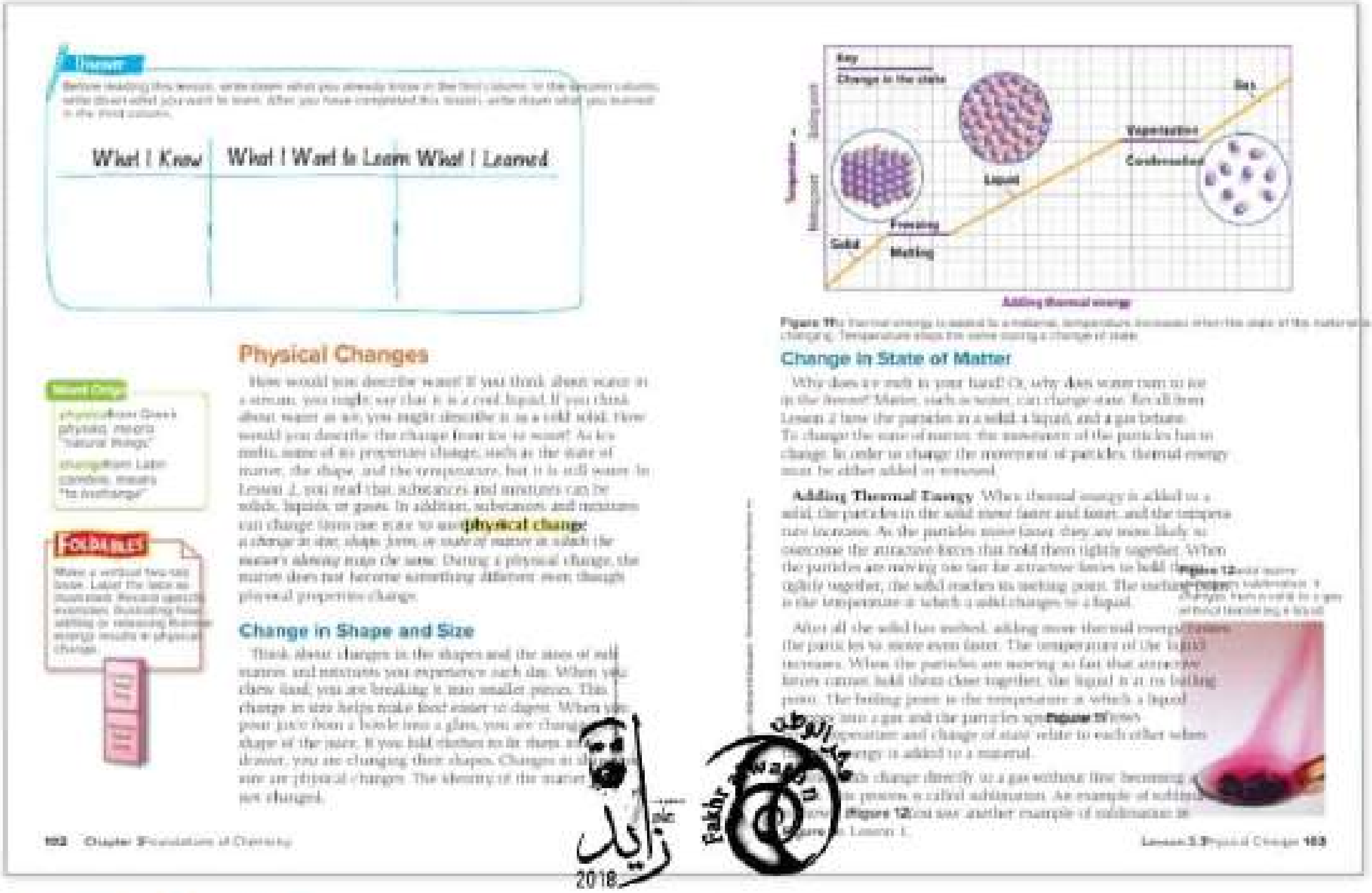
Guide the Investigation

- Suggest that one team member hold the flask and a second hold the balloon as the third team member stretches the neck of the balloon over the flask. Remind students to keep the balloon down at the side of the flask so that the sugar doesn't enter the water before step 5.
- **Troubleshooting** If the mass changes even the smallest amount, students might say it changed. Emphasize precision and accuracy; have them mass a clean flask in the middle and again at the sides of the pan.

Think About This
Students might not know the answers to all questions. Encourage them to hypothesize.

1. Students might say that the sugar is still present because sugar water tastes sweet like sugar, and the mass doesn't change.
2. When matter undergoes a physical change, such as dissolving or changing state, its mass stays the same because the same amount of matter is still present.

Teacher Notes



Physical Changes

After students read the paragraph, ask them to provide examples of physical changes: a change in shape, size, form, or state.

Word Origin

physical change

Note for students that the definition in the text is similar to changing the nature of matter, the idea behind the word origin.

Change in Shape and Size

Help students apply the idea of physically changing the shape and size of matter. Ask them to explain how the shape and size of the wood in the photo opener changed (wood pieces are being cut and reshaped), and how chopped food changes (when you chop you break up food into smaller pieces).

Change in State of Matter

Students are familiar with objects becoming hot, but they are not as likely to have thought about why they are hot. Reinforce the particle view of matter and ensure that students understand that thermal energy affects the motion of the particles in a substance. Have students read the paragraphs on this page and study **Figures 11 and 12**. Then use the following questions to help guide the students into a deeper understanding of these concepts.

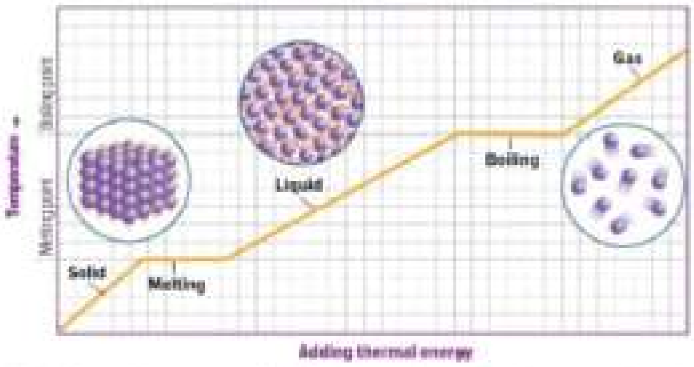
Guiding Questions

OL **What physical property identifies the temperature at which the attraction between particles in a substance becomes less, which allows particles to slide past each other?** *melting point*

BL **What kinds of forces must a particle in a liquid overcome in order to become a gas?** *Particles must gain enough thermal energy to overcome the attractive forces between them and spread out from one another.*

Visual Literacy: Changing States

The diagram shows **Figure 11** shows how a substance changes as thermal energy is added. Ask the following questions to assess students' understanding.



Ask: How do the particles in the substance change when it reaches its melting point? *The particles begin to move faster and slide by each other.*

Ask: How would the diagram look if the graph showed the effect of removing thermal energy instead? *The graph would be in reverse. It would begin with a gas that changes to a liquid and then to a solid, and it would show the condensing and freezing points instead of the boiling and melting points.*

Change in State of Matter (continued)

Have students read the paragraphs and examine **Figure 12**. Have students identify the water shown in each image and describe its current state. Explain that the ability of a substance to change state can provide a number of benefits, some of which might not be obvious. For example, soup can be turned from a liquid into a powder by evaporating the water within it. The resulting powder can be shipped in small packets instead of cans .

Guiding Questions

AL How does the freezing point of a substance compare to the melting point?	*It is the same. A substance freezes from a liquid to a solid at the same temperature that it melts from a solid to a liquid.*
OL How can removing thermal energy affect the state of matter?	*Decreasing thermal energy can change a liquid to a solid or a gas to a liquid. For some substances, it can change a gas directly to a solid.*
BL Describe how the movement of particles in water vapor changes when enough thermal energy is removed to cause deposition.	*The speed of the particles decreases and they slow down to the point that they only vibrate back and forth.*

Differentiated Instruction

AL **Create a Graph** After students have completed the following **Melting Points of Similar Materials** activity, have this group of students use the data to create a bar graph of their results. Ask them to explain how the difference in melting points might affect how each item is used.

BL **Melting Points of Similar Materials** Have students work in pairs to find the melting points of several similar materials, such as butter, margarine, solid vegetable shortening, and coconut oil. Then ask them to create a graph of their results. Have them work together with the **Create a Graph** group to make a class presentation of the results.

LA **Words Related to Change** Have students work in pairs to generate flash cards of words that describe the various changes that they have learned about with other students.

Teacher Toolbox

Fun Fact

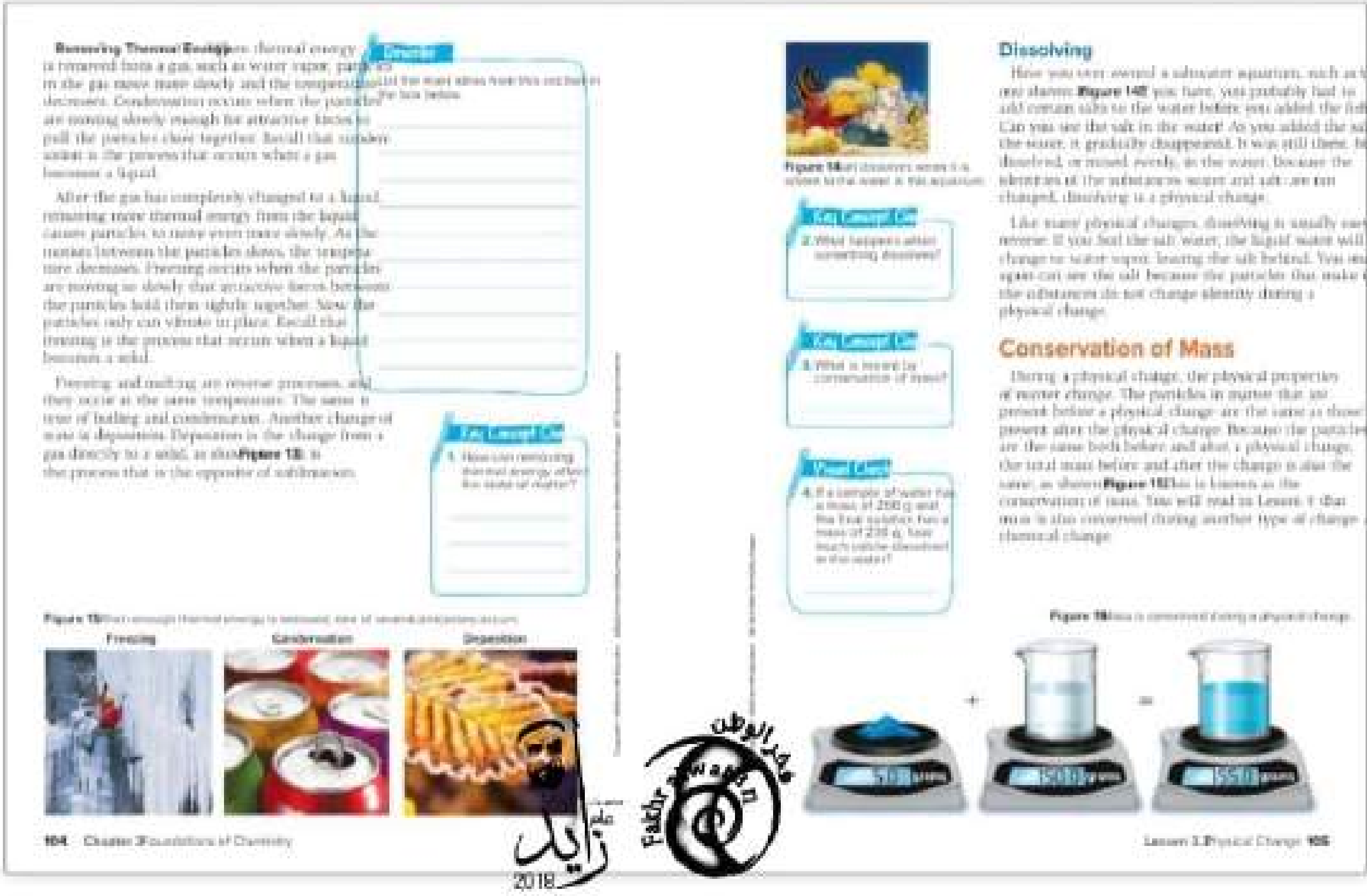
Ethanol Since ethanol has been chosen as a supplement to oil-based fuel, there has been a large increase in ethanol production. Ethanol is separated from water by distillation, made possible because the boiling point of ethanol is 78°C, whereas water is 100°C.

Reading Strategy

Summarize Have students summarize the ways that matter can change state using bullet points in **Changes in State of Matter**. Bullet points are an efficient way to summarize topics and supporting details.

Real-World Science

Companies that ship food long distances can use dry ice. Dry ice is another name for frozen carbon dioxide. In its solid state, dry ice has two properties that make it better for shipping than frozen water. As a solid, its surface temperature is extremely cold, -78.5 Celsius; when it changes state, it does not melt into a liquid but rather sublimates, changing directly into a gas. Melting frozen water would make a liquid mess. Dry ice leaves no mess at all.


Dissolving
Conservation of Mass
Freezing
Condensation
Deposition
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Lesson 3.2 Physical Change 105

Dissolving

Remind students that when a substance dissolves, its particles evenly disperse throughout a solution. Then have them read the paragraphs and study **Figure 14**. Ask the following questions to assess your students' understanding.

Guiding Questions

AL **Why is dissolving an example of a physical change?**	*The identities of the substances don't change; they are just mixed together.*
OL **What happens when something dissolves?**	*One substance breaks into small particles that mix evenly throughout another substance.*
BL **What is one way to separate a substance that is dissolved in water?**	*If the boiling point of the substance is higher than 100°C, you can boil off the water and the substance remains. If the boiling point is lower than 100°C, add thermal energy to the solution and collect any gases that leave the solution.*

Conservation of Mass

Have students read the paragraph. Explain to students that if an ice cube melts into liquid water, its state, shape, and volume change but its mass remains the same. The amount of water in the liquid is the same as in the solid because the same number of particles is present in both.

Visual Literacy: Conservation of Mass

Have students examine **Figure 15**. Ask them to identify the mass of the two substances on the left and the mass of the combined substances in the solution on the right.

> **Ask:** **How is mass conserved when making a solution?** *The mass of the solution equals the total mass of all the substances in the solution.*

Ask: **If a sample of water has a mass of 200 g and the final solution has a mass of 230 g, how much solute dissolved in the water?** *30 g of solute dissolved.*

Ask: **What is meant by conservation of mass?** *Mass is conserved because it remains the same after a change, such as a physical change.*

Intervention Plann

Based on the results of the Lesson Review, use the cha below to address individual needs.

Use Vocabulary (1)

- Word Origin, Physical Changes
- Content Vocabulary

Understand Key Concepts (2–4)

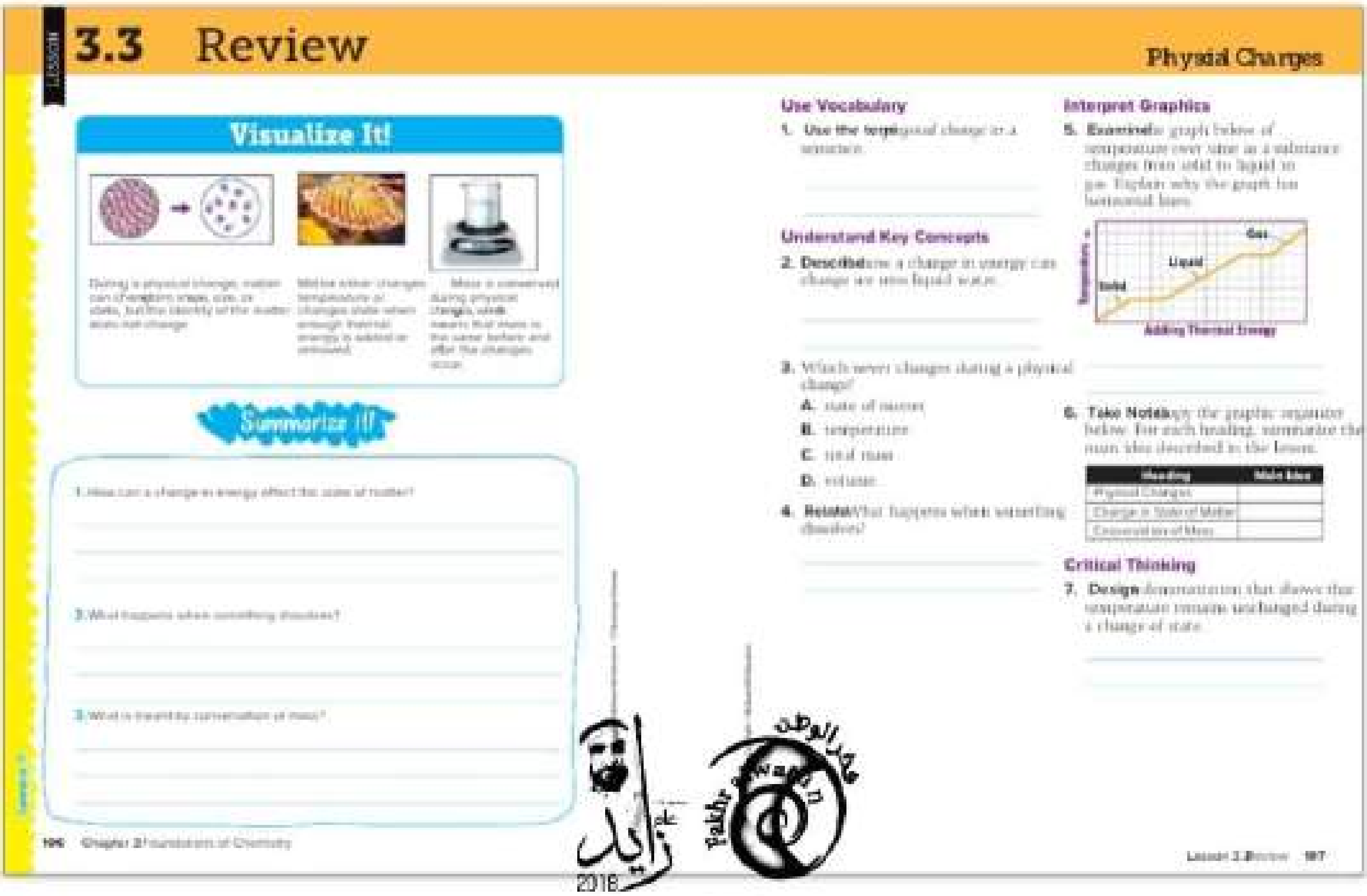
- Guiding Questions, Dissolving
- Key Concepts Builder

Interpret Graphics (8–9)

- Visual Literacy: Changing States

Critical Thinking (7)

- Visual Literacy: Changing States
- Enrichment
  Challenge


LESSON 3.3 Review

Physical Changes

Visualize It!

Summarize It!

1. How can a change in energy affect the state of matter?

2. What happens when something dissolves?

3. What is meant by conservation of mass?

Use Vocabulary

1. Use the term physical change in a sentence.

Understand Key Concepts

2. Describe how a change in energy can change ice into liquid water.

3. Which never changes during a physical change?

A. state of matter

B. temperature

C. total mass

D. volume

4. Relate What happens when something dissolves?

Interpret Graphics

5. Examine the graph below of temperature over time as a substance changes from solid to liquid to gas. Explain why the graph has horizontal lines.

6. Take Notes Copy the graphic organizer below. For each heading, summarize the main idea described in the lesson.

Heading	Main Idea
Physical Changes	
Change in State of Matter	
Conservation of Mass	

Critical Thinking

7. Design a demonstration that shows that temperature remains unchanged during a change of state.

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Lesson 3.3 Review 107

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: To which Key Concept does each image relate?**

Summarize it!

- Physical Changes
- Conservation of Mass

Use Vocabulary

1. Sample answer: A change in the state of matter is an example of a physical change.

Understand Key Concepts

2. When you heat ice, the energy of its particles increases, and the temperature of the ice increases. When it reaches its melting point, increasing thermal energy further causes the ice to melt.

3. C. total mass

4. When something dissolves, one substance mixes evenly in another substance.

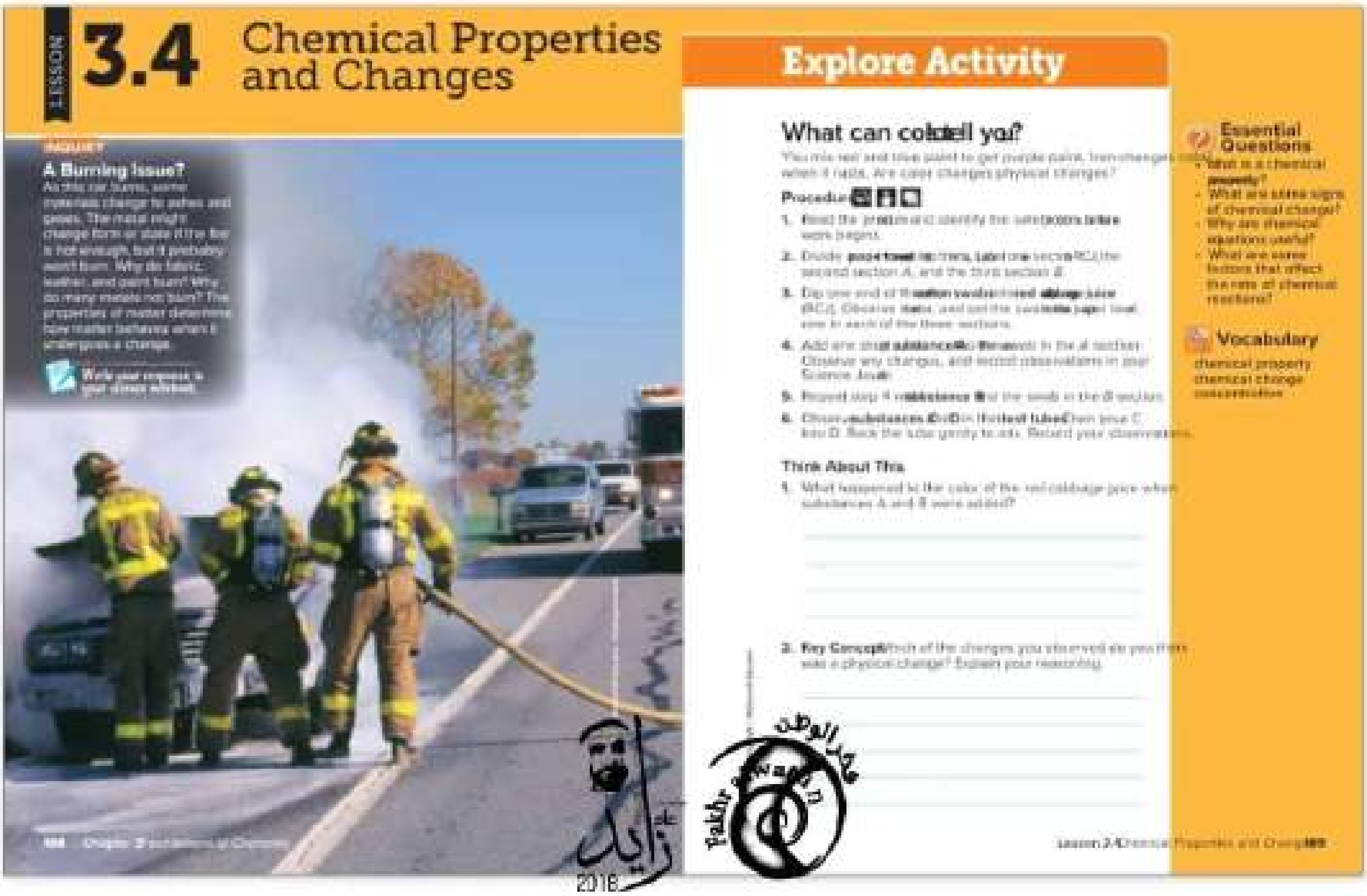
Interpret Graphics

5. The horizontal lines indicate that the temperature of a substance does not change during a change of state.

6. Sample answers: Physical Changes: A physical change is a change in matter in which the identity of the matter stays the same. Change in State of Matter: Changing energy can change the state of matter. Conservation of Mass: Mass is conserved during physical changes.

Critical Thinking

7. Sample answer: You could measure the temperature of ice water as you heat it and it changes from ice to liquid water to water vapor.



INQUIRY

About the Photo A Burning Issue? This firefighter is extinguishing a burning car. The ability to burn is a chemical property. Some materials burn easily, while others do not. But regardless of how quickly a material burns, it always undergoes a chemical change in the process.

Guiding Questions

Level	Question	Answer
AL	**Why do you think metal is often used to make screens for fireplaces?**	*Most metal does not burn or melt at temperatures reached in fireplaces.*
OL	**How has the metal in this car changed? How is it the same?**	*Its color, shape, and texture have changed. It is still metal.*
BL	**What materials in the car are now entirely different materials than those in the original car? What do you think caused this change?**	*Sample answer: Anything that was fabric, leather, or plastic is now composed of different materials. Changes caused by the fire caused the materials to change identity.*

LABManager

All the labs for this lesson can be found in the *Student Lab Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Properties v. Changes

1. Discuss with students the differences between properties of matter and changes in matter.
2. Ask: **What physical properties of a substance are related to the potential for the substance to undergo physical change?** TIP If students have difficulty with this concept, begin by listing physical properties and ask students to think about the physical change that is associated with that property. *Sample answers: state of matter, because it relates to a substance changing states; melting point and boiling point, because they also relate to a substance changing states; solubility, because it relates to a substance dissolving and becoming part of a solution*
3. Based on their responses, have students speculate about the possible connections between a chemical property and a chemical change.

Explore Activity

What can colors tell you?

Prep *5 min* **Class** *15 min*

Purpose
To observe that not all color changes are physical changes.

Materials
Student Team paper towels, beaker, cotton swabs, 2 dropper bottles labeled A and B, 1 mL white vinegar, 1 mL of water with ammonia, test tubes labeled C and D, 5 mL water with yellow food coloring, 5 mL water with blue food coloring, 3 mL of red cabbage juice in test tube labeled *RCJ*

Before You Begin
Prepare the red cabbage indicator by gently boiling grated red cabbage in enough water to cover for 20 min. Strain the liquid into a clean container. Provide each team with 2–3 mL of the juice in a small test tube.

Guide the Investigation
Encourage students to suggest color changes that they observe in nature.

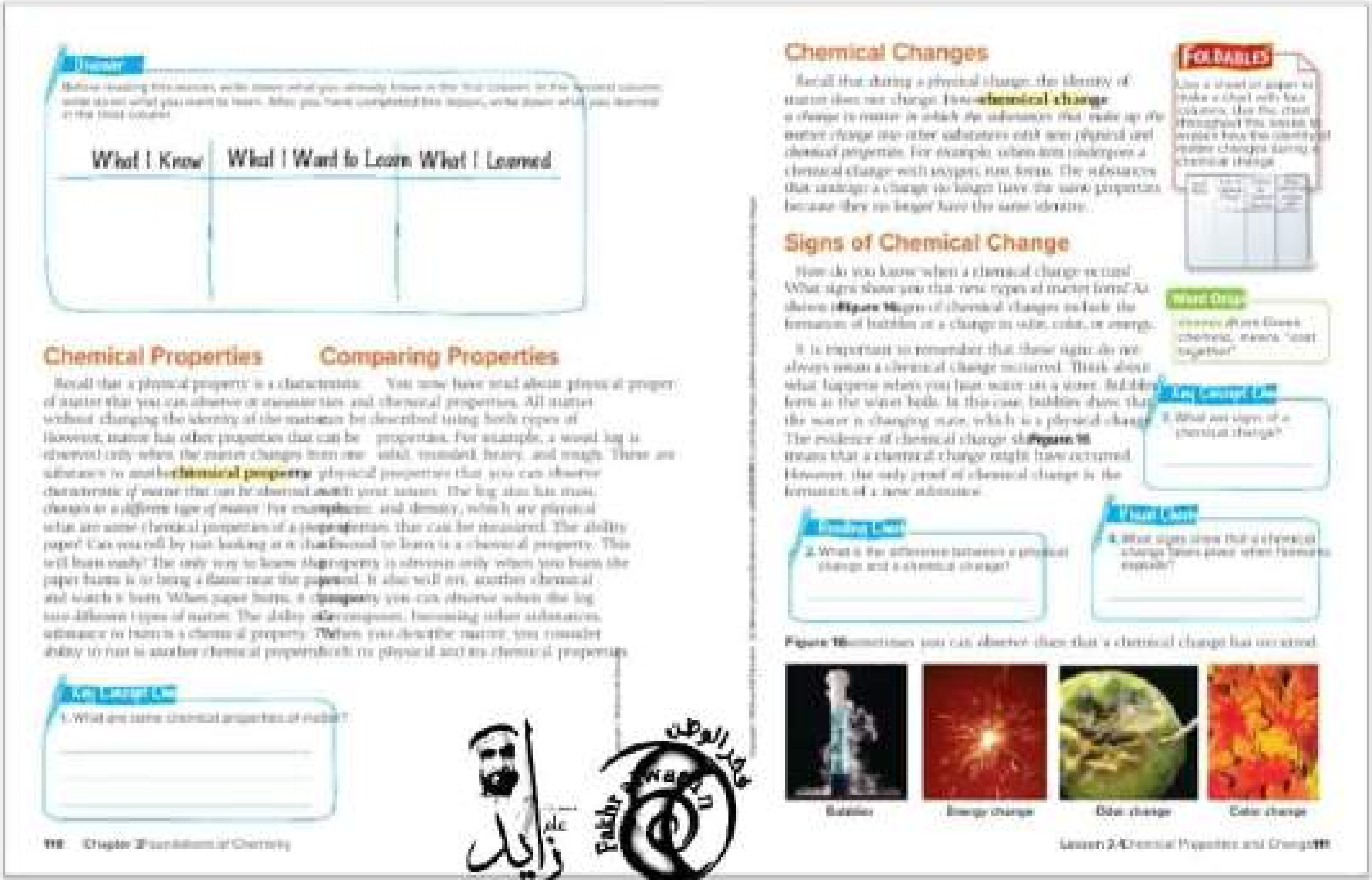
Think About This

Students might hypothesize.

1. The juice turned from purple to pink with Substance A and from purple to blue with Substance B.

2. **Key Concept** Students might say that mixing the food coloring was a physical change because they were both colored in the first place and the colors just mixed. Substances A and B were colorless, but the colors still changed.

Teacher Notes



Chemical Properties

Substances are able to undergo a wide range of chemical changes. Knowing the chemical properties of a substance can be helpful if you are trying to cause a change or avoid an unwanted change.

Comparing Properties

Discuss the following questions to help students review and distinguish between physical and chemical properties .

Guiding Questions

OL **What are some chemical properties of matter?**	*Sample answer: ability to burn, ability to rust, ability to rot*
BL **How could you determine whether substance has the ability to rust?**	*Sample answer: Determine if it is made of substances that rust, or test it by getting it wet and exposing it to air, and then observe what happens over time.*

Chemical Changes

To help students visualize how a chemical change impacts physical properties, encourage them to focus on the atoms in the substances involved. As each substance undergoes a change, th atoms rearrange into different combinations. Chemical changes create new substances with their own physical properties. Use th following questions to assess your students' understanding of thi concept.

Guiding Questions

AL **How does rust form?**	*A chemical change occurs between iron and oxygen.*
OL **What is the difference between a physical change and a chemical change?**	*During a physical change, no new substance forms. During a chemical change, new substances form.*

Signs of Chemical Change

Explain to students that to understand what happens during a chemical change, it is necessary to describe each substance at th beginning and at the end of the change, and then determine what happened during the process.

For example, a fresh apple has a certain color and odor. But shortl after the apple is cut, a chemical change occurs as the apple reac with oxygen. As a result, the color of the fruit darkens, and its odo changes.

To help students consider the signs of chemical change, have them read the paragraphs, study **Figure 16**, and compare the different signs. Then ask the following questions.

Guiding Questions

AL Does the formation of bubbles always indicate a chemical change?	*No, because bubbles form when water boils, which is a physical change, not a chemical change.*
OL What are signs of a chemical change?	*Sample answer: formation of bubbles, energy change, change in color or odor*
OL What signs show that a chemical change takes place when fireworks explode?	*Sample answer: There is an energy change when light and thermal energy are released.*
BL Do you think a chemical change occurs when you bake cookies? Why or why not?	*Yes, because the physical properties of the ingredients used to bake the cookies change as they cook in the oven. The dough changes color and odor, and new products form.*

Word Origin

chemical

Have students read the Greek origin of chemical, then ask the following questions.

Ask: **Is the word *chemical* a verb or an adjective?** *adjective* **Is the Greek origin of *chemical* a descriptive term or an action?** *It is an action.*

Ask: **How do you think the action in the Greek origin relates to the way we use the word chemical today?** *Sample answer: During a chemical reaction, substances are "cast together," which causes a chemical change. The action leads to a change that can be described with the adjective chemical.*

Differentiated Instruction

AL **Create a Change and Property Grid** Have pairs of students work together to prepare a grid with two colu (physical and chemical) and two rows (properties and changes). In each box, instruct students to write appro terms that correspond to that cell. (For example, *meltin point* would be placed in the cell for physical propertie

BL **Everyday Chemical Changes** Have students identify two or three chemical changes that occur in their classrooms, homes, or neighborhoods. Have them res these changes to learn more about them. Then have students discuss what they learned as a group and cre flowchart of the changes to the substances involved fr the beginning to the end of each kind of change.

LA **Physical Change or Chemical Change?** Write a list of physical changes, such as freezing, dissolving, and cha in shape and size, and a list of chemical changes, such burning, rotting, and rusting. Then have the class divid groups and play a speed game of Physical or Chemica Change? Call out one of the changes from the lists an students to identify it as physical or chemical.

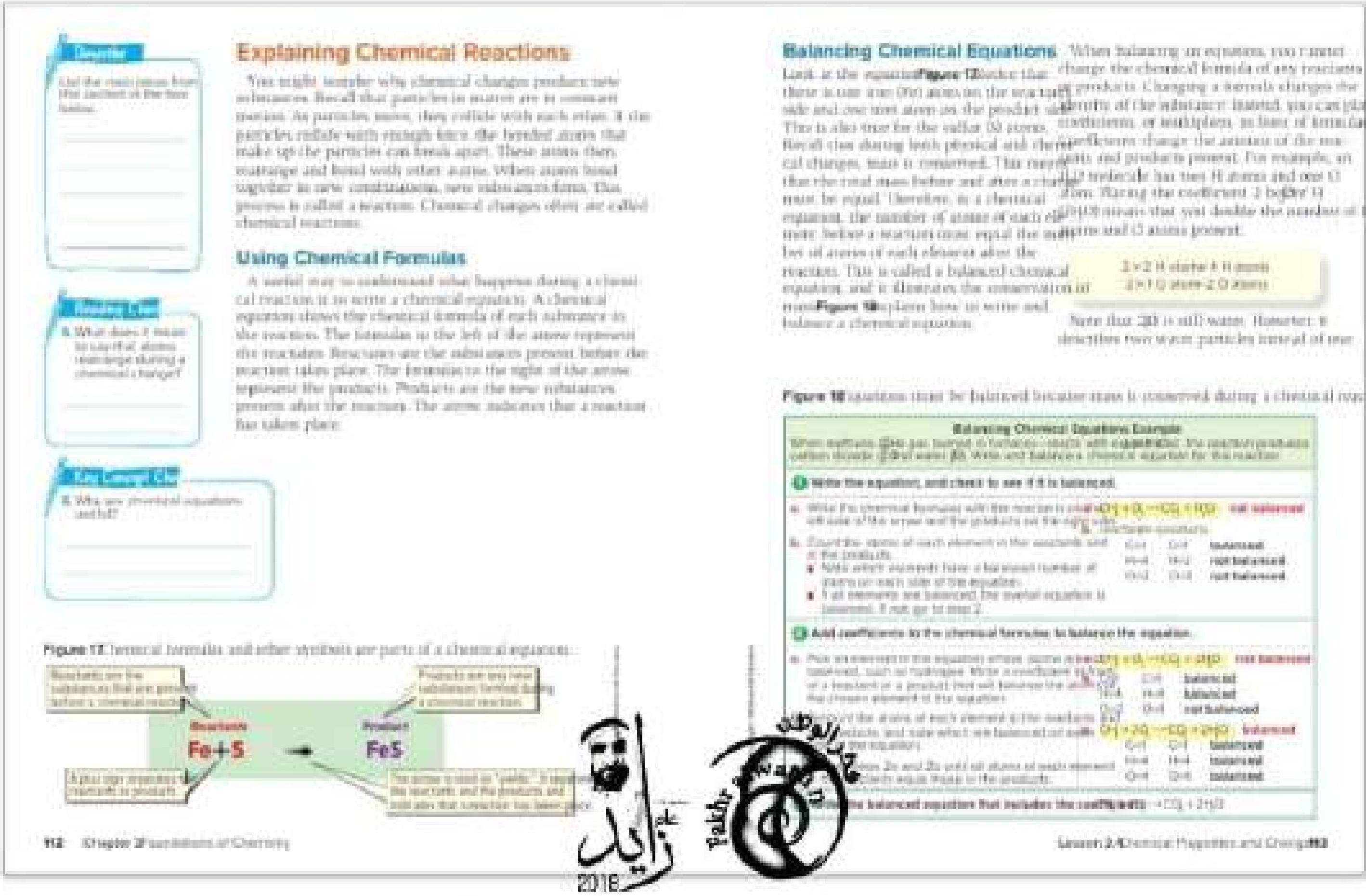
Teacher Toolbox

Fun Fact

Explosive! Nitroglycerin is a compound that is highly unstable under certain conditions. It can be explosive, is why it is used as a component in dynamite. When it undergoes a chemical change during an explosion, it produces carbon dioxide, water, nitrogen, and oxygen gases.

Teacher Demo

Cleaning a 1-fils coin? Obtain some old 1-fils coins and ac them to a beaker of vinegar for a few minutes. Ask stu to predict what will happen. Then carefully remove the with tongs and place them onto a paper towel to dry. I students observe that each coin appears cleaner. Expl that the acid in the vinegar reacts with the tarnish on t outside and removes it, exposing the shiny copper lay



Explaining Chemical Reactions

Using Chemical Formulas

A chemical change involves bond-breaking and bond-making.

Guiding Questions

OL What does it mean to say that atoms rearrange during a chemical change?	*The same atoms are present before and after a chemical reaction, they are in different substances as products.*
OL Why are chemical equations useful?	*A chemical equation shows the chemical formula and number of units of each substance in the reaction.*

Balancing Chemical Equations

Have students read the paragraphs and **Figure 18**. Use the following questions to guide students through the balancing of chemical equations.

Guiding Questions

AL When balancing a chemical reaction, can you change the chemical formulas of the reactants or products? Why or why not?	*No; by changing chemical formulas, you would indicate that different substances were involved in the chemical reaction.*
OL What part do coefficients play in a chemical equation?	*They are used to show the number of units of each reactant and product involved in the reaction, showing that mass is conserved in a chemical reaction.*
OL How do you know that a chemical equation is balanced?	*The total number and types of atoms in the reactants equals the total number and types of atoms in the products.*

Visual Literacy: Balancing Chemical Equations

The process that is shown in **Figure 18** is a good model of how to write and balance equations. Go through the process with students, using the example given. Have students take a closer look at the equation in **Figure 17** and compare it to the table in **Figure 18**. Then ask the following questions.

Ask: **Why is the equation in Figure 17 considered to be a balanced equation?** *The number and type of atoms in the reactants equals the number and type of atoms in the products.*

Have students point to part 2a in their textbooks.

a. $CH_4 + O_2 \rightarrow CO_2 + H_2O$ **not balanced**

b. C=1 C=1 balanced
H=4 H=4 balanced
O=2 O=4 not balanced

c. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ **balanced**
C=1 C=1 balanced
H=4 H=4 balanced
O=4 O=4 balanced

Ask: **If the numbers of each type of atom in the reactants and products are not equal, is the equation balanced?** *No; it means that different amounts of each reactant and product are involved in the reaction.*

Ask: **Is it necessary to add coefficients only to the products?** *reactants and products could have coefficients other than 1.*

Have students balance a sample equation on their own, using **Figure 18.**

Ask: **What is the balanced chemical equation for the reaction between iron (Fe) and oxygen (O_2) to form iron (III) oxide (Fe_2O_3)?** *$4Fe + 3O_2 \rightarrow 2Fe_2O_3$*

Differentiated Instruction

AL Molecular Models Provide groups of students with cl[ay] and toothpicks. Instruct them to use the materials to b[uild] two hydrogen gas molecules, H_2, and one oxygen gas molecule, O_2. Then have them demonstrate that using these three models, they can create two water molecu[les], H_2O.

BL Balancing Equations Research a few basic chemical equations, such as the reaction of vinegar with baking [soda], the combustion of butane, or the production of ammo[nia] from hydrogen and nitrogen gas. Write each equation [on] the board without the coefficients. Ask students to bal[ance] each equation.

LA Plan a Demonstration Organize students into teams and have them plan a demonstration to model balanci[ng an] equation for the rest of the class. For example, two stu[dents] could wear signs with Os for oxygen and four students could wear signs with Hs for hydrogen. Have them for[m] H_2 molecules and one O_2 molecule and then rearrang[e] themselves to form two water molecules.

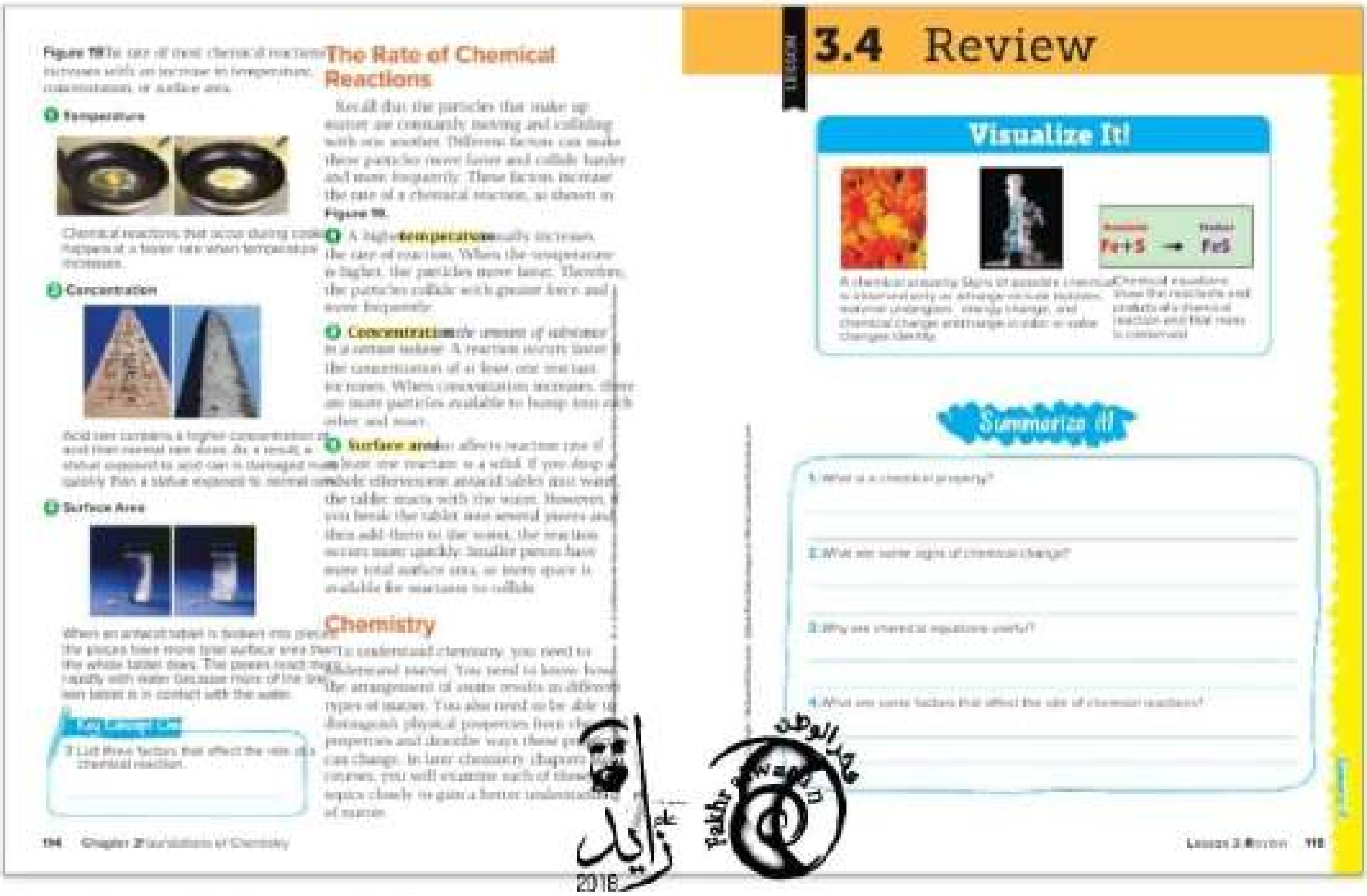
Teacher Toolbox

Reading Strategy

Semantic Mapping Guide the class in building a semanti[c] map of the terms related to chemical change. Have st[udents] suggest any term related to chemical change, and wri[te] these on the board. Then have students break into sm[all] groups to organize the terms into a web pattern with t[he] main ideas attached to *chemical change* and the seco[ndary] ideas as branches.

Real-World Science

Common Chemical Reactions Provide students with the reactants and products for an everyday chemical reac[tion] and ask them to write a balanced chemical equation. F[or] example, when propane burns, propane reacts with o[xygen] and produces carbon dioxide and water. A balanced equation would be $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. Anoth[er] example is the reaction between zinc and hydrochlori[c acid] ($Zn + 2HCl \rightarrow ZnCl_2 + H_2$).



The Rate of Chemical Reactions

Chemical changes involve particle collisions that might or might not result in a chemical reaction, depending on how fast the reactant particles are moving and how reactive they are. Temperature, concentration, surface area, and even orientation can affect how many collisions occur between reactants and the amount of force with which they collide.

Have students read the paragraphs and **Figure 19**. Ask them to describe how the different factors affect the chemical reactions in each photo. Then ask the following Guiding Questions to assess students' understanding of this concept.

Guiding Questions

AL **In general, how does an increase in temperature affect a chemical reaction?** *In general, increasing thermal energy makes it possible for the particles in the substances to move faster and collide harder than at a lower temperature. This speeds up the chemical reaction.*

OL **List three factors that affect the rate of a chemical reaction.** *Temperature, concentration, and the amount of surface area affect reaction rate.*

BL **If digestion involves chemical reactions, why would chewing food into tiny pieces before swallowing make digestion easier?** *Chewing food into tiny pieces increases the surface area of the food, which then increases the reaction rates of digestion so food is broken down sooner and more easily in the digestive system.*

Chemistry

Review with students how chemistry connects the atomic world to everyday observations. By understanding the core principles of chemistry, we are able to both appreciate and predict chemical reactions in nature as well as those occurring in the lab. Use the following questions to summarize what the students have learned about chemistry.

Guiding Questions

AL **Can you understand matter without understanding how it changes?** *No; the properties of a substance are important, but understanding physical and chemical change is necessary to understanding matter.*

OL **How do the properties of the reactants in a chemical reaction compare to the properties of the products of the reaction?** *If the atoms in a substance are configured into a different arrangement, the properties will change because new substances form.*

BL **How do you think understanding chemistry can help you better understand the world around you?** *Sample answer: Understanding chemistry can help in understanding why chemical and physical changes take place in our world and ways to prepare for them or avoid them.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: To which Key Concept does each image relate?**

Summarize it!

- Chemical Properties
- Comparing Properties
- Chemical Changes
- Signs of Chemical Change
- Explaining Chemical Reactions
- The Rate of Chemical Reactions
- Chemistry

Intervention Plann

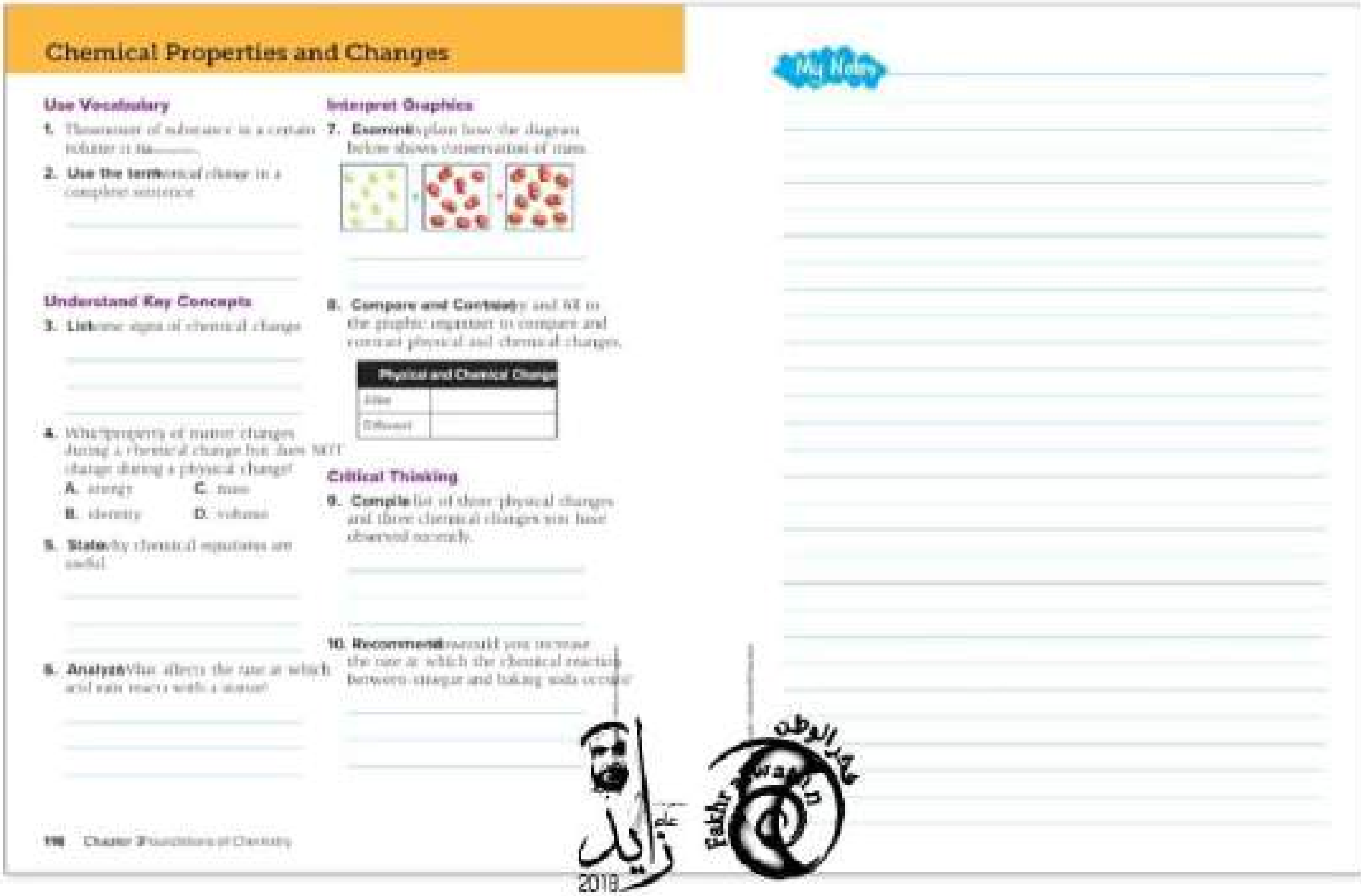
Based on the results of the Lesson Review, use the cha below to address individual needs.

Use Vocabulary (1–2)
TE Word Origins, Signs of Chemical Change
CR Content Vocabulary

Understand Key Concepts (3–6)
TE MiniLab, Can you spot the clues for chemical chang
CR Key Concept Builder

Interpret Graphics (7-8)
TE Guiding Questions, Signs of Chemical Change

Critical Thinking (9-10)
TE Guiding Questions, The Rate of Chemical Reaction
CR Enrichment
Challenge


Chemical Properties and Changes

Use Vocabulary

1. The amount of substance in a certain volume is its ____.
2. **Use the term** chemical change in a complete sentence.

Understand Key Concepts

3. **List** some signs of chemical change.
4. Which property of matter changes during a chemical change but does NOT change during a physical change?
   A. energy C. mass
   B. identity D. volume
5. **State** why chemical equations are useful.
6. **Analyze** What affects the rate at which acid rain reacts with a statue?

Interpret Graphics

7. **Examine** Explain how the diagram below shows conservation of mass.
8. **Compare and Contrast** Copy and fill in the graphic organizer to compare and contrast physical and chemical changes.

Physical and Chemical Changes	
Alike	
Different	

Critical Thinking

9. **Compile** a list of three physical changes and three chemical changes you have observed recently.
10. **Recommend** How could you increase the rate at which the chemical reaction between vinegar and baking soda occurs?

My Notes

116 Chapter 3 Foundations of Chemistry

Use Vocabulary

1. concentration
2. Sample answer: A chemical change occurs when you bake a cake. This change in matter creates bubbles and wonderful smells.

Understand Key Concepts

3. Sample answers include formation of bubbles, energy change (light, heat), and change in odor or color.
4. B. identity
5. Sample answer: Chemical equations provide a simple yet clear way to describe what happens during a chemical reaction.
6. The concentration of acid in the rainwater or the temperature of the water affects the rate at which the reaction occurs.

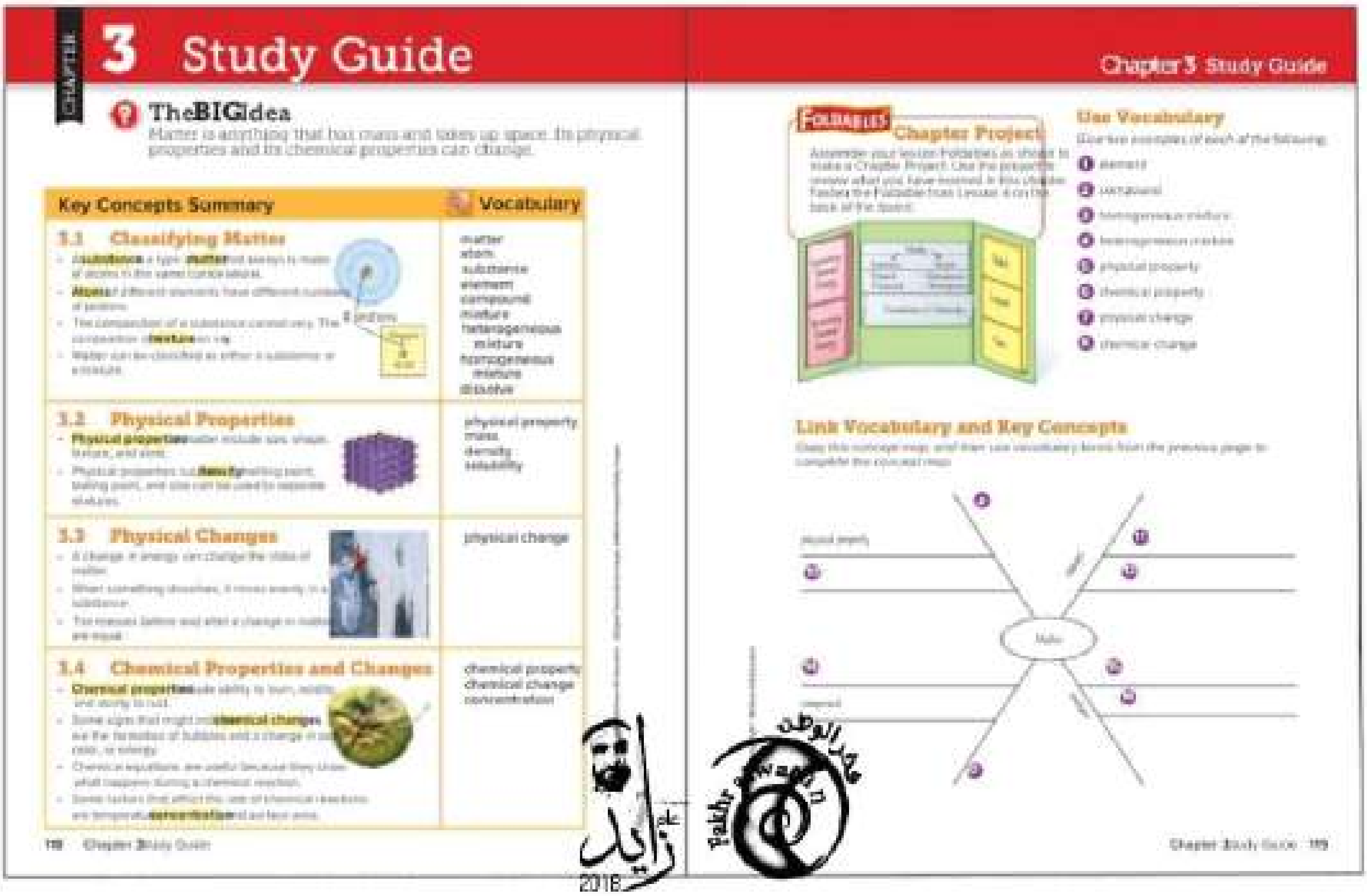
Interpret Graphics

7. The number of each type of atom in the reactants equals the number of each type of atom in the products.
8. Sample answer:

Physical and Chemical Changes	
Alike	Both change physical properties. Atoms present before and after the change are the same.
Different	Physical changes do not change the identity of matter, but chemical changes do.

Critical Thinking

9. Sample answers: Physical changes are folding paper, melting ice, and breaking glass. Chemical changes are burning wood, rusting metal on a bicycle, and baking cookies.
10. Sample answer: You can increase the temperature or increase the concentration of one or both of the reactants.



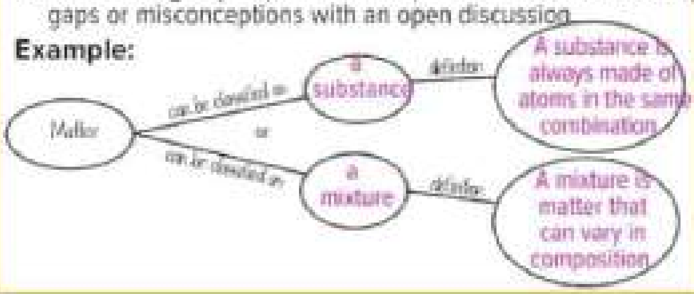
Key Concepts Summary

Study Strategy: Concept Web

Have students create a concept web that defines the concepts as it also shows their interconnections.

1. Organize students into groups and provide a large sheet of paper or poster board for them to use to create a concept web.
2. Prompt students to read the Key Concepts Summary. For each Key Concept, have them create a box for the concept and arrows connecting that concept to other related concepts. Along each arrow, students should include an explanation of the connection between the two concepts.
3. Have each group explain their map to the class. Address any learning gaps or misconceptions with an open discussion.

Example:



Vocabulary

Study Strategy: I Have... Who Has...?

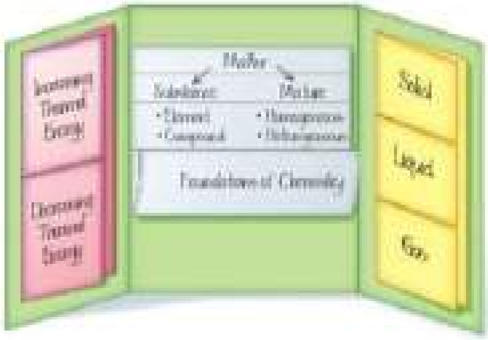
Divide index cards into left and right halves. Write *START HERE* on the top of the first card. On the left side write *I have* and write a vocabulary term. On the right side write, *Who has* and write a definition for a different vocabulary term. On the next card write *I have* and write the vocabulary term that matches the definition on the right side of the previous card. Repeat this process until all vocabulary terms are used. The definition on the last card should define the term on the first card.

1. Distribute the cards to the students in random order. The student with the *START HERE* card begins the game by reading the *I have* statement and asking the *Who has* question. Then, the student who has the answer to the question reads their card. For example: "I have *substance*. Who has *anything that takes up space and has mass?*"
2. Continue playing until all of the cards are read and the last question ends with the answer on the first card.

Example:

I Have...	Who Has...
substance	anything that takes up space and has mass?

FOLDABLES



Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

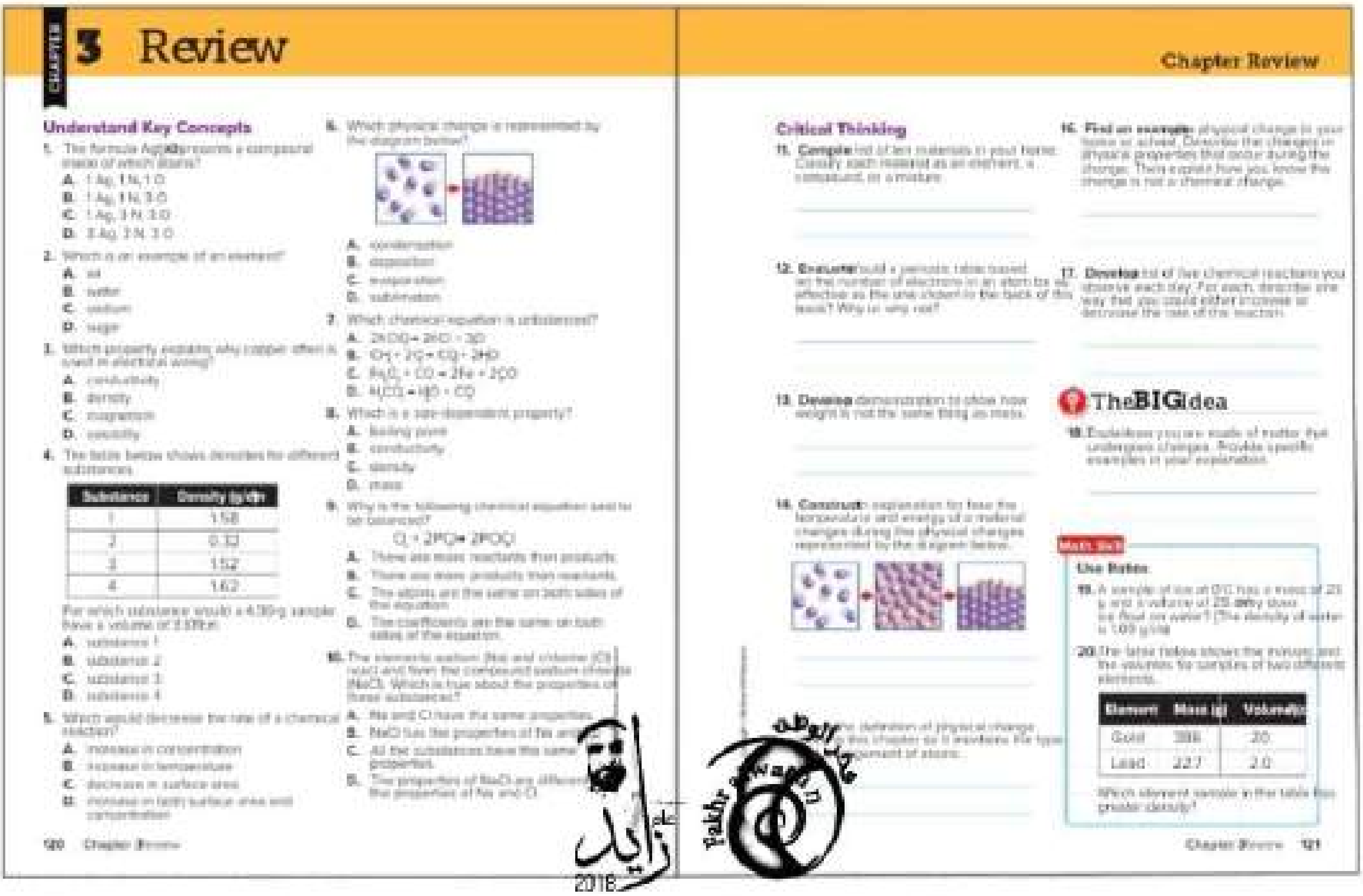
Teacher Notes

Use Vocabulary

1. element: carbon, aluminum
2. compound: sodium chloride, carbon dioxide
3. homogeneous mixture: salt water, bronze
4. heterogeneous mixture: powdered drink mix, granite
5. physical property: roughness of sandpaper, round shape of a basketball
6. chemical property: ability of iron to rust, ability of wood to burn
7. physical change: cutting a piece of paper, water boiling
8. chemical change: logs burning in a fireplace, bicycle left outside rusting

Link Vocabulary and Key Concepts

9. properties
10. chemical property
11. 12. physical change/ chemical change
13. substance
14. element
15. 16. homogeneous/ heterogeneous



CHAPTER 3 Review

Chapter Review

Understand Key Concepts

Substance	Density (g/cm³)
1	1.58
2	0.32
3	1.52
4	1.62

Critical Thinking

TheBIGIdea

Math Skills

Use Ratios

Element	Mass (g)	Volume (cm³)
Gold	386	20
Lead	227	2.0

Understand Key Concepts

1. B. 1 Ag, 1 N, 3 O

2. C. sodium

3. A. conductivity

4. A. substance 1

5. C. decrease in surface area

6. B. deposition

7. B. $Fe_2O_3 + CO \rightarrow 2Fe + 2CO_2$.

8. D. mass

9. C. The atoms are the same on both sides of the equation.

10. D. The properties of NaCl are different from the properties of Na and Cl.

Critical Thinking

11. Sample answers: salad, heterogeneous mixture; water, compound; copper used in wiring, element.

12. A periodic table based on number of electrons would not be as effective, because the number of electrons in an atom can change. The number of protons cannot change without changing the type of element.

13. If students have difficulty, refer them to the **MiniLab** in **Lesson 2.**

14. Sample answer: As energy is removed from the gas, its temperature decreases. At its condensation point, the temperature remains constant, and the gas changes to a liquid. The temperature then continues to decrease. At its freezing point, the temperature again remains constant, and the liquid changes to a solid.

15. Sample answer: A physical change is a change in matter in which the type of atoms and the way in which those atoms are arranged do not change.

16. Sample answer: Using sandpaper to sand a piece of wood changes the texture of the wood. It is not a chemical change because the material is wood before and after the change.

17. Accept all reasonable responses. Sample answers: increase the heat in order to cook eggs faster, refrigerate fruit to slow the rate of its spoiling, decomposing organic material, burning wood, digesting food, cleaning or polishing metals.

The BIG Idea

18. Sample answer: Skin changes into smaller pieces and flakes off (physical change), and sugar burns in cells (chemical change).

Math Skill

Use Ratios

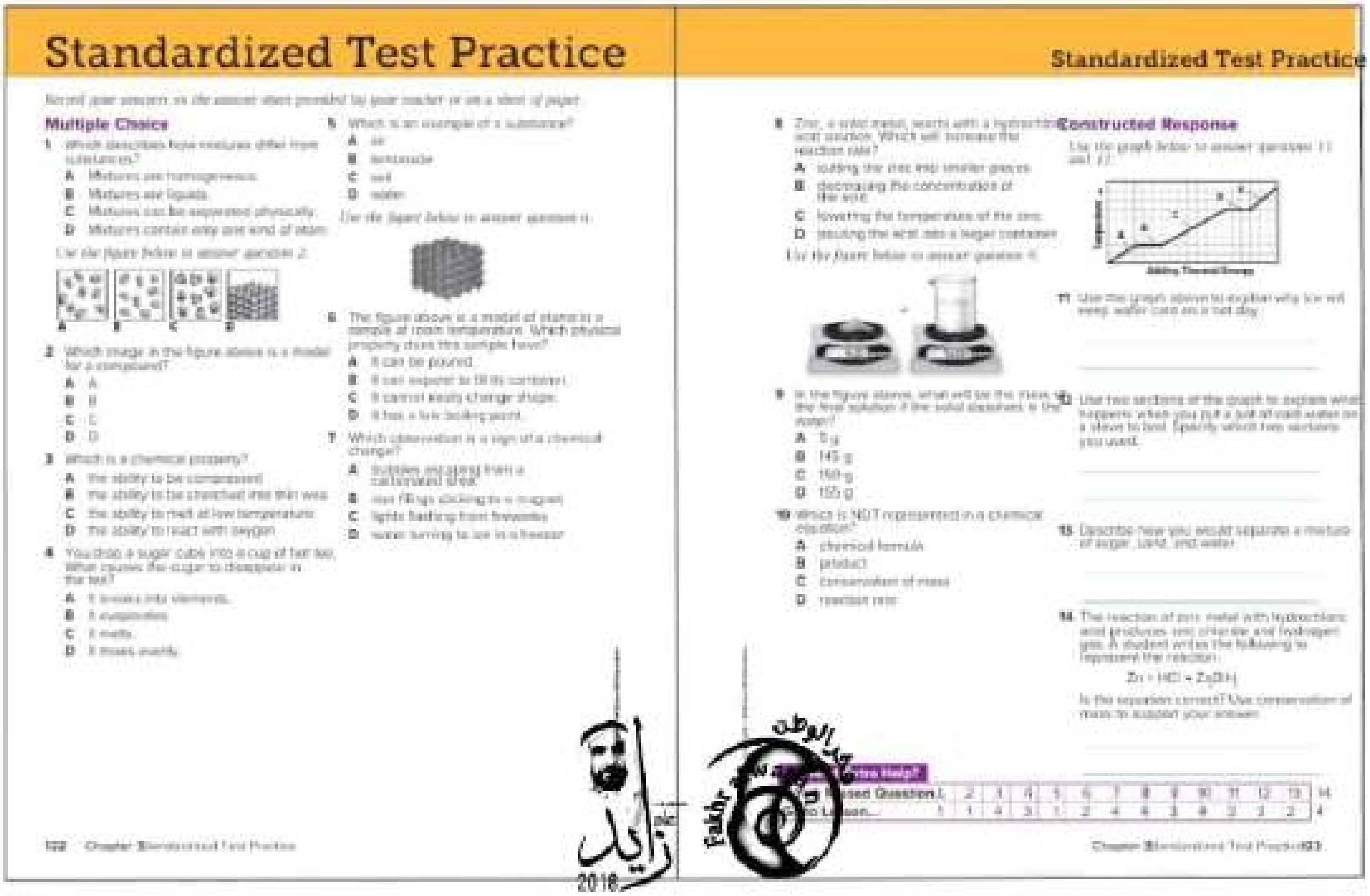
19. The density of the ice is 0.92 g/cm^3. It floats in liquid water because its density is less than that of liquid water.

20. Gold has greater density (19.3 g/cm^3 compared to 11.4 g/cm^3 for lead).

Intervention Plann

Based on the results of the Chapter Review, use the char below to address individual needs.

Lesson	Questions	Intervention Options
Understand Key Concepts		
1	1–2	Key Concept Builders; Content Practice; Animations: Atomic Structure; States of Matter and Molecular Motion; Temperature and Molecule Motion; Interactive Concept Map: Matter; Personal Tutors: Parts of an Atom; Chemical Formula; Density; Balancing a Chemical Equation
2	3–4, 8	
3	6	
4	5, 7, 9-10	
Critical Thinking		
1	11–12	Enrichment; Challenge; Virtual Lab: What is a balanced chemical equation?; WebQuests: Solutes, Solvents, and Solubility; The Chemistry of Fireworks
2	13	
3	14–16	
4	17	
Writing in Science		
1	18	Language Arts Enrichment; WebQuests: Solutes, Solvents, and Solubility; The Chemistry of Fireworks
Review the Big Idea		
4	19-20	Content Practice; Enrichment; Challenge; Online Test Practice
Math Skills		
2	21–22	Math Skills; Math Practice: Use Ratios; Math Personal Tutor: Find Unit Rates



Standardized Test Practice

Multiple Choice

Constructed Response

Standardized Test Practice

Multiple Choice

1 **C—Correct.** A: Incorrect. Not all mixtures are homogeneous. B: Incorrect. Not all mixtures are liquids. D: Incorrect. Mixtures contain more than one kind of atom.

2 **C—Correct.** A, B, D—All show models in which the atoms are the same.

3 **D—Correct.** A, B, C—All are physical properties.

4 **D—Correct.** A: Incorrect. This describes a reaction (decomposition). B, C: Incorrect. The solid does not change state when it dissolves.

5 **D—Correct.** A, B, C—All are mixtures.

6 **C—Correct.** A: Incorrect. This is a property of only liquids and gases. B: Incorrect. This is a property of only gases. D: Incorrect. The sample is a solid at room temperature. That means its melting point is higher than room temperature and its boiling point must be higher than its melting point.

7 **C—Correct.** A, D: Incorrect. Both are signs of physical changes. B: Incorrect. This is a physical property.

8 **A—Correct.** B, C: Incorrect. Both will decrease the rate of the reaction. D: Incorrect. This will have no effect on the rate of th reaction.

9 **D—Correct.** A, B, C—None show the conservation of matter.

10 **D—Correct.** A, B, C—All are shown in a chemical equation.

Constructed Response

11 Part B on the graph shows that the temperature does not increase as a solid melts. As the ice in water melts, the temperature of the water and the ice will stay at the melting point of water, 0°C.

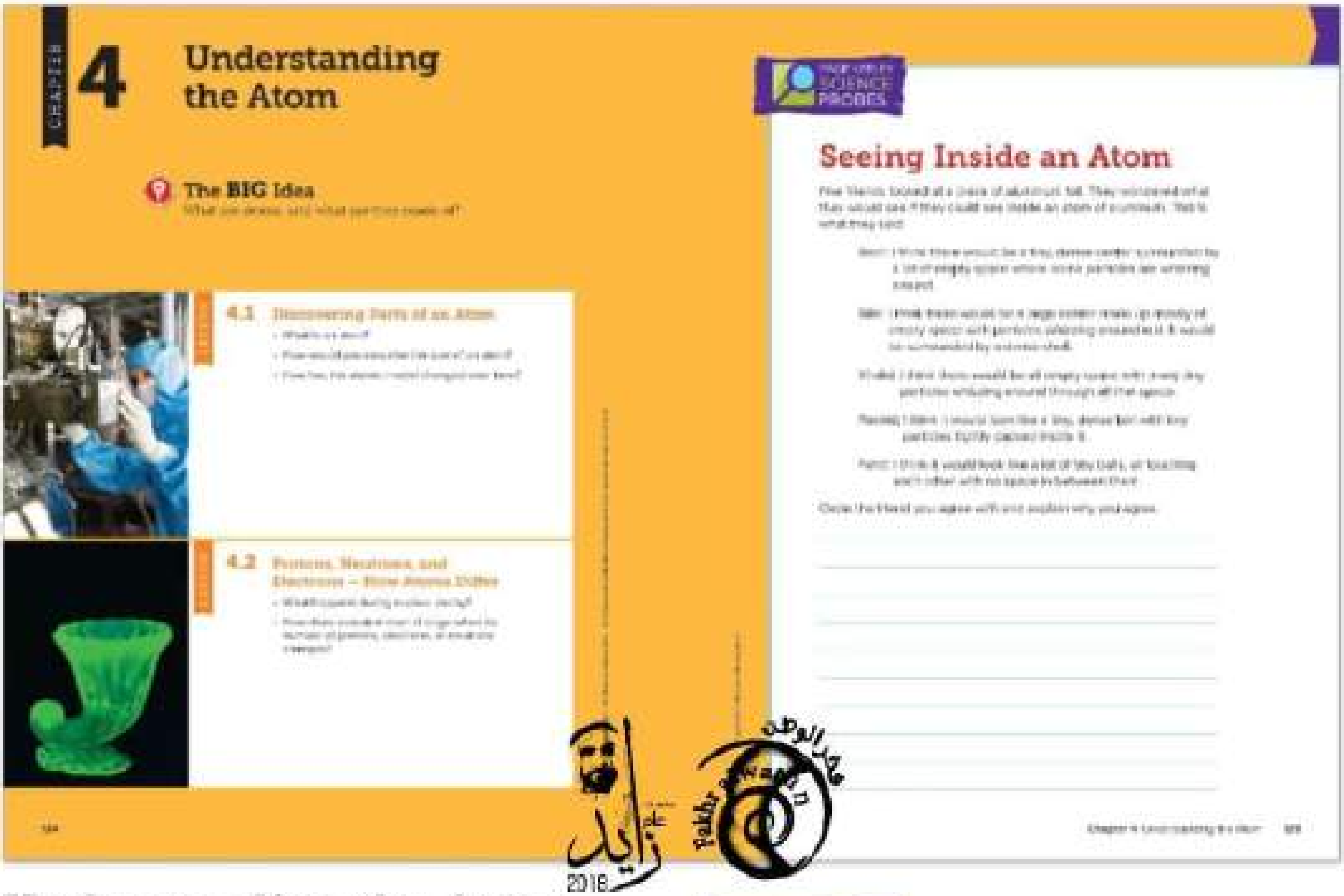
12 Parts C and D of the graph show what happens to cold water that is put on a stove to boil. First the temperature of the water will increase as energy is added to it. Then, when the water begins to boil, the temperature stays at the boiling point of water.

13 The first step would be to filter the mixture to separate the sand from the water and sugar. The next step would be to boil the mixture to make the water evaporate. The sugar will be left behind.

14 The equation is incorrect because it is not balanced. A correct equation would show conservation of mass by showing equal numbers of atoms for each element on both sides of the arrow. The products side shows more hydrogen and chlorine atoms.

Answer Key

Question	Answer
1	D
2	D
3	D
4	D
5	C
6	D
7	A
8	B
9	D
10	C
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answer.



Understanding the Atom

TheBIGIdea

There are no right or wrong answers to these questions. Write student-generated questions produced during the discussion on chart paper and return to them throughout the chapter.

Guiding Questions

AL If you could see an atom, what do you think it would look like?	*Accept all reasonable responses. You may also want to show students images of atoms from magazines or the Internet.*
OL Why is it sometimes hard to imagine that visible matter is made up of atoms?	*Atoms are too small to see with the unaided eye.*
BL Describe an atom using the modern atomic model.	*The modern atomic model has a nucleus made up of protons and neutrons. The majority of the weight of an atom is in the nucleus. Electrons form an electron cloud. The electron cloud is the area around the nucleus where an electron is most likely to be located.*

PAGE KEELEY SCIENCE PROBES Seeing Inside an Atom

Answers to the Page Keeley Science Probe can be found in the Teacher's Edition of the *Activity Lab Workbook.*

Get Ready to Read

What do you think?

Use the anticipation guide to gauge students' background knowledge and preconceptions about the atom. At the end of each lesson, ask students to read and evaluate their earlier responses. Students should be encouraged to change any of their responses.

Anticipation Set for Lesson 1

1. The earliest model of an atom contained only protons and electrons.

Disagree Early models of the atom were small, solid objects that could not be divided, created, or destroyed.

2. Air fills most of an atom.

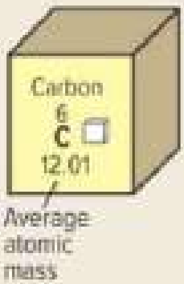
Disagree Most of an atom is filled with empty space.

Science Content Background

Lesson 2

Protons, Neutrons, and Electrons—How Atoms Differ

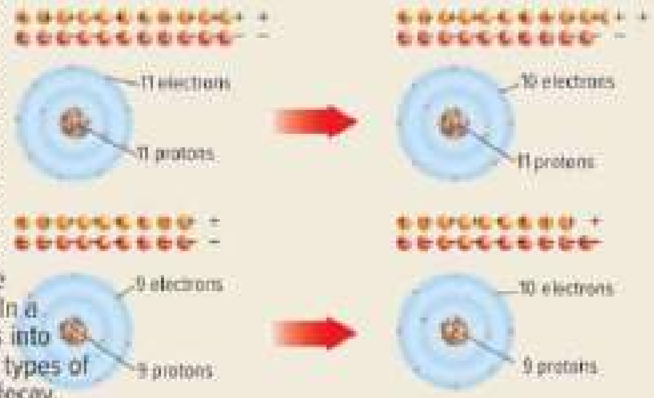
Isotopes Nearly the entire mass of an atom is determined by protons and neutrons. The mass number of an atom is defined as the sum of the protons and neutrons in the nucleus. Isotopes are atoms of the same element that have different numbers of neutrons. Most atoms have several isotopes. The average atomic mass of an element is a weighted average of all of the naturally occurring isotopes of that element. To calculate the average atomic mass, each exact atomic mass is multiplied by its percentage of abundance, expressed as a decimal. The results are then added together.



Radioactivity Elements that spontaneously emit radiation are radioactive. Radioactive elements contain unstable nuclei. In a process called nuclear decay, an unstable nucleus changes into another more stable nucleus by emitting radiation. Several types of adiation can be emitted during the process of radioactive decay.

The radiation can be alpha, beta, or gamma. An alpha particle is basically a helium nucleus—two protons and two neutrons. When an atom emits an alpha particle, the resulting atom has two fewer protons and two fewer neutrons. Beta decay occurs when a neutron changes into a proton and a beta particle. A beta particle is a fast-moving electron. When an atom emits a beta particle, the resulting atom has one more proton and one fewer neutron. Gamma rays do not contain particles, just energy. The release of gamma rays does not change the number of protons or neutrons an atom has.

Ions Ions are atoms that have a positive or negative charge. An ion is formed when a neutral atom gains or loses electrons. When a neutral atom loses electrons, it has fewer electrons than protons. As a result, it has a positive charge. A positively charged ion is called a cation. When a neutral atom gains electrons, it has more electrons than protons. As a result it has a negative charge. A negatively charged ion is called an anion.



Strand Map

Required Background Knowledge

To understand the Key Concepts of this chapter, students should have the following background knowledge:

* Materials may be composed of parts that are too small to be seen without magnification.

* A lot of different materials can be made from the same basic materials.

* Substances may move from place to place, but they never appear out of nowhere and never just disappear.

* A model of something is similar to, but not exactly like, the thing being modeled. Some models are physically similar to what they are representing, but others are not.

* American Association for the Advancement of Science (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Lesson 1 Discovering Parts of an Atom

1. If you were to divide an element into smaller and smaller pieces, the smallest piece would be an atom.

2. Atoms are so small that they can be seen only through powerful scanning microscopes.

... first model of the atom was a solid ... Now, scientists know that an atom ... dense positive nucleus surrounded by an electron cloud.

Lesson 2 Protons, Neutrons, and Electrons—How Atoms Differ

4. Nuclear decay occurs when an unstable atomic nucleus changes into another more stable nucleus by emitting radiation.

5. Different elements contain different numbers of protons. Two isotopes of a given element contain different numbers of neutrons. When a neutral atom gains or loses an electron, it becomes an ion.

An Atom Isn't Flat

Find Out What Students Think

Students may think that...

... atoms are two-dimensional objects. This misconception may arise because students see atoms as diagrams on paper. They may need help conceptualizing that the smallest piece of an element has volume.

Discussion

Have students consider the flat-looking aluminum foil in **Figure 2**, the more three dimensional sphere in **Figure 3**, and the Modern Atomic Model in **Figure 10**. **Ask:** What are the limitations of drawing models to represent atoms? **Drawings are two-dimensional, but atoms are three-dimensional.** Obtain a basketball or rubber playground ball. Cut a large circle from a piece of cardboard or poster board. Try to cut the circle so that it is about the size of the ball. **Ask:** What is the difference between these two objects? **One is a circle and the other is a sphere. The circle has two dimensions and the ball has three dimensions.** **Ask:** Which object would more accurately represent the shape of the atom? **The ball.** Explain to students that objects in the real world are three-dimensional. They are sometimes drawn in two dimensions because it is easier to show their parts that way. **Ask:** Do you think atoms are two-dimensional like the circle, or three-dimensional like the ball? **They are three-dimensional.** **Ask:** Why does the aluminum foil in **Figure 2** look so flat if it is made up of atoms with three dimensions? **The atoms are so small that the aluminum appears two dimensional to the eye. Under a microscope, it has three dimensions, as shown in Figure 3.**

Promote Understanding

Activity Have each student redraw The Modern Atomic Model in **Figure 10** on a sheet of paper. Then tell students they will use the materials in front to them to construct a three-dimensional representation of the model.

1. Hand out large polystyrene balls, gumdrops, raisins, and toothpicks. Remind students never to eat any food in the lab.
2. Ask students to refer to their drawing and decide which three-dimensional object they will use to represent the atomic model, the nucleus, and its protons and neutrons.
3. If students have a difficult time with relative size, point them to **Table 2** in **Lesson 2**.
4. Ask students to recreate their two-dimensional drawing using the three-dimensional objects and connecting them with toothpicks.
5. Facilitate a discussion with students about how much easier it is to represent an atom in two dimensions, yet how the three-dimensional objects' models accurately represent the structure of an atom and of each of its components. Also discuss with students the limitations of both types of models in representing the true structure of atoms..

Is It Crowded in There?

Find Out What Students Think

Students may think that...

... the electron cloud is "crowded" with electrons. This misconception may arise because they may have seen diagrams of the electron cloud model that show probability patterns as clouds, and students may think that these diagrams show numerous electrons. An understanding of probability and how a probability distribution is obtained will help clear up this misconception.

Discussion

Explain to students that probability is a measure of how likely something will occur. You may want to review the concept of probability with students using a pair of number cubes and the following questions. **Ask:** If I were to roll a number cube one time, what is the probability of it landing on the number 4? **There is a 1 in 6, or 17%, chance of landing on the number 4.** **Ask:** If I were to roll a number cube one time, what is the probability of it landing on an even number? **There is a 1 in 2, or 50%, chance of landing on an even number.** Connect this demonstration to the probability model used for electron clouds by asking students to work through the demonstration below.

Promote Understanding

Activity Students can use a marker and a target to demonstrate the probability distribution of an electron in relation to the nucleus.

1. Tell students to create a target by drawing a large circle on a sheet of paper. Have them draw another, slightly smaller circle inside of the first, and repeat until they have created a target with a total of 10 successively smaller circles.
2. Instruct students to place the target on the floor, and to drop a marker from about 90 cm above the target 50 times.
3. Explain to students that the 'crowded areas', the areas with the most marks, represent areas where the marker has a high probability of landing, and the less-crowded areas represent areas where the marker has a low probability of landing.
4. Have students number each circle beginning with the smallest circle. Then have them count the number of marks on each circular ring and record this information in a data table.
5. Have students create a bar graph of area number (x-axis) v. the number of marks (y-axis).
6. Explain to students that the graph they created shows the probability of finding a single electron in an atom. Remind students that the probability of finding an electron increases then decreases as the distance from the nucleus increases. Have students check to see if their graphs represent this fact

PAGE KEELEY SCIENCE PROBES

INQUIRY

About the Photo A Microscopic Mountain Range? The scanning tunneling microscopic (STM), which provided the first images of individual atoms, was not invented until 1981. However, scientists had known of the existence of atoms and had understood a great deal about their structure well before these images were obtained.

Guiding Questions

AL What are these tiny particles?	*Individual atoms.*
OL How small do you think they are?	*Accept all reasonable answers. Students should understand that atoms cannot be viewed with the unaided eye and that a STM is much more powerful than a microscope they may have in their classroom.*
OL How might scientists have learned so much about atoms before being able to see them?	*Scientists used observations and experiments to study atoms before being able to see them.*
BL Why do you think it would be useful for scientists to be able to see objects at the atomic level?	*Possible answers: Scientists can study the behavior of atoms and how they join together to form molecules.*

LAB Manager

All the labs for this lesson can be found in the **Student Resource Handbook** and the **Activity Lab Workbook**.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Modeling an Atom

1. Have students create models of an atom before and after exploring this lesson. Instruct students to draw a large circle on a sheet of notebook paper. Then have students draw a smaller circle inside the large circle. Students should use their prior knowledge to label the model of an atom by placing the vocabulary terms in the appropriate places on and inside the large and small circles. Have students pair up to compare their models and to make changes, if necessary.
2. Have students create another model of an atom by drawing a large circle on a new sheet of paper. As new information is explored in this lesson, students should use the information

to add vocabulary terms to their models. At the end of the lesson, have students compare their two atomic models. Facilitate a discussion with students about what they have learned in this lesson. You may want to use this as an opportunity to clear up any misconceptions they may have about the structure of an atom and to discuss the limitations of models.

Teacher Notes

Explore Activity

What's in there?

Prep *5 min* **Class** *10 min*

Purpose
To learn the concept of relative size.

Materials
Materials per team of two students: test tube filled with two to three cm of table salt (sugar or sand also work), waxed paper, toothpick

Before You Begin
Explain to students that before the invention of tools such as microscopes philosophers and scientists relied on observations and experiments to develop ideas about matter. In this lab, students will observe certain properties of matter and hypothesize what might be there that they cannot see.

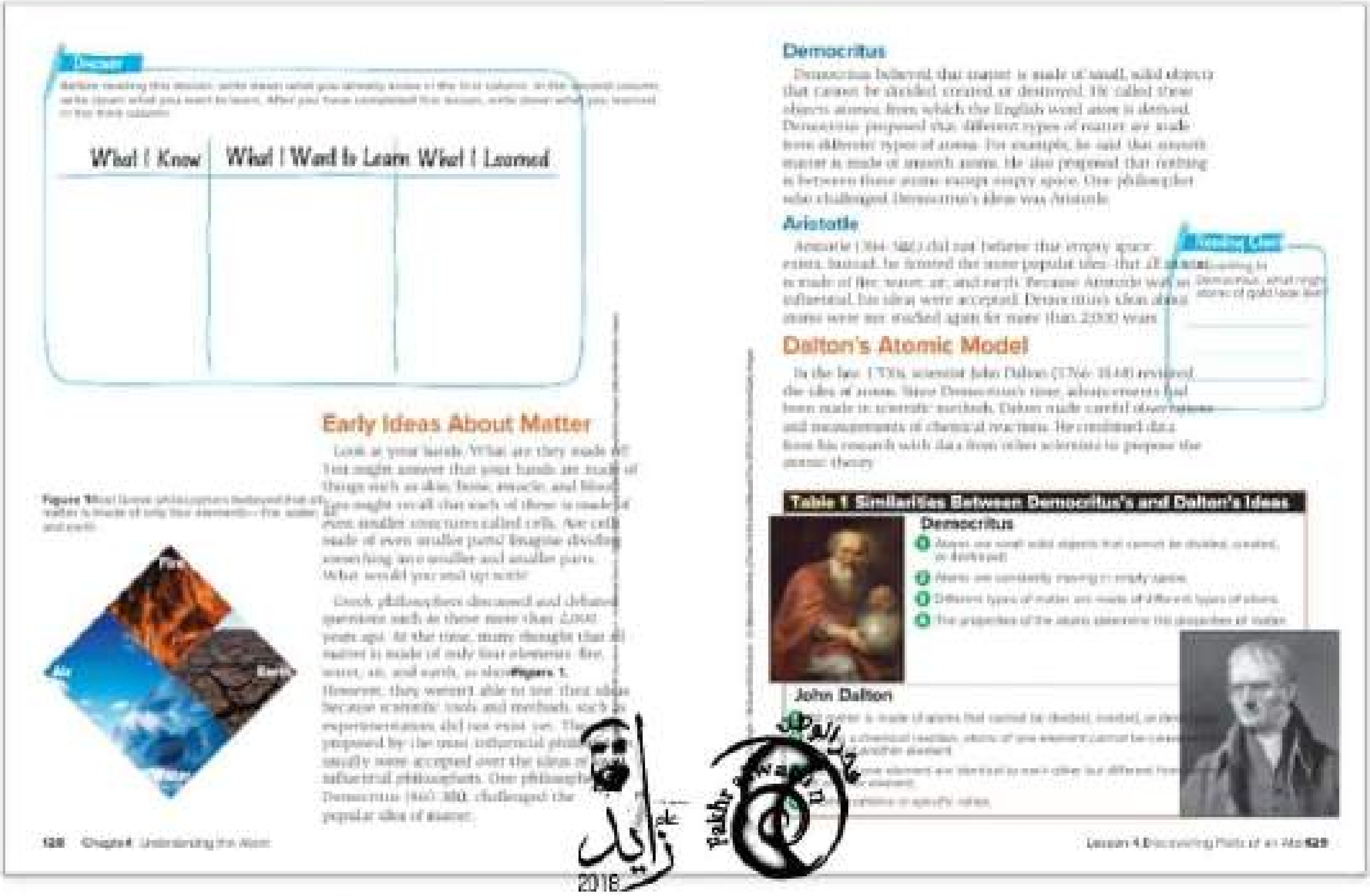
Guide the Investigation

- Have students take turns viewing the test tube from a distance. Ask students to observe the test tube as if they know nothing about what it contains and to simply record what they observe.
- When they pour the substance onto the waxed paper, some of the particles will separate out. It should become obvious that the apparently "solid" white substance is made of smaller pieces.
- As they mentally "zoom in," remind students of movies or television programs that "zoom in" on parts that normally can't be seen or "zoom in" from outer space to a single person on Earth.

Think About This

Students may not know the answers to all questions. Encourage them to hypothesize.

1. Answers will vary. Some students may say that the particle is made of smaller particles that look the same because the larger one can be smashed. Some students may say that the substance is not made of smaller particles because they cannot see any smaller particles.
2. **Key Concept** Answers will vary. Some students may propose that the particle is made of smaller versions of the larger particle. Some students may think that the particle is the smallest unit of the substance and would not look any different under a microscope.



Early Ideas About Matter

In this lesson, students will explore how the concept of the atom has changed over time beginning with the early Greek philosophers. Use these questions to help students focus on the ideas the early philosophers held about matter, and why they held those ideas.

Guiding Questions

AL **Why do you think the early philosophers thought that matter was made of fire, water, air, and earth?**	*They thought that matter was made up of the things that were around them—things that they could see and feel.*
BL What do you know about matter that conflicts with the ideas proposed by these early philosophers?	*Possible answers: Matter is anything that has mass and occupies space. Matter is made up of atoms. A substance made up of only one kind of atom is an element. These atoms also can combine to form compounds. Air and water are not elements.*

Democritus

Students should understand that Democritus was a Greek philosopher who proposed the idea that matter is made up of small, solid spheres he called *atomos*.

Ask: **According to Democritus, what might atoms of gold look like?** *Democritus thought that matter was made of atoms that share the characteristics of the matter. The atoms of gold might b[e] gold-colored and shiny. Scientists now know that atoms all look similar and have different numbers of protons, neutrons, and/or electrons.*

Aristotle

Both Aristotle and Democritus were philosophers who had ideas about matter. Aristotle favored the more popular idea—that matte[r] is made of fire, water, air, and earth. Aristotle was a more influent[ial] philosopher than Democritus, so his ideas were more widely accepted.

Ask: **In what ways were Aristotle's and Democritus's ideas abou[t] matter different, and in what ways were they similar?** *Possible answers: Differences include: Aristotle's ideas were more popular than Democritus's ideas, Aristotle did not think that empty space exists, while Democritus did, and Aristotle thought that matter is made of water, fire, air, and earth while Democritus thought that matter is made of atoms. Similarities include: Both ideas were based on philosophy rather than experimentation. Both ideas attempted to describe what matter is made of.*

Dalton's Atomic Model

Use these questions to guide students in comparing and contrasting Democritus's and Dalton's atomic theories.

Guiding Questions

OL **How did Dalton's and Democritus's methods differ in determining their atomic theories?**	*Democritus philosophized about atoms, whereas Dalton made observations and took measurements to reach his conclusions.*
BL **Part of Dalton's atomic theory states that matter is made up of atoms that cannot be divided, created, or destroyed. How does this compare to today's atomic theory?**	*This statement does not apply to today's atomic theory, because we know an atom can be broken down into smaller particles—protons, electrons, and neutrons.*

The Atom

Students learn that all matter is made of atoms with empty space between them. Students might think that this empty space is made of air. Tell students that air is made of atoms that are very far apart and with much more empty space between them than is the case with solids. Point out that students can feel the atoms in the air by blowing on their skin. The pressure they feel is the pressure of the atoms in the air. Use the following questions to guide students in understanding exactly what an atom is.

Guiding Questions

OL **What is a copper atom?**	*A copper atom is the smallest piece of copper that still has the properties of copper.*
BL **Why is it inaccurate to define an atom as "the smallest part of an element"?**	*An atom is not the smallest part of an element. This definition is incomplete because an atom contains smaller particles. However, an atom is the smallest part of an element that still has the properties of that element.*

The Size of Atoms

Students often have difficulty visualizing the size of an atom. Help students by explaining that the number of carbon atoms that could fit into the period at the end of the last sentence in the paragraph is 75 followed by 11 zeros. You may want to write this number (7,500,000,000,000) on the board or chart paper. Use these questions to guide students in understanding the size of atoms.

Guiding Questions

OL **How would you describe the size of an atom?**	*Students should demonstrate that they understand that atoms are far too small to be seen even by most microscopes. Students might say that they are so small that 7.5 trillion atoms take up the space of a period at the end of a sentence.*
BL **Which is smaller, a cell or an atom?**	*Atoms are smaller than cells. Cells are made up of atoms.*

Differentiated Instruction

AL **Democritus v. Dalton** Have students use the information in **Table 1** to create a Venn diagram comparing and contrasting the atomic theories of Democritus and Dalton.

BL **Inaccuracies in Dalton's Atomic Theory** Have students write the statements of Dalton's atomic theory in **Table 1**. Ask students to note how these statements have been proved or disproved as they explore the information in the chapter.

LA **Illustrate Concepts** Have students create an index card for each of the three major ideas explored so far in this lesson. Instruct students to write the major idea on one side of an index card. On the other side, they should illustrate the idea. For example, students could illustrate the early ideas about matter by drawing Aristotle arguing with Democritus.

Teacher Toolbox

Cultural Diversity

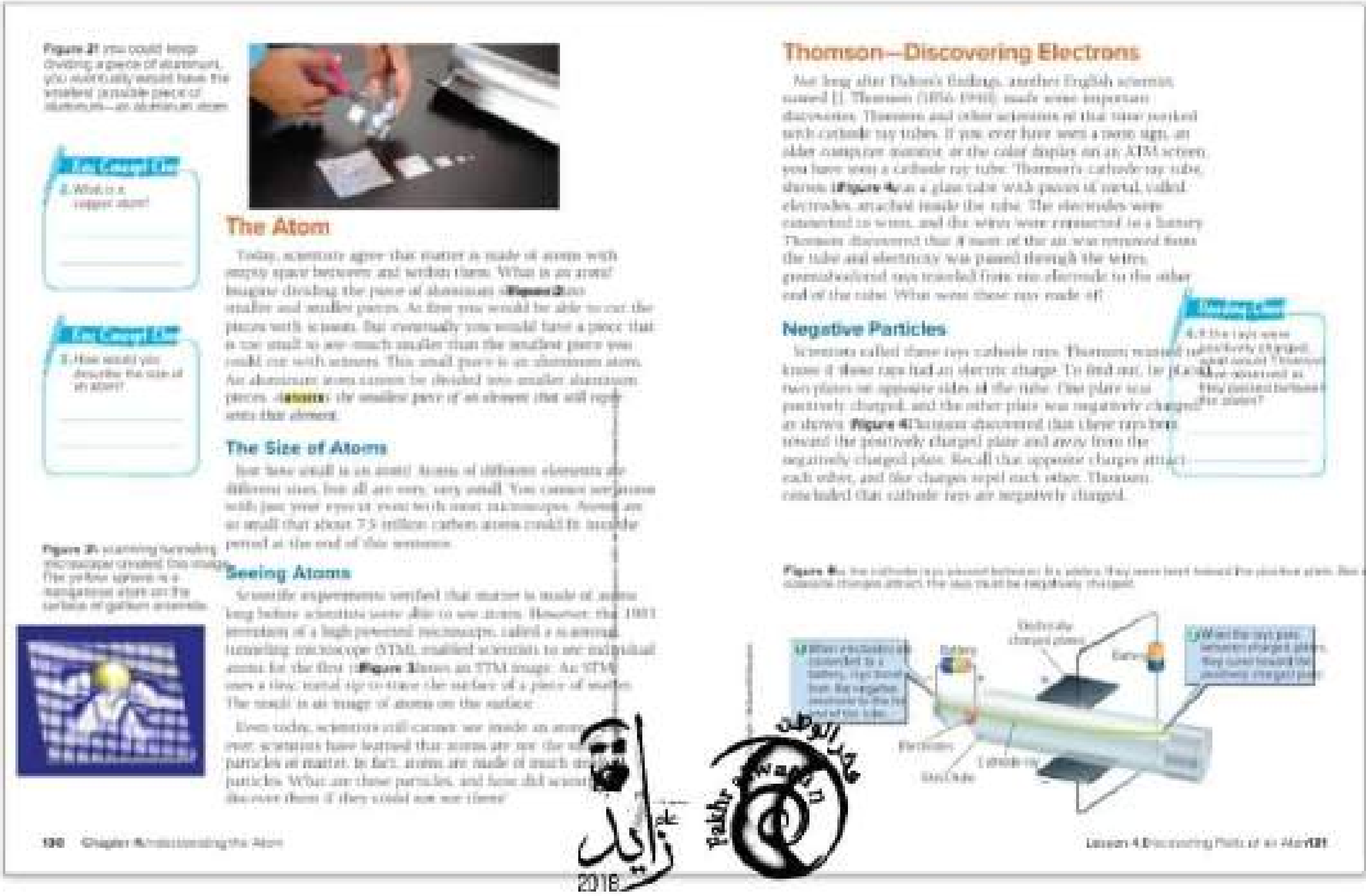
Early Atomic Theory in India Some of the earliest known ideas about atoms arose in ancient India between the 6th and 2nd century B.C. Kanada, a Hindu philosopher, thought that atoms were inactive and did not have physical properties on their own. Another Indian theory of atoms linked the behavior of matter to the nature of its atoms.

Teacher Demo

How small is an atom? Give each student a 1-fils coin. Write the number 2.4×10^{22} in standard form on the board or chart paper. Explain to students that although small coins haven't been made of pure copper since 1837, if a one-fils coin was made of pure copper, it would contain 2.4×10^{22} copper atoms. To put it into perspective, remind students that the population of the world is less than 7 billion, so the number of copper atoms in a pure copper 1-fils coin is more than three times the population of the world.

Fun Fact

Moving Individual Atoms Scanning tunneling microscopes can be used not only to see atoms, but can also be used to move them. In 1989, after figuring out how to move individual atoms in a process called atom manipulation, scientists at IBM used 35 xenon atoms to write the letters IBM on a nickel surface. The scientists were able to do this by changing the current in the tip of the scanning tunneling microscope first to attract the individual atoms and then let them go in another place on the surface.


The Atom

The Size of Atoms

Seeing Atoms

Thomson—Discovering Electrons

Negative Particles

Seeing Atoms

Use these questions to guide students in understanding the importance of the invention of the scanning tunneling microscope on the study of atoms.

Guiding Questions

OL	How do you think scientists have been able to conclude that atoms are made of smaller particles even though these particles cannot be seen even with a scanning tunneling microscope?	*Scientists performed experiments to verify that atoms contain subatomic particles.*
BL	What are some reasons why it was important for scientists to be able to see atoms even after their existence had been verified by scientific experiments?	*Scientists wanted to see the shapes of atoms and how they interact with one another.*

Thomson—Discovering Electrons

J.J. Thomson discovered electrons through experimenting with cathode ray tubes. Use these questions to introduce students to the cathode ray tube.

Guiding Questions

OL	What are some examples of modern cathode ray tubes?	*Examples include neon signs, older computer monitors, and ATM screens.*
BL	What do you think the rays are made of?	*The rays are made of electrons.*

Negative Particles

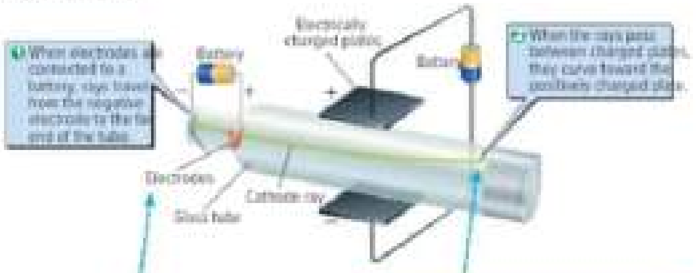
Use these questions to emphasize to students that cathode rays are negatively charged and to prepare students to be introduced to the electron.

Guiding Questions

OL	Why did Thomson conclude that the rays were negatively charged?	*The rays bent toward the positively charged plate and away from the negatively charged plate.*
OL	If the rays were positively charged, what would Thomson have observed as they passed between the plates?	*Because opposite charges attract, the rays would have bent toward the negatively charged plate.*

Visual Literacy: Thomson's Cathode Ray Tube Experiment

Students may need help understanding the set-up and implementation of the cathode ray experiment. Use the questions below to help students analyze **Figure 4** and to assess their understanding of the results of Thomson's cathode ray tube experiment.



Ask: How was Thomson's cathode ray experiment set-up? *A glass tube was fitted at the end with two electrodes. The electrodes were connected to a battery. Electrically charged plates connected to another battery were placed on either side of the tube.*

Ask: How are the charged plates affecting the ray in the cathode tube? *The ray is bending toward the positively charged plate and away from the negatively charged plate. This indicates that the ray is attracted to the positively charged plate and repelled by the negatively charged plate.*

Parts of Atoms

Thomson's cathode ray experiment did not in itself prove the existence of electrons. Thomson used other scientific observations and measurements to reach his conclusions. Use these questions to help students understand the evidence that led Thomson to conclude that atoms contain smaller particles.

Guiding Questions

AL What part of an atom did Thomson discover?	*the electron*
OL What is an electron?	*A particle with a single negative charge*
BL Based on Thomson's findings, how would you describe the structure of an atom?	*An atom contains electrons—small particles with a single negative charge. However, since an atom is not electrically charged, it must also contain a positive charge to balance the negative charges.*

Thomson's Atomic Model

Use this question to compare and contrast Thomson's atomic model with Dalton's atomic model.

Guiding Questions

OL How did Thomson's atomic model differ from Dalton's atomic model?	*Thomson's model is not a solid sphere, as proposed by Dalton. Thomson's model contains negatively charged electrons embedded in a sphere of positive charge.*

Differentiated Instruction

AL **Write a Newspaper Article** Have students write a newspaper article announcing Thomson's discovery of electrons. Instruct students to include appropriate illustrations. Encourage them to use factual information explored so far in this lesson.

BL **Write a Skit** Have students work in pairs to write and act out a short skit of a fictional conversation between Dalton and J.J. Thomson. Instruct students to imagine w their conversation would have been like if they had me after Thomson discovered electrons. Encourage studer use factual information explored so far in this lesson.

LA **Visual Literacy** Have students examine **Figure 4** and **Figure 5** in this section before reading the captions. Encourage students to think first of a description of wh happening in each figure. Then have them record their thoughts on paper. Finally, instruct students to compare their written descriptions with the captions.

Teacher Toolbox

Reading Strategy

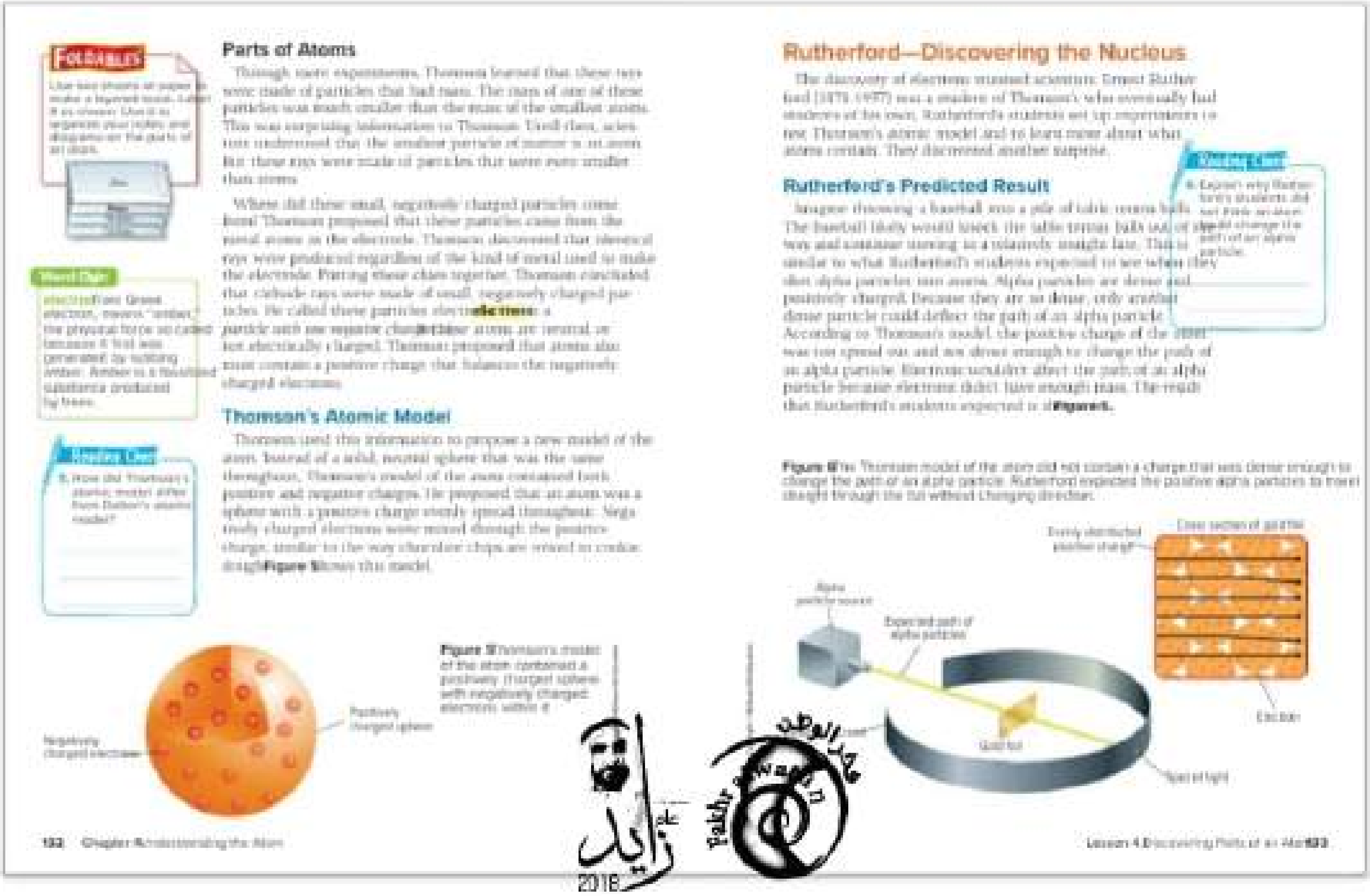
Summarize Have students write a one-paragraph summ about Thomson's discovery of electrons. Instruct stude turn each heading in this section into a sentence and include it in the paragraph.

Teacher Demo

Like Charges Repel Demonstrate that like charges repel blowing up two balloons and rubbing them both on a of wool. Explain to students that rubbing the balloons the wool creates a buildup of negative charge. Ask stu to predict what will happen when the balloons are mo closer to each other. Then move the balloons close to other. Explain to students that when the balloons are n next to each other, the collection of like charges cause balloons to move away from each other.

Real-World Science

Modern Cathode Ray Tubes Prior to the last decade, most televisions and computer monitors were powered by cathode ray tubes, or CRTs. In devices powered by CR images are produced when an electron beam strikes a screen coated with phosphor. The collision of electron the phosphor causes it to glow and display different co



Word Origin

electron

Ask: **Does the word electron sound like any other scientific word with which you are familiar?** *Possible answers:* electric, electricity, electrolyte, electronics, *and* electroscope

Ask: **What do these words have in common?** *They have to do with electrical charge.*

Ask: **Why do you suppose Thomson named the particle with a single negative charge after the Greek word for amber?** *Amber was known to generate electrical charge.*

Visual Literacy: Thomson's Atomic Model

Thomson proposed a new atomic model based on his findings. Use these questions to help students analyze Thomson's atomic model in **Figure 5**.

Ask: **What do the little circles represent in Thomson's atomic model?** *the negatively charged electrons*

Ask: **What does the sphere represent in Thomson's atomic model?** *The sphere is the whole atom.*

Ask: **What is indicated by the cutaway part of the diagram?** *The cutaway part of the diagram indicates that the electrons are mixed throughout the positively-charged sphere, not just on the surface of the sphere.*

Rutherford—Discovering the Nucleus

Remind students that scientists test their theories via experiments. Sometimes those experiments yield the expected results and the scientists confirm their ideas. Other times scientists make an unexpected discovery. Connect this to the learning students do in the many labs they perform. When Rutherford's students set up an experiment to test his idea, they made an unexpected discovery.

Rutherford's Predicted Result

It is important for students to understand the predicted results of Rutherford's experiment in order to appreciate the significance of the actual results.

Guiding Questions

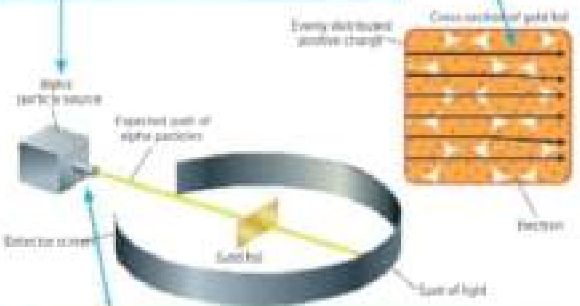
AL	**How would you describe an alpha particle?**	*An alpha particle is a dense and positively charged particle.*
OL	**Explain why Rutherford's students didn't think an atom could change the path of an alpha particle.**	*According to Thomson's model, an atom didn't contain a dense, positive charge that could change the path of the positive alpha particle.*
BL	**How did the experiment test Thomson's atomic model of a sphere with particles?**	*If there was nothing inside an atom that had a mass and density higher than the alpha particle, then the alpha particle would travel straight through the gold foil.*

Visual Literacy: Rutherford's Predicted Result

Students may have difficulty understanding the set-up of Rutherford's experiment. Use these questions to help students analyze the diagram.

Ask: **What do the arrows represent in the cross section of the gold foil?** *The alpha particles traveling in a straight path through the foil.*

Ask: **Where do the alpha particles originate?** *at the alpha particle source*



Ask: **What was the expected path the particles would take?** *Particles were expected to travel in a relatively straight line through the gold foil and strike the detector screen.*

The Gold Foil Experiment

Use these questions to facilitate a discussion with students on how the gold foil experiment was set up and implemented.

Guiding Questions

AL **Identify the three components of the gold foil experiment.**	*an alpha particle source, gold foil, and a screen*
OL **Why was it important to surround the gold foil with a screen?**	*The screen would show where the alpha particles hit. Rutherford's students would then know the starting point and the ending point of the alpha particles' path.*

The Surprising Result

Based on Thomson's atomic model, the alpha particles were expected to pass through the gold foil unchanged. Instead, some particles struck the foil and bounced off to the side, while a few bounced straight back. Explain to students that the term shell in the phrase "fifteen-centimeter shell" refers to a projectile that would be launched from a cannon. Imagine launching a cannonball larger than a basketball at a piece of tissue paper and the cannonball bouncing back! This is why Rutherford's team was so surprised by the result of their gold foil experim ent.

Guiding Questions

OL **Given the results of the gold foil experiment, how do you think an actual atom differs from Thomson's model?**	*If a dense, positive charge is needed to change the path of an alpha particle, then an atom must contain a dense positive charge. This is different from Thomson's model that proposed that the positive charge was spread throughout an atom.*
BL **Explain how Rutherford and his students knew the object the alpha particles struck was positively charged.**	*Alpha particles are positively charged. In order for them to be deflected, they would have to come into contact with an object of like charge.*

Differentiated Instruction

AL **Play a Word Game** Have students write a paragraph or two to summarize what they have read about atomic models, the parts of atoms, and how those parts were discovered. They should leave a blank space for each vocabulary word or scientist included in their paragraph. Then have them swap their paragraphs with those of other students to fill in the blanks.

BL **Concise and Correct Contest** Challenge interested students to describe Rutherford's experiment as concisely and correctly as possible. Have the rest of the class choose the student who is able to correctly describe the experiment using the fewest words. Encourage them to use the baseball and table tennis ball analogy explained in the section Rutherford's Predicted Result.

LA **Visual Literacy** Have students redraw **Figure 6** in their Science Journal using a pencil. Then have them use a pen and annotate that drawing with the real results in **Figure 7**. Have students write a paragraph below their drawing that explains how the alpha particles behaved in the experiment.

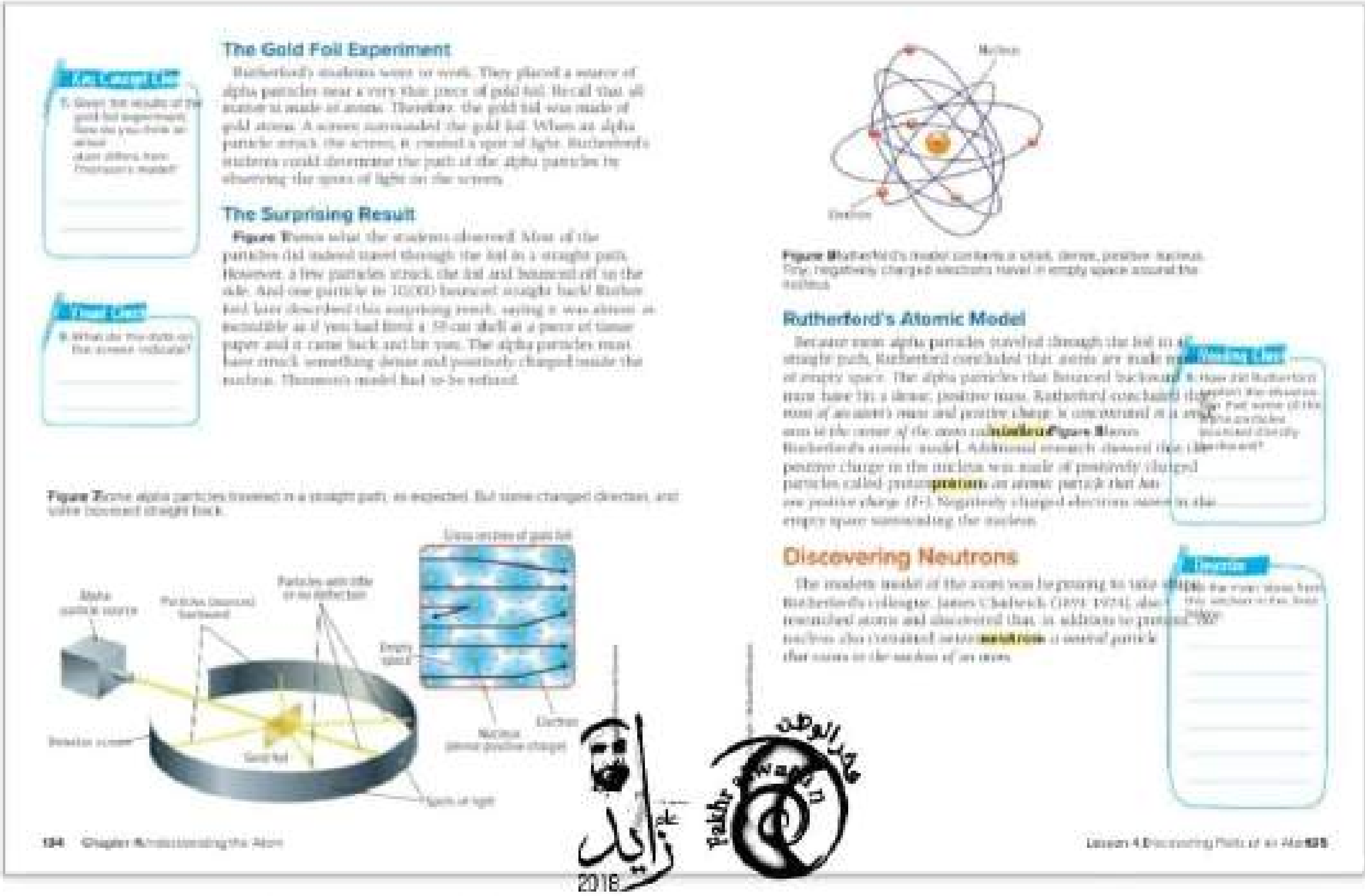
Teacher Toolbox

Reading Strategy

Write a Class Summary On the board or chart paper, have students collaborate in order to write a class summary of this section. Instruct them to use the reading checks and key concept checks as their guide. Have one student start up with the first sentence, and have student volunteers contribute additional sentences until the entire section has been summarized.

Real-World Science

Smoke Detectors Most common household smoke detectors contain a small amount of the alpha emitter americium-241. Alpha particles released from the americium remove electrons from the atoms of the air, forming ions in a chamber inside of the alarm. Once the air is ionized, a small amount of current is able to run through it. Smoke particles neutralize the ions, which stops the electric current, setting off an alarm.


The Gold Foil Experiment

Rutherford's students went to work. They placed a source of alpha particles near a very thin piece of gold foil. Recall that all matter is made of atoms. Therefore, the gold foil was made of gold atoms. A screen surrounded the gold foil. When an alpha particle struck the screen, it created a spot of light. Rutherford's students could determine the path of the alpha particles by observing the spots of light on the screen.

The Surprising Result

Figure 7 shows what the students observed. Most of the particles did indeed travel through the foil in a straight path. However, a few particles struck the foil and bounced off to the side. And one particle in 10,000 bounced straight back! Rutherford later described this surprising result, saying it was almost as incredible as if you had fired a 15-cm shell at a piece of tissue paper and it came back and hit you. The alpha particles must have struck something dense and positively charged inside the nucleus. Thomson's model had to be refined.

Key Concept Check: 7. Given the results of the gold foil experiment, how do you think an actual atom differs from Thomson's model?

Visual Check: 8. What do the dots on the screen indicate?

Figure 7 Some alpha particles traveled in a straight path, as expected. But some changed direction, and some bounced straight back.

Figure 8 Rutherford's model contains a small, dense, positive nucleus. Tiny, negatively charged electrons travel in empty space around the nucleus.

Rutherford's Atomic Model

Because most alpha particles traveled through the foil in a straight path, Rutherford concluded that atoms are made mostly of empty space. The alpha particles that bounced backward must have hit a dense, positive mass. Rutherford concluded that most of an atom's mass and positive charge is concentrated in a small area in the center of the atom called the **nucleus**. **Figure 8** shows Rutherford's atomic model. Additional research showed that the positive charge in the nucleus was made of positively charged particles called protons. A **proton** is an atomic particle that has one positive charge (1+). Negatively charged electrons move in the empty space surrounding the nucleus.

Reading Check: 9. How did Rutherford explain the observation that some of the alpha particles bounced directly backward?

Discovering Neutrons

The modern model of the atom was beginning to take shape. Rutherford's colleague, James Chadwick (1891–1974), also researched atoms and discovered that, in addition to protons, the nucleus also contained neutrons. A **neutron** is a neutral particle that exists in the nucleus of an atom.

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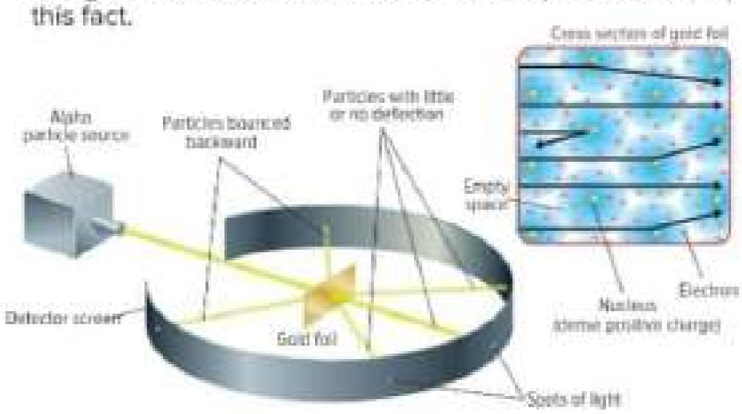
Visual Literacy: The Surprising Result

The position of the dots of light on the screen provided evidence that the alpha particles struck something dense and positively charged inside of the nucleus. Use these questions to emphasize this fact.



Ask: **How would you describe the position of the dots on the detector screen?** *The dots appear in various places on the screen.*
Ask: **What do the dots on the screen indicate?** *The dots show the end of the path of each alpha particle.*

Rutherford's Atomic Model

Use these questions to guide students in understanding how the results of the gold foil experiment led Rutherford to conclude that an atom contains a small, dense, positively charged center called the nucleus.

Guiding Questions

OL **How did Rutherford explain the observation that some of the alpha particles bounced directly backward?**	*Rutherford concluded that some alpha particles bounced directly backward because they came into contact with a dense, like-charged mass—the nucleus.*
BL **How does Rutherford's atomic model differ from the Thomson model of an atom?**	*Rutherford's model contains positively charged protons. Instead of the positive charge being spread through an atom like Thomson's model, the charge is concentrated in the center of an atom.*

Discovering Neutrons

James Chadwick discovered the third major subatomic particle, the neutron. Use these questions to help students understand the properties of neutrons and to review the properties of protons and electrons.

Guiding Questions

AL Based on Chadwick's discoveries, describe the composition of the nucleus.	*The nucleus contains positive protons and neutral neutrons. The overall charge of the nucleus is positive.*
OL What are the names, charges, and locations of the three major subatomic particles?	*The proton is positive and is located in the nucleus. The neutron is neutral and is located in the nucleus. The electron is negative and is located outside of the nucleus.*

Bohr's Atomic Model

The Rutherford atomic model depicted the composition of the nucleus accurately, but it failed to depict the arrangement of electrons in an atom accurately. Use this question to guide students in understanding the limitations of the Rutherford atomic model.

Guiding Questions

BL Which aspect of atomic structure was Rutherford's atomic model able to explain and which aspect was it unable to explain?	*Rutherford's atomic model explained the composition of the nucleus, but was unable to explain the behavior of the electrons.*

Electrons in the Bohr Model

The Bohr model of an atom attempted to describe the arrangement of electrons in atoms. Use these questions to guide students in understanding the arrangement of electrons in the Bohr atomic model and the observations that led to that arrangement.

Guiding Questions

AL Describe the arrangement of electrons in the Bohr atomic model.	*In the Bohr model, electrons move in circular energy levels around the nucleus.*
OL What is the relationship between an electron's location around the nucleus and the amount of energy it has?	*The farther away from the nucleus an electron is located, the more energy it has.*
BL How did the Bohr model explain the observation that if certain elements are heated in a flame they give off specific colors of light?	*In the Bohr model, electrons are arranged around the nucleus in increasing energy levels. When electrons gain energy, they move from a lower energy level to a higher energy level. When the electrons return to a lower energy level, they release energy in the form of light.*

Limitations of the Bohr Model

The Bohr model was not able to depict the arrangement of electrons in atoms with more than one electron. Use these questions to facilitate a discussion with students about the importance of the Bohr model, as well as the other atomic models explored so far.

Ask: **How did Bohr's model of the atom differ from Rutherford's?** *In Bohr's model, electrons travel in circular orbits around the nucleus and have different and specific amounts of energy. In Rutherford's model, electrons move in the empty space around the nucleus.*

Differentiated Instruction

AL **Create a Venn Diagram** Have students create a three-circle Venn diagram of the similarities and differences among the Thomson, Rutherford, and Bohr atomic mod[els]. Instruct students to include an illustration of each mod[el].

BL **Create a Timeline** Have students create a timeline illustrating and organizing the progression of the atom[ic] model from the Dalton model through the Bohr model. Instruct students to include the principal scientists and [a] brief description of their experiments, along with illustrations.

LA **Play a Card Game** Have students create a set of inde[x] cards with various information about each of the three subatomic particles explored in this lesson. Each card [should] include one piece of information (particle name, the sc[ientist] who discovered it, its charge, or its location in an atom). Shuffle the cards and work in teams to arrange them i[n a] logical manner.

Teacher Toolbox

Reading Strategy

What's the Main Idea? Have students write down what th[ey] think is the main idea of each section. Then have pairs [of st]udents discuss the section's ideas in order to reach [a de]cision on what they think is the main idea of each s[ection]. Next have each pair combine with another pair of stud[ents] to discuss and decide what they think is the main idea [of] each section. Finally have each group share their resu[lts] with the class.

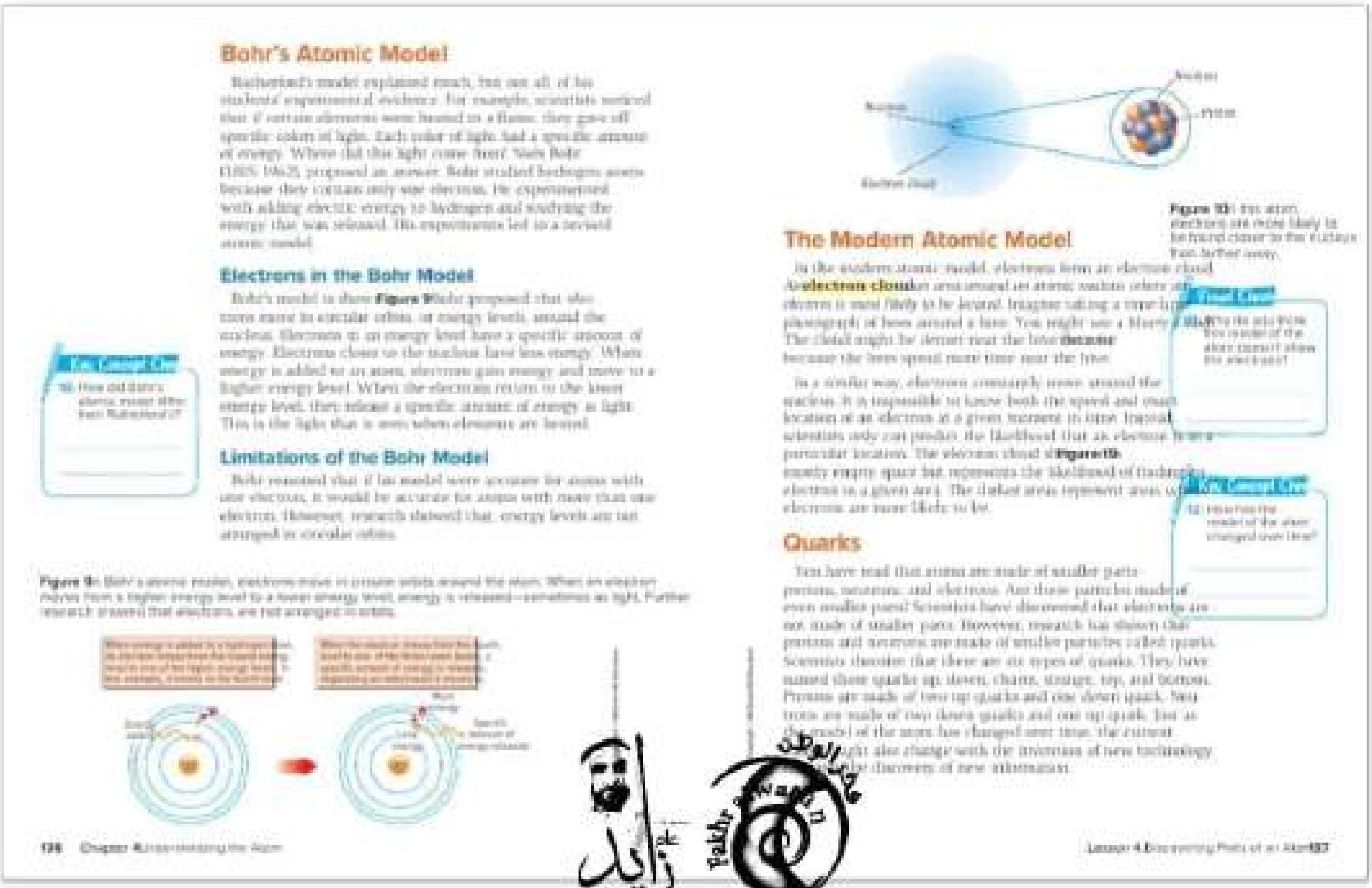
Fun Fact

All in the Family Niels Bohr was awarded the Nobel Priz[e] in physics in 1922 for his investigation of the structure [of] atoms and of the radiation emanating from them. His s[on] Aage Bohr, shared the Nobel Prize with two other phy[sicists] in 1975 for the discovery of the connection between collective motion and particle motion in atomic nuclei [and] the development of the theory of the structure of the a[tomic] nucleus that was based on this connection.

Teacher Demo

Electron Energy Levels Place a ring-shaped wintergreen candy between the jaws of a pair of pliers. Turn out th[e] lights and use the pliers to break the candy. When the candy is crushed, electrons in the wintergreen flavor molecules become excited, absorb energy, move to a higher energy level, then move back to the lower ener[gy] level, releasing the energy in the form of light. Be sure [to] practice this demonstration on your own ahead of time[;] some brands of wintergreen candy work better than o[thers].

AL Approaching Level OL On Level BL Beyond Level LA Language Acquisition



The Modern Atomic Model

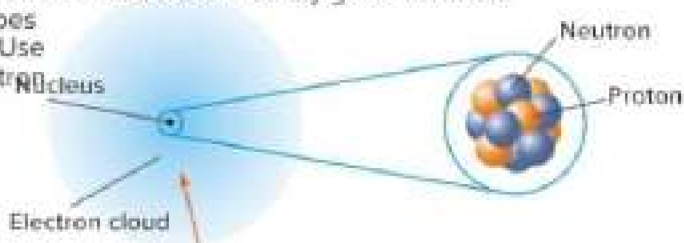
The modern atomic model is based on the idea that it is impossible to know both the speed and exact location of an electron at a given moment. Scientists can only predict the likelihood that an electron is in a particular location. The electron cloud describes the region of an atom where electrons are most likely to be. Use these questions to guide students in understanding the electron cloud concept.

Guiding Questions

AL What is the electron cloud?	*It is an area around an atomic nucleus where an electron is most likely to be.*
OL How has the model of an atom changed over time?	*The model has changed from a solid sphere to a sphere that contains protons and neutrons in a nucleus, and electrons in an electron cloud.*
BL What does "more likely to be" mean?	*means that there is a higher probability of finding an electron in a particular place than in other places.*
BL What are the limitations in using the analogy of bees around a hive to illustrate electrons in the electron cloud?	*Possible answers: Bees can freely leave the hive, whereas electrons need energy to be removed from the electron cloud. Scientists cannot be sure of the exact position and speed of an electron at a given moment, but these could be determined for a bee around a hive.*

Visual Literacy: The Modern Atomic Model

Help students understand that the electron cloud is represented as mostly empty space because it is impossible to predict exactly where electrons are at any given moment.



Ask: **Where are electrons most likely to be?** *darker areas—closer to the nucleus*

Ask: **Why do you think the model of an atom above doesn't show the electrons?** *It doesn't show electrons because it is impossible to know both the speed and exact location of an electron at a given moment in time. The cloud represents the likelihood of finding an electron in a given location.*

Quarks

Some students may have a difficult time understanding that protons and neutrons are made up of three even smaller particles called quarks.

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Which Key Concept does each image relate to?**

Summarize it

- Early Ideas about Matter
- Dalton's Atomic Model
- The Atom
- Thomson – Discovering Electrons
- Rutherford – Discovering the Nucleus
- Discovering Neutrons
- Bohr's Atomic Model
- The Modern Atomic Model
- Quarks

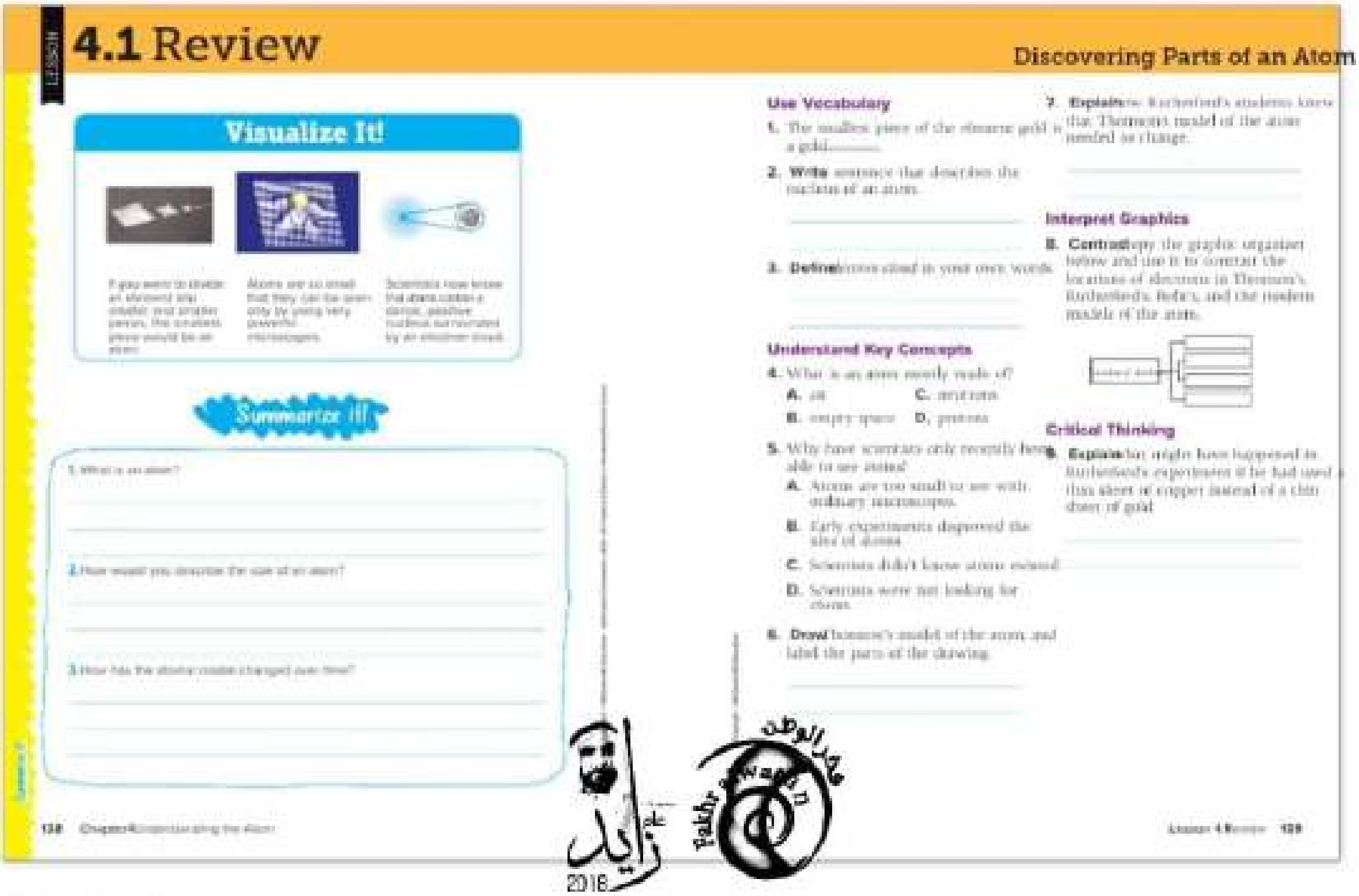
Teacher Toolbox

Fun Fact

Naming the Quark The quark was named by Murray Gell Mann, an American theoretical physicist and Nobel Pri winner. He selected the name because it sounds like t sound that ducks make. In the novel *Finnegans Wake* James Joyce, Gell-Mann came across the line "Three for Muster Mark," and he decided then that the particl would become known as the quark.

Technology Activity

Create a Museum Exhibit Have students use available technology to create an exhibit of the atomic models, principal scientists, and subatomic particles explored i this lesson.



Use Vocabulary

1. atom
2. Possible answer: The nucleus is the area at the center of an atom that contains both protons and neutrons.
3. The electron cloud is made up of the electrons and empty space that surround an atom's nucleus.

Understand Key Concepts

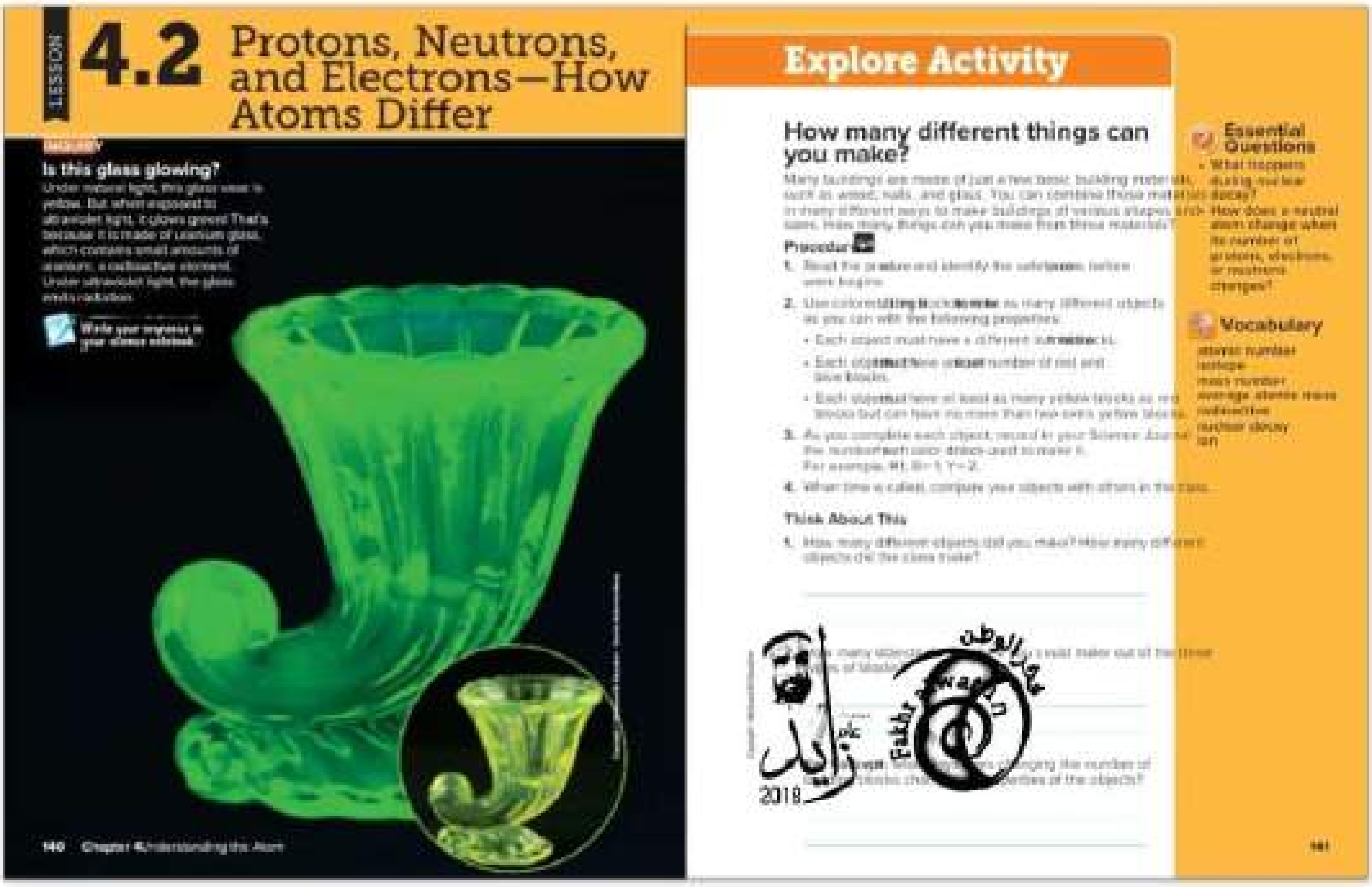
4. C empty space
5. A Atoms are too small to see with ordinary microscopes.
6. Students' drawings should show that Thomson's model had a positively charged sphere with electrons evenly distributed through it.
7. They knew this because the alpha particles bounced back when they struck the foil. This meant that the atom contained a dense, positive charge, which was not part of the Thomson atomic model.

Interpret Graphics

8. Location of electrons
   - Thomson: embedded in positively charged sphere
   - Rutherford: in empty space around the nucleus
   - Bohr: in circular orbits around the nucleus
   - modern model: in an electron cloud—region of empty space around the nucleus in which electrons are most likely to be.

Critical Thinking

9. The observations would match those seen with gold, because copper atoms also contain a dense nucleus surrounded by mostly empty space.



INQUIRY

About the Photo Is this glass glowing? Uranium glass was first made during the 19th century. It contains a small amount of uranium, which gives the glass a yellow tint. While uranium glass will give a Geiger counter reading, it does not register harmful levels of radiation.

Guiding Questions

AL What happens when uranium glass is exposed to ultraviolet light?	*It glows green.*
OL How could you identify the presence of uranium in a yellow glass vase?	*Expose it to ultraviolet light. If it glows a green color, then it is made with uranium.*
BL How can you explain, in terms of electron energy levels, why the energy from the ultraviolet light causes the uranium glass to glow?	*The ultraviolet light provides energy that causes uranium electrons to move to higher energy levels. When the electrons move back to lower energy levels, energy is released and is seen through our eyes as a green glow.*

LABManager

All the labs for this lesson can be found in the *Student Resource Handbook* and the *Activity Lab Workbook*.

Essential Questions

After this lesson, students should understand the Essential Questions and be able to answer them. Have students write each question in their interactive notebooks. Revisit each question as you cover its relevant content.

Vocabulary

Prior Knowledge

Students are likely to have heard about some of these terms from previ
science classes and others through advertising and popular media.

1. Call on volunteers to share with the class any vocabulary ter
they have heard before and anything they may know about i
2. Start with the term *radioactive*. Point students to the sentenc
in the lesson opener that uses the word and have them consider context clues.
Ask: **What might the word radioactive mean?** Sample *answers: an element that is "activated" by some type of energy; matter that emits radiation.*
3. Continue with atomic number and average atomic mass. Students should understand that these vocabulary words relate to the properties of atoms.

4. Use this opportunity to gauge student understanding, point out correct responses, and address any misconceptions.
5. Continue through the list. Leave blank words for which students cannot make an educated guess. Revisit this list as students read the lessons in the chapter.

Teacher Notes

ExploreActivity

How many different things can you make?

Prep: *10 min* **Class:** *15 min*

Purpose
To observe how many different objects can be constructed from only three basic parts.

Materials per student:
self-sealing plastic bag containing 40 interlocking building blocks (10 red, 10 blue, 20 yellow)

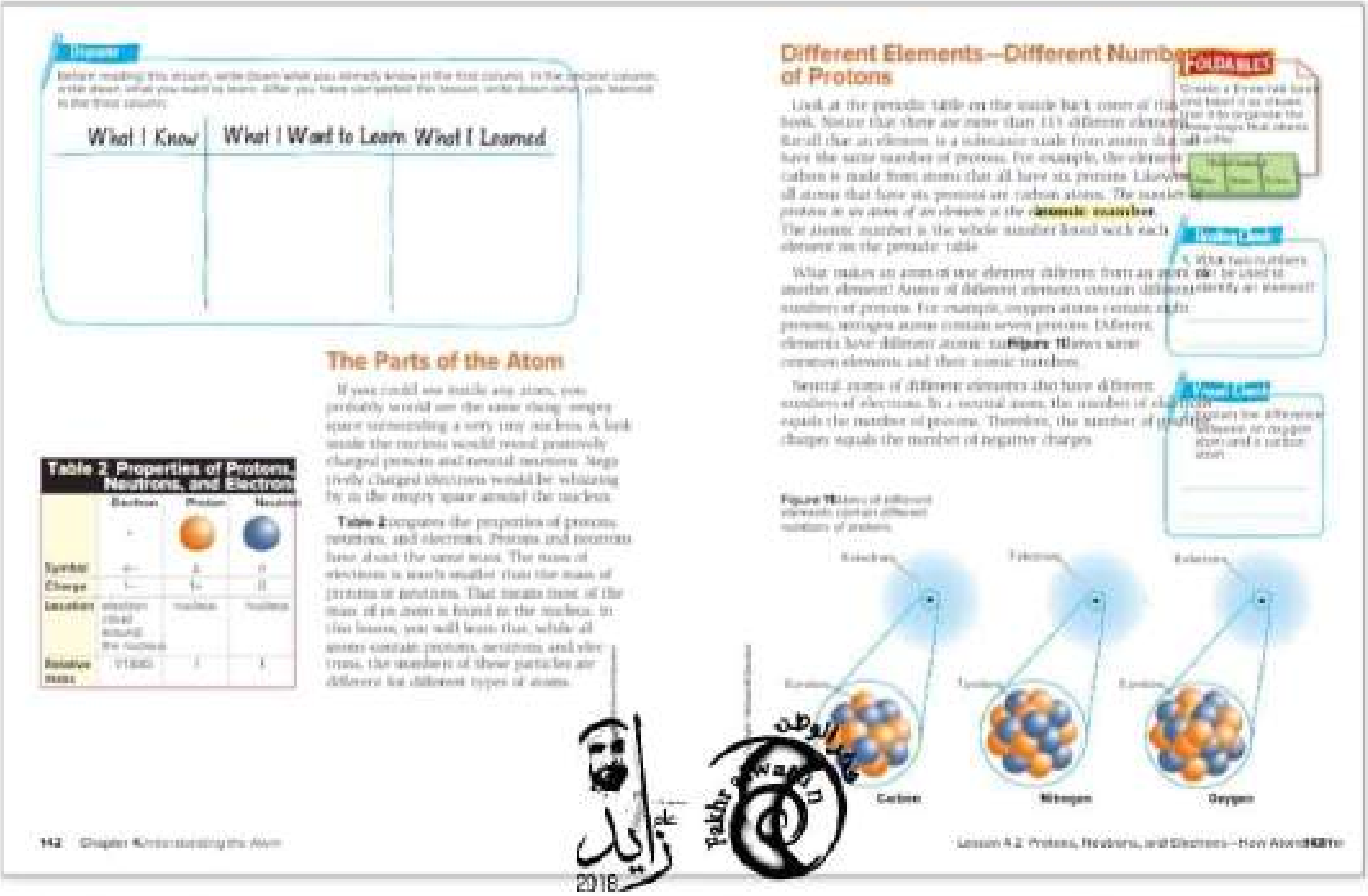
Before You Begin
Assemble the plastic bags containing the building blocks for each student. Use a common example, such as baking cakes, cookies, or bread, to discuss how many different things can be made from a few basic ingredients (flour, milk or water, eggs). Tell students this investigation will challenge them to make many different objects out of only three materials.

Guide the Investigation
Review the three conditions that each object must satisfy. Do not tell students that the different colors represent protons, neutrons, and electrons. When time is up, have a volunteer list the "composition" of his or her objects on the board. Invite other students to add objects they made with different compositions.

Think About This

Students may not know the answers to all questions. Encourage them to hypothesize.

1. Students should have made at least ten objects. The class may have made 30 different objects if they added one or two yellow blocks to the original ten objects.
2. Answers will vary. Students may say they can make as many different objects as they have red blocks, assuming they have at least an equal number of blue and yellow blocks.
3. **Key Concept** The shape and mass of each object is different.



The Parts of the Atom

Use these questions to review the properties and locations of protons, neutrons, and electrons, and to emphasize the relative masses of each.

Guiding Questions

OL **Which two particles are responsible for the mass of an atom, and which two particles are responsible for the charge of an atom?**	*The protons and neutrons are responsible for the mass of an atom, and the protons and electrons are responsible for the charge of an atom.*
BL **How does the density of the nucleus compare to the density of the rest of an atom?**	*The nucleus is denser than the rest of an atom.*

Different Elements—Different Numbers of Protons

The number of protons in an atom of an element is the element's atomic number. Atoms of different elements have different atomic numbers, and atoms of the same element have the same atomic number. For a neutral atom, the number of protons (the atomic number) equals the number of electrons. Later in this lesson, students will explore ions, so you may wish to emphasize to students that the number of protons is equal to the number of electrons in a neutral atom only. Use these questions to guide students in understanding these concepts.

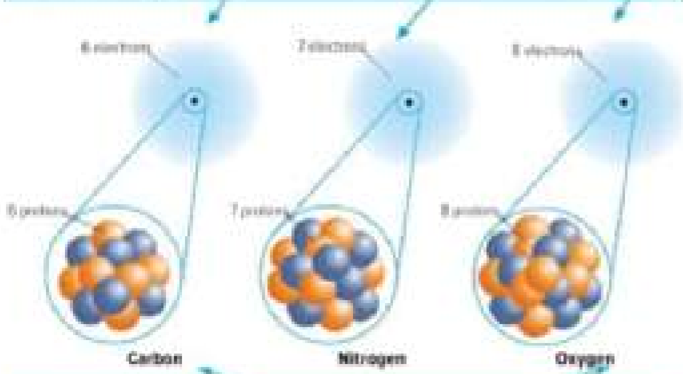
Guiding Questions

OL **What two numbers can be used to identify an element?**	*the atomic number and the number of protons*
BL **How is an element's atomic number like a person's fingerprints?**	*Fingerprints can be used to identify a person. An atomic number can be used to identify an element, because each element has its own unique atomic number.*

Visual Literacy: Different Elements

Use this diagram to allow students the opportunity to practice determining the atomic number of an element. Use the questions to emphasize that atoms of different elements have different numbers of protons (in other words, different atomic numbers) and that for a neutral atom the number of protons is equal to the number of electrons.

Ask: **What are the atomic numbers of carbon, nitrogen, and oxygen?** *The atomic number of carbon is 6. The atomic number of nitrogen is 7. The atomic number of oxygen is 8.*



Ask: **Explain the difference between an oxygen atom and a carbon atom.** *An oxygen atom has eight protons. A carbon atom has six protons.*

Differentiated Instruction

Ask all students in the class to draw the Modern Atomic Model in **Figure 10**. Explain to students that everything they will read in this lesson relates to the inner workings of an atom. Instruct them to keep the visual representation of **Figure 10** in mind as they read.

AL Look Ahead Have students label their version of **Figure 10** as *Generic Model of an Atom.* Have them look at **Figure 11** and draw a model of carbon below it and label that *Model of a Carbon Atom.* Ask students to make a list of the specific information they have about the carbon atom. They should be able to point out that they know the number of protons and electrons.

BL Explain to the Class Ask students to create a poster-size version of the carbon model that will be displayed in the classroom throughout the lesson. Instruct them to label the nucleus with its protons and to label the electron cloud. The poster should include three brief captions, below the appropriate labels, that explain the relative size of the nucleus, where protons are located, and why electrons are represented as a cloud.

LA Hydrogen v. Uranium Model Ask students to look at the generic model of an atom in **Figure 10**. Tell them that a hydrogen atom contains one electron and one proton. Ask students to draw a representation of a hydrogen atom. Tell students that the uranium atom includes 92 protons and electrons. **Ask:** **How would a drawing of the uranium atom be different from the two models we've already drawn?** If students can express this idea, help them write a script for a one-minute explanation they can give to the class.

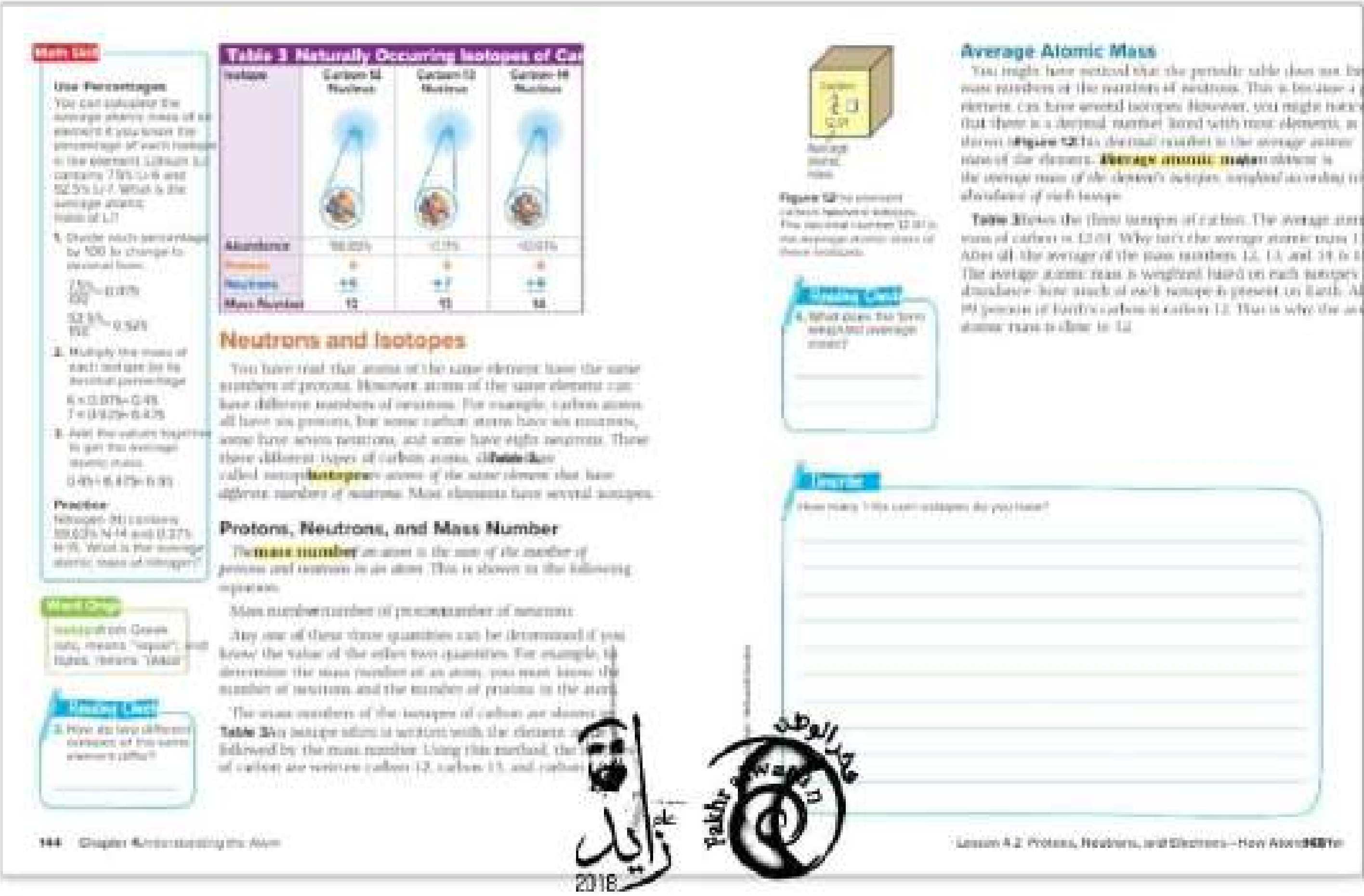
Teacher Toolbox

Real-World Science

Uranium Deposits Uranium, the same element used to make uranium glass glow, is used for a variety of other purposes, including as an alternative energy resource to replace coal. Uranium is a naturally occurring element in Earth's crust.

Teacher Demo

A Pea-Sized Nucleus Inside an Atom-Sized Stadium Explain to students that every atom of an element is very small, and each atom's nucleus is exponentially smaller. To demonstrate this concept, bring some peas into class along with a picture of a football stadium cut out of a sports magazine. Hold up one pea and the picture. Tell students that the stadium represents each atom, and the pea, each atom's nucleus. Ask students to guess the relative size of the pea inside the stadium. Point out that the nucleus is 100,000 times smaller than the atom as a whole.



Neutrons and Isotopes

Students may need to be reminded that although isotopes of the element have different numbers of neutrons, they have the same number of protons. Use these questions to guide students in understanding these concepts.

Guiding Questions

OL How are isotopes of an element alike? *They have the same number of protons.*

BL Explain how the number of neutrons affects the mass of an atom. *Atoms with more neutrons have more mass than do atoms with fewer neutrons.*

Word Origin

isotope

Ask: The Greek phrase isos topos means "equal (or same) place." What do you think "place" refers to? *Sample response: location on the periodic table*

Ask: Why do you think the Greek phrase isos topos is suitable for describing isotopes? Explain. *Isotopes occupy the same place on the periodic table of elements because they have the same number of protons (atomic number).*

Protons, Neutrons, and Mass Number

The mass number is the sum of the protons and neutrons in the nucleus of an atom. Isotopes of an element have different mass numbers because they have different numbers of neutrons. These questions provide an opportunity for students to practice calculations involving mass numbers isotopes.

Guiding Questions

OL How do two different isotopes of the same element differ? *Two different isotopes of an element have different numbers of neutrons, but the same number of protons.*

BL How many protons, neutrons, and electrons are in neutral atoms of hydrogen-1, hydrogen-2, and hydrogen-3? *Hydrogen-1 has 1 proton, 0 neutrons, and 1 electron. Hydrogen-2 has 1 proton, 1 neutron, and 1 electron. Hydrogen-3 has 1 proton, 2 neutrons, and 1 electron.*

Math Skill

Use Percentages

Help students conceptualize. Remind them that when they read about percentages, they are seeing numbers that represent parts of a whole.

Practice

$(0.9963 \times 14) + (0.0037 \times 15) = 14.0037$ average atomic mass for N

Average Atomic Mass

Some students may find it difficult to understand the concept of average atomic mass because they may not have been exposed to weighted averages. Use these questions to help students understand this sometimes confusing concept. Showing students examples of how average atomic mass is calculated is often the best way to reinforce this concept.

Guiding Questions

AL **Why is it necessary to calculate the average atomic mass?**	*Because a given element has multiple isotopes*
OL **What does the term *weighted average* mean?**	*Weighted average means that some data points contribute more to the average, or are more abundant, than others.*
BL **How is the average atomic mass of an element calculated?**	*The abundance of each isotope is changed into a decimal form. The mass of each isotope is multiplied by its corresponding decimal percentage. All the values are adding together to determine the average atomic mass.*

Differentiated Instruction

AL **Atomic Number Contest** Write the names of 10 elements on the board or on chart paper. Instruct stud to record the time it takes for them to locate the eleme on the periodic table and write down their atomic num Encourage students to repeat this activity until they are to cut their original time in half.

BL **Write a Children's Book** Have students convert the information in **Table 2** into an illustrated children's book about the parts of the atom. Instruct students to write t books in terms that a third or fourth grader could understand.

LA **Describing Isotopes** Create a sample of "beanium" by mixing several types of dry beans, such as pinto, navy, kidney, and lima. Give each pair of students a handful containing the mixture. Instruct students to pretend tha each type of bean is an isotope of a new element calle "beanium." Tell them to describe how the isotopes are a and how they are different.

Teacher Toolbox

Real-World Science

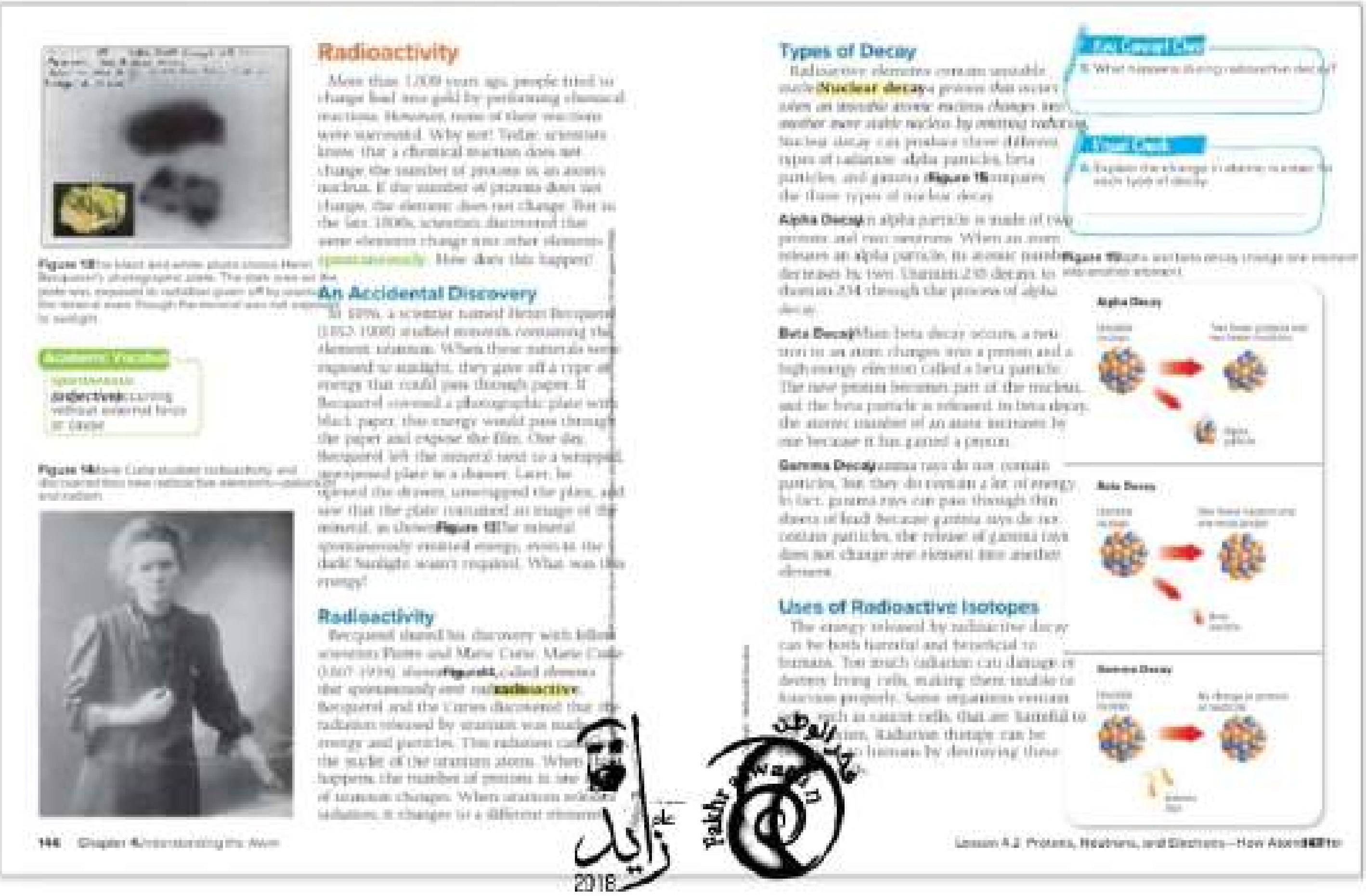
Isotopic Analysis Isotopic analysis involves determining proportion of the isotopes in a sample. Isotopic analys used in various fields such as archaeology, space scie forensics, food science, and medicine. It is used to ide the origins of meteorites, discriminate among bullet ty determine the origins of cotton fiber used to make counterfeit money, detect alterations of food, and to v the authenticity of organically grown crops.

Teacher Demo

Calculating Grades Compare the method of calculating average atomic mass to the method of calculating grad On the board or chart paper, show students an exampl how grades are calculated, using actual assignment we from your class. Explain to students that, in the exampl assignment weights are analogous to the percentage o each isotope, whereas the average grade for each cat is analogous to the mass number.

Reading Strategy

What's the Main Idea? Have each student record the mai idea of each section and the two sentences that best support the main idea. Read key sentences in the text a have students raise their hands if they recorded that sentence. Call on individuals to defend their choices.



Radioactivity

Students need to know that atoms of one element cannot be changed into atoms of another element by ordinary chemical reactions. Yet, some elements change into atoms of other elements spontaneously.

Ask: **Why is it not possible to change the number of protons in an atom's nucleus and still have the same element?** *Atoms of an element have the same number of protons. Only atoms of different elements have different numbers of protons.*

Academic Vocabulary

spontaneous

Ask: **What do you think the phrase *spontaneous laughter* means?** *laughing for no apparent reason or without an external cause*

An Accidental Discovery

Students may not know what photographic plates are. Explain to students that photographic plates are the precursors to photographic film. Many students may not have ever seen photographic film before, so you may want to bring in a sample for students to see. Use these questions to guide students in understand Becquerel's experiments with uraniumcontaining minerals.

Ask: **What was the difference between the first and second times the image of the mineral appeared on the plate?** *The first time the minerals were exposed to sunlight. The second time they were exposed in the absence of sunlight.*

Radioactivity

Radioactive elements spontaneously emit radiation. When the atoms emit radiation, they are changed into a different element. Use these questions to help students understand this process.

Guiding Questions

AL **What happens when an element emits radiation?**	*The number of protons changes, and the element changes into a different element.*
BL **Predict what the element uranium becomes when it loses two protons.**	*Uranium becomes thorium. Students should be able to determine this answer by looking at the periodic table of elements and finding the element with two less protons than uranium. Students may need reminded that the atomic number is equal to the number of protons in an atom.*

Types of Decay

Unstable nuclei become stable by releasing energy through the process of radioactive decay. The energy released is called radiation. Use these questions along with **Figure 15** to guide students in understanding these concepts.

Guiding Questions

AL How does an unstable atomic nucleus change into a more stable nucleus?	*by emitting radiation through the process of radioactive decay*
OL What happens during radioactive decay?	*An unstable atomic nucleus changes into another more stable nucleus by emitting radiation.*
BL How does the sum of the mass numbers of the starting materials compare to the sum of the mass numbers of the products of nuclear decay?	*Use this opportunity to review that the mass number of an atom is the sum of the protons and neutrons. The mass numbers are conserved.*

Visual Literacy: Types of Decay

Use **Figure 15** along with the text to guide students in understanding the process of nuclear decay, the types of radiation produced in the process, and the properties of the resulting atoms. Point out to the students that both alpha and beta decay result in the formation of a different element. Have students use **Figure 15** while you ask these questions.

Ask: **Explain the change in atomic number for each type of decay.** *In alpha decay the atomic number decreases by two. In beta decay the atomic number increases by one. In gamma decay the atomic number remains the same.*

Ask: **Explain the change in mass number for each type of decay.** *In alpha decay the mass number decreases by four. In beta decay the mass number remains the same. In gamma decay the mass number remains the same.*

Uses of Radioactive Isotopes

Students may have the impression that radioactive isotopes are always harmful to humans. Use this question to guide students in understanding that there are beneficial uses of radioactive isotopes as well.

Guiding Questions

AL What is an example of a beneficial use of radioactive isotopes?	*Radioactive isotopes are used to destroy cancer cells.*
OL Why can radiation both improve and hurt the health of humans?	*Radiation can damage or destroy cells. This is good if the cells are cancer cells attacking the body, but harmful if they are good cells and too many are killed.*

Differentiated Instruction

AL **Modeling Radioactive Decay** Have students work in groups to model the nuclear decay process shown in **Figure 15**. Instruct students to determine who will be protons and who will be neutrons. Find an open space where students can move around freely. Call out a type of decay (alpha, beta or gamma) and ask students to demonstrate each type of decay.

BL **Find "Bad" Science** Students are likely to have heard about radioactivity in popular media. Have students bring examples of bad science related to radioactivity from b[...] including comic books. Have them quote the claim, reference the source, and explain what is wrong.

LA **Visual Literacy** Have students draw **Figure 15** without the captions, and use their drawings to explain the pro[...] of nuclear decay, the types of radiation produced in th[...] process, and the properties of the resulting atoms.

Teacher Toolbox

Reading Strategy

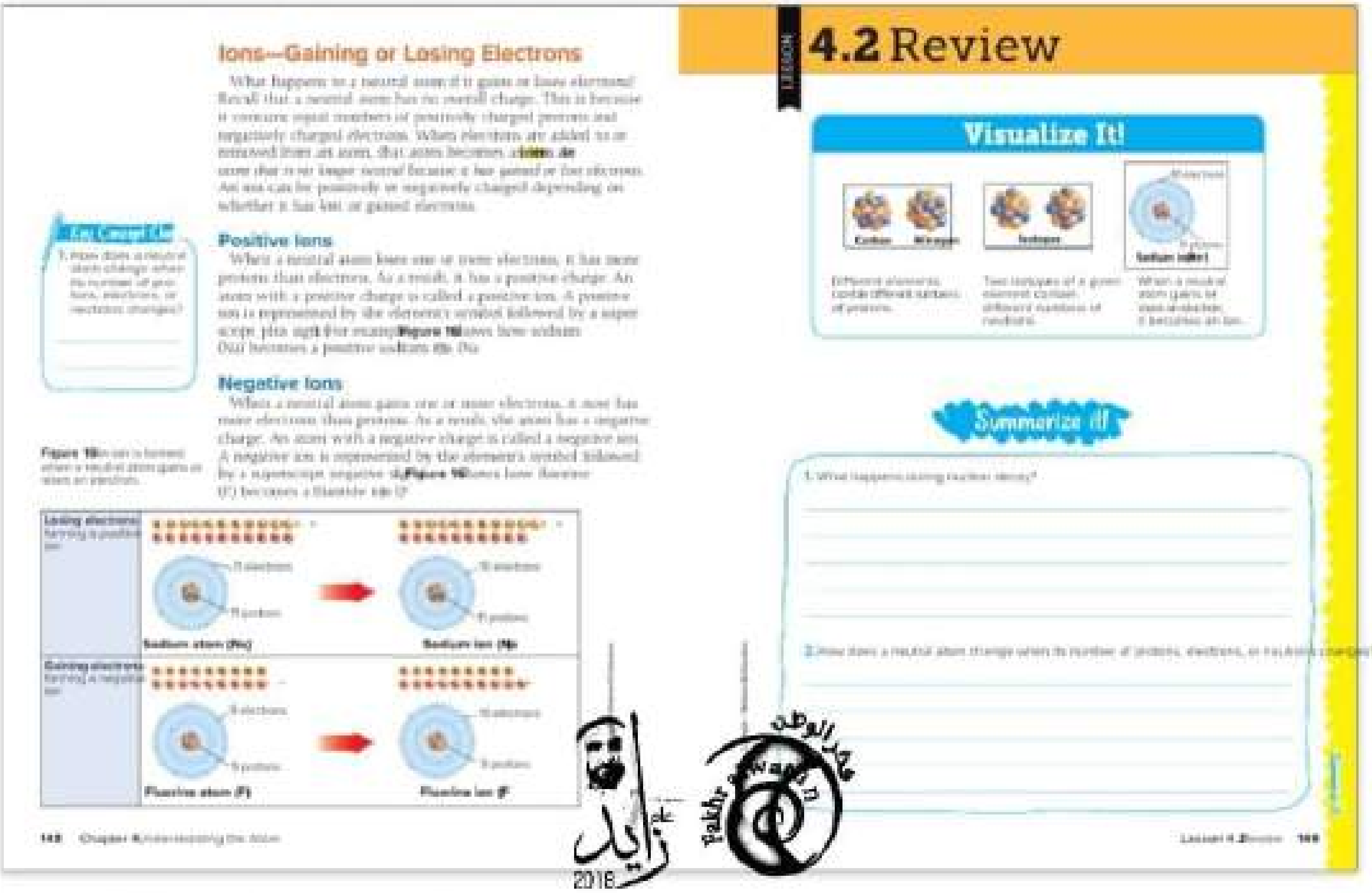
Prepare to Read Before reading, have students write do[...] the headings of the section on types of decay. As they [...] instruct students to write notes under the appropriate headings and to include drawings of **Figure 15.**

Teacher Demo

Radiation Photographs Self-developing film can be exposed by radioactive items, such as some smoke detectors, gas lantern mantles, and radium-dial watch [...] Cover the film with heavy black paper to prevent visibl[...] from exposing the film, place and secure the radioacti[...] material on the covered photographic film. Leave for a[...] 4 days.

Real-World Science

Radioactive Products Before the health effects of radiatio[...] were known, radioactive products were thought to be [...] for you. In the early 1900s radioactive isotopes were u[...] many products including toothpaste, hair tonics, water, [...] cream, blankets, medicines, and candy. Many users lat[...] developed skin, mouth and throat, and other cancers.



Ions—Gaining or Losing Electrons

Students often confuse ions and isotopes. Explain to students that an ion has more electrons or fewer electrons than a neutral atom, whereas isotopes differ in the number of neutrons. Use these questions to guide students in understanding ions and isotopes in terms of protons, neutrons, and electrons.

Guiding Questions

AL **What happens to a neutral atom when it gains or loses electrons?**	*It becomes a negative or positive ion.*
OL **Summarize the difference between ions and isotopes in terms of protons, neutrons, and electrons.**	*Isotopes have the same number of protons but different numbers of neutrons. The number of electrons is equal to the number of protons in an isotope. An ion is an atom that has more electrons or fewer electrons than protons. The number of neutrons remains the same in an ion as it was in a neutral atom.*
BL **What is wrong with the statement "an atom has more electrons than protons"?**	*Atoms are neutral. If the particle has more electrons than protons, then it is not an atom; it is an ion.*

Positive Ions

Because electrons are negative, loss of an electron from a neutral atom results in an ion with a positive charge. Because they may associate loss with negativity, students often have difficulty understanding how the loss of a particle from an atom can result in it developing a positive charge. You may want to explain this concept using the following analogy: If you have negative friends you may have a tendency to become a more negative person. If you stop spending time with those negative friends, you may have a tendency to become more positive.

Negative Ions

You may want to review **Table 2** and point out to students that protons and electrons are responsible for the charge of an atom or ion, whereas protons and neutrons are mostly responsible for an atom's mass. Use this question to help students understand the ways a neutral atom can change.

Guiding Questions

OL **How does a neutral atom change when its number of protons, electrons, or neutrons is changed?**	*If the number of protons changes, the atom changes to a new element. If the number of electrons changes, the atom becomes an ion. If the number of neutrons changes, the atom becomes an isotope of the atom.*

Visual Summary

Concepts and terms are easier to remember when they are associated with an image. **Ask: Which Key Concept does each image relate to?**

Summarize it

- The Parts of an Atom
- Different Elements -- Different Numbers of Protons
- Neutrons and Isotopes
- Radioactivity
- Ions – Gaining or Losing Electrons

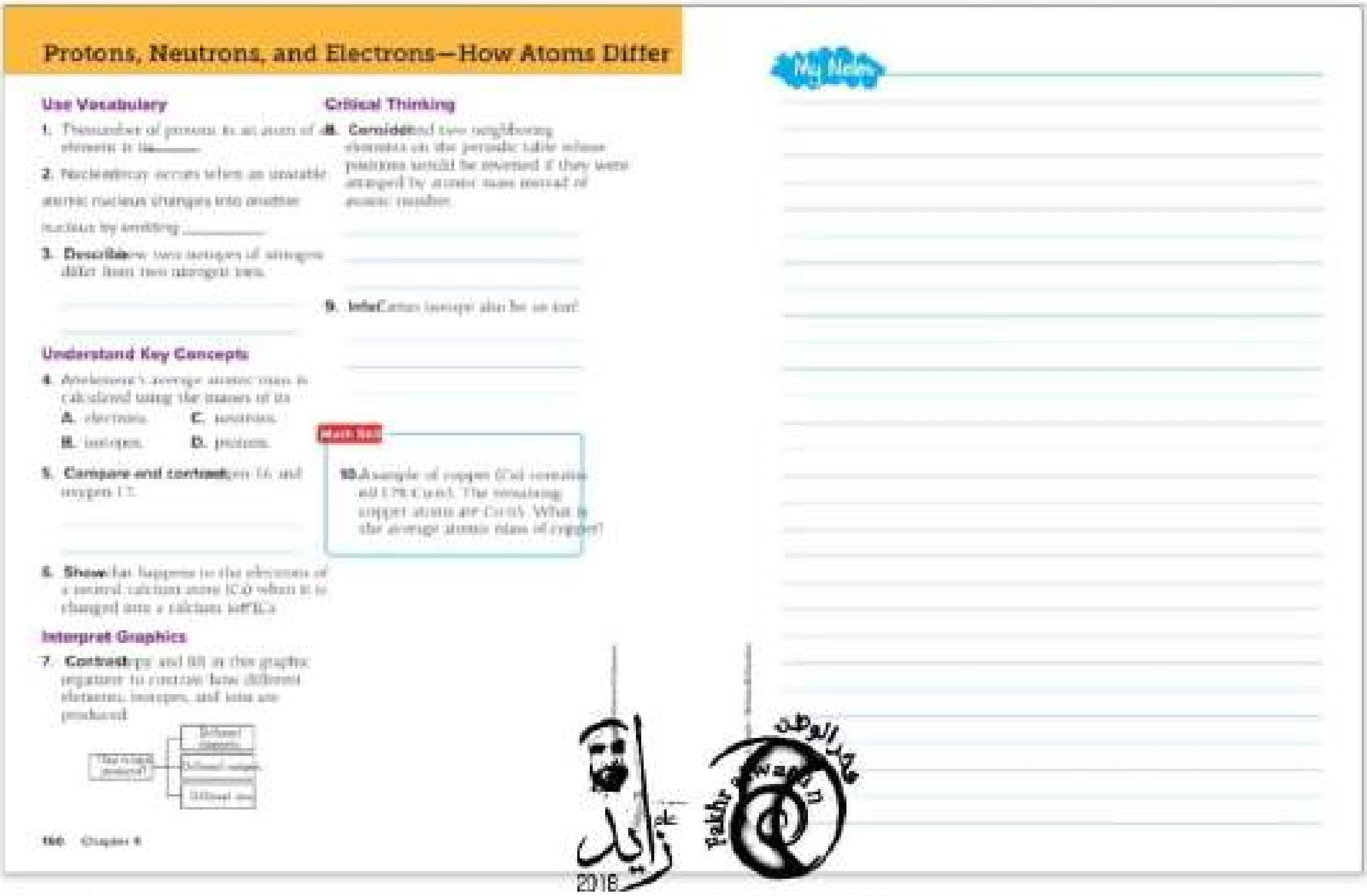
Teacher Toolb

Teacher Demo

Plastic Toy Hoop Models Use plastic toy hoops and construction paper circles to model the concepts in thi lesson. Obtain three plastic toy hoops. Cut 45 circles w diameter of about 10 cm from colored construction pap Cut 15 circles of each color. Use the plastic toy hoops a colored circles to illustrate that: atoms of a given elem contain the same number of protons; atoms of differen elements contain different numbers of protons; isotope atoms of a given element that contain different numbe neutrons; and ions are atoms that have more electrons fewer electrons than protons. Give groups of students materials and have them re-create **Figure 11** (neutral atoms), **Table 3** (isotopes), and **Figure 16** (ions). Have students present their models to the class, identifying numbers protons, neutrons, and electrons.

Reading Strategy

Compare and Contrast Have students write a short paragraph to compare and contrast ions and isotopes. They should briefly explain the relationship between th subatomic particles in each.



Protons, Neutrons, and Electrons—How Atoms Differ

Use Vocabulary

Critical Thinking

Understand Key Concepts

Math Skill

Interpret Graphics

150 Chapter 4

Use Vocabulary

1. atomic number

2. radiation

3. Two different isotopes of nitrogen have the same numbers of protons but different numbers of neutrons. Two different ions of nitrogen have the same numbers of protons but different numbers of electrons.

Understand Key Concepts

4. B. isotopes

5. They have the same numbers of protons but different numbers of neutrons.

6. Calcium loses two electrons.

Interpret Graphics

7.

How is each produced?	
	If protons change, a different element is produced.
	If neutrons change, a different isotope is produced.
	If electrons change, an ion is formed.

Critical Thinking

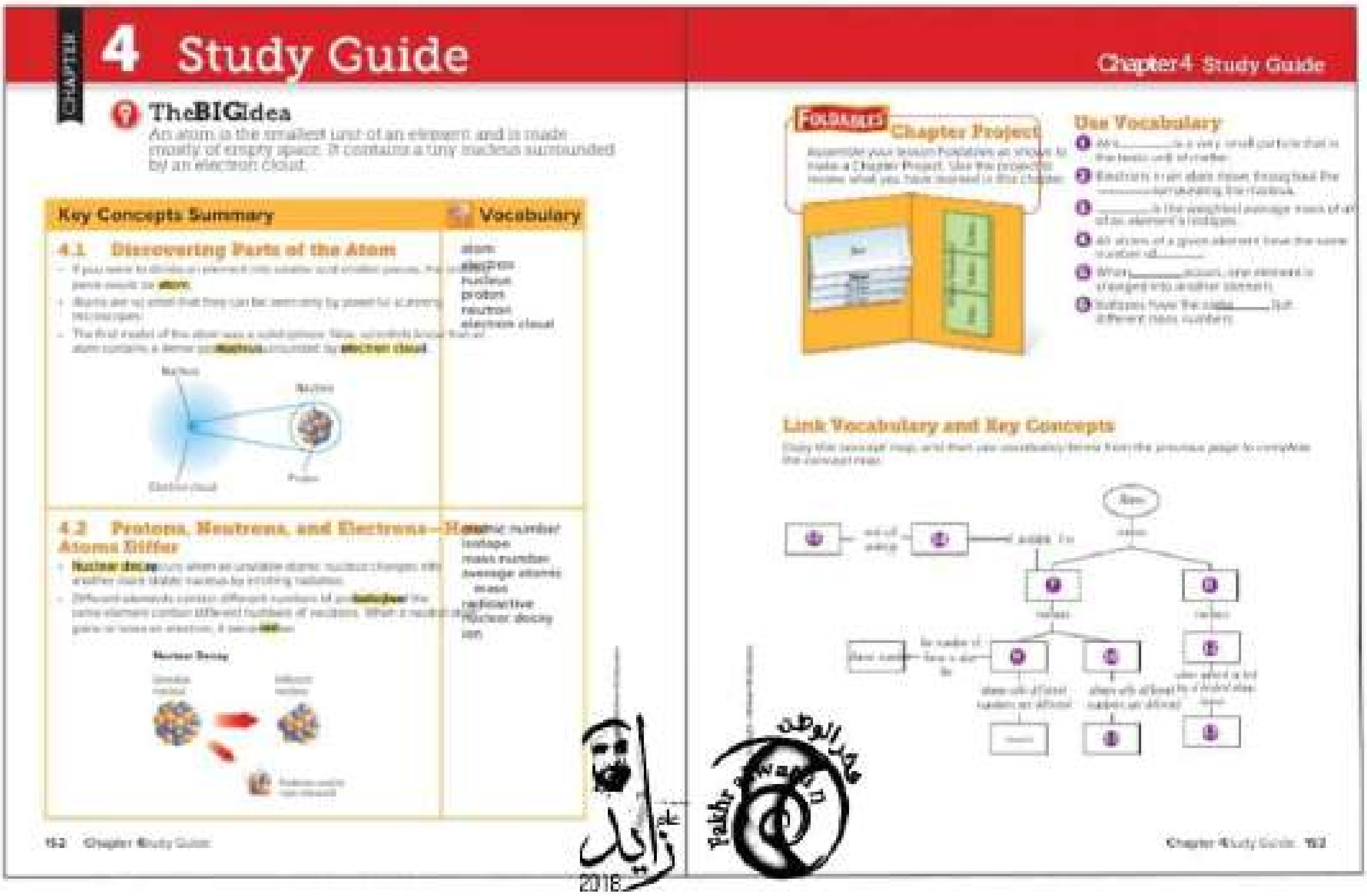
8. There are five instances where the elements would be reversed if the periodic table were arranged by atomic mass. Co and Ni, Te and I, U and Np, Fm and Es, Md and No

9. All atoms of a given element are isotopes. For example, all oxygen atoms are oxygen-15, oxygen-16, or oxygen-17. These are all isotopes. The formation of an ion doesn't change the number of neutrons. Therefore, an ion of oxygen will have 15, 16, or 17 neutrons. If all atoms are isotopes, then all ions are isotopes too.

Math Skill

10. abundance of Cu-65 = 100% − 69.17% = 30.83%

$(0.6917 \times 63) + (0.3083 \times 65) = 63.62$



Key Concepts Summary

Study Strategy: Two Truths and a Lie

Have students play a review game called "Two Truths and a Lie." In this game, a group of students create three statements. Two of the statements need to be true, and the third statement should be false. It is the job of another group of students to correctly identify which of the three statements is false. This game provides a fun and interactive way to engage students in reviewing Key Concepts explored in the lesson.

1. Organize students into groups of four.
2. For each statement in the Key Concepts summary, have students write two true statements and one false statement. Encourage students to write the statements so that it will be very difficult for the members of another group to identify the false statement.
3. Have each group of students exchange papers with another group of students.
4. Ask the pairs of groups to take turns attempting to correctly determine which of the three statements is false.
5. Encourage the pairs of groups to discuss what makes each false statement false and how they could change the statement to make it true.

Vocabulary

Study Strategy: Self-Assessment

Students often overestimate the number of vocabulary terms they know. This activity provides a way for students to assess their learning of the vocabulary words explored in this chapter and to learn the meanings of the terms that they may not know.

1. Ask students to write a three-column list containing the vocabulary words whose meanings they know, words whose meanings they think they know, and words whose meanings they do not know.
2. Instruct students to define the words they placed in the first two columns.
3. Have students go through the chapter, taking note of their accuracy in defining the words in the first two columns, correcting any incorrect definitions, and defining the words in column three.
4. Encourage students to create flash cards to help them learn the meanings of terms they were not able to correctly define.
5. Finally, have students write a summary of the chapter, underlining all of the vocabulary terms in their summaries.

FOLDABLES Chapter Project

Use the Foldables® Chapter Project as a way to connect Key Concepts.

1. Ask students to organize their Foldables® in a way that reflects how the concepts in each Foldable relate to each other.
2. Use glue or staples to hold the sheets together as needed.
3. When complete, ask students to place their Foldables® Chapter Project at the front of the room. Have the class critique and discuss the way in which students have organized their Foldables®.

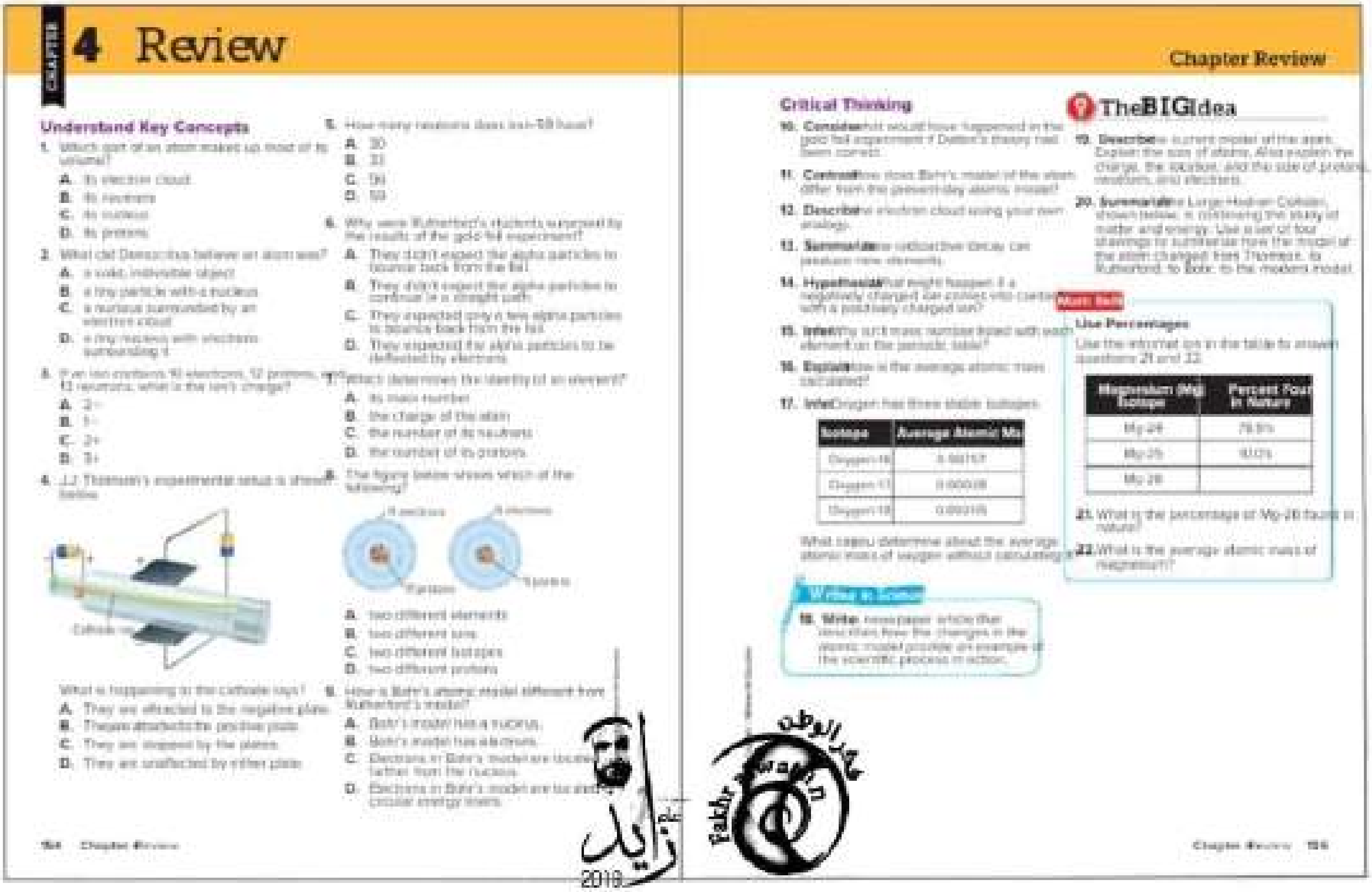
Use Vocabulary

1. atom
2. electron cloud
3. average atomic mass
4. protons
5. nuclear decay
6. atomic number

Link Vocabulary and Key Concepts

7. nucleus
8. electron cloud
9. protons
10. neutrons
11. isotopes
12. electrons
13. ions
14. radioactive
15. nuclear decay

Teacher Notes



Understand Key Concepts

1. A. its electron cloud
2. A. a solid, invisible object
3. C. 2+
4. B. They are attracted to the positive plate.
5. B. 33
6. A. They didn't expect the alpha particles to bounce back from the foil.
7. D. the number of its protons
8. A. two different elements
9. D. Electrons in Bohr's model are located in circular energy levels.

Critical Thinking

10. If Dalton's theory had been correct, the gold foil would have been made of atoms that were solid spheres. Instead of only a few alpha particles bouncing back, all of the alpha particles would have bounced back from the gold foil.
11. In the Bohr model, electrons moved in circular orbits around th nucleus. In the modern model, electrons move in an electron cloud. It is impossible to locate the exact position and speed o an electron in any given moment. Instead, one can only identi the likelihood that an electron will be in a given location.
12. Answers will vary. Encourage students to provide an analogy along with how the electron cloud is similar to the analogy and how it differs.
13. During radioactive decay, the nucleus of the atom is transmutated That means that the number of protons, neutrons, and/or electro is changed. Since the number of protons is changed, that means that the atomic number is changed. A change in atomic number corresponds to a change in the type of element present.
14. Negative charges attract positive charges. If the charges are equal in magnitude, the ions would attract each other to creat a neutral molecule.

15. A given element can have more than one isotope and each isotope has a unique mass number. It wouldn't make sense to only select one of these mass numbers to list and there isn't enough room to list them all.

16. Average atomic mass is calculated by first multiplying the atomic mass of each isotope by its respective percent isotopic abundance in nature and then adding these sums together.

17. The average atomic mass of oxygen is approximately 16 because oxygen-16 atoms make up over 99.7% of the atoms in nature.

Writing in Science

18. Students' articles should note that scientific models are open to change as new information is discovered. Often, the invention of new technology leads to the discovery of new information. The current model of the atom is also open to modification if information is learned that contradicts or enhances the current model.

TheBIGIdea

19. The current model of the atom is a tiny nucleus that contains positively charged protons and neutral neutrons surrounded by an electron cloud that contains negatively charged electrons. Atoms are so small that they can only be seen by special microscopes called Scanning Tunneling Microscopes.

20. The Thomson model should show a sphere of positive charge that contains negatively charged electrons. The Rutherford model should show a positive nucleus surrounded by negatively charged electrons. The Bohr model should show a nucleus with positively charged protons and neutral neutrons surrounded by electrons arranged in circular orbits. The modern model should show a nucleus similar to Bohr's model but surrounded by an electron cloud that is darker near the nucleus and lighter near the edge of the atom.

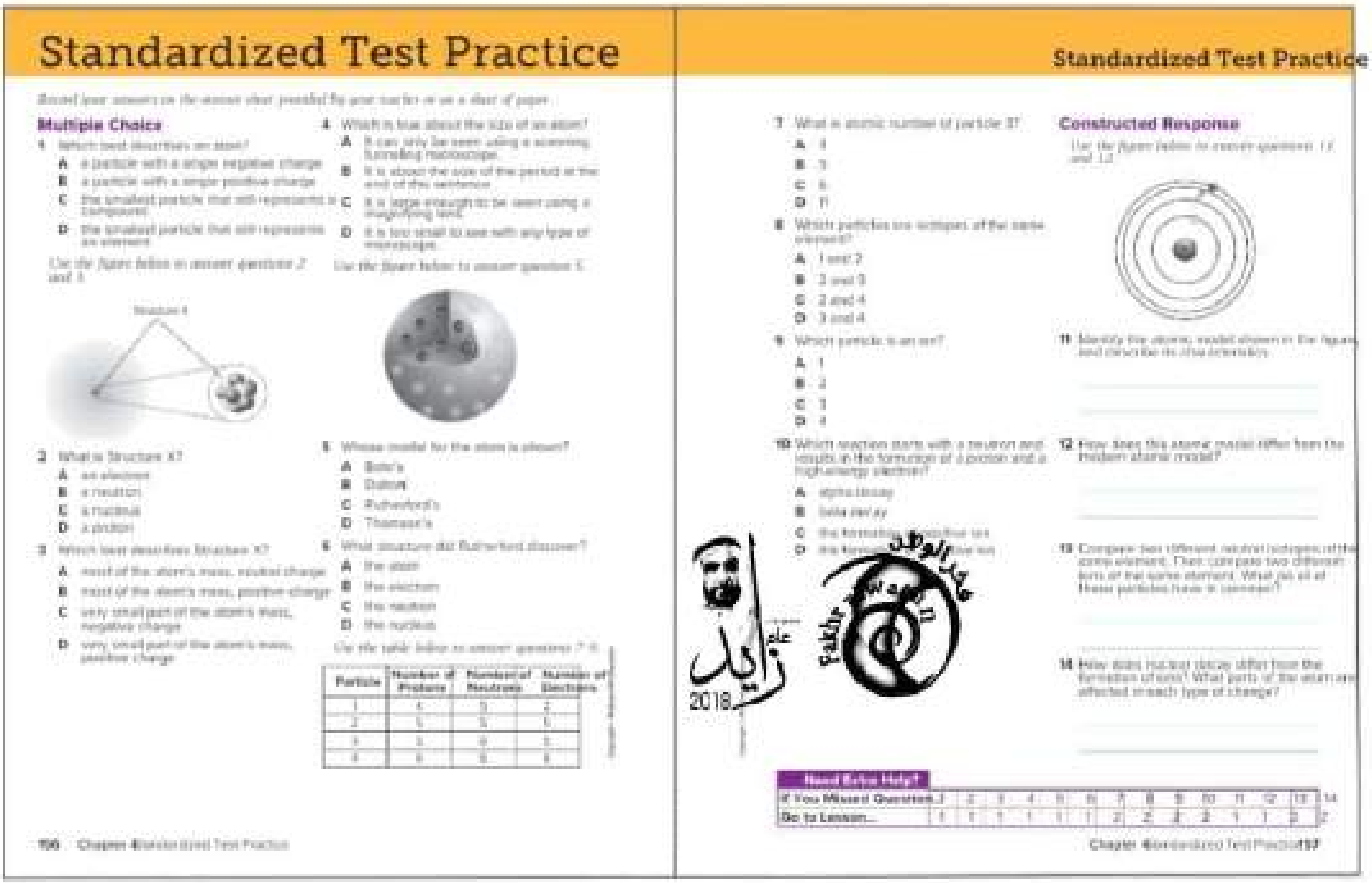
Math Skill

Use Percentages

21. 11.1% is Mg-26

22. 24.3

Teacher Notes


Standardized Test Practice

Multiple Choice

1 Which best describes an atom?
A a particle with a single negative charge
B a particle with a single positive charge
C the smallest particle that still represents a compound
D the smallest particle that still represents an element

2 What is Structure X?
A an electron
B a neutron
C a nucleus
D a proton

3 Which best describes Structure X?
A most of the atom's mass, neutral charge
B most of the atom's mass, positive charge
C very small part of the atom's mass, negative charge
D very small part of the atom's mass, positive charge

4 Which is true about the size of an atom?

5 Whose model for the atom is shown?
A Bohr's
B Dalton
C Rutherford's
D Thomson's

6 What structure did Rutherford discover?
A the atom
B the electron
C the neutron
D the nucleus

Standardized Test Practice

Constructed Response

Multiple Choice

1 **D—Correct.** A describes an electron, B describes a proton, and C describes a molecule.

2 **C—Correct.** A is found in the cloud that surrounds the nucleus, and B and D are particles that make up the nucleus.

3 **B—Correct.** A correctly describes the mass of a nucleus but incorrectly describes its charge. C describes an electron. D correctly describes the charge of a nucleus but incorrectly describes its size.

4 **A—Correct.** B and C describe atoms as much too large. D is incorrect because atoms can be imaged with an STM.

5 **D—Correct.** A (Bohr's model) would show a nucleus with protons and neutrons and electrons traveling in defined paths around it. B (Dalton's model) would describe a particle with no subatomic particles. C (Rutherford's model) would describe a positive nucleus with electrons surrounding it and no neutrons.

6 **D—Correct.** A was first described by Dalton. B was discovered by Thomson. C was discovered by Chadwick.

7 **B—Correct.** A is its arbitrary label. C is the number of neutrons. D is its mass number.

8 **B—Correct.** A and D describe particles with the same number of neutrons. C describes particles that have a neutral charge.

9 **A—Correct.** B, C, and D have the same numbers of protons and electrons and are thus neutral.

10 **B—Correct.** A names nuclear decay that emits an alpha particle, and C and D involve loss or gain or electrons to produce charged ions.

Constructed Response

11 Bohr's atomic model is shown. In the Bohr model, electrons move in circular orbits around the positive nucleus composed of protons and neutrons.

12 The Modern Atomic Model has moving electrons within the 3-dimensional space of an electron cloud. They do not move in the set orbits described by Bohr's model.

13 Two different neutral isotopes of the same element have different numbers of neutrons and the same numbers of protons and electrons. Two different ions of the same element have different numbers of electrons and the same numbers of protons. All particles of one element have the same number of protons.

14 Nuclear decay involves a change in the number of protons and/or neutrons in an atom's nucleus; one element changes to another in nuclear decay. The formation of ions involves a change in the number of electrons (a loss or gain of electrons); the nucleus is not affected and the element does not change to a different element.

Answer Key

Question	Answer
1	D
2	C
3	B
4	A
5	D
6	D
7	B
8	B
9	A
10	B
11	See extended answer.
12	See extended answer.
13	See extended answer.
14	See extended answer.