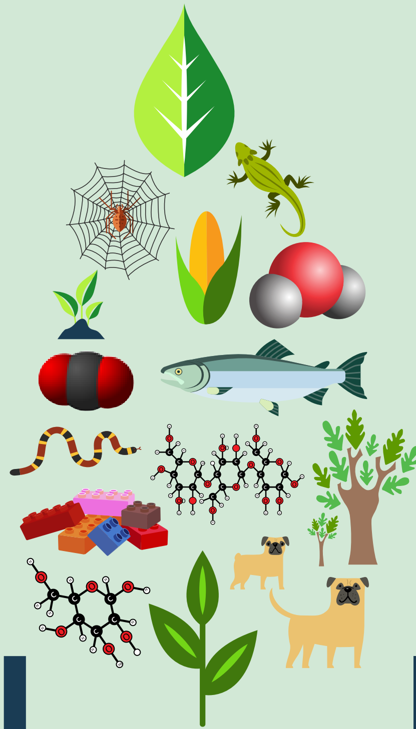

Toward High School Biology

Understanding Growth in Living Things

Teacher Edition

AAAS
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National Science Teachers Association

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Claire Reinburg, Director
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Art and Design
Will Thomas Jr., Director

Printing and Production
Catherine Lorrain, Director

National Science Teachers Association
David L. Evans, Executive Director
David Beacom, Publisher

1840 Wilson Blvd., Arlington, VA 22201
www.nsta.org/store
For customer service inquiries, please call 800-277-5300.

20 19 18 17 4 3 2 1

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Library of Congress Cataloging-in-Publication Data
Names: National Science Teachers Association.
Title: Toward high school biology : understanding growth in living things.
Other titles: Understanding growth in living things
Description: Teacher edition. | Arlington, VA : National Science Teachers Association, 2017.
Identifiers: LCCN 2017021524 (print) | LCCN 2017025654 (ebook) | ISBN 9781681405612 (e-book) | ISBN 9781681405605 (print)
Subjects: LCSH: Growth--Juvenile literature. | Growth--Study and teaching (Secondary)
Classification: LCC QH511 (ebook) | LCC QH511 .T69 2017 (print) | DDC 571.8--dc23
LC record available at https://lccn.loc.gov/2017021524

Contents

Note: Color images of models are available on the book's Extras page at *www.nsta.org/towardhsbio*.

AAAS Project 2061 Team

Jo Ellen Roseman, Principal Investigator
Cari Herrmann-Abell, Senior Research Associate
Jean Flanagan, Research Associate
Ana Cordova, Research Assistant
Caitlin Klein, Research Assistant
Bernard Koch, Research Assistant
Mary Koppal, Communications Director
Abigail Burrows, Senior Project Coordinator

External Review Team

Marlene Hilkowitz, Temple University, Philadelphia, PA
Michele Lee, Temple University, Philadelphia, PA
Barb Neureither, Michigan State University, East Lansing, MI
Edward Smith, Michigan State University, East Lansing, MI

Consultant

Kathy Vandiver, Massachusetts Institute of Technology, Boston, MA

Acknowledgments

The *Toward High School Biology* unit has benefited immensely from the many contributions of the staff at BSCS, who worked in partnership with AAAS during the first three years of the project (2010 through 2013). In particular, we are grateful to Janet Carlson, Rhiannon Baxter, Brooke Bourdélat-Parks, Elaine Howes, Rebecca Kruse (currently at the National Science Foundation), Stacey Luce, Chris Moraine, Kathleen Roth, and Kerry Skaradzinski for their expertise and tireless efforts. Recent contributions (2014 to 2016) of Rebecca Kruse were funded by the National Science Foundation Independent Research/Development Program. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

We would also like to thank the many excellent teachers and their students in Colorado, the District of Columbia, Maryland, and Massachusetts who participated in pilot- and field-testing the unit. Their insights and feedback have been invaluable.

Development of *Toward High School Biology* was funded by the U.S. Department of Education Institute of Education Sciences, Grant #IES-R305A100714. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the funding agency.

INTRODUCTION

About the Teacher Edition

The Teacher Edition is designed to provide easy access to essential background information and support needed for using the *Toward High School Biology* (*THSB*) unit effectively in the classroom. Additional teacher support materials (e.g., brief video demonstrations, color images from the unit, and tutorials) are provided on the book's Extras page at *www.nsta.org/towardhsbio*. The Teacher Edition and the online materials aim to provide both a "big picture" sense of the unit and its goals as well as the specific information and guidance needed to teach each lesson and carry out each activity.

Features of the Teacher Edition

At the unit level, the **Unit Overview** describes the overarching goal of the unit as it relates to the central questions students should be able to answer and the core disciplinary ideas they should understand after completing the unit. **Alignment With National Science Education Framework and Standards** describes the disciplinary core ideas, science practices, and crosscutting concepts from the National Research Council's *A Framework for K–12 Science Education* (the *Framework*; NRC 2012) around which the unit is developed and the performance expectations from *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013) that the unit contributes to. **Structure of the Unit** describes and **Content Storyline** represents where in the unit specific science ideas are developed and how the ideas build on each other from chapter to chapter. **Unique Aspects of the Unit** describes the rationale for the unit's approach to the science content, including its use of science terminology in the Student Edition. **Student Edition Conventions** presents the design principles guiding the development of lessons and describes the purpose and key features of each section of a lesson.

At the chapter level, the **Chapter Overview** describes the concepts developed in that chapter and provides a short synopsis of what students will do and think about in each lesson. **Background Knowledge for Teachers** provides information about key ideas to be developed in the chapter, as well as what phenomena, data, and models may be used to develop or illustrate those ideas. When appropriate, intended observations and rationale for selection are discussed. **Prerequisite Knowledge for Students** describes assumptions about where students are likely to be in their understanding of the science ideas that are central to each chapter and identifies knowledge from other disciplines (e.g., English and Language Arts) that students are expected to have. **Common Student Ideas and Misconceptions** outlines a small number of common confusions and misunderstandings from the research literature and from our own experiences in previous work that may be encountered in teaching the unit.

At the lesson level, each lesson begins with a **Lesson Guide** that provides an overview of the lesson, including the key question, targeted sciences ideas and practices, materials and advance preparation needed, and a summary chart describing key phenomena, data and models used, intended observations, and the pedagogical purpose of each. The remaining pages of the lesson consist of facing **Student Edition Page and Answer Key** and **Teacher Facilitation Notes** pages. Student Edition pages are identified as "**SE p. 1,**" "**SE p. 2,**" and so on so that the page numbers are consistent with those that students see in their workbooks. Each Student Edition Page and Answer Key page includes the Student Edition page plus ideal student responses (in gray text) written to reflect what students are likely to understand at that point in the lesson. Each page of the Teacher Facilitation Notes has a header that corresponds to a header on the facing student page and includes a time estimate in parentheses. The time each activity takes may vary according to each classroom's needs. Each lesson concludes with the heading *Closure and Link*, which is only in the Teacher Edition. Closure and Link is a description of the discussion that should arise at the end of each lesson/chapter. Ideally, students would come to the listed ideas and conclusions through a facilitated discussion. Teacher Facilitation Notes also include *Teacher Talk and Actions*, strategies for facilitating each page of the Student Edition, including partner/small group work, prompts for whole-class discussion, issues/ideas to highlight, and additional Science Notes for the teacher to be aware of. The Teacher Facilitation Notes are not a script; instead the Notes provide the essence of the developers' intent and suggest reasonable ways to adjust the curriculum to address the needs of particular students or classroom situations while still maintaining consistency with that intent.

Unit Overview

In developing the *Toward High School Biology: Understanding Growth in Living Things* unit, the American Association for the Advancement of Science (AAAS) and Biological Sciences Curriculum Study (BSCS) team was guided by learning theory and research evidence showing that students' science understanding develops from (a) having a wide range of experiences with the natural world that are explainable by a coherent set of ideas and (b) having an opportunity to interpret and make sense of what they experience in terms of those ideas. To help students generate conceptual understanding, however, they must also be guided in thinking about what they observe and in connecting their observations about instances to general principles and to what they already know. Student understanding of the learning goals increases when students (a) observe phenomena and representations that are explicitly targeted to the learning goals and are selected to address common student difficulties and (b) are actively engaged in interpreting the phenomena and representations in light of the learning goals and their own initial ideas. Consistent with these views, the *THSB* unit supports student learning by

- focusing on a coherent set of ideas and making the connections among those ideas clear,
- providing information about commonly held student ideas (both troublesome ideas and ideas teaching can build on) and questions to collect information about a particular group of students' ideas and to monitor their progress,
- including a variety of relevant and engaging phenomena and representations, and
- including activities that foster students' sense making, such as modeling tasks, to help students relate the phenomena and representations to the science ideas and to reconcile differences between their ideas and the science ideas.

With these design principles in mind, the AAAS and BSCS team developed the unit to address specific goals for student learning.

Goals for the Unit

The overarching goal of the *Toward High School Biology* unit is for students to apply ideas about what happens to atoms and molecules during chemical reactions to explain observable phenomena in nonliving systems and in the bodies of living organisms. Specifically, to grow and repair body structures, plants and animals build polymers through chemical reactions that link monomers and also produce water molecules. Animals get many of the monomers from breaking down other polymers in the foods they eat, whereas plants make monomers through other chemical reactions. During all these chemical reactions, atoms are rearranged and conserved; therefore, total mass is conserved.

By the end of the unit, students will be able to answer the following unit questions in terms of the rearrangement and conservation of atoms:

a. How do living things grow bigger?

b. Where does all the extra stuff come from as living things grow bigger?

The unit also addresses a number of important goals for science learning that are identified in the *Framework* (NRC 2012) and *NGSS* (NGSS Lead States 2013).

Alignment With National Science Education Framework and Standards

The *THSB* unit is designed to address core disciplinary ideas, science practices, and crosscutting concepts recommended as goals for learning in the National Research Council's *Framework* and in the *NGSS*. The core disciplinary ideas targeted in the unit are listed next and were drawn from the *Framework*, which provides a detailed description of them at each grade level. Science practices and crosscutting concepts are drawn from the *NGSS*, which clarifies them for each grade level in Appendix F and G, respectively. Parts of ideas and practices specifically targeted in the unit are shown in boldface, and a rationale for this selection is provided in the **Background Knowledge for Teachers** at the beginning of each chapter.

Disciplinary Core Ideas from the *Framework*

Physical Science, Structure and Properties of Matter (PS1.A, p. 108, Grade 8):

All substances are made from some 100 **different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Pure substances are made from a single type of atom or molecule; each pure substance has characteristic** physical and chemical **properties** (for any bulk quantity under given conditions) **that can be used to identify it.**

Physical Science, Chemical Reactions (PS1.B, p. 111, Grade 8):

Many substances react chemically with other substances to form new substances with different properties. This change in properties results from the ways in which atoms from the original substances are combined and rearranged in the new substances. However, the total number of each type of atom is conserved in any chemical process, and thus mass does not change either. Some chemical reactions release energy; others store energy.

Life Science, Organization for Matter and Energy Flow in Organisms (LS1.C, p. 148, Grade 8):

Plants, algae, and many microorganisms use the energy from light to **make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used** immediately or stored **for growth** or later use**. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth,** or to release energy. …

Science Practices from the *NGSS*, Volume 2, Appendix F

Practice 2, Developing and Using Models (p. 53)

- Develop and/or **use multiple models to** predict and/or **describe phenomena.** (Grades 6–8)

Practice 4, Analyzing and Interpreting Data (p. 57)

- **Analyze and interpret data to provide evidence for phenomena.** (Grades 6–8)

Practice 6, Constructing Explanations and Designing Solutions (p. 61)

- **Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.** (Grades 6–8)

Practice 8, Obtaining, Evaluating, and Communicating Information (p. 65)

- **Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural** and designed **world(s).** (Grades 6–8)

Crosscutting Concepts from the *NGSS*, Volume 2, Appendix G

Energy and Matter: Flows, Cycles, and Conservation (p. 86)

- **Matter is conserved because atoms are conserved in physical and chemical processes. …** (Grades 6–8)

These standards are addressed throughout the unit, and all three dimensions of science learning—core disciplinary ideas, science practices, and crosscutting concepts—are carefully integrated in each chapter. Students construct evidence-based explanations about phenomena. The evidence comes from direct observations students make during classroom activities and from patterns in data reported in the scientific research literature and summarized for students in the unit. Students use a variety of models to help them link the evidence to core ideas about atom rearrangement and conservation during chemical reactions in nonliving and living systems.

Performance Expectations from the *NGSS*, Volume 1

The unit contributes to the following middle and high school Performance Expectations:

- Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. (MS-PS1-2)
- Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. (MS-PS1-5)
- Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. (MS-LS1-7)
- Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. (MS-LS1-6)
- Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. (HS-LS1-6)

Structure of the Unit

The unit consists of 19 lessons organized into four chapters. Each chapter is organized around one or more of the core disciplinary ideas and crosscutting concepts that were listed. Students develop their understanding as they engage in the science practices of **analyzing and interpreting data, using models, constructing explanations, and reading scientific texts to obtain information and evidence.** Every lesson in the sequence supports students in developing the chapter learning goal, starting with the ideas and thinking students have as they enter the unit. Students have multiple exposures to the chapter learning goal throughout the chapter (and throughout the unit). Moreover, the learning goals in Chapters 1 and 2 are reinforced in Chapters 3 and 4, giving students the opportunity to examine examples of how the learning goals apply in both living and nonliving contexts. Many students require multiple examples to develop deep understanding of general principles; all students are not expected to grasp a new idea in the first lesson they encounter it.

Chapters 1 and 2 help students develop an understanding of chemical reactions by focusing on simple, nonliving systems. In Chapter 3 and 4, the central concepts developed in the first two chapters are applied to the more complex context of growth and repair in living organisms.

- Chapter 1 (Lessons 1.1–1.6) develops six science ideas related to the properties of substances and the production of new substances during chemical reactions and the molecular explanation for their production. Students first encounter the concepts in reactions involving only small molecules and apply them to reactions involving the formation of large macromolecules (polymers) and water molecules from small carbon-based molecules (monomers). Polymer formation is an important type of chemical reaction for understanding growth in living things, because plants and animals need to make polymers to build their body structures. Students develop explanations of phenomena using evidence from their observations and reasoning from science ideas and models.
- Chapter 2 (Lessons 2.1–2.3) develops four science ideas about mass conservation during chemical reactions and its molecular explanation. Students revisit the reactions they examined in Chapter 1, focusing on what happens to the mass when the reactions are carried out in closed versus open systems. They use models to visualize why even though atoms, and therefore total mass, remain the same (are conserved) during chemical reactions, the measured mass of a system can change if reactants or products enter or leave the system.
- Chapter 3 (Lessons 3.1–3.5) develops four science ideas as it applies the concepts of atom rearrangement and conservation to plant growth and repair: Through chemical reactions, plants build glucose monomers from CO_2 and H_2O they take in from the environment and link those glucose monomers to make the carbohydrate polymers (cellulose and starch) used to build body structures (which are made mainly of carbohydrate polymers). A plant's measured mass increases even though total mass is conserved. The increase in a plant's mass comes from mass in its environment (mainly from carbon dioxide gas): The more atoms that are added to a plant's body, the fewer atoms are in its environment.
- Chapter 4 (Lessons 4.1–4.5) develops three science ideas as it applies the concepts of atom rearrangement and conservation to animal growth and repair: Through chemical reactions, animals digest protein polymers in their food to amino acid monomers and use the monomers to build different protein polymers that make up their body structures (which are made mainly of protein polymers). An animal's measured mass increases even though total mass is conserved. The increase in an animal's mass comes from mass in its environment (mainly from the food it eats): The more atoms that are added to an animal's body, the fewer atoms are in its environment. In Lesson 4.5, students apply ideas about atom rearrangement and conservation in chemical reactions to the growth of mushrooms on a fallen dead tree.

Phenomena and Data

The unit is designed to provide students with opportunities to both experience phenomena directly and to examine data collected by scientists that can serve as evidence for the science ideas or for their explanatory power. The phenomena and data include numerous examples from both living and nonliving contexts. The unit includes tasks and questions that help students (1) explain observable phenomena and data using accepted science ideas and models of underlying molecular events and (2) apply science ideas developed in nonliving contexts to living contexts, thus making visible a coherent science content storyline for the molecular basis of growth and repair in living organisms.

Representations

The unit uses a variety of representations of atoms, molecules, and chemical reactions. By the end of the unit, students should be able to translate fluently among these representations and use them to communicate what happens during chemical reactions.

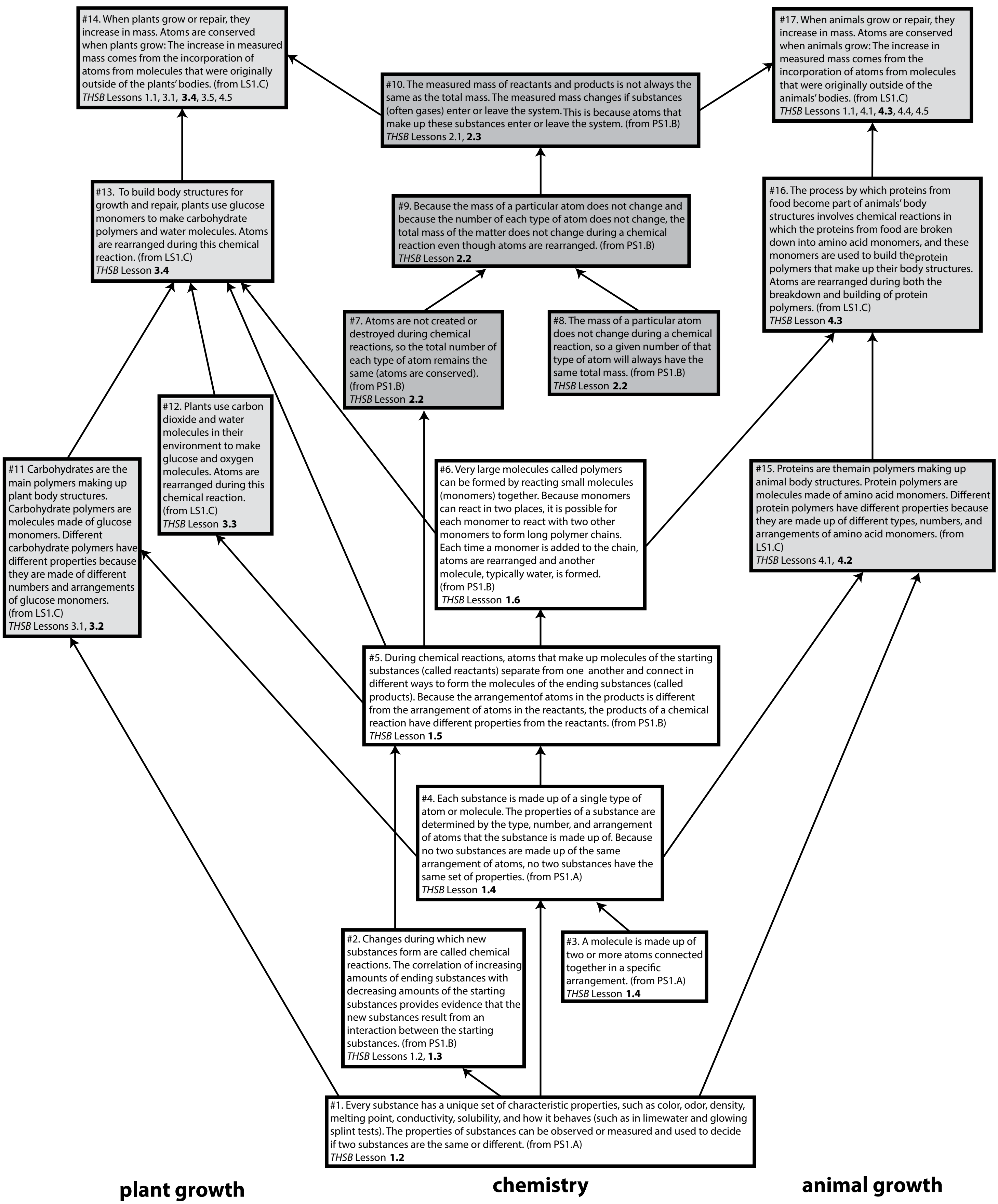
LEGO models are used to represent atoms and molecules. In LEGO models, an atom is represented by a LEGO brick, and different-colored LEGO bricks represent different kinds of atoms. Colors follow scientific conventions. A molecule is represented by attaching LEGO bricks together in specific ways. When representing a certain molecule, the LEGO bricks are always attached to the same points, facing the same direction, and with the same number of clicks. LEGO models do not accurately represent molecular shape or show bonds between atoms. However, they can be used to represent atom rearrangement and conservation and are easy for students to manipulate when modeling the changes substances undergo during chemical reactions. While we use "rules" for assembling LEGO models, it is not necessary that students know these rules. The point to make when using LEGO models is that bricks of starting models are rearranged into different models (Chapter 1), and this rearrangement, without the need to add or eliminate LEGO bricks, represents the conservation of atoms during chemical reactions, which accounts for conservation of mass (Chapter 2).

Molecular models include two-dimensional **space-filling models** and three-dimensional **ball-and-stick** models, photographs, or drawings of those models. In these models, each atom is represented as a sphere. Spheres of different colors and sizes represent different types of atoms. Colors follow scientific conventions. Color images of models are available on the book's Extras page at *www.nsta.org/towardhsbio*. You might want to remind students that atoms do not really have these colors—this is just a tool for identifying different kinds of atoms. A molecule is represented by two or more spheres connected together in a specific arrangement, without sticks (space-filling models) or with sticks (ball-and-stick models). These models show us the types of atoms that make up a molecule and how many of each type. They also show how the atoms are arranged. This gives us an idea of how molecules are shaped and how much space they occupy (how small or large they are) in comparison with other molecules. When using the ball-and-stick models, you should purposely limit the discussion about sticks to "a way to represent connections between atoms."

Chemical names, symbols, and **formulas** are used to represent atoms and molecules. Each type of atom is represented with a **symbol** that is an abbreviation of its English or Latin name. A symbol is usually one or two letters, with the first letter always capitalized. A molecule is represented with a **formula** that shows the symbol of each atom making up the molecule and follows the symbol with a subscript indicating the number of atoms of that type that are present. If no number follows a symbol, it implies that the molecule has only one of that type of atom. Formulas do not show how the atoms making up a molecule are connected.

Chemical reactions are represented by **model-building activities, equations,** and **chemical reaction mats**. Students manipulate LEGO or ball-and-stick models to convert molecules of reactants into molecules of products, and weigh models in sealed versus open baggies to represent mass conservation and changes in measured mass. They use word equations with chemical names (e.g., iron in steel wool and oxygen in the air reacts to form iron oxide) and equations with chemical symbols and formulas ($4\ Fe + 3O_2 \rightarrow 2\ Fe_2O_3$). And they look at chemical reaction mats showing words, formulas, and photos of molecular models of reactants on one side (green) and flip the mats to the other (yellow) side to see the words, formulas, and photos of molecular models of products. The act of flipping the mat over represents the "react to form" arrow in the equation.

Toward High School Biology (*THSB*) Content Storyline



Unique Aspects of the Unit

Understanding some of the thinking that went into the design of *Toward High School Biology* and what the unit is intended to do can help you support students in achieving the unit's learning goals. This section briefly describes the development team's rationale for decisions about how the core science ideas, practices, and crosscutting concepts would be integrated in the unit, what vocabulary students would be expected to know and use, and the extent to which the unit contributes to students' understanding of the nature of science.

Integrating Physical and Life Science Ideas About Chemical Reactions

In many school districts, life science is offered in the seventh grade and physical science in the eighth grade, so students typically encounter photosynthesis and cellular respiration before they are taught what chemical reactions are. Unless physical science and life science teachers coordinate instructional planning with coherence in mind, students will emerge from both courses with fragmented knowledge of the natural world. The THSB unit takes a different approach, treating ideas about chemical reactions in both living and nonliving contexts together and taught by the same teacher, so that connections among the ideas can be readily made. This integration of physical and life science content is consistent with recommendations of the *NGSS* in general and in particular with its crosscutting concepts related to matter and energy. Content support is provided in both the Teacher Edition and in professional development so that teachers of either life or physical science can become confident teaching all aspects of the unit.

Matter

The unit targets all of the core ideas about changes in matter that the *NGSS* recommend for middle school students. This includes ideas about chemical reactions in physical and life science at both the substance and at the atomic/molecular levels. These are the ideas needed to understand how new substances can be produced for growth and repair of living organisms from starting substances that appear quite different and why mass increases accompanying the growth of animals and plants do not violate conservation principles. The unit does not target more sophisticated high school ideas about atomic structure and chemical bonding because the development team felt that adding those ideas would needlessly diminish the unit's coherence.

Energy

In addressing *NGSS* core ideas and crosscutting concepts related to matter and energy, we needed to make decisions about what an eight-week unit that also targeted science practices could realistically accomplish. As a result, the unit focuses mainly on ideas dealing with matter and does not target energy ideas explicitly. There were both practical and conceptual reasons for this decision. Assessment data from AAAS's prior work indicated that students lacked mental models of both matter transformation and energy transformation, so we did not think eight weeks would be sufficient time to tackle both. Because matter transformation could easily be made concrete with physical models, we opted to start there. During pilot testing of an early version of the unit, we experimented with including a single simplified idea about energy ("atoms don't turn into energy and energy doesn't turn into atoms") to address a common misconception. We did find a decrease in the prevalence of the matter-from-energy misconception when students used that initial version of the unit. However, we observed that (a) only a few students actually invoked the idea when challenging their classmates' explanations, so we questioned its utility in the context of the unit and (b) only a few students were able to use an atomic/molecular model to explain chemical reactions in open systems, so we knew there was still much more work to be done in this area. With only eight weeks of instructional time available to us, we decided to focus subsequent versions of the unit entirely on matter ideas.

Cells

For several reasons, the *THSB* unit "black boxes" events related to biological growth and repair at the cellular level. Because the main goal of the unit is to help students understand the role of chemical reactions in biological growth and repair, we wanted to keep the focus on the properties of the biomaterials (protein polymers, carbohydrate polymers, and composites of them), which provides students with a more powerful—and demonstrable—explanation for the properties of body structures (e.g., muscle tissue or plant stems) than the fact that they are made up of cells. We also wanted to preserve the content storyline, which connects reactions in nonliving systems (e.g., polymerization of nylon) to similar reactions in living organisms (e.g., polymerization of proteins and carbohydrates). Focusing on the role of cells in biosynthesis would have distracted from that central storyline. Moreover, we thought that a consistent focus on linking mass/matter/materials/atoms to growth would be more likely to extinguish the common student misconception that cell division alone accounts for growth, which tends to be reinforced by existing curriculum materials.

Science Practices

Engaging students in scientific practices is central to the design of the *THSB* unit. Students use a variety of molecular models to make sense of atom rearrangement and conservation in chemical reactions; they analyze data drawn from their reading of simplified accounts of scientific research; they use science ideas and evidence from firsthand observations and data to support explanations of real-world phenomena. Not only do we want students to understand and appreciate the role these practices play in constructing scientific knowledge and evaluating explanations, we also view them as highly motivating and engaging instructional strategies. Designing learning experiences to promote the scientific practices of modeling, data analysis, and communication was a fairly straightforward task, and we were guided by the recommendations in the *Framework* and in the *NGSS*. Considerable effort went into designing and testing scaffolds to support explanation writing as described below.

Constructing Explanations

The *THSB* unit engages students in constructing scientific explanations of phenomena. Because of the complexity of this practice and the reported difficulty students have with constructing explanations, *THSB* provides support consistent with the cognitive apprenticeship model (Brown, Collins, and Duguid 1989; Collins, Brown, and Newman 1989). In the beginning of the unit, students are provided with an example of a valid explanation, and the essential elements of an explanation—claim, relevant science ideas, and evidence that will be linked to the claim using science ideas—are defined. The early lessons also establish Explanation Quality Criteria that students can use in judging an explanation's quality and introduce a template to remind them about the essential elements and help them organize their thinking and writing. After students experience modeling activities, a new element is added to the explanation template—models/modeling as tools for thinking about how something might work—and from then on students are expected to include models in their reasoning. The cognitive apprenticeship cycle is then repeated using the full explanation template. As the unit proceeds, students are reminded to use ideas about atoms in their explanations and to be sure that their explanations meet the Explanation Quality Criteria. The explanation template is faded in the Student Edition but is available in the Teacher Edition if the teacher feels the students still need it. At the end of the unit, the scaffolding is almost completely removed with the exception of a reminder that students can use science ideas from anywhere in the unit in their explanation.

The Teacher Edition and web-based teacher resources support teachers in helping students construct evidence-based explanations. The Teacher Edition provides ideal responses for each explanation task and for each element of the explanation template. Online teacher resources provide rubrics for explanation tasks recommended for use as embedded assessments. Rubrics list the specific elements of a complete explanation of each phenomenon, including claim, science ideas to be invoked, evidence to be cited that is consistent with those science ideas, reasoning that uses the science ideas, and, when appropriate, reasoning that uses ideas from modeling activities.

Nature of Science

Although the THSB unit was not designed to make ideas about the nature of science explicit, there are many opportunities throughout the unit for students to experience how science works. For instance, students consistently use models to think about and visualize atom rearrangement and conservation during a variety of chemical reactions and they analyze data and develop evidence-based explanations in ways that are consistent with what is expected of scientists. Students are repeatedly asked to list examples of phenomena they have observed in class that are consistent with presented science ideas and are told that the reason they can legitimately use the science ideas to support explanations of similar phenomena is because the science ideas are consistent with a wide range of observations and data—not just the small number they examined in class. Finally, students read simplified versions of scientific papers and examine how scientists use data in supporting their conclusions.

Nonetheless, the *NGSS* notes that while integrating science practices, core ideas, and crosscutting concepts “sets the stage for teaching and learning about the nature of science” (NGSS Lead States 2013, p. 97, Appendix H), engaging in such activities is not sufficient. Students would also need to reflect on their model-building, data analysis, and explanation activities and to compare their work to the work of scientists, which would likely involve examination of historical case studies. The THSB unit uses Van Helmont’s willow tree experiment as a case study. However, given the time that these additional activities would require and the risk they might pose to the coherence of the content storyline, we reluctantly decided not to focus more instructional time on nature of science learning goals.

Vocabulary

We have intentionally limited the number of technical terms to those that students need to communicate about their experiences. As a result, the unit avoids several terms typically used in eighth grade classrooms (e.g., element, compound, ion) while using other terms that are less typical (e.g., monomer, polymer). The terms *element, compound,* and *ion* are not needed for students to communicate their ideas about atom rearrangement and conservation, although students do need to correctly use the terms *atom* and *molecule* to do so. The terms *monomer* and *polymer* are used instead of alternatives like *small molecule* and *large molecule* because they convey more precisely the common features of carbohydrates and proteins and how they can be assembled from or disassembled to a small number of building blocks. We also leave out some details that are more likely to confuse than to help students develop and communicate their ideas. For example, solutions are referred to as liquids and ionic compounds are referred to as molecules.

The unit expects students to understand and correctly use the following terms in **bold** related to matter:

> **Atoms** and **molecules.** While students may have already been taught definitions of these terms, many do not consistently distinguish them in their talking or writing or in their use of models. It is essential that students know that atoms make up molecules, not the other way around. The unit expects students to know that an individual atom is represented by a ball or LEGO brick, that different colored balls or bricks represent different types of atoms, and that two or more balls or bricks linked together represent molecules.

Monomers and **polymers.** Rather than relying on vague descriptions like *small and large molecules,* which provide no information about how the small and large molecules are related, we opted to introduce the terms *monomer* and *polymer*. Using these terms in the context of chemical reactions involved in nylon formation, protein formation, and cellulose formation highlights their similarities (all involve formation of polymers and water molecules from monomers) and eliminates the need for students to know the names of most of the specific monomers involved (e.g., hexamethylenediamine, adipic acid, amino acids). However, students are expected to know that **glucose** is the monomer used to build carbohydrate polymers, such as cellulose and starch. The term *glucose* is singled out so that students can distinguish its formation (during **photosynthesis**) from its use to make polymers needed to build plant body structures for growth. Because the term *carbohydrates* refers to both polymers and monomers, accuracy requires that we use the term *carbohydrate polymers*. Students are expected to know that proteins are **polymers**.

Substances, materials, and **body structures.** The unit distinguishes pure substances (such as water, glucose, cellulose, and ovalbumin that are made of a single type of molecule) from materials (such as egg white that are made up of several types of molecules) from body structures (such as muscles and plant stems that are made from a variety of materials). The unit does not digress to discuss the relationship between molecular structure and properties of substances or materials made from them, which requires an understanding of atomic structure and chemical bonding.

Chemical reactions. Students are expected to know that chemical reactions produce **products** from **reactants**, that products have different **characteristic properties** from the reactants because they are made up of different molecules, but that the molecules making up the products are made from the atoms of the reactants. Students are expected to distinguish chemical reactions from changes in matter that do not involve chemical reactions based on comparing the molecules of the starting substances to the molecules of the ending substances. (Irreversibility is not a criterion for distinguishing chemical reactions from other changes—this is a common misconception). Students are expected to know that **photosynthesis** and **digestion** and the synthesis of proteins and complex carbohydrates involve chemical reactions.

Mass conservation and **measured mass.** Students are expected to know that while **total mass** of the reactants and products does not change during a chemical reaction (total mass is **conserved**), the **measured mass** may change if one or more substances enter or leave the **system**. The term *measured mass* is introduced to help students understand why conservation principles aren't violated during biological growth; that is, the added mass has to have come from somewhere outside the system being measured (the plant or animal's body). The unit engages students in weighing models of reactants and products of reactions in both closed and open systems to help them visualize that both mass and atoms (though not necessarily molecules) are conserved during chemical reactions.

The unit expects students to understand and correctly use the following terms in **bold** related to constructing and evaluating explanations:

Evidence. Students are expected to know that **data** from observations and measurements can be used as evidence for an explanation if the data are relevant to the answer and can be confirmed by others. Students are also expected to know that a **model** can sometimes be used to get ideas about how the thing being modeled actually works, but there is no guarantee that these ideas are correct if they are based on the model alone. Consequently, ideas from models do not provide evidence to support claims but should be consistent with claims.

Explanation. As noted in the *NGSS*, "the goal of science is to construct explanations for the causes of phenomena" (NGSS Lead States, 2013, p. 60, Appendix F). Throughout the unit, students are expected to explain phenomena in terms of underlying molecular events. Students are also expected to evaluate explanations of others. Students learn that an explanation must be consistent with all the evidence, relevant science ideas, and models.

Student Edition Conventions

Each chapter of the *Toward High School Biology* unit consists of carefully sequenced lessons and activities designed to (1) draw upon students' prior knowledge and experiences relevant to classroom activities; (2) support students as they investigate and make sense of phenomena and models; (3) guide students in developing, analyzing, and critiquing explanations (e.g., of a hypothetical student, of their peers, and of those of the scientific community) in light of their experiences; (4) provide opportunities for students to apply or extend science ideas and practices to new phenomena; and (5) help students synthesize their ideas and reflect on changes in their thinking.

Section Headings and Purposes

Each lesson is designed with particular features that are denoted by their section headings.

What do we know and what are we trying to find out?

This introductory section situates the lesson in the content storyline by making links between science ideas of previous lesson(s) and the key question of the current lesson. This section does not "give away the answers" but provides students with some sense of what they will be working toward understanding in the lesson.

Key Question

Each lesson begins with and returns to a key question that the lesson is designed to answer. The key question aligns with the lesson's main learning goal and frames the students' inquiry. The key question is posed at the beginning of the lesson to give each student a chance to express his or her initial ideas and to give teachers a sense of the range of ideas students hold. At the end of the lesson, the question is posed again and can be used to monitor students' progress.

Activity

Each lesson includes activities designed to engage students with phenomena and representations relevant to the learning goals. Some phenomena, particularly those in nonliving systems, can be observed directly and others, particularly those occurring in the bodies of living organisms, require inferences from data. Activities also engage students in modeling invisible aspects of the phenomena, particularly atom rearrangement and conservation. Each activity includes questions to focus and guide students in observing and interpreting the phenomena. Activities are structured to encourage discussion by having students work either with a partner or a small group.

Some activities consist of short readings and questions to (1) help students make sense of ideas presented in text, (2) encourage students to ponder what they have just read in manageable chunks, and (3) help students use and apply the ideas they have read in the text.

Other activities provide opportunities for students to learn to construct explanations, evaluate sample explanations, and develop their own explanations for phenomena they encounter in the unit and in their everyday lives.

Participating in a whole-class discussion at the end of an activity can help students reach consensus on their observations of phenomena, data, and models and on the ideas that emerge from their interpretations of them.

Science Ideas

At critical points in the unit, particularly after students have developed ideas based on phenomena, data, or models, students are asked to generalize across their experiences. Only then are relevant science ideas introduced to students as generalizations about how the world works based on a wider range of observations and data. (Each science idea, followed by a list of the lessons in which it plays a role, is shown in a box on the Content Storyline map on p. xi. Lesson numbers in bold indicate where a science idea is first introduced.) Students have opportunities to compare the ideas they are developing with established science ideas and find examples from their work that support the science ideas.

Science ideas are used in writing explanations, so they will often precede an activity in which explanations are evaluated or developed. Or, they may precede a Pulling It Together section in which students are expected to construct an explanation.

Pulling It Together

These questions provide opportunities for students to individually (1) revisit and answer the lesson key question or related questions to summarize their current understanding or new learning, (2) use and apply the ideas they are developing to a new context or phenomenon, and (3) begin to link the ideas to the next lesson(s). The linking question elicits student ideas and predictions about the key question of the next lesson or about how an idea developed in nonliving contexts might apply to growth in living things.

References

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Collins, A., J. S. Brown, and S. Newman. 1989. Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In *Knowing, learning, and instruction: Essays in honor of Robert Glaser,* ed. L. B. Resnick, 453–494. Hillsdale, NJ: Erlbaum.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards*.

NRC (National Research Council). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

The following page has a blank explanation chart. Initially all explanation tasks have this writing scaffold. As the unit progresses, the scaffold is removed. If students need additional scaffolding later in the unit, teachers may copy the blank chart for use with their students.

Question	
Claim	
Science Ideas	
Evidence	
Models	

Explanation:

Toward High School Biology

Chapter 1

Teacher Edition

Chapter 1 Overview

Students are familiar with many everyday changes that matter undergoes, in both living and nonliving things. They observe substances changing naturally and they participate in changing other substances themselves. Students may also be quite familiar with atoms and molecules. Too often, however, students do not share scientists' ideas about an "atom rearrangement model" when it comes to explaining the changes they witness on a daily basis. Chapter 1 helps students develop the concepts that **different substances have different characteristic properties because they are made up of different arrangements of atoms** and that **new substances form during chemical reactions because atoms making up molecules of the reactants rearrange to form molecules of the products.**

Lesson 1.1 provides students with an opportunity to observe changes in matter that makes up both living and nonliving things. Students are asked to try to identify similarities in these changes (e.g., new materials form or "grow," the matter of new materials comes from other materials, and the weight of the new matter increases as it "grows"), but they will have numerous opportunities throughout the unit to revisit and revise their ideas as they learn more concretely how these changes are similar.

Lesson 1.2 transitions students from changes in complex mixtures of substances or materials that make up living things to three examples of pure substances reacting in simple systems that will be used to illustrate and help students generalize important concepts about chemical reactions. Students gather firsthand observations of samples of reactants, chemical reactions, and samples of the products and examine data to form the generalization that different substances have different sets of characteristic properties that can be used to tell one substance from another. Students are introduced to criteria for judging the quality of explanations and use the criteria to evaluate and construct evidence-based explanations to support claims that new substances form during these changes.

Lesson 1.3 revisits the same three chemical reactions introduced in Lesson 1.2 but focuses students on observing changes in the amounts of starting and ending substances as the reaction proceeds, specifically that as the amounts of the ending substances forming increase, the amounts of starting substances decrease. From their observations, students should infer that the ending substances probably come from the starting substances.

Lesson 1.4 investigates why, for each change, the ending substances have different properties from the starting substances. Students examine models to visualize differences in the type of atoms, number of each type, and how the atoms are arranged in different substances and generalize that whenever substances have different properties they are made up of different arrangements of atoms. Students also begin making sense of the three reactions in terms of the types of atoms and molecules that make up the ending substances as compared with starting substances from which they are made.

Lesson 1.5 is a structured modeling activity with LEGO bricks that guides students in developing the concept that atoms making up molecules of the reactants are rearranged to form the molecules of products during chemical reactions. Students are introduced to the role that models can play in supporting explanations. The activity focuses on the iron rusting reaction and the reaction between baking soda and vinegar and to having students expand their explanations to include what is happening to the atoms and molecules to account for the production of ending substances with different properties.

Lesson 1.6 applies the overarching concepts about chemical reactions to the formation of very large molecules (polymers) from small molecules (monomers). Students examine characteristic properties of the monomers and the polymer and use ball-and-stick models to model the atom rearrangement that occurs when nylon and water molecules are formed from hexamethylenediamine and adipic acid monomers. Typical of polymerization reactions that students will encounter in Chapters 3 and 4, nylon formation involves the rearrangement of only a few atoms as the monomers are linked and water molecules are formed.

Chapter 1 Background Knowledge for Teachers

The Three Chemical Reactions for Chapters 1 and 2

Three chemical reactions are the backbone of the first two chapters: the reaction between baking soda and vinegar, between iron and oxygen, and between hexamethylenediamine and adipic acid. Students investigate these chemical reactions in depth—from both macroscopic and microscopic perspectives. Chapter 1 focuses on how the rearrangement of the atoms making up the molecules of the starting substances can explain the production of substances with different properties: atom rearrangement produces different molecules, giving the products different properties from the starting substances. Chapter 2 focuses on helping students understand that if atoms are merely rearranged, the type and number of atoms does not change (atoms are conserved); therefore, the total mass does not change (total mass is conserved). It also helps students reconcile conservation ideas with changes in mass of a system: While atoms are not created or destroyed, the mass being measured may change if atoms enter or leave the system. The Chapter 2 Background Knowledge document contains discussion of mass for each chemical reaction.

Baking Soda and Vinegar

The reaction between vinegar (acetic acid, $HC_2H_3O_2$) and baking soda (sodium bicarbonate, $NaHCO_3$) actually involves two steps—an acid-base reaction followed by a decomposition reaction. When vinegar and baking soda are mixed, hydrogen ions (H^+) from the acetic acid in vinegar react with the bicarbonate ions (HCO_3^-) from the baking soda to form a new chemical called carbonic acid (H_2CO_3):

$$H^+ \text{ (aq)} + HCO_3^- \text{ (aq)} \rightarrow H_2CO_3 \text{ (aq)}$$

The carbonic acid formed then decomposes into carbon dioxide gas (CO_2) and water (H_2O). It is carbon dioxide gas that you see bubbling as soon as you mix baking soda and vinegar together.

$$H_2CO_3 \text{ (aq)} \rightarrow H_2O \text{ (l)} + CO_2 \text{ (g)}$$

The following chemical equation describes the net reaction between vinegar and baking soda that forms soluble sodium acetate ($NaC_2H_3O_2$), water, and carbon dioxide gas:

$$\mathbf{HC_2H_3O_2 \text{ (aq)} + NaHCO_3 \text{ (s)} \rightarrow NaC_2H_3O_2 \text{ (aq)} + H_2O \text{ (l)} + CO_2 \text{ (g)}}$$

Intended observations: Students are expected to see gas bubbles forming, hear fizzing, and feel increased gas pressure in the container when the clear, colorless liquid and white powder are mixed. Students may also observe a diminished odor if enough of the vinegar is consumed during the reaction.

Rationale for including this reaction: This acid-base neutralization reaction provides an example of non-gaseous reactants yielding gaseous products. It is used in Chapter 2 to provide evidence that gases have mass, because students can observe that the mass of the container decreases when gas is allowed to escape.

Steel Wool (Iron) and Air (Oxygen)

Steel wool is made mostly of the element iron (Fe). To prevent the iron from rusting, steel wool is made with an oil-based coating, which can be removed with vinegar or heating. The rusting of iron is a complex electrochemical process that begins with the transfer of electrons from iron to oxygen and involves multiple oxidation/reduction and acid-base reactions. The products of rust formation depend on the amount of oxygen and water present (i.e., FeO in oxygen-depleted conditions, Fe_2O_3 in oxygen-rich conditions). The following chemical equation is commonly used to represent the process overall, leaving out various intermediate products that occur temporarily along the way:

$$\mathbf{4\ Fe\ (s) + 3\ O_2\ (g) \rightarrow 2\ Fe_2O_3\ (s)}$$

The reaction of Fe and O_2 is relatively slow but is speeded up by water and ions, which is why cars rust when in contact with salted roads. Given sufficient time and oxygen, any iron sample will eventually covert completely to rust. The Fe_2O_3 rust product is a delicate and brittle reddish-brown solid that breaks apart with the slightest touch. This change in texture often leads to misconceptions that rusting causes a decrease in mass (which is what happens when rust falls off), as opposed to the increase in mass caused by chemically combining iron and oxygen.

Intended observations: Students should observe rust products that form on steel wool. By carrying out the reaction in a flask sealed with a balloon, they will also have evidence that a gas in the flask is involved in the reaction (i.e., the balloon is pushed or inverted into the flask as the oxygen in the air is used, causing the pressure inside the flask to decrease). Trace amounts of water speed up the reaction but is regenerated at the end, so the amount doesn't change from start to finish. Because the rusting reaction releases heat, the water may vaporize during the reaction and then condense once the reaction is complete. Students may think that water is a product, but the water was there from the start. Point this out to focus students' attention on the overall reaction.

Rationale for including this reaction: In Chapter 1, rusting provides an example of a gaseous reactant yielding a solid product. This is analogous to photosynthesis reactions that "fix" gaseous carbon dioxide from the air to form solid glucose for building plant materials.

Hexamethylenediamine and Adipic Acid

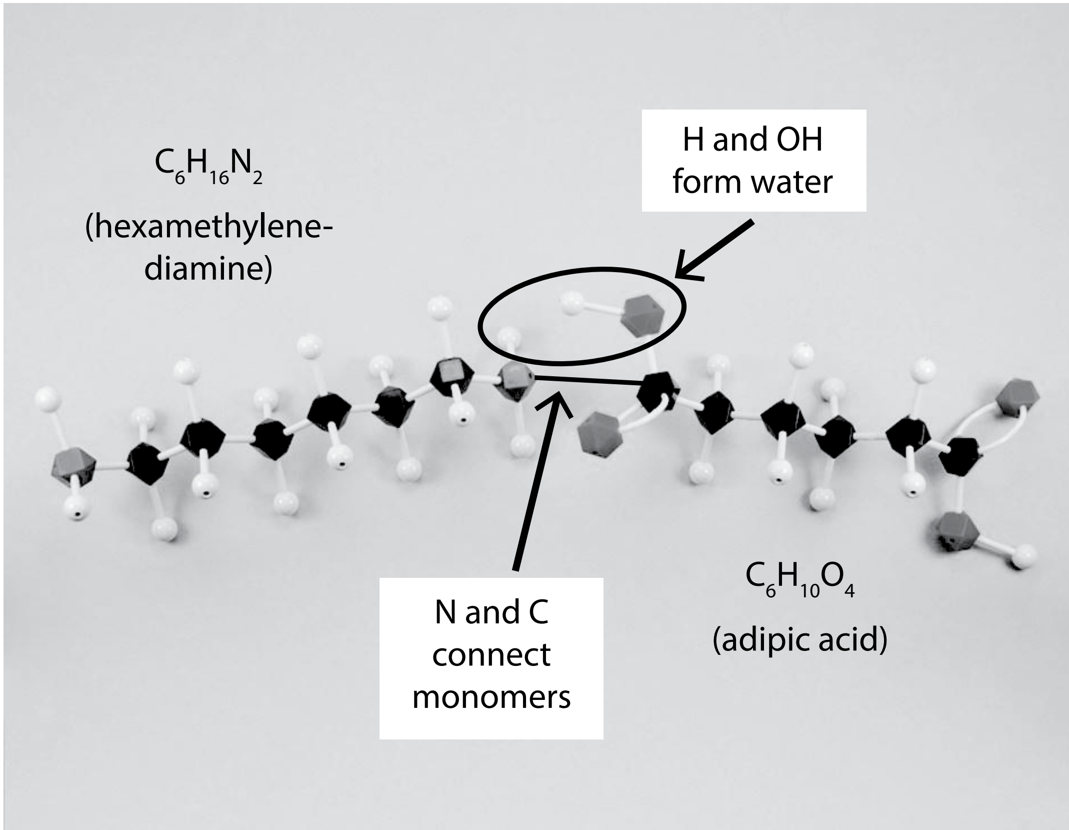
Nylon is formed at the interface of two non-mixing liquids—a diamine, hexamethylenediamine ($NH_2(CH_2)_6NH_2$) and a diacid, adipic acid ($HOOC(CH_2)_4COOH$). When the film is drawn or spooled from the interface of the two liquids, a thread of nylon polymer forms. This thread is composed of huge numbers of polymer molecules that are cross-linked together.

The reaction between one hexamethylenediamine monomer and one adipic acid monomer is shown below:

$$\mathbf{C_6H_{16}N_2 + C_6H_{10}O_4 \rightarrow C_{12}H_{24}O_3N_2 + H_2O}$$

Many chemical reactions that form polymers, including nylon and biological polymers, also produce water. Often this type of chemical reaction occurs between two or more different carbon-based small molecules (monomers) that will alternate in the polymer chain. Each monomer has specific functional groups (arrangements of atoms) at both ends of the molecule—either a carboxylic acid group (COOH) or an alcohol group (OH) and/or an amine group (NH2) that allow it to link to other monomers of the growing polymer chain.

During the chemical reaction, an OH from one monomer reacts with an H from another monomer to form a water molecule and a longer polymer as shown below.



Because each end of a monomer can react, long polymers can form. As each monomer is added to a growing polymer chain, a water molecule is produced.

Intended observations: Students should observe the formation of a white fibrous solid (nylon) from two clear, colorless liquids. Students should also observe that as the nylon is formed the amount of the liquids in the beaker decreases.

Rationale for including this reaction: The formation of nylon from hexamethylenediamine and adipic acid is an example of the formation of polymers from monomers through chemical reactions in which only a limited number of atoms rearrange. Polymer formation is key to understanding the formation of protein- and cellulose-based body structures through the polymerization of amino acids and glucose, respectively.

Chapter 1 Prerequisite Knowledge for Students

Lessons 1 and 2 provide entry points for most students, despite their prior knowledge. However, the chapter assumes that students know that all matter is made up of atoms. (The lessons will develop the idea that atoms can link together to form a variety of different molecules.)

Although the unit does not emphasize physical changes, students will learn that because atoms do not rearrange to form new molecules during physical changes, such changes are not chemical reactions.

Chapter 1 Commonly Held Student Ideas and Misconceptions

Researchers have documented many incorrect ideas that students commonly have about chemical reactions. This document provides a brief summary of most of the more common incorrect ideas, but it is not exhaustive. Listen for these ideas in your class, but also for other variants that your particular students may have. Actual student responses will usually be shorter and less precise than those listed here. The descriptions here are meant to fully explain the nature of the incorrect idea and to highlight what is unsaid as much as what is said.

Some students have trouble distinguishing between atoms and molecules, and are often imprecise in the language, referring generally to "atoms and molecules." Students may say:

- *Atoms are "in" matter (rather than "make up" matter).*
- *Atoms and molecules are basically the same—they are all just very small particles.*
- *Molecules make up atoms.*

Some students have trouble distinguishing one substance from another based on their characteristic properties. Students may say:

- *If two substances share one characteristic property, then they must be the same substance.*
- *If most of the listed characteristic properties are the same, the substances must be the same.*
- *Substances can change their characteristic properties but still remain the same substance.*
- *The properties of a substance are determined (only) by the types of atoms that make up the substance (with no reference to the number of atoms or the way in which the atoms are arranged into molecules.)*
- *Two substances that are made up of molecules that have the same number of the same types of atoms are the same substance (regardless of how the atoms are arranged.)*

Many students use incorrect criteria for deciding whether or not a chemical reaction has occurred. Students may say:

- *Whenever matter changes, it is a chemical reaction.*
- *Chemical reactions happen whenever you combine two substances/chemicals.*
- *Chemical reactions always have two reactants ($A + B \rightarrow C$ OR $A + B \rightarrow C + D$).*
- *Chemical reactions are irreversible changes. If you can "change it back," it is not a chemical reaction.*
- *If there are "chemicals" (judged based on their chemical names) involved, it must be a chemical reaction.*
- *A change of state is a chemical reaction.*
- *Whenever a gas forms, it is a chemical reaction.*
- *If heat is involved, it is a chemical reaction.*
- *If it has explosions, smoke, or color changes, it is a chemical reaction. Less visible changes are not chemical reactions.*

Many students may also have difficulty understanding how the products relate to the reactants of a chemical reaction. Students may say:

- *The products do not form from the reactants. The reactants disappear and the products appear.*

- *The products are just mixtures of the reactants, not totally new substances.*
- *The products are the same substances as the reactants, just with different properties.*

Students also commonly have misunderstandings about what happens to the atoms and molecules during a chemical reaction. Students may say:

- *The atoms of the reactants are transformed into other types of atoms to form the products. For example, an oxygen atom could become a carbon atom.*
- *All the atoms must rearrange (none can maintain attachments) for a chemical reaction to occur.*
- *During a chemical reaction, the molecules of the reactants stay the same and just stick together at their ends to form one big molecule, which is the product.*
- *The molecules of any one product must include every type of atom from the reactants.*

Lesson Guide
Chapter 1, Lesson 1.1
Changes in Living and Nonliving Things

Focus: This lesson focuses students' attention on changes that occur in living and nonliving things, encouraging them to consider what these changes have in common. For example, students might notice that in both nonliving and living systems new materials form or "grow," the "stuff" of new materials comes from other materials, and the weight of the new stuff increases as it "grows." Students will have numerous opportunities throughout the unit to revisit and revise their ideas as they learn more concretely how these changes are similar.

Key Question: How are changes in the matter that makes up living and nonliving things similar?

Target Idea(s) Addressed

Note: The lesson serves to promote and elicit students' thinking about similarities in the changes that occur in living and nonliving things. There are no target ideas or science practices specifically addressed in this lesson, but the phenomena related to changes in matter will contribute to students' understanding of how new substances form during chemical reactions.

Materials

Activity 1: Videos: *Puppy Grows Into a Dog*, *Corn Growth, Spider Spinning Silk, Hexamethylenediamine and Adipic Acid*

Phenomena, Data, or Models	Intended Observations	Purpose	Rationale and Notes
Activity 1 Time-lapse photography of dog growth and corn growth. Video of a spider spinning a web and video of nylon formation.	Changes occur in living and nonliving things. During these changes the following happens: • New materials are made (e.g., fur, skin, bones, and muscle) as a puppy grows. • New materials are made (e.g., leaves, stem, fruit) as a corn plant grows. • New materials are made from other materials (e.g., nylon thread is made from the liquids in the beaker that are used up and spider silk is made from substances in the spider's body).	To focus students' attention on similarities in the changes that occur in living and nonliving things.	Identifying similarities in the changes that occur in living and nonliving things may suggest to students that changes occurring in both living and nonliving things are guided by the same "fundamental principles" of science. Some students may struggle to make the connections we identified in the intended observations. Do not make the connections for them at this point. They will have numerous opportunities throughout the unit to revisit and revise their ideas as they learn more concretely how these seemingly unrelated changes are connected through fundamental chemical principles.

Lesson 1.1—Changes in Living and Nonliving Things

What do we know and what are we trying to find out?

Everything in the world—both things that are alive and things that aren't—is made of "stuff" that is changing all of the time. Scientists call this "stuff" matter. For example, a bicycle is matter, and when it is left outside, it becomes covered with rust, which is also matter. Matter changes when a baker makes a cake from flour, sugar, eggs, baking powder, and butter. Students mix vinegar with baking soda and change these ingredients into a foaming "volcano." Wood burns in a campfire and turns to ashes. Scientists in the lab combine different substances to create new products.

Living things are also made of matter, and most of them—including you—change as they grow and repair their bodies (see the color version of Figure 1.1 that your teacher will project). A small puppy grows into a big dog. A tiny seed sprouts a seedling that then grows into a giant sequoia tree. The skin on your finger heals around a cut. A lizard regrows a tail that it lost to a predator.

Figure 1.1. Changes in Matter

You can probably think of many more examples of how matter changes. But how do these changes happen? Do living and nonliving things change in the same way?

To answer these questions, we need to understand more about the "stuff" that makes up living and nonliving things and how it changes. In this lesson, you will observe some of these changes and begin thinking about the Key Question (there is no need to respond in writing now).

Key Question: How are changes in the matter that makes up living and nonliving things similar?

Teacher Talk and Actions
What do we know and what are we trying to find out? (3 min)
Whole class: Read text aloud and examine with the class the images shown under "What do we know and what are we trying to find out?"
Key Question (1 min)
Introduce the Key Question: **How are changes in the matter that makes up living and nonliving things similar?** Usually, you will use the Key Question to elicit and probe student ideas. In Lesson 1.1, students do not need to respond to it before experiencing the activity. The activity is intended to provide students with concrete examples of changes in living and nonliving things that they can compare. The lesson culminates in students answering the Key Question based on their observations and comparisons of the changes.

Activity 1: Observing Changes in Living and Nonliving Things

In this activity, you will watch a series of videos that show different changes that occur in living and nonliving things.

Procedures and Questions

1. Your teacher will show two videos. Watch each video and record what you see happening in Table 1.1. Be sure to include any observations that suggest change is occurring.

Table 1.1. Changes in Living Things

	Observations
Video 1–Puppy Growth	New materials are made when the puppy grows, such as fur, skin, bones, and muscle. The dog gets bigger (gains weight/mass) as it grows.
Video 2–Corn Growth	New materials are made when the corn grows, such as leaves, stem, and fruit. The corn plant gets bigger (gains mass) as it grows.

2. Discuss these questions with your class. Use your observations from Table 1.1 to support your ideas.
   a. What matter is there before each change takes place?
   b. Do you think any new matter is being made during each change?
   c. If so, what is the new matter and where do you think it comes from?

Teacher Talk and Actions

Activity 1 **(25 min)**

Whole class:

Complete Step 1 together.

For Video 1—Puppy growth:

• Show Video—*Puppy Grows Into a Dog*.

• Students record their observations in Table 1.1.

For Video 2—Corn growth:

• Show Video—*Corn Growth*.

• Students record their observations in Table 1.1.

Lead discussion. Invite students to share ideas about the discussion questions (Step 2).

The goal is primarily eliciting and probing student ideas here. Ask questions like these:

• Why do you think so?

• How do you think that happens?

• What evidence do you have for that idea from the video?

Do not make the connections for students at this point if they struggle to see the similarities between changes in living things.

3. Your teacher will show two more videos. Watch each video and record what you see happening in Table 1.2. Be sure to include any observations that suggest change is occurring.

Table 1.2. Changes in Nonliving and Living Things

	Observations
Video 1– Nylon Formation	*A new material (a white, threadlike material) comes out of the spider's body.* *As more of the white, threadlike material is produced, the web grows (gets heavier/more massive).*
Video 2– Spider Spinning Silk	*New material (a white, stringy material) is made at the interface of the two liquids.* *The white, stringy material probably gains weight/mass as it grows.*

4. Discuss these questions with your class. Use your observations from Table 1.2 to support your ideas.

   a. What matter is there before each change takes place?

   b. Do you think any new matter is being made during each change?

   c. If so, what is the new matter and where do you think it comes from?

   d. What do you think has happened to the matter that was there in the beginning?

Teacher Talk and Actions
Activity 1 (cont)
Whole class: Complete Step 3 together. For Video 1—Nylon formation: • Show Video—*Hexamethylenediamine and Adipic Acid*. • Students record their observations in Table 1.2. For Video 1—*Spider Spining Silk*: • Show Video—*Spider Spinning Silk*. • Students record their observations in Table 1.2. Lead discussion. Invite students to share ideas about the discussion questions (Step 4). The goal is primarily eliciting and probing student ideas here. Ask follow-up questions like these: • Why do you think so? • How do you think that happens? • What evidence do you have for that idea from the video? Do not make the connections for students at this point if they struggle to see the similarities between changes in nonliving and living things. They will have a chance to revisit their ideas later in the unit.

Pulling It Together

Work on your own to answer the question. Be prepared for a class discussion.

1. After observing and discussing the changes shown in the videos, how would you answer the Key Question, **How are changes in the matter that makes up living and nonliving things similar?**

   In both cases, new materials may be made or "grow." The new materials might have come from other materials that are used up. When new materials are made or "grow," there may be a change (e.g., increase) in weight/mass of the "growing" thing (e.g., dog; corn plant; stringy, white material).

Teacher Talk and Actions

Pulling It Together **(5 min)**

Individuals:

Direct students to answer the Key Question on their own, in detail. Not all students will write something similar to the ideal response provided. At this point, they should know that the mass increases, but it is OK if they aren't sure where it comes from.

Closure and Link **(2 min)**

Whole class:

Summarize the lesson:

We have observed some similarities in changes that occur in living and nonliving things. One similarity we noticed is that new stuff can be made.

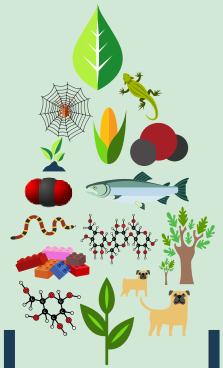
Link to the next lesson:

Tell students:

You will have more opportunities during the unit to think about how these changes are similar.

You already noticed that living things are made up of a lot of stuff (e.g., fur, skin, bones, muscles, and much more!). And so are nonliving things. In the rest of Chapter 1 we'll focus on simpler stuff that makes up nonliving things and the changes that stuff undergoes. The ideas we learn will eventually help us explain what happens when living things grow and repair their bodies.

Toward High School Biology



Understanding Growth in Living Things

Teacher Edition

"The developers of *Toward High School Biology* have focused the materials to support teachers in providing students with a three-dimensional learning experience that the *NGSS* envision. In the unit, students will need to make sense of some unusual phenomena, such as egg-eating snakes or hydrogen peroxide bubbling on a wound, which will engage students as they learn and use important scientific ideas and practices."

—Joseph Krajcik, PhD, Lappan-Phillips Professor of Science Education and Director of the CREATE for STEM Institute, Michigan State University

Through 19 carefully sequenced lessons and activities, this unit gets middle schoolers ready for next-level learning. Students explore what happens at the molecular level so they can understand how living things grow and repair their body structures. Using Legos, ball-and-stick models, videos, and print manipulatives helps them retain what they learn so they can apply that knowledge later.

Both effective and engaging, *Toward High School Biology*

- **Draws on a research-based development approach.** Multiple cycles of design and revision based on results from classroom field tests, feedback from teachers, expert scientific input, and criteria-based evaluations ensure the high quality of the unit.
- **Takes an interdisciplinary approach.** Lessons focus on phenomena related to chemical reactions that take place in both physical and life science contexts, from the rusting of a metal bicycle to the production of muscles in humans.
- **Supports the *Next Generation Science Standards.*** All three dimensions of science learning—science and engineering practices, disciplinary core ideas, and crosscutting concepts—are carefully integrated in each chapter.
- **Is refreshingly easy to use.** The Teacher Edition should be used in conjunction with the Student Edition, which provides complete lesson plans and instructions for carrying out the activities. Complementary video demonstrations and tutorials are available online.

Between the print and digital materials, you'll gain a big-picture sense of the unit plus explicit guidance to teach each lesson, conduct each activity, and prepare students to succeed in science classes to come.

GRADES 6–8

AAAS/Project 2061

NSTA press
National Science Teachers Association

PB434XT
ISBN: 978-1-68140-560-5

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