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United Arab Emirates Edition

Mc Graw Hill

Grade 11 Advanced

Teacher Edition

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Biology

United Arab Emirates Edition

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"Extensive knowledge and modern science must be acquired. The educational process we see today is in an ongoing and escalating challenge which requires hard work.
We succeeded in entering the third millennium, while we are more confident in ourselves."

H.H. Sheikh Khalifa Bin Zayed Al Nahyan
President of the United Arab Emirates

Contents in Brief

Unit 1

Student Resources

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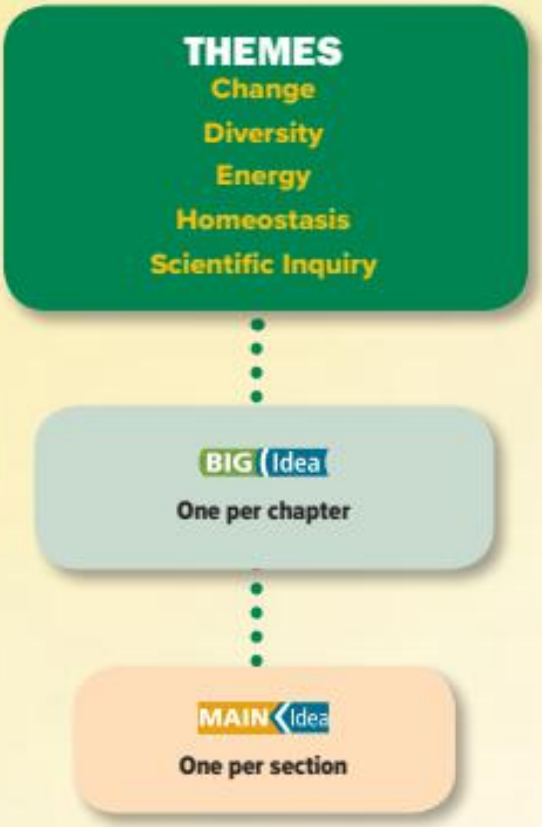
Contents

Your book is divided into units and chapters that are organized around Themes, Big Ideas, and Main Ideas of biology.

THEMES are overarching concepts used throughout the entire book that help you tie what you learn together. They help you see the connections among major ideas and concepts.

BIG Idea appear in each chapter and help you focus on topics within the themes. The Big Ideas are broken down even further into Main Ideas.

MAIN Idea draw you into more specific details about biology. All the Main Ideas of a chapter add up to the chapter's Big Idea.



Student Guide

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Science Kit and Boreal Laboratories
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FOLDABLES®

by Dinah Zike

Folding Instructions

The following pages offer step-by-step instructions to make the Foldables study guides.

Layered-Look Book

1. Collect three sheets of paper and layer them about ½ inch apart vertically. Keep the edges level.
2. Fold up the bottom edges of the paper to form six equal tabs.
3. Fold the papers and crease well to hold the tabs in place. Staple along the fold. Label each tab.

Trifold Book

1. Fold a vertical sheet of paper into thirds.
2. Unfold and label each row.

Three-Tab Book

1. Fold a vertical sheet of paper from side to side. Make the front edge about 2 cm shorter than the back edge.
2. Turn lengthwise and fold into thirds.
3. Unfold and cut only the top layer along both folds to make three tabs. Label each tab.

Two- and Four-Tab Books

1. Fold a sheet of paper in half.
2. Fold in half again. If making a four-tab book, then fold in half again to make three folds.
3. Unfold and cut only the top layer along the folds to make two or four tabs. Label each tab.

Four-Door Book

1. Find the middle of a horizontal sheet of paper. Fold both edges to the middle and crease the folds.
2. Fold the folded paper in half, from top to bottom.
3. Unfold and cut along the fold lines of the top layers to make four tabs. Label each tab.

Concept-Map Book

1. Fold a vertical sheet of paper from top to bottom. Make the top edge about 2 cm shorter than the bottom edge.
2. Turn lengthwise and fold into thirds.
3. Unfold and cut only the top layer along both folds to make three tabs. Label the top and each tab

Vocabulary Book

1. Fold a vertical sheet of notebook paper in half.
2. Cut along every third line of only the top layer to form tabs. Label each tab.

Folded Chart

1. Fold a sheet of paper lengthwise into thirds.
2. Fold the paper widthwise into fifths.
3. Unfold, lay the paper lengthwise, and draw lines along the folds. Label the table.

Reviewers, Consultants, and Contributing Writers for the Teacher Edition

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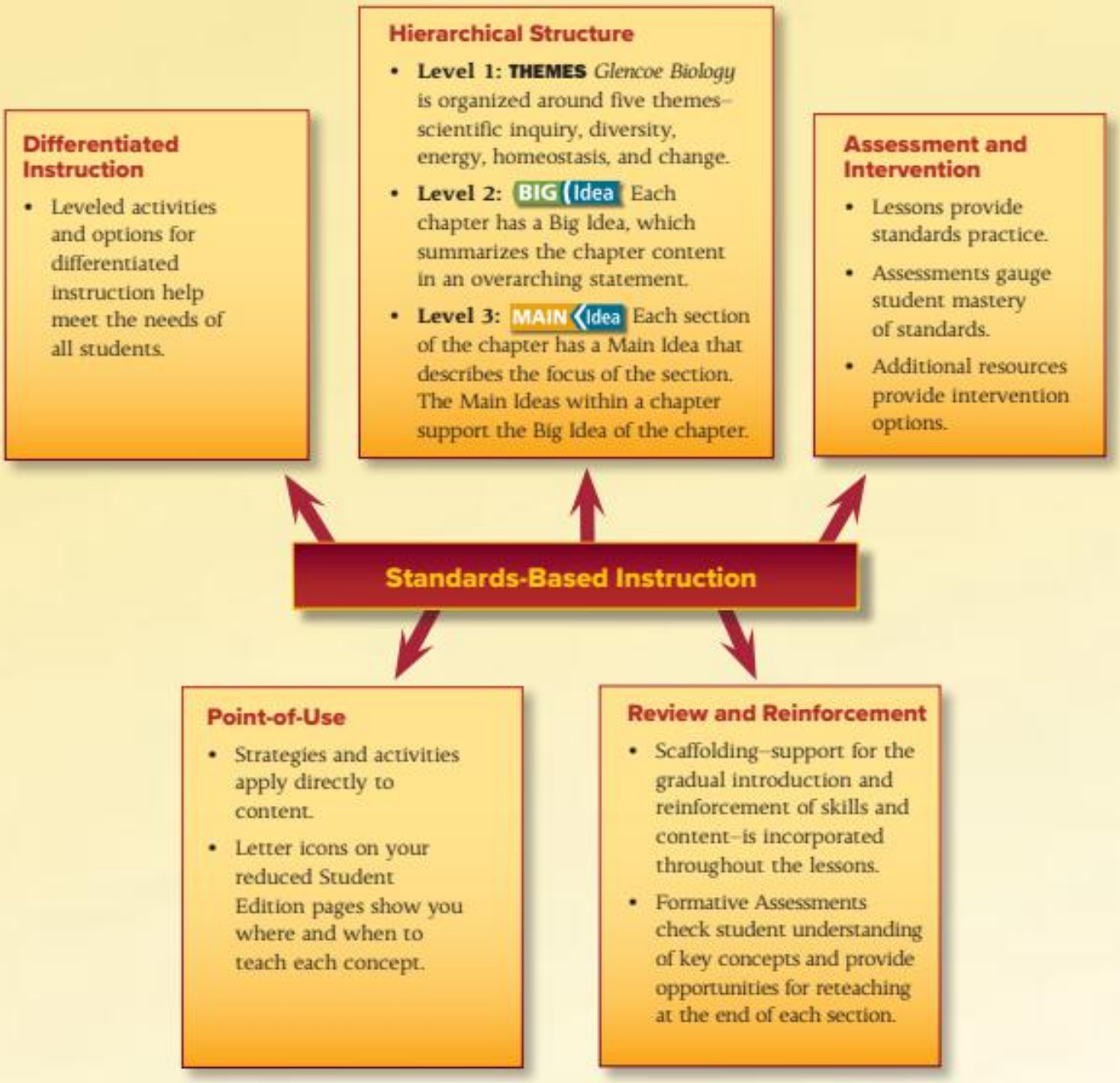
Teacher Handbook

Table of Contents

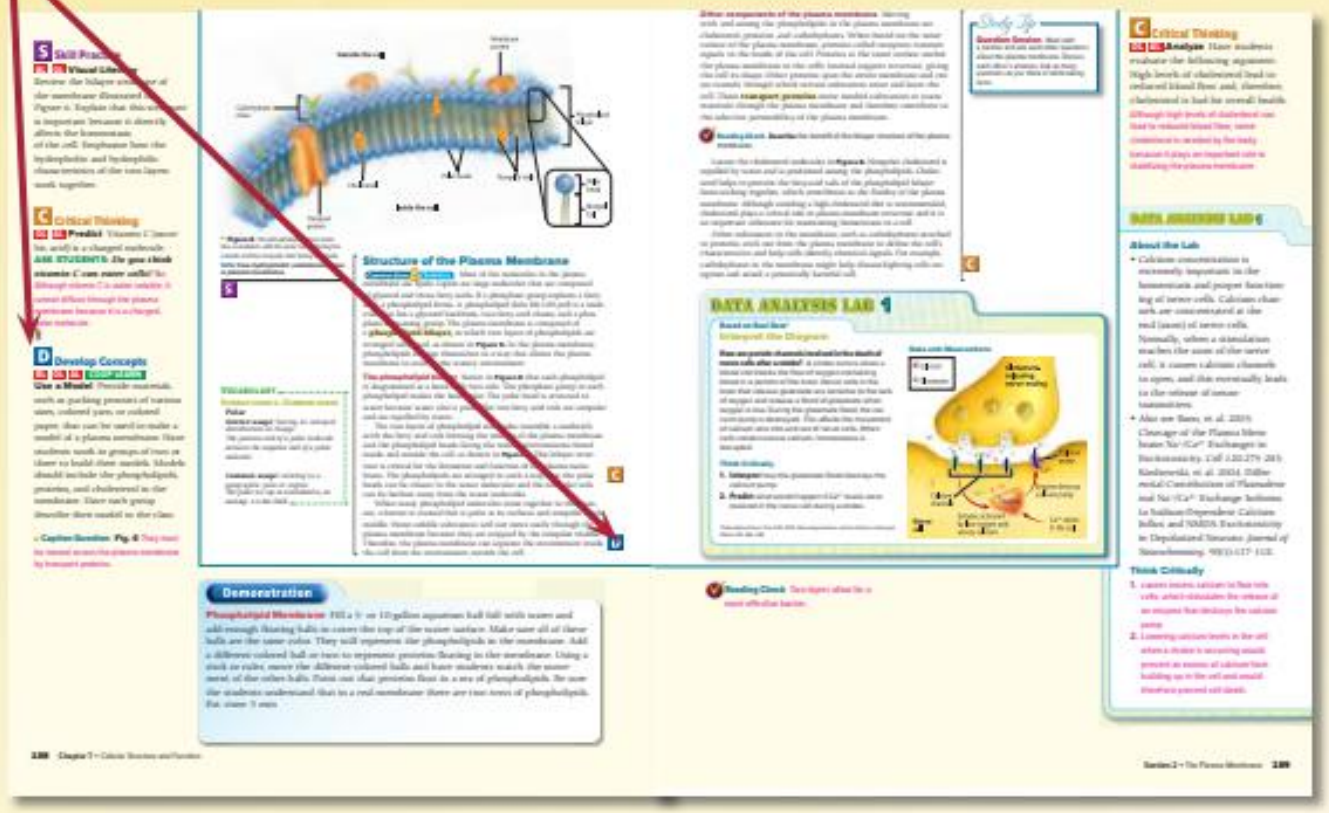
Program Design

Welcome to the Teacher Edition of *Glencoe Biology*. We have created this teacher edition based on input from experienced biology teachers and educational consultants. Our goal is provide you with research-based teaching strategies and activities, which are labeled for you at point-of-use.



Understanding the Letter Icons

The letter icons on the reduced Student Edition pages identify the type of strategy or activity. They are placed at point-of-use to show you where and when to teach each concept. See the key below to learn about the various types of strategies and activities.



Key for Using the Teacher Edition

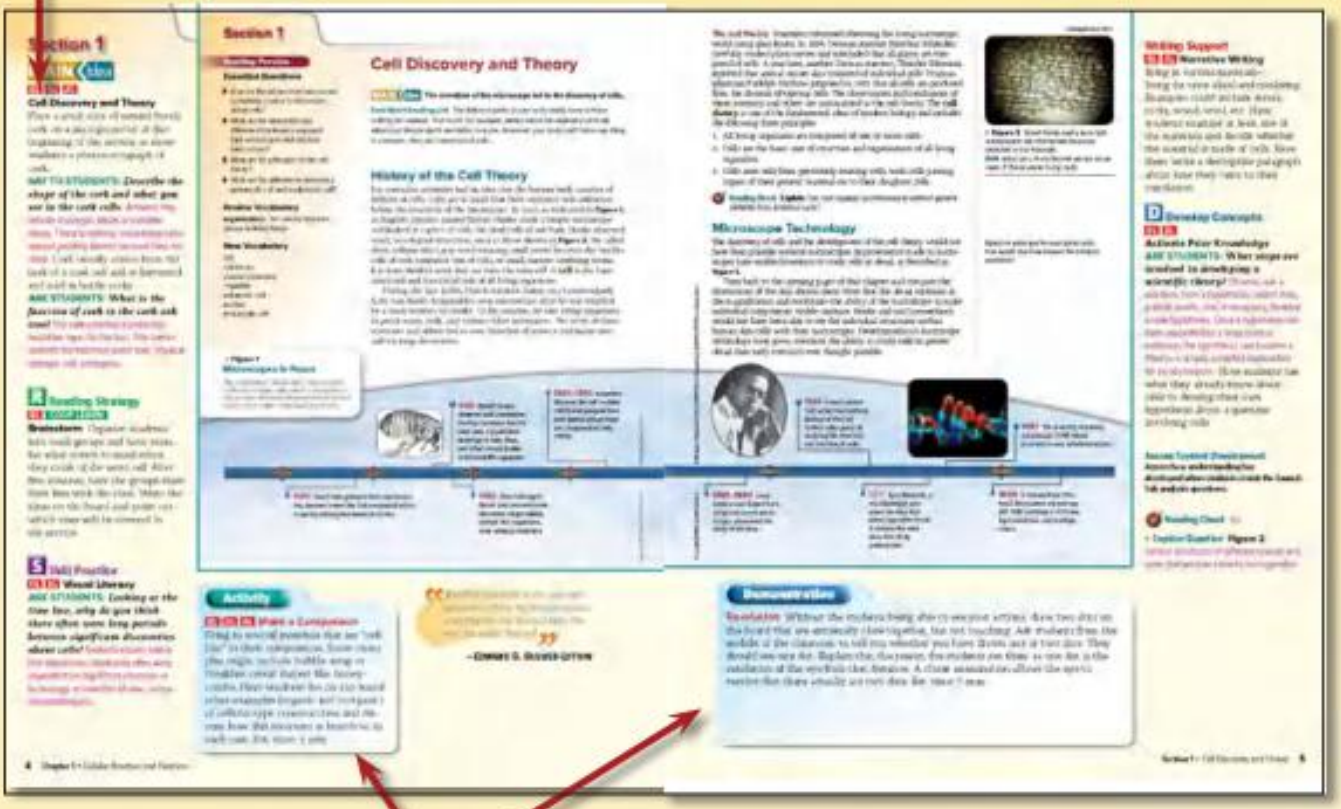
- **R** **Reading Strategy** activities help you teach reading skills and vocabulary.
- **C** **Critical Thinking** strategies require students to use higher-order thinking skills to apply and extend what they have learned.
- **S** **Skill Practice** strategies help students organize information and use visuals for comprehension.
- **W** **Writing Support** activities provide writing opportunities that help students comprehend the content.
- **D** **Develop Concepts** activities use various strategies, such as scaffolding and clarifying misconceptions, to help teachers gauge and plan for students' concept development.

Differentiated Instruction

Activity Leveling

Teaching strategies and activities have been coded for ability level appropriateness. A competency level is given for each activity using the following code:

AL Activities for students working above grade level
OL Activities for students working on grade level
BL Activities for students working below grade level



Answers and Additional Support

Along the bottom of the Teacher Edition, you will find

- answers to questions in the student edition;
- demonstrations and activities that help you quickly and easily address key concepts;
- *Content-Background* elements that provide you with additional content information;
- *Differentiated-Instruction* strategies that help you meet the needs of all students;
- *Research Citations* that highlight specific educational strategies and cite the research that supports them.

Planning and Teaching the Unit

Preview the Unit activity helps students make connections among the content areas covered in the unit.

Clarify a Misconception elements provide a question to elicit common student misconceptions and an explanation to help dispel that misconception.

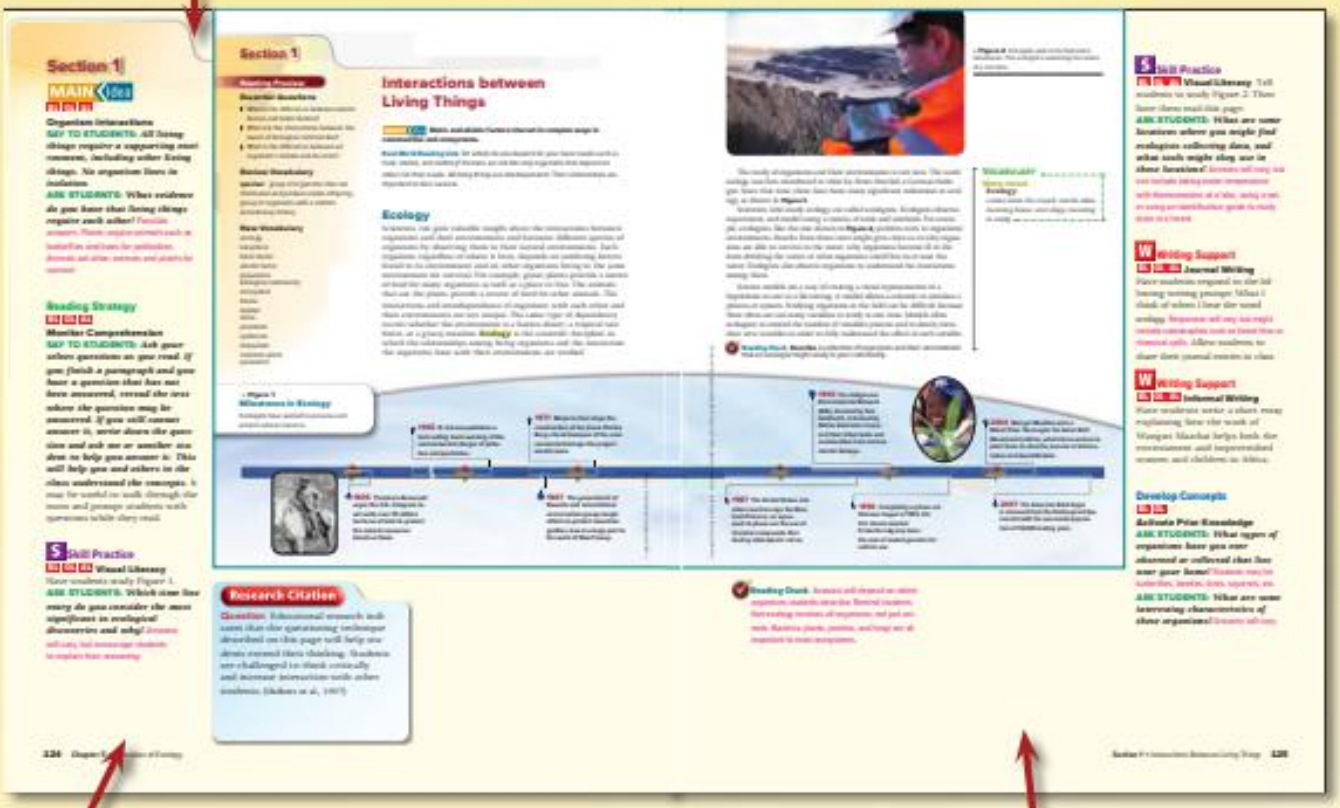
5-Minute Unit Launch is a short preteaching activity that will help you introduce students to the content covered in the unit.

Themes give an overview of how each of the five themes of *Glencoe Biology* is covered in the unit.

Planning the Chapter

Planning pages appear at the beginning of each chapter.

Chapter Organizers detail all section objectives, standards covered, and materials needed to teach the chapter.



Lesson Pacing provides three different pacing suggestions for the chapter. When used in conjunction with the Pacing Guide on page 36T, you can tailor the pace of your instruction to the individual needs of your classes.

Leveling Key describes the differentiated instruction labels used throughout the Teacher Edition.

Teaching the Chapter

Introduce the Chapter and *Big Idea* at the beginning of each chapter will help you to teach the standards.

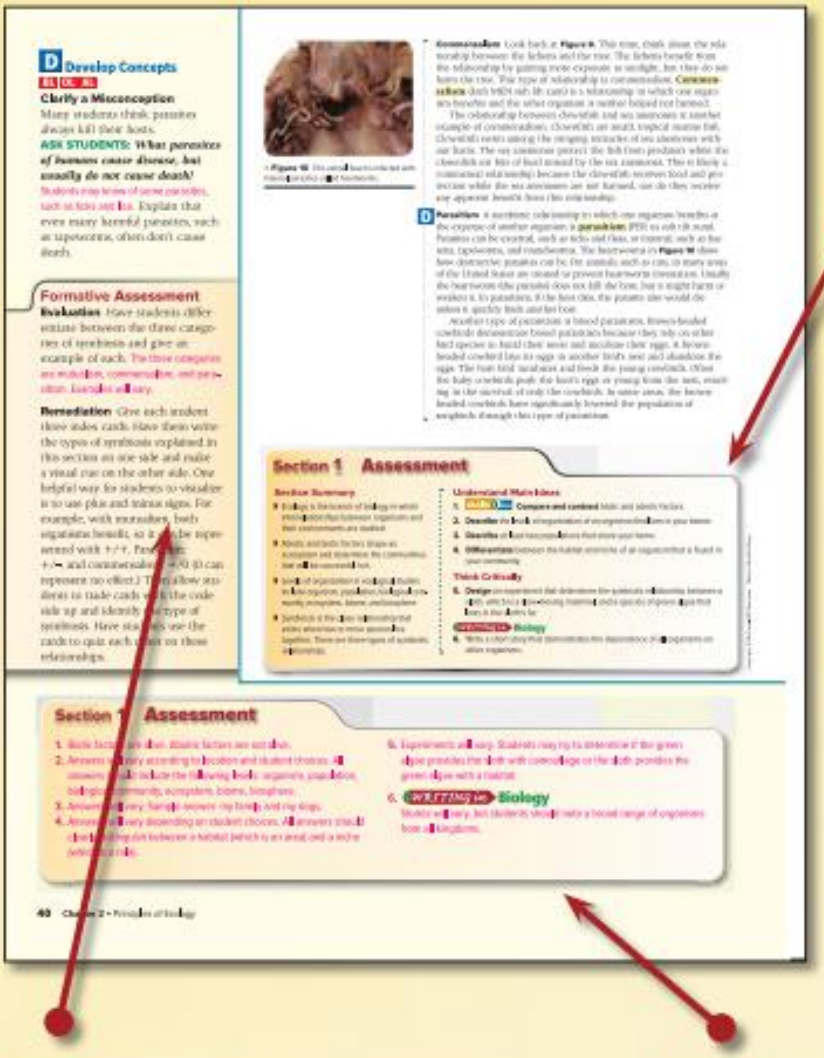
Introduce the Chapter is a question about the chapter opening photo. The image and question will engage students in the chapter content.

Themes are listed for each chapter in the teacher wrap. Use this information to help students make connections among the themes of biology and the content they are studying.

BIG Idea activities help students understand the conceptual structure of the chapter–starting with the Big Idea overarching the chapter to the Main Ideas that are the focus of each section.

Review: Sections

Student activities and questions throughout the book provide opportunities for ongoing assessment and remediation.



Formative Assessments provide a mid-chapter evaluation of a key concept and a reteaching activity for students struggling to meet that learning objective.

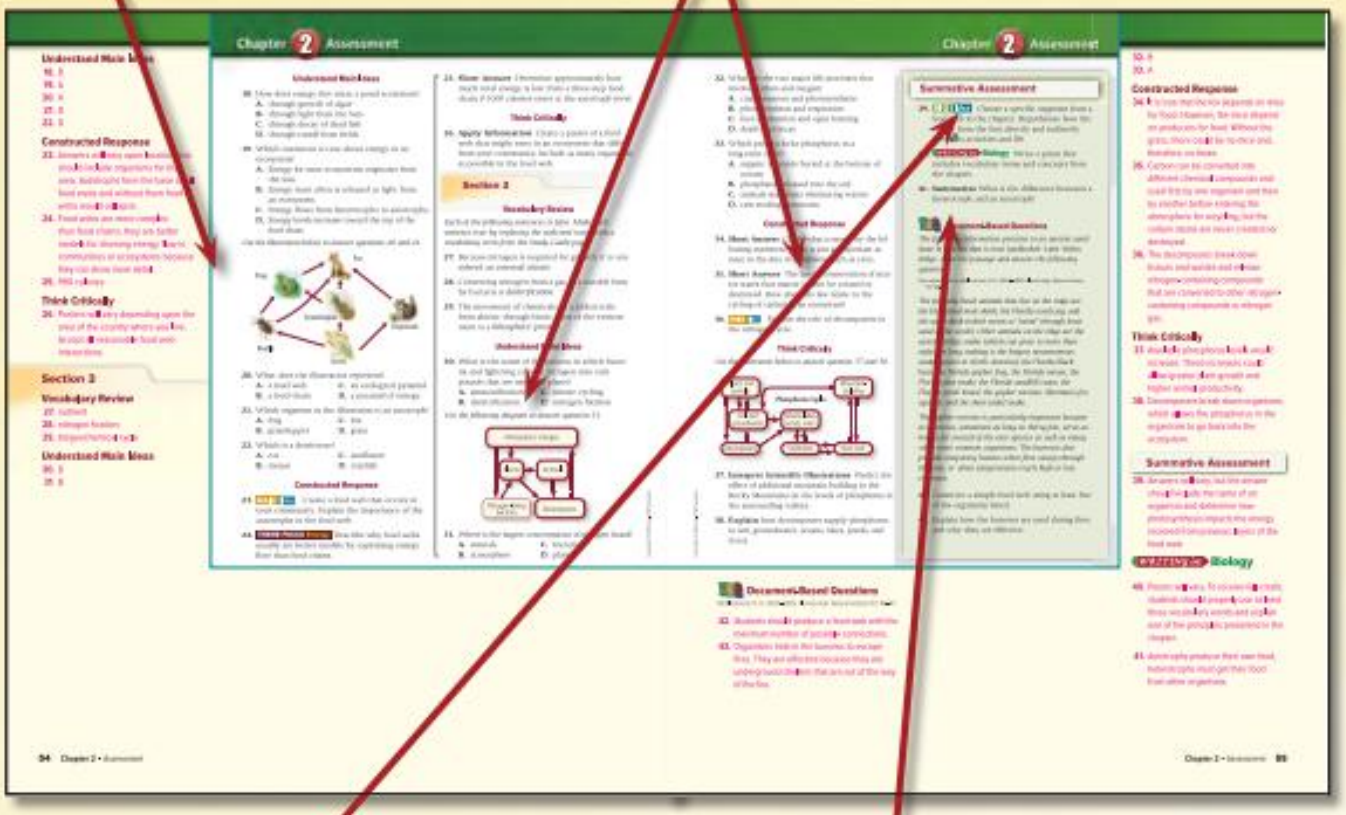
Section Assessments provide students with summary statements and questions that tie to the learning objectives for that section.

Answers to all assessment questions are found in the Teacher Edition.

Review: Chapters

Vocabulary Review and **Understand Main Ideas** assess comprehension of the vocabulary and concepts in each section.

Constructed Response and **Think Critically** require students to demonstrate higher-order thinking and use their writing skills.



Big Idea Question asks students to apply everything that they have learned in the chapter.

Document-Based Questions connect students to real-world applications as they evaluate real data from current research. Students analyze graphs, charts, and other displays of data from recognized scientific journals and classic historic documents.

Backward Mapping

How can my instruction help students succeed in a standards-based system?

by Emily M. Schell, Ed.D.

Content standards articulate what students should know and be able to do in every biology classroom. Effective instructional planning based in the standards and maximizing available resources is essential for meaningful teaching and learning of biology. Planning instruction with educational goals in mind makes for the most effective teaching.

How do I map my curriculum?

Mapping the curriculum from beginning to end, and from the end to the beginning–backward mapping–makes for solid instruction.

Mapping out the curriculum allows teachers to achieve several goals. These goals include a better understanding of the standards and content-specific objectives, organization and pacing of the curriculum, and focused assessment related to specific goals and objectives.

- ✓ **Analyze the Biology Content Standards** To begin, teachers analyze the body of content standards for biology. Then they compare and contrast these standards to additional sources of information that support effective teaching and learning in biology. This process works best with colleagues who bring varying perspectives and expertise to teaching the subject. As a result of this collaboration, strengths and weaknesses of the standards become apparent. Teachers will have a better understanding of the standards and identify concerns and questions for follow-up while mapping.
- ✓ **Analyze the Organization of the Standards-Based Content** Most biology teachers agree with researchers that biology is best taught in order from simple to complex living organisms. However, some state standards either do not or cannot present the content in order from simple to complex living organisms. Rich discussions about themes and concepts tend to emerge, and teachers identify meaningful methods for presenting complicated and overlapping information. In this way, students will see the connections that transcend the "simple to complex" order.
- ✓ **Identify the Content and Order of Teaching** A plan is developed to present content in a certain order. Incorporating content that is either missing from the standards or is essential in building background knowledge with students enters the curriculum map as well. Outside resources brought into the classroom are good supplements.
- ✓ **Separate Overlapping Units** Identify areas of instruction related to the Themes, Big Ideas, or Main Ideas. It is at this stage that backward planning is introduced for the development of instructional units, which will support the grade-level curriculum map. The instruction must support the planned assessment.
- ✓ **Map Curriculum at Each Grade Level** Curriculum planning should be shared among all subject-area teachers. Teachers will have a better understanding of what knowledge and skills students bring to their coursework if they take into consideration what has been learned previously.

How do I use backward mapping?

After a year-long course of study is mapped out, further develop each unit through backward mapping. Start with the end in mind–know your curricular goals and objectives at the outset, which are often found in the content standards and articulated in the curriculum maps.

Once goals have been determined, teachers develop assessments that will show progress toward those goals and objectives. In the final step of this backward mapping process, teachers determine meaningful teaching and learning strategies and identify useful resources that support the assessment.

To use backward mapping in developing your units of instruction, consider the following steps:

Step One: Know Your Targets

First, identify exactly what students must know and do in this unit. Analyze content standards and any other resources that support curricular goals and objectives for this unit. As you plan, ask yourself:

- ✓ What do I want my students to know as a result of this unit?
- ✓ What skills will students develop during the course of this unit?
- ✓ How do I describe these goals clearly and concisely to my students so they understand where we should be at the end of this unit?
- ✓ What essential knowledge will students need to access to make sense of this information?
- ✓ Do my instructional goals align with strategies identified in the curriculum map?
- ✓ Have I introduced any Big Ideas that are pertinent to this content?

Step Two: Identify and Develop Assessments

Second, consider the multiple forms of formal and informal assessments that will help you determine to what degree each student has achieved the stated goals and objectives seen in Step One. Some assessments are embedded throughout the instructional unit, while others come at the end of the unit. Some assessments are performance-based, while others are not. Some are authentic applications of information and skills, while others require the formal recall of information.
Ask yourself:

- ✓ What do I want to know and see from each student?
- ✓ What are the best methods for students to demonstrate what they know and can do based on the goals and objectives?
- ✓ How many assessments do I need to determine what students know and can do?
- ✓ How will I balance informal and formal assessments?
- ✓ How will I assess students with diverse learning styles, skills, and abilities?
- ✓ How can I prepare and support students?
- ✓ How will these assessments promote student progress in biology?
- ✓ At what time(s) during the unit will I administer these assessments?

Step Three: Develop Meaningful Instruction

After the assessments for the unit have been determined, consider the meaningful and effective teaching strategies that will support learning and student achievement on assessments. While developing lesson plans for instruction, ask yourself:

- ✓ How will students learn what they are expected to know?
- ✓ How will I engage students in the concepts of this unit?
- ✓ In what ways might students relate or connect to this information?
- ✓ What research-based strategies will be most effective with my students and in these studies?
- ✓ How will I differentiate my instruction to meet the diverse needs of my students?
- ✓ How will I scaffold or provide access to the curriculum for my struggling learners?
- ✓ What vocabulary requires attention in this unit?
- ✓ How much time will I have to effectively teach this unit?
- ✓ How will I use the textbook and other resources to support the goals and objectives for this unit?
- ✓ What lessons will I develop?
- ✓ In what sequence will I teach these lessons during this unit?
- ✓ How will these lessons support the assessments from Step Two?

Step Four: Locate and Manage Resources

Effective teaching and learning of biology requires the use of multiple forms of text and varied resources. Consider what you have available in your classroom, including your textbook, and identify resources you will add in order to teach this unit successfully. Ask yourself:

- ✓ What parts of the textbook are required for the lessons determined in Step Three?
- ✓ What ancillary materials are needed for the lessons in this unit?
- ✓ What Web sites will I recommend to students to support these lessons?
- ✓ Do I need to contact guest speakers or obtain outside resources?
- ✓ What literature resources are available to support this unit?

Emily Schell is a visiting professor at San Diego State University and social studies education director at SDSU City Heights Educational Collaborative, San Diego, CA.

Meeting the Diverse Needs of Students

by Douglas Fisher, Ph.D.

Today's classroom contains students from a variety of backgrounds with a variety of learning styles, strengths, and challenges. As teachers, we are facing the challenge of helping each student reach their educational potential. With careful planning, you can address the needs of all students in the biology classroom. The basis for this planning is universal access. When classrooms are planned with universal access in mind, fewer students require specific accommodations.

What is universal design?

Universal design was first conceived in architectural studies when businesspeople, engineers, and architects began making considerations for physical access to buildings. The idea was to plan the environment in advance to ensure that everyone had access. As a result, the environment would not have to be changed later for people with physical disabilities, people pushing strollers, workers who had injuries, or others for whom the environment would be difficult to negotiate. The Center for Universal Design, defines universal design as: *The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.*

Universal Design and Access in Education

Researchers, teachers, and parents in education have expanded the development of built-in adaptations and inclusive accommodations from architectural space to the educational experience, especially in the area of curriculum.

In 1998, the National Center to Improve the Tools of Educators (NCITE), in partnership with the Center for Applied Special Technology (CAST), proposed an expanded definition of universal design focused on education: *In terms of learning, universal design means the design of instructional materials and activities that allow the learning goals to be achievable by individuals with wide differences in their abilities to see, hear, speak, move, read, write, attend, organize, engage, and remember.*

How does universal design work in education?

Universal design and access, as they apply to education and schooling, suggest the following:

- ✓ **Inclusive Classroom Participation** Curriculum should be designed with all students and their needs in mind. *Glencoe Biology* was designed for a wide range of students. For example, students who struggle with reading will use this textbook, vocabulary is specifically taught and reinforced. Similarly, the teacher-support materials provide multiple instructional points to be used depending on the needs of the students in each class. Further, the main ideas are identified for all learners. Throughout the text, there are multiple opportunities to activate students' prior knowledge. Connections between what students know and think about are made throughout the text.
- ✓ **Maximum Text Readability** In universally designed classrooms that provide access for all students, texts use direct language, clear noun-verb agreements, and clear construct-based wording. In addition to these factors, the *Glencoe Biology* text uses embedded definitions for difficult terms, provides for specific instruction in reading skills, uses a number of visual representations, and includes note-taking strategies.
- ✓ **Adaptable and Accommodating** The content in this textbook can be easily translated, read aloud, or otherwise changed to meet the needs of students in the classroom. The section and end-of-chapter assessments provide students with multiple ways of demonstrating their content knowledge while also ensuring that they have practice with thinking in terms of multiple-choice questions. Critical thinking and analysis skills also are practiced.

How is differentiated instruction the key to universal access?

To differentiate instruction, teachers must acknowledge student differences in background knowledge and current reading, writing, and language skills. They also must consider student learning styles and preferences, interests, and needs, and react accordingly. There are a number of general guidelines for differentiating instruction in the classroom to reach all students, including:

Link Assessment With Instruction Assessments should occur before, during, and after instruction to ensure that the curriculum is aligned with what students do and do not know. Using assessments in this way allows you to plan instruction for whole groups, small groups, and individual students. Backward mapping, in which you establish the assessment before you begin instruction, is also important.

Clarify Key Concepts and Generalizations Students need to know what is essential and how this information can be used in their future learning. In addition, students need to develop a sense of the Big Ideas–ideas that transcend time and place.

Emphasize Critical and Creative Thinking The content, process, and products used or assigned in the classroom should require that students think about what they are learning. While some students may require support, additional motivation, varied tasks, materials, or equipment, the overall focus on critical and creative thinking allows for all students to participate in the lesson.

Include Teacher- and Student-Selected Tasks A differentiated classroom includes both teacher- and student-selected activities and tasks. At some points in the lesson or day, the teacher must provide instruction and assign learning activities. In other parts of the lesson, students should be provided choices in how they engage with the content. This balance increases motivation, engagement, and learning.

Below is an example of a classroom activity for teaching Mendelian inheritance. It is followed by an example of the methods this text provides teachers for differentiating instruction to meet all students' needs.

Classroom Activity	Strategies for Differentiating this Activity:
Display an illustration that shows a simple monohybrid cross of the traits studied by Gregor Mendel. Next to the illustration, show a Punnett square that predicts the results of such a cross. Discuss with students general information regarding Mendel, his studies, and the particular monohybrid cross that is displayed.	• Ask students to imagine that they are reporters living in the time when Mendel performed his research. Have them write a newspaper article introducing the general public to Mendel's research. • Have students create a concept map tracing a monohybrid cross through the second generation. Be sure they indicate dominant and recessive alleles. • Obtain and display some of Mendel's actual data for monohybrid crosses. Ask students to compare the real data to the ratios predicted by Punnett squares. Ask them how they think scientists recognize patterns in data. • Have students research Mendel and the environment in which he worked. Ask them to write a two-page report on Mendel and his contributions. • Give students an assortment of large and small paper clips. Have them use two coin flips to choose two paper clips (heads = large; tails = small). Repeat 20 times. Tell them that large clips represent dominant traits, and small clips represent recessive ones. Ask them to compare their paper clip ratios to the predicted results of a monohybrid cross of heterozygous parents.

Classroom Solutions

How do I support individual students?

The majority of students will thrive in a classroom based on universal access and differentiated instruction. However, wise teachers recognize that no single option will work for all students and there might be students who require unique systems of support to be successful.

Tips for Instruction

The following tips for instruction can support your efforts to help all students reach their maximum potential.

- ✓ Survey students to discover their individual differences. Use interest inventories of their unique talents so you can encourage contributions in the classroom.
- ✓ Be a model for respecting others. Adolescents crave social acceptance. The student with learning differences is especially sensitive to correction and criticism, particularly when it comes from a teacher. Your behavior will set the tone for how students treat one another.
- ✓ Expand opportunities for success. Provide a variety of instructional activities that reinforce skills and concepts.
- ✓ Establish measurable objectives and decide how you can best help students meet them.
- ✓ Celebrate successes and make note of and praise "work in progress."
- ✓ Keep it simple. Point out problem areas if doing so can help a student affect change. Avoid overwhelming students with too many goals at one time.
- ✓ Assign cooperative group projects that challenge all students to contribute to solving a problem or creating a product.

How do I reach students who have learning disabilities?

- ✓ Provide support and structure. Clearly specify rules, assignments, and responsibilities.
- ✓ Practice skills frequently. Use games and drills to help maintain student interest.
- ✓ Incorporate many modalities into the learning process. Provide opportunities to say, hear, write, read, and act out important concepts and information.
- ✓ Link new skills and concepts to those already mastered.
- ✓ If possible, allow students to record answers on audiotape.
- ✓ Allow extra time to complete assessments and assignments.
- ✓ Let students demonstrate proficiency with alternative presentations, including oral reports, role plays, and art or musical projects.
- ✓ Provide outlines, notes, or tape recordings of lecture material.
- ✓ Pair students with peer helpers, and provide class time for pair interaction.

How do I reach students who have behavioral challenges?

- ✓ Provide a structured environment with simple and clearly defined schedules, rules, seat assignments, and safety procedures.
- ✓ Reinforce appropriate behavior and model it for students.
- ✓ Cue distracted students back to the task through verbal and nonverbal signals and teacher proximity.
- ✓ Set small goals that can be achieved in the short term. Work for long-term improvement in the big areas.

How do I reach students who have physical challenges?

- ✓ Openly discuss with the student any uncertainties you have about when to offer aid.
- ✓ Ask parents or therapists and students what special devices or procedures are needed and whether any special safety precautions need to be taken.
- ✓ Welcome students with physical challenges into all class activities, including field trips, special events, and classroom and community projects.
- ✓ Provide information to assist class members and parents in their understanding of support needed.

How do I reach students who have visual impairments?

- ✓ Facilitate independence. Modify assignments as needed.
- ✓ Teach classmates how and when to serve as visual guides.
- ✓ Limit unnecessary noise in the classroom if it distracts the student with visual impairments.
- ✓ Provide tactile models whenever possible.
- ✓ Foster a spirit of inclusion. Describe people and events as they occur in the classroom. Remind classmates that the student with visual impairments cannot interpret gestures and other forms of nonverbal communication.

- ✓ Provide taped lectures and reading assignments for use outside the classroom.
- ✓ Team the student with a sighted peer for written assignments.

How do I reach students who have hearing impairments?

- ✓ Seat students where they can see your lip movements easily and where they can avoid any visual distractions.
- ✓ Avoid standing with your back to the window or other light source.
- ✓ Use an overhead projector so you can maintain eye contact while writing information for students.
- ✓ Make sure students sit where they can see all speakers.
- ✓ Post all assignments on the board, or hand out written instructions.
- ✓ If the student has a manual interpreter, allow both student and interpreter to select the most favorable seating arrangements.
- ✓ Teach students to look directly at each other when they speak.

How do I reach students who are working above level?

- ✓ Make arrangements for students to take selected subjects early and to work on independent projects.
- ✓ Ask "what if" questions to develop high-level thinking skills. Establish an environment safe for risk taking in your classroom.
- ✓ Emphasize concepts, theories, ideas, relationships, and generalizations about the content.
- ✓ Promote interest in biology by inviting students to make connections to other disciplines that interest them.
- ✓ Let students express themselves in alternative ways, such as creative writing, acting, debates, simulations, drawing, or music.
- ✓ Provide students with a catalog of helpful resources, including agencies that provide free and inexpensive materials, appropriate community services and programs, and community experts who might be called upon to speak to your students.
- ✓ Assign extension projects that allow students to solve real-life problems related to their communities.

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Academic Vocabulary

How can I help my students learn academic vocabulary?

What is academic vocabulary?

Academic vocabulary is the language used by the educated and by leaders in business, academic, and other professional disciplines. It is the language used in courts of law and in professional books, including textbooks. This type of vocabulary contains specific linguistic features that are associated with academic disciplines like biology. Proficiency in reading and using academic vocabulary is especially related to long-term success in all parts of life.

Academic vocabulary is the basis for academic knowledge. By reinforcing academic vocabulary, teachers can help learners to access authentic, academic texts–not simplified texts that "dummy down" the content. In this way, they can provide information that will help build their students' background knowledge rapidly.

By the time children have completed elementary school, they must have acquired the knowledge needed to understand academic vocabulary. How many words should they acquire to be able to access their textbooks? A basic 2,000-word vocabulary of high-frequency words makes up 87 % of the vocabulary of academic texts. Eight hundred other academic words comprise an additional 8 % of the words. Three percent of the remaining words are technical words. The remaining 2 % are low-frequency words. There might be as many as 123,000 low-frequency words in academic texts.

Why should students learn academic vocabulary?

Students who have mastered a basic 2,000-word vocabulary are ready to acquire the majority of general words found in their academic texts.

Knowledge of academic words combined with continued acquisition of general words can significantly boost a student's comprehension level of academic texts. Students who learn and practice these words before they graduate from high school are likely to be able to master academic material with more confidence and speed. They waste less time and effort in guessing words or consulting dictionaries than those who only know the basic 2,000 words that characterize general conversation.

Also, consider academic success in terms of measurement and assessment–state standards-based assessments, the SAT, and the ACT–with regard to word mastery. All demand an understanding of academic vocabulary.

How do I include academic vocabulary in my teaching?

- ✓ Teachers can provide their students with rich samples of academic vocabulary and help students understand and attend to the academic vocabulary in their text.
- ✓ To develop academic vocabulary, learners must have already acquired a basic proficiency in grammar.
- ✓ Academic vocabulary should be taught within contexts that make sense. In terms of instruction, teaching academic vocabulary includes providing students with access to core curriculum–in this case, biology.
- ✓ An understanding of academic vocabulary arises not only from knowledge of a linguistic code and cognition, but also from social practices in which it is used to accomplish communicative goals. The acquisition of academic vocabulary and grammar is necessary to advance the development of authentic, academic language.

Tips for Teaching Academic Vocabulary

Expose students to academic vocabulary. Provide students with sufficient exposure to academic words.
Do not ignore struggling learners in this process. They can learn academic vocabulary before they completely understand academic material.
Encourage broader learning by helping students build academic vocabulary. Students who have mastered the basic academic vocabulary are ready to continue acquiring words from the rest of the groups.

To help determine which words are in the 2,000-word basic group, refer to Coxhead's Academic Word List.

Guidelines for Teaching Academic Vocabulary:

There are a number of guidelines that teachers can use when teaching academic vocabulary.

- ✓ direct and planned instruction
- ✓ models–that have increasingly difficult language
- ✓ attention to form–pointing out linguistic features of words
- ✓ practice
- ✓ motivation
- ✓ instructional feedback
- ✓ assessment–on a regular basis

Classroom Activity: Writing About Ecology

As an example of teaching academic vocabulary, when the class studies ecology, you could give students an impromptu writing assignment. Ask them to write a short essay about one of the topics listed below in the left column. Have students use as many of the academic vocabulary words in the right column as they can in their essays. Give students a time limit for their writing. When students have completed the assignment, ask student volunteers to share their writing. Help them use academic words correctly.

Topic	Academic Vocabulary
Cycles in nature (water, carbon, nitrogen, phosphorus)	chemical
	cycle
	energy
	environment
	interact
Conservation and change in wilderness areas	area
	benefit
	challenge
	community
	diverse
	implement
	regulate
	stress
	succession
	sustain

Test-Taking Strategies

How can I help my students succeed on tests?

It's not enough for students to learn biology facts and concepts–they must be able to show what they know in a variety of test-taking situations.

How can I help my students do well on objective tests?

Objective tests might include multiple choice, true/false, and matching questions. Applying the following strategies can help students do their best on objective tests.

Multiple-Choice Questions

- ✓ Students should read the directions carefully to learn what answer the test requires–the best answer or the right answer. This is especially important when answer choices include "all of the above" or "none of the above."
- ✓ Advise students to watch for negative words in the questions, such as *not*, *except*, *unless*, and *never*. If the question contains a negative, the correct answer choice is the one that does not fit.
- ✓ Students should try to mentally answer the questions before reading the answer choices.
- ✓ Students should read all the answer choices and cross out those that are obviously wrong. Then they should choose an answer from those that remain.

True/False Questions

- ✓ It is important that students read the entire question before answering. For an answer to be true, the entire statement must be true. If one part of a statement is false, the answer should be marked *False*.
- ✓ Remind students to watch for words like *all*, *never*, *every*, and *always*. Statements containing absolute words such as these are often false.

Matching Questions

- ✓ Students should read through both lists before they mark any answers.
- ✓ Unless an answer can be used more than once, students should cross out each choice as they use it.
- ✓ Using what they know about grammar can help students find the right answer. When matching a word with its definition, the definition is often the same part of speech (noun or verb, for example) as the word.

How can I help my students do well on essay tests?

Essay tests require students to write a thorough and well-organized answer to a question or questions. Help students use the following strategies on essay tests.

Read the Question

The key to writing successful essays lies in reading and interpreting questions correctly. Teach students to identify and underline key words in the questions, and to use these words to guide them in understanding what the question asks. Help students understand the meaning of some of the most common key words, listed in the chart below.

Analyze	To **analyze** means to systematically and critically examine all parts of an issue or event.
Classify or Categorize	To **classify** or **categorize** means to put people, things, or ideas into groups, based on a common set of characteristics.
Compare and Contrast	To **compare** is to show how things are similar, or alike. To **contrast** is to show how things are different.
Describe	To **describe** means to present a sketch or impression. Rich details help to flesh out a description.
Discuss	To **discuss** means to systematically write about all sides of an issue or event.
Evaluate	To **evaluate** means to make a judgment and support it with evidence.
Explain	To **explain** means to clarify or make plain.
Illustrate	To **illustrate** means to provide examples or to show with a picture or other graphic.
Infer	To **infer** means to read between the lines or to use knowledge and experience to draw conclusions, make a generalization, or form a prediction.
Justify	To **justify** means to prove or to support a position with specific facts and reasons.
Predict	To **predict** means to tell what will happen in the future, based on an understanding of prior events and behaviors.
State	To **state** means to briefly and concisely present information.
Summarize	To **summarize** means to give a brief overview of the main points of an issue or event.

Plan and Write the Essay

After students understand the question, they should follow the steps below to develop and write their essays.

Step 1 → Map out an answer. Make lists, webs, or an outline to plan the response.

Step 2 → Write an opening statement that directly responds to the essay question.

Step 3 → Write the essay. Expand on the opening statement. Support key points with specific facts, details, and reasons.

Step 4 → Write a closing statement that brings the main points together.

Step 5 → Proofread to check for spelling, grammar, and punctuation.

SAT/ACT Prep: How can I help my students prepare for the SAT, the ACT, and other standardized tests?

Students can follow the steps below to prepare for a standardized test.

- ✓ **Read About the Test** Students can familiarize themselves with the format of the test, the types of questions that will be asked, and the amount of time they will have to complete the test.
- ✓ **Review the Content** Consistent study throughout the school year will help students build biology knowledge and understanding. If there are specific objectives or standards that are tested on the exam, help students review these facts or skills to be sure they are proficient.
- ✓ **Practice** Provide practice, ideally with released tests, to build students' familiarity with the content, format, and timing of the actual exam. Students should practice all the types of questions they will encounter on the test–multiple choice, short answer, and extended response.
- ✓ **Analyze Practice Results** Help students improve test-taking performance by analyzing their test-taking strengths and weaknesses. Spend time discussing students' completed practice tests, explaining why particular answers are right or wrong. Look for patterns in errors and then tailor your instruction to the appropriate skills or biology content.

Alternative Assessment Strategies

How can I go beyond tests to assess students' understanding of biology facts and concepts?

In response to the growing demand for accountability in the classroom, educators must use multiple assessment measures to accurately gauge student performance. In addition to quizzes, tests, essay exams, and standardized tests, assessment today uses a variety of performance-based measures and portfolio opportunities.

What are some typical performance-based assessments?

There are many kinds of performance-based assessments. They all share one common characteristic: they challenge students to create written or oral reports that demonstrate what they know. One good way to present a performance assessment is in the form of an open-ended question.

Writing

Performance-based writing assessments challenge students to apply their knowledge of biology concepts and information in various ways. Writing activities are most often completed by one student, rather than by a group.

- ✓ **Journals** Students write from the perspective of a biologist, either current or historical.
- ✓ **Letters** Students compose a letter from one biologist to another or from a biologist to a family member or other audience.
- ✓ **Position Paper or Editorial** Students explain a controversial issue and present their own opinion and recommendations, supported with strong evidence and convincing reasons.
- ✓ **Newspaper** Students write a variety of stories from the perspective of a reporter.
- ✓ **Biographies and Autobiographies** Students write about biologists either from the third-person point of view (biography) or from the first person (autobiography).
- ✓ **Creative Stories** Students integrate scientific events into a piece of fiction.
- ✓ **Poems and Songs** Students follow the conventions of a particular type of song or poem as they tell about a biologist or scientific event.
- ✓ **Research Reports** Students synthesize information from a variety of sources into a well-developed report.

Oral Presentations

Oral presentations allow students to demonstrate their biology literacy before an audience. Oral presentations are often group efforts, although this need not be the case.

- ✓ **Simulations** Students hold simulations, or reenactments, of actual events, such as famous experiments or discoveries.
- ✓ **Debates** Students debate two or more sides to a scientific policy or issue. Students can debate from a contemporary perspective or through role-playing, from the viewpoint of a historical character.
- ✓ **Interview** Students conduct a mock interview of a biologist.
- ✓ **Oral Reports** Students present the results of research efforts in an oral report.
- ✓ **Skits and Plays** Students use scientific events as the basis for a play or skit.

Visual Presentations

Visual presentations allow students to demonstrate their scientific understanding in a variety of visual formats. Visual presentations can be either group or individual projects.

- ✓ **Model** Students make a model to demonstrate or represent a process or structure.
- ✓ **Museum Exhibit** Students create a rich display of materials around a topic. Typical displays might include models, illustrations, photographs, videos, writings, and audiotaped presentations.
- ✓ **Graph or Chart** Students analyze and represent scientific data in a line graph, bar graph, table, or other chart format.
- ✓ **Drawing** Students represent or interpret a scientific event or period through illustration, including political cartoons.
- ✓ **Posters and Murals** Posters and murals might include graphs, charts, tables, maps, time lines, diagrams, illustrations, photographs, and text that reflect students' understanding of scientific information.
- ✓ **Quilt** Students sew or draw a design for a patchwork quilt that shows a variety of perspectives, events, or issues related to a key topic.
- ✓ **Videotapes or DVDs** Students film a video or DVD to preserve a simulation of a scientific event. Students can also film plays they have written that incorporate biology in some way.
- ✓ **Multimedia Presentation or Slideshow** Students create a computer-generated multimedia presentation containing scientific information and analysis.

How are performance assessments scored?

There are a variety of means available to evaluate performance tasks. Some or all of the following methods can be used.

- ✓ **Scoring Rubrics** A scoring rubric is a set of guidelines for assessing the quality of a process and/or product. It sets out criteria used to distinguish acceptable responses from unacceptable ones, generally along a scale from excellent to poor.
- ✓ **Models of Excellent Work** Teacher-selected models of excellent work give a concrete illustration of what is expected and help students set goals for their own projects.
- ✓ **Student Self-Assessment** Common methods of self-assessment include ranking work in relation to the model, using a scoring rubric, and writing their own goals and then evaluating how well they have met these goals. Regardless of the method or methods students use, they should be encouraged to evaluate their behaviors, processes, and the finished product.
- ✓ **Peer or Audience Assessment** Many of the performance tasks target an audience other than the classroom teacher. If possible, an audience of peers should give the students feedback. Have the class work together to create rubrics for specific projects.
- ✓ **Observation** As students carry out their performance tasks, you might want to formally observe students at work. Start by developing a checklist, identifying the specific behaviors and knowledge you expect students to demonstrate. Then observe students as they carry out performance tasks and check off these items on your checklist as you observe them.
- ✓ **Interviews** As a form of ongoing assessment, you might want to conduct interviews with students, asking them to analyze, explain, and assess their participation in performance tasks. When projects take place over an extended period of time, you can hold periodic interviews as well as exit interviews. In this way, you can gauge the status of the project and guide students' efforts along the way.

Research Bibliography

In the bottom wrap of the Teacher Edition, you will find Research Citations that highlight research that supports teaching strategies used in the TE. The research is cited at point-of-use in the TE, but the full citations are listed here. Use these resources for additional professional development and discovery about various educational strategies to enhance the effectiveness of your teaching.

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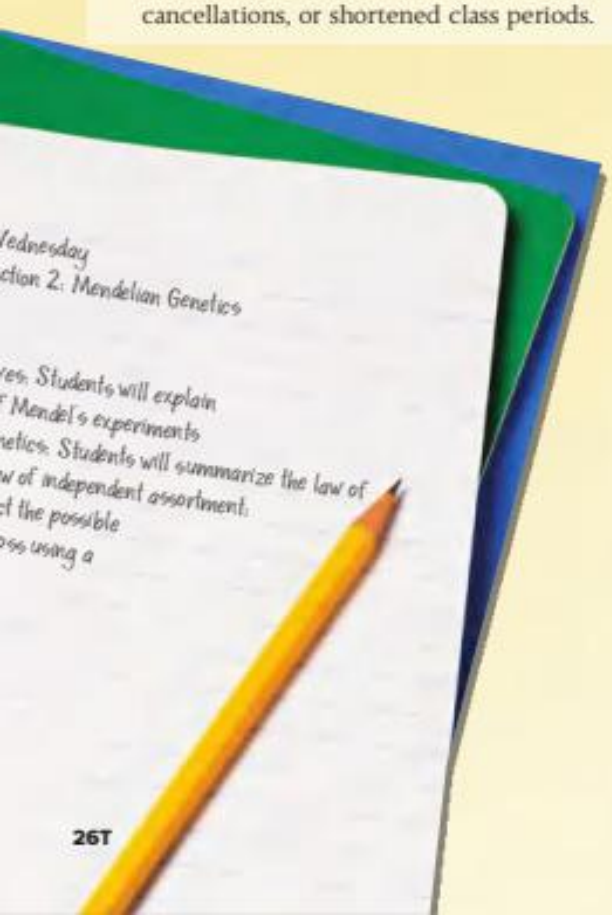
Pacing Guide

Planning Your School Year

Glencoe Biology provides a complete selection of core concepts that are presented to effectively meet the needs of all students. The following Pacing Guide offers general suggestions for pacing your students through the book. Three different class levels and two different schedule types are provided to assist you in

- designing a biology course that meets the needs of your individual students and classes;
- setting the pace at which the content is covered;
- determining what material should be given the most emphasis.

For the following pacing guides, a regular period is defined as one 45-minute class period, and a block period is defined as one 90-minute class period. The total number of days in each level of pacing is fewer than the typical 180-day school year to allow for flexibility in planning due to testing, school cancellations, or shortened class periods.



Basic Biology Course – For this option, teachers should spend more time on the core areas and then choose one of the groups to finish the school year.

Core Areas		
Chapter	Regular Periods	Block Periods
1	8	4
2	6	3
3	5	2.5
4	9	4.5
5	7	3.5
6	9	4.5
7	6	3
8	6	3
9	8	4
10	7	3.5
11	9	4.5
12	8	4
13	7	3.5
14	6	3
15	8	4
16	8	4
17	9	4.5
plus one of the groups below		
Units 5 & 6		
18	4	2
19	7	3.5
20	5	2.5
21	7	3.5
22	5	2.5
23	5	2.5
Units 7 & 8		
24	5	2.5
25	6	3
26	5	2.5
27	3	1.5
28	3	1.5
29	4	2
30	4	2
31	4	2
Unit 9		
32	5	2.5
33	6	3
34	5	2.5
35	6	3
36	6	3
37	6	3

General Biology Course - This option offers a more accelerated pace and covers more material than the basic course.

Core Areas		
Chapter	Regular Periods	Block Periods
1	6	3
2	8	4
3	7	3.5
4	5	2.5
5	6	3
6	8	4
7	8	4
8	6	3
9	6	3
10	5	2.5
11	6	3
12	8	4
13	5	2.5
14	4	2
15	7	3.5
16	5	2.5
17	7	3.5
18	4	2
19	6	3
20	5	2.5
21	7	3.5
22	5	2.5
23	5	2.5
plus one of the groups below		
Unit 7		
24	5	2.5
25	5	2.5
26	5	2.5
27	3	1.5
Unit 8		
28	4	2
29	4	2
30	5	2.5
31	5	2.5
Unit 9 (part 1)		
32	6	3
33	7	3.5
34	5	2.5
Unit 9 (part 2)		
35	5	2.5
36	6	3
37	7	3.5

Honors Biology Course - This option is designed to take students through the content at the depth and pace appropriate for an honors class.

Core Areas		
Chapter	Regular Periods	Block Periods
1	3	1.5
2	4	2
3	5	2.5
4	5	2.5
5	3	1.5
6	9	4.5
7	8	4
8	9	4.5
9	5	2.5
10	8	4
11	6	3
12	7	3.5
13	7	3.5
14	4	2
15	8	4
16	1	0.5
17	2	1
18	8	4
19	5	2.5
20	2	1
21	4	2
22	4	2
23	4	2
24	4	2
25	5	2.5
26	4	2
27	2	1
28	4	3
29	3	1.5
30	2	1
31	2	1
plus one of the groups below		
Unit 9 (part 1)		
32	4	2
33	4	2
34	5	2.5
Unit 9 (part 2)		
35	4	2
36	4	2
37	5	2.5

Safety in the Laboratory

The Need for Safety: Creating a Safety Culture

Creating a culture of safety requires the development of a safety ethic based on the understanding of teacher responsibilities, student responsibilities, and the creation of a safe science environment. A safety ethic as an entity is difficult to define. It is a target rather than a thing. It is exhibited through our actions and what we strive to achieve.

It is impossible to anticipate all the safety issues that teachers might face within their science curriculum. The study of biology brings with it a unique set of safety concerns for the student and teacher. Teachers are not expected to be superhuman in their efforts. Rather, they are expected to be reasonable and prudent within their training and teaching experiences when anticipating safety concerns and adjusting accordingly. Such a safety ethic should include habits of observing carefully and critically within the biology lessons students will study. Common sense and the safety ethic in conjunction with a teacher's experience are the keys to keeping teachers and students safe.

Teacher Responsibilities

There is extensive agreement within the profession that the "hands-on, minds-on" approach to teaching and learning science, described within the NSES, is more effective for everyone. However, this curriculum results in serious safety challenges for uninformed teachers and students. This situation is further exacerbated in old and/or poorly equipped or maintained facilities.

According to Gerlovich, et al. (2004), as a teacher, the only way you can be certain that your students are safe when they are involved in inquiry-based active science learning is to assure that you address the following five concerns.

- ✓ First, you must be vigilant in *what activities you select* for student involvement.
- ✓ Second, you must be certain that *students are instructed in and understand the hazards* associated with these labs/activities.
- ✓ Third, you must verify that they are *properly supervised* throughout these activities.
- ✓ Fourth, you must be certain that *all equipment is in operating order* and accessible during emergencies.
- ✓ Fifth, it is imperative that facilities are *properly maintained.*

In each of the biology labs, you are provided specific activity **Safety Precautions** to assist you in addressing safety concerns. It is your responsibility to communicate this information clearly and emphatically to your students prior to performing labs. It is the students' responsibility to reflect their understanding of them in writing, using the *Lab Safety Form.*

The student responses must be sufficiently clear and accurate so that you can recognize that he/she is restating the most important safety details in his or her own words. You can then approve the student's safety responses by initialing or signing in the appropriate space on the form. Be sure to keep the form on file. Only at this point can you be confident that the students can safely proceed with the lab/activity.

Following this plan will not only protect students, it will also protect you by documenting that you have met all of your duties–instruction, supervision, and maintenance.

Only basic safety guidelines have been provided within this text. The purpose of the safety segment of this material is to encourage you to be cautious in all of your work with students. It is your responsibility to model and instill a safety ethic in all scientific investigations and create a classroom safety culture for everyone.

In addition to these guidelines, *Safety Symbols* have been provided in many of the student labs and activities. Understanding and applying the safety precautions communicated by these symbols along with the *Lab Safety Form* should combine to help prevent injury to students and you as teacher.

Field Experiences

It is the teacher's responsibility to understand the unique safety issues relating to in-the-field experiences. Prior to the field trip, the field-experience site should be pre-evaluated for safety hazards (for example: poison ivy, ticks, terrain, etc.) and applicability to the educational goals. Special attention should be paid to unique clothing and protective equipment needed by the students (helmets, goggles, gloves, etc.) for the site being studied. Students should be informed of any hazards associated with the site. The adult/student ratio should be limited to 1:10. If students with special needs are present, each represents two students in that ratio.

Each student's parent or guardian should complete a school-authorized field trip permission form indicating approval of their child's participation. The accompanying adults should be informed of the purpose of the trip, be familiarized with the site, and cautioned about any potential hazards on the site. You should be aware of any student medical problems (hay fever, allergies, etc.) that may exist and be prepared to address those. A question concerning student health issues should be included in the permission form so that parents have the opportunity to indicate issues related to their child.

A buddy system for the students should be established and the responsibilities of each student explained. Prearranged meeting sites should be established and shared with adults and students. It is recommended teachers have a means of communication (cell phone, two-way radio) in case of emergency while off school grounds.

For much more comprehensive science safety information, including applicable laws, codes, and professional standards as well as comprehensive, customizable safety audits, chemical management systems, safety videos, safety research studies, and hundreds of applicable Web links, teachers may wish to investigate the following interactive CD-ROM.

The Total Science System (CD-ROM) © 2005
JaKel, Inc. Waukee, IA

Chemical Storage and Disposal

General Guidelines

The following are guidelines commonly used. It is the responsibility of each teacher to be informed of school, city, county, state, and federal regulations for the handling, storage and disposal of chemicals. Teachers who use chemicals should consult the book entitled *Prudent Practices in the Laboratory* (National Academy Press, 1995) from the National Research Council. Current laws in your area would supersede the information in this book.

1. Separate chemicals by reaction type. Strong acids should be stored together. Likewise, strong bases should be stored together and should be separated from acids. Oxidants should be stored away from easily oxidized materials, and so on.
2. Be sure all chemicals are stored in labeled containers indicating contents, concentration, source, date purchased (or prepared), any precautions for handling and storage, and expiration date.
3. Dispose of any outdated or waste chemicals properly according to accepted disposal procedures.
4. Do not store chemicals above eye level.
5. Wood shelving is preferable to metal. All shelving should be firmly attached to the wall and should have anti-roll edges.
6. Store only those chemicals that you plan to use.
7. Hazardous chemicals require special storage containers and conditions. Be sure to know which chemicals those are and the accepted practices for your area. Some substances must be stored outside the building.
8. When working with chemicals or preparing solutions, observe the same general safety precautions that you would expect from students. These include wearing an apron and goggles during lab preparation, activity, and cleanup. Wear gloves and use the fume hood when necessary.
9. If you are a new teacher in a particular laboratory, it is your responsibility to survey the chemicals stored there to be sure they are stored properly. Consult chemical storage and disposal information from local, state, and federal governments.

DISCLAIMER

McGraw-Hill Education makes no claims to the completeness of this discussion of laboratory safety and chemical storage. The material presented is not all-inclusive, nor does it address all of the hazards associated with handling, storing, and disposing of chemicals, or with laboratory management.

Laboratory Preparation

Preparation of Solutions

It is most important to use safe laboratory techniques when handling chemicals. Many substances may appear harmless but are, in fact, toxic, corrosive, or very reactive. Always check with the supplier. Chemicals should never be ingested. Be sure to use proper techniques to smell solutions or other agents. Always wear safety goggles, gloves, and an apron. Observe the following precautions.

1. *Poisonous/corrosive liquid and/or vapor*–use in the fume hood; Examples: acetic acid, nitric acid, hydrochloric acid, ammonium hydroxide
2. *Poisonous and corrosive to eyes, lungs, and skin;* Examples: acids, limewater, iron(III) chloride, bases, silver nitrate, iodine, potassium permanganate
3. *Poisonous if swallowed, inhaled, or absorbed through the skin;* Examples: glacial acetic acid, copper compounds, barium chloride, lead compounds, chromium compounds, lithium compounds, cobalt(II) chloride, silver compounds
4. Always add acids to water, never the reverse.
5. When sulfuric acid and sodium hydroxide are added to water, a large amount of heat is released. Sodium metal reacts violently with water. Use extra care when handling any of these substances.

Alcohol testing solution: Wear goggles, gloves, and an apron. In a fume hood, add 20 g of potassium dichromate powder to a glass beaker. Pour 20 mL concentrated H_2SO_4 into the beaker and stir with a glass stirring rod to dissolve the powder. Slowly and carefully pour the solution into 60 mL distilled water in a glass beaker and continue to stir. The solution becomes VERY HOT. Allow it to cool. Powder may precipitate out after cooling. Pour only the liquid solution into dropper bottles for student use. The solution has a shelf life of one year.

Baking soda (sodium bicarbonate) solution: To prepare a 0.25% solution, dissolve 0.5 g baking soda (sodium hydrogen carbonate) in 200 mL of water.

Benedict's solution: Dissolve 173 g sodium citrate and 100 g sodium carbonate in 700 mL water over a hot plate. Filter. Dissolve 17.3 g copper sulfate in 100 mL water. Slowly add to the first solution. Add water to a total volume of 1 L.

Bromothymol blue: Add 0.5 g bromothymol blue powder to 500 mL distilled water to make a BTB stock solution. Dilute 40 mL BTB stock solution to 2 L with distilled water. Solution should be bright blue. If not, add one drop of NaOH at a time, swirling to mix. Check color.

Cola, dilute solution: Add 1 part cola to 1 part distilled water.

Congo red: Add 0.1 g Congo red powder to 50 mL distilled water.

Cough medicine, dilute: Add 2 mL of cough medicine (syrup) to 98 mL distilled water. Stir before use.

Ethyl alcohol, dilute: Add 2 mL ethyl alcohol to 98 mL distilled water. Stir.

Fertilizer solution: To make a 1% fertilizer solution, mix 1 g 5-10-5 fertilizer with 99 mL water. For a 0.1% serial dilution, mix 1 mL 1% solution with 9 mL water. For a 0.01% serial dilution, mix 1 mL 0.1% solution with 9 mL water.

Gelatin solution: Soften 1 g gelatin in 20 mL water; then add 80 mL hot, not boiling, water to dissolve. Cool to room temperature before using.

Glucose solution: For 1% glucose solution, dissolve 1 g of glucose in 99 mL water.

Gum arabic solution: Dissolve 1 g gum arabic in 100 mL warm water. Cool to room temperature before use.

Hydrochloric acid (HCl) solution: To make a 10% solution, add 27 mL concentrated hydrochloric acid to 73 mL water while stirring. To make a 0.1M solution, add 1 mL concentrated hydrochloric acid to 100 mL water while stirring.

Iodine solution/Iodine stain: Dilute 1 part Lugol's solution with 15 parts water.

Lugol's solution: Dissolve 10 g potassium iodide in 100 mL distilled water; then add and dissolve 5 g iodine. Store in dark bottle. Keeps indefinitely.

Methylene blue stain: Dissolve 1.5 g methylene blue in 100 mL ethyl alcohol. Dilute by adding 10 mL of solution to 90 mL water.

Methylcellulose solution: Add 20 g methylcellulose to 40 mL of boiling distilled water. Let stand for 30 min, then add 40 mL distilled water. Stir until uniform. Solution will be very thick.

Pancreatic solution: Blend a goat or sheep pancreas with 150 mL 30% ethyl alcohol. Allow the solution to stand for 24 h, shaking occasionally. Strain the solution through cheesecloth and then filter. Neutralize with KOH until you get near the end point, then use 0.5% sodium carbonate.

Potassium chloride (KCl) solution: To make a 0.5 M solution, dissolve 3.73 g of potassium chloride in 60 mL of distilled water, then add distilled water to make 100 mL final volume.

Salt (NaCl) solution: For a 3.5% salt solution that simulates the concentration of ocean water, dissolve 35 g salt in 965 mL water. For a 1% solution, dissolve 1 g of salt in 99 mL of water. For a 3% solution, dissolve 3 g of salt in 97 mL of water. For a 5% solution, dissolve 5 g of salt in 95 mL of water. For a 6% solution, dissolve 6 g of salt in 94 mL of water.

Silver nitrate solution: Add 4 g silver nitrate to 250 mL distilled water.

Sodium hydroxide (NaOH) solution: To make a 1% solution, dissolve 1 g NaOH in 99 mL of water. For a 0.04% serial dilution, mix 4 mL 1% solution with 96 mL water.

Solutions of various pHs: To make acidic solutions, add 50 mL 0.1M HCl to 450 mL distilled water. Test the pH level and continue diluting the solution until the desired pH levels are obtained. Do the same with NaOH to make a variety of basic solutions.

Starch solution: Make a 1% solution by stirring a slurry of 1 g cornstarch and 50 mL cold water into 1 L boiling water. Cool before using.

Sterile pond water: Filter pond water and place it in flat pans. Boil for 15 min. Allow to cool before using.

Sucrose solution: For a 1% sucrose solution, dissolve 1 g sucrose in 99 mL water. For a 2% sucrose solution, dissolve 2 g sucrose in 98 mL water. For a 5% sucrose solution, dissolve 5 g sucrose with 95 mL water. For a 10% sucrose solution, dissolve 10 g of sucrose in 90 mL water. For a 20% sucrose solution, dissolve 20 g of sucrose in 80 mL of water. For a 30% sucrose solution, dissolve 30 g of sucrose in 70 mL of water. For a 40% sucrose solution, dissolve 40 g of sucrose in 60 mL of water.

Sugar solution: Add 1 tablespoon of sugar to 1 cup of warm water in a deep jar or flask. Stir to dissolve.

Tetrazolium solution: Dissolve 1 g of 2,3,5-triphenyl tetrazolium chloride in 100 mL of water. Store in dark glass bottle.

Tobacco solution: Grind tobacco from one cigarette into a fine powder. Mix the powder with 100 mL of a 1% glucose solution.

Urine (artificial) solutions: Normal: Add 1 tsp. of salt and 4 drops of yellow food coloring to 500 mL of tap water. Stir to dissolve. Abnormal: Add 1 tsp. of salt, 2 tsp. of glucose or honey, and 4 drops of yellow food coloring to 500 mL of tap water. Stir to dissolve.

Yeast culture: Add 1/5 package dry baker's yeast to 200 mL distilled water.

Laboratory Materials

This table of equipment and inexpensive, easily accessible materials can help you prepare for your biology classes for the year. Refer to the Chapter Organizer in front of each chapter for a list of equipment and materials used for each laboratory activity in the chapter.

Consumables		Labs		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
aged tap water	4240 mL		10 mL	500 mL, 10 mL
aluminum foil	several rolls		2×2 cm	20×20 cm
antibiotic discs	40			1–5 per dish
apple	8		1	
autoclave disposable bag	8			1
beans (three sizes)	480 (160 each size)			60 (20 each size)
beef broth	800 mL			100 mL
beef liver	8 g			1 g
black paper	10 sheets	3×3 cm		1 sheet
bread	32 slices		2 slices	2 slices
cardboard (pieces or boxes)	8 sheets/8 boxes			1 sheet, 1 shoebox
celery stalk (cross section)	1 stalk,thinly sliced			1
cellulose dialysis tubing	16			2
cheesecloth (30×30 cm squares)	32			4
clay (colored sticks)	32	2 (different colors)	2 (different colors)	
colored markers	8 sets			1 set
conifer cones	8–40		1–5	
conifer leaf samples	16–40		2–5	
contact lens cleaning tablet (containing papain)	8			1
cooked egg white	1 egg		1 small piece	
corn kernels	400 g			50 g
cotton swabs	generous supply including long handle swabs		1	1 per dish, 1 per cup, 1
crackers (3 kinds)	8 each kind			1 each kind

Consumables		Labs		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
dishwashing liquid	8 mL			1 mL
disinfectant	clean up			clean up
disks	8–40			1–5
distilled water	± 4 L	100 mL	10 mL, 5 mL	1 L, 1 L, 3 mL
dried beans	generous supply			supply
dry yeast packet	8		1	
dye (stain)	1 mL		1 drop	
eudicot flowers	several samples			sample
felt pieces	samples			several
filter paper	40		1	1, 3
flowers	cut flowers at various times	several	several	several
food substances (with labels)	32 different		4 different	
gelatin (plain powdered)	8 packets			1 packet
glue	8 bottle/stick			1 bottle/stick
graph paper	32 sheets		1 sheet	1 sheet
hardboiled egg white	8	1		
ice	supply at different times			ice bath
labeled food items	32	4		
leaf litter sample	8 samples		sample	
lemon juice	600 mL		75 mL	
lily flower	8		1	
marigold or radish seeds	1008			126
marking pen	8			1
masking tape	320 cm		30 cm	10 cm
materials to produce stimulus in protozoa	unknown			unknown
meat tenderizer (homogenization medium)	800–1200 mL			100–150 mL
monocot flowers	several samples			sample
nitrate test kit	1–8		1	

Laboratory Materials

Consumables		Labs		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
nontoxic dye	8 mL			1 mL
onion epidermis	1 onion		1 cm square	
paper	ream			1 sheet
paper cups (small)	24			2
paper plates (small)	8			1
paper towels	generous supply	clean up	1	3, clean up
peanuts (with hulls)	8	1		
pear tissue	1 pear		small piece	
pH test strip (indicator)	1 roll			several strips
pipe cleaners	32	4		
plant fertilizer	8 g			1 g
plant leaves (variety)	80		10	
plastic bags (large)	16			2
plastic wrap	generous supply (several colors of cellophane)		2 sheets	20×20 cm, sheet
pond mud	Large supply			large sample
pond water	10 L		10 mL	500 mL
poster board	10 sheets	1/4 sheet		1 sheet
potato slices	2 small potatoes		1	several
potting soil	several bags			6 pots full, 2 pots full
prepared agarose gel	match to number of plates available			electrophoresis plate
prepared gelatin (in small cup)	4 cups			1/2 cupful
printed maze	8 ±		1	
raw beef liver	small chunk			small piece
raw chicken wing treated with bleach	8 wings	1 whole wing	1 whole wing	
red paper	10 sheets	3×3 cm		
salt	10 g		1 g	
sample-loading dye (electrophoresis)	10 mL			1mL

Consumables		Labs		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
sand	generous supply			50 cc, unknown quantity
seeds, various sizes (alternative material)	generous supply		alternative material: 10	alternative material
skinned chicken wing	8		1	
soil	generous supply		several containers full, sample	sample, 100 cc, unknown quantity
spring water	4010 mL		1 mL	500 mL
sterile nutrient agar	8 Petri dishes			1 Petri dish
straw (plastic or paper)	8		1	
sugar	32 g		3 g	1 g
sunscreen products	10 mL each of several products		1 drop	1 mL
sun sensitive paper	1 sheet		1 piece	
tape	several rolls		10 cm	unknown
toothpicks	several boxes			unknown
vegetable oil	40 mL		5 mL	
water	10 L plus water for clean up, water baths, etc.	30 mL	water bath, 75 mL, 2 drops, unknown, 100 mL, 250 mL, 2 drops, 125 mL	unknown, water bath, 250 mL
water, soapy	for hand washing and clean up		unknown	
water from a saltwater aquarium	1600 mL	± 200 mL		
water samples from various sources	8 each source		1 each	
wooden sticks (various sizes)	dozens			several
yeast extract dextrose (YED) agar plates	80			10

Laboratory Materials

Non-Consumables			
Item	**Launch Lab**	**MiniLab**	**BioLab**
acrylic (1 m^2 piece)			
aluminum foil or plastic wrap			
aquarium			
art supplies (pencils, chalks in various colors)			
balance			
beads (three sizes)			
beaker			
beaker (250-mL)			
beaker (400-mL)			
beaker (500-mL)			
binoculars			
blender			
blood pressure chart			
blood pressure cuff			
bones (small) and bone fragments			
book			
books describing characteristics of organisms			
bunsen burner			
calculator			
cereal box			
circular paper DNA sequence			
closed door			
coat hangers			
coins			
collection vials			
colored plastic ribbon			
compound microscope			
container			
cooler			
copies of small world maps			
cup			
deck of cards			
diagrams of skeletal remains			

Non-Consumables			
Item	Launch Lab	MiniLab	BioLab
dish (clear)			
dish cloth			
dishpan			
dissecting kit			
dissecting pan			
dissection scissors			
DNA model building kit			
DNA model building kit			
dirham bill			
droppers			
echinoderm reference book			
electrophoresis chamber			
envelopes containing paper bones and clues			
Erlenmeyer flasks			
Erlenmeyer flasks (250 mL)			
examples of cladograms			
field guide for local birds			
field guide for trees			
field guide of area species (plant, animal, and fungus)			
field guide of arthropods			
field guide of North American mammals			
field guide of trees			
field guides for birds and reptiles			
field journal			
foam container			
forceps			
funnel			
glass or plastic clear gallon jars			
glass probe			
glass rod			
glass spooling hook			
globe			
gloves			

Laboratory Materials

Non-Consumables			
Item	Launch Lab	MiniLab	BioLab
gooseneck lamp			
graduated cylinder			
graduated cylinder (10 mL)			
graduated cylinder (50 mL)			
high-wattage lightbulb and lamp			
hot plate			
impressions of three unknown bones			
incubator			
Internet access			
jar			
knife			
labeled and unlabeled ultrasound images of fetuses			
labeled diagram of earthworm cross section			
labeled diagram of hydra cross section			
labeled drawing of a lily flower			
lamp with incandescent bulb			
lamp with reflector and 150 W bulb			
light microscope			
light source			
magnifying lens			
marbles			
metric ruler			
microcentrifuge tubes and rack			
micropipette and tips			
microprojector			
microscope			
mortar and pestle			
net			
objects (nonliving)			
observation dish			
paintbrush			
pan (square or rectangular)			

Non-Consumables			
Item	Launch Lab	MiniLab	BioLab
paper			
paper cutouts			
Pasteur pipets			
pencil			
pencil eraser			
permanent marker			
petition or sign-up sheet with 50 names			
petri dish			
photo or illustration of desert ecosystem			
photographs of mammals			
photographs of various organisms			
photos of a rusted nail			
photos of each of the three groups of fishes			
photos of skeletal remains			
photos or videos of animal behavior			
ping pong ball			
plastic bottle caps in various colors			
plastic centrifuge tube (30-50 mL)			
plastic plate			
plastic pots (9 cm)			
plastic tubing			
pop beads			
power source			
reference materials			
resource materials about health choices			
ring stand			
rocks			
rubber band			
ruler			
scalpel			
science textbook			
scissors			

Laboratory Materials

Non-Consumables			
Item	Launch Lab	MiniLab	BioLab
self-sealing bag			
set of clues			
shallow tray for pots			
shells (small) and shell fragments			
shoe			
shoelaces			
short-nosed pliers			
small flowerpots or other growing containers			
small gardening trowel			
spray bottle			
spoon			
staining and destaining containers			
stakes (1m)			
stereomicroscope			
sterile pipettes			
sterile spreaders			
stethoscope			
stirring rod			
stopper			
stopwatch or watch with second hand			
straight paper DNA sequence			
string			
table of gene-pair crossover frequency			
table of inherited human facial characteristics			
test tubes			
test tubes (15 mL)			
test tubes (18 mm × 150 mm)			
test-tube rack			
thermometer			
tongs			
tray			
tweezers			
used cutting board			

Non-Consumables			
Item	Launch Lab	MiniLab	BioLab
UV lamp			
vase			
wading boots			
watch glasses			
watering can or bottle			
wax pencil			
wire mesh			

Living Organisms		Labs		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
arthropod (live)	1		1	
bacteria cultures	8 set ups			1
black worms (live)	16		1	1
dilution of UV sensitive yeast	1 culture			1 culture
earthworm (live)	16	1	1	
fern plant (frond)	8	1		
fishes (live)	8–32	3 photos	1–4	
freshwater algae samples (slide)	8 (minimum)		1	
fruit flies (mixed sexes)	24	3		
isopods	24–40			3–5
land snails	8			1
live green algae cultures	24		3	
live sea star	8	1		
living brine shrimp	24		3	
living hydra	24		3	
living pond organisms	many			several
mold	several samples			sample
moss	8	1		
objects (living)	many		several	
planaria	16		1	1
potted dwarf-pea plant seedlings	24–32			3–4
potted plant	8	1		
preserved specimen of pill bugs	8	1		

Laboratory Materials

Living Organisms		Labs		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
protozoa cultures	several			several
Venus flytrap plant	1–8		1	
vinegar eels	8			1
Chemicals		**Labs**		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
anhydrous Benedict's reagent	2.5 mL			3 drops
anhydrous calcium chloride	320 g	40 g		
bile salt	8 g		1 g	
biuret reagent	2.5 mL			3 drops
DNA samples	several sources			several
Epsom salts	320 g	40 g		
ethanol (70%)	1 L			100 mL
ethanol (95%)	1 L			12 mL, 90 mL
gibberillic acid in various concentrations	supply			unknown
homogenization medium	800–1200 mL			100–150 mL
iodine stain	2.5 mL		3 drops	
isopropyl alcohol (95%) — alternative	100 mL			12 mL
phenol red (alternative)	25 mL		24–30 drops	
pheolphthalein	25 mL		24–30 drops	
restriction enzyme	2 mL			5 drops
testing indicator	3 mL			3 drops
zinc oxide	1 mL		1 drop	
Solutions		**Labs**		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
albumin solution	400 mL			50 mL
amylase solution	24 mL			3 mL
baking soda solution (0.25%)	1 box			unknown
Benedict's solution	40 mL		5 mL	

Solutions		Labs		
Item	Quantity (8 set-ups per class)	Launch Lab	MiniLab	BioLab
bromthymol blue (BTB) solution	800 mL		100 mL	
buffer solutions (pH 5, pH 6, pH 7, pH 8)	generous quantity			unknown
glucose solution	400 mL			50 mL
HCl solution	80 mL	10 mL		
hydrogen peroxide (3%)	several liters			unknown
iodine solution	30 mL			3 drops, several mL
NaCl solution (salt water)	410 mL		2 drops	50 mL
NaOH solution	200 mL		10 mL	10 mL
pancreatic solution	40 mL		5 mL	
pepsin solution	40 mL	5 mL		
silver nitrate solution	2.5 mL			3 drops
starch solution	400 mL			50 mL
sugar solution	600 mL		75 mL	

Preserved Specimens			
Item	Launch Lab	MiniLab	BioLab
animal skeletons			
aquatic plant material			
arthropod specimens			
crayfish specimens			
dried mount of a fan coral			
dried mount of a species of red algae			
fish specimens			
fungi samples			
male and female conifer cones			
mammal specimens			
mammal teeth and skulls			
monarch butterfly specimens			
plant specimens			
prepared slide of cross section of a hydra			
prepared slide of cross section of an earthworm			

Laboratory Materials

Preserved Specimens			
Item	Launch Lab	MiniLab	BioLab
sand dollar specimen			
sea cucumber specimen			
sea star specimen			
sea urchin specimen			
skeletal parts			
slides of algae cells			
slides of animal cells			
slides of bacteria			
slides of cancerous human liver cells			
slides of cells			
slides of egg cells			
slides of healthy human liver cells			
slides of human cells			
slides of onion root tip cells			
slides of plant cells			
slides of protist cells			
slides of sperm cells			
slides of various protists			
slides of various slime molds			
teeth			
viceroy butterfly			

CHAPTER 1

Launch Lab
What do you know about human inheritance?

Est. Time 30 min

Teaching Strategies

- Have students work individually or in small groups.
- Check answers to the genetics quiz below:
  - **A.** True. A sperm cell carries either a Y or an X chromosome. XY pairing produces a male; XX pairing produces a female.
  - **B.** True. Genetic traits not expressed in one generation may be expressed in later generations.
  - **C.** True. Because identical twins form from the same fertilized egg, they must be the same gender.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Read the statements below carefully and determine whether they are true or false.

   Statements:

   A. The father determines the gender of the child.

   B. Individuals may transmit characteristics to their offspring which they themselves do not show.

   C. Identical twins always are of the same gender.
3. Discuss your answers with your classmates and teacher.

Analysis

1. **Assess** which question was missed most often by the entire class. Discuss reasons why.
   Answers will vary, but should give some insight into the knowledge, background, and experiences your students have regarding human heredity. Identify and correct any misconceptions.
2. **Analyze** why it is helpful to understand human heredity. Knowledge of human heredity is necessary to understand legal, social, and moral issues that involve inherited traits. Such knowledge could help people make certain health decisions.

CHAPTER 1

Complex Inheritance and Human Heredity

Launch Lab
What do you know about human inheritance?

As knowledge and understanding of human inheritance increases, long-standing ideas regarding the facts of human heredity must be reexamined. Any ideas disproven by new discoveries must be rejected.

FOLDABLES

Make a vocabulary book and label each tab with the name of a different genetic disorder. Use it to organize your notes on genetic disorders.

2 Chapter 1 • Complex Inheritance and Human Heredity

THEME FOCUS Diversity
Complex forms of inheritance result in a wide diversity of characteristics.

BIG Idea **Human inheritance does not always follow Mendel's laws.**

Introduce the Chapter

Inheritance

ASK STUDENTS: ***What physical abilities should a good soccer player have?*** Answers may include good coordination, good running ability, and muscular strength. ***What physical features are not important for a good soccer player to have?*** Answers may include eye color, shape of nose, and curly or straight hair. List characteristics in two columns on the board as students share answers. Use this list to spark a discussion that can lead to human inheritance of physical features and the influence of environmental factors such as diet and exercise.

BIG Idea

Tongue-Rolling Ability

ASK STUDENTS: ***Can you roll your tongue? Discuss whether other members of your family have this trait.*** Tongue-rolling ability is dominant in humans. Use this example to discuss that traits are inherited. Tell students that in this chapter they will learn some other types of inheritance that were unknown by Mendel and are variations of Mendel's concept of dominance.

THEMES

Scientific Inquiry The discovery of DNA led to an understanding of the inheritance of traits from one generation to the next.

Diversity Complex inheritance patterns account for some of the vast genetic diversity in humans.

Energy Some genetic diseases, such as Tay-Sachs disease, affect metabolism.

Homeostasis Inheritance of genes from generation to generation helps maintain homeostasis among species.

Change Mutations in genes allow possible changes in inheritance to occur.

Section 1

MAIN Idea

BL OL AL COOP LEARN

Tracing Traits Remind students that the trait for the ability to roll one's tongue is dominant (*TT*). Then, ask student to imagine a family with three children. Two of the children cannot roll their tongues.

ASK STUDENTS: ***What are the genotypes of the parents?*** Students should use Punnett squares to conclude that either one parent is heterozygous dominant (*Tt*) and the other parent is homozygous recessive (*tt*) or that both parents are heterozygous (*Tt*).

Develop Concepts

BL OL AL

Clarify a Misconception

ASK STUDENTS: ***If someone looks more like one parent than the other, did that person inherit more genes from that parent?*** no

Some students might think that because children look more like one parent than the other, the child received more genetic material from one of the parents. Clarify that the child receives one set of chromosomes from one parent and the second set from the other parent. Review meiosis, the combination of chromosomes, and the concept of dominant and recessive traits.

Reading Strategy

BL OL

Find Supporting Details Have students create a three-column chart. In the first column, have them write the name of each genetic disorder that they will read about in this chapter. After they read, have them write whether the disorder is dominant or recessive in the middle column. In the last column, have them write any symptoms of the disorder.

Section 1

Essential Questions

- How can genetic patterns be analyzed to determine dominant or recessive inheritance patterns?
- What are examples of dominant and recessive disorders?
- How can human pedigrees be constructed from genetic information?

Review Vocabulary

genes: segments of DNA that control the production of proteins

New Vocabulary

carrier
pedigree

Basic Patterns of Human Inheritance

MAIN Idea **The inheritance of a trait over several generations can be shown in a pedigree.**

Real-World Reading Link Knowing a purebred dog's ancestry can help the owner know health problems that are common to that dog. Similarly, tracing human inheritance can show how a trait was passed down from one generation to the next.

Recessive Genetic Disorders

Connection to History Gregor Mendel's work was ignored for more than 30 years. During the early 1900s, scientists began to take an interest in heredity, and Mendel's work was rediscovered. About this time, Dr. Archibald Garrod, an English physician, became interested in a disorder linked to an enzyme deficiency called alkaptonuria (al kap tuh NYUR ee uh), which results in black urine. It is caused by acid excretion into the urine. Dr. Garrod observed that the condition appeared at birth and continued throughout the patient's life, ultimately affecting bones and joints. He also noted that alkaptonuria ran in families. With the help of another scientist, he determined that alkaptonuria was a recessive genetic disorder.

Today, progress continues to help us understand genetic disorders. Review **Table 1,** and recall that a recessive trait is expressed when the individual is homozygous recessive for that trait. Therefore, those with at least one dominant allele will not express the recessive trait. An individual who is heterozygous for a recessive disorder is called a **carrier.** Review **Table 2** as you read about several recessive genetic disorders.

Table 1 Review of Terms

Term	Example	Definition
Homozygous	True-breeding yellow-seed pea plants would be *YY*, and green-seed pea plants would be *yy*. 	An organism with two of the same alleles for a particular trait is said to be homozygous for that trait.
Heterozygous	A plant that is *Yy* would be a yellow-seed pea. 	An organism with two different alleles for a particular trait is said to be heterozygous for that trait. When alleles are present in the heterozygous state, the dominant trait will be observed.

Content Background

Teacher FYI Sir Archibald Garrod, a British physician, discovered a pattern of inheritance leading to alkaptonuria, a disorder in which urine turns black. Alkaptonuria also causes severe arthritis later in life. Garrod concluded that the dark urine is caused by an inherited biochemical abnormality. Considering that he worked in the early 1900s, Garrod's ideas were ahead of his time.

4 Chapter 1 • Complex Inheritance and Human Heredity

Table 2 Recessive Genetic Disorders in Humans

Disorder	Occurrence in the U.S.	Cause	Effect	Cure/Treatment
Cystic fibrosis	1 in 3500	The gene that codes for a membrane protein is defective.	• Excessive mucus production • Digestive and respiratory failure	• No cure • Daily cleaning of mucus from the lungs • Mucus-thinning drugs • Pancreatic enzyme supplements
Albinism	1 in 17,000	Genes do not produce normal amounts of the pigment melanin.	• No color in the skin, eyes and hair • Skin susceptible to UV damage • Vision problems	• No cure • Protect skin from the Sun and other environmental factors • Visual rehabilitation
Galactosemia	1 in 50,000 to 70,000	Absence of the gene that codes for the enzyme that breaks down galactose	• Mental disabilities • Enlarged liver • Kidney failure	• No cure • Restriction of lactose/ galactose in the diet
Tay-Sachs disease	1 in 2500	Absence of a necessary enzyme that breaks down fatty substances	• Buildup of fatty deposits in the brain • Mental disabilities	• No cure or treatment • Death by age 5

Cystic fibrosis One of the most common recessive genetic disorders among Caucasians is cystic fibrosis, which affects the mucus-producing glands, digestive enzymes, and sweat glands. Chloride ions are not absorbed into the cells of a person with cystic fibrosis but are excreted in the sweat. Without sufficient chloride ions in cells, water does not diffuse from cells. This causes a secretion of thick mucus that affects many areas of the body. The thick mucus clogs the ducts in the pancreas, interrupts digestion, and blocks the tiny respiratory pathways in the lungs. Patients with cystic fibrosis are at a higher risk of infection because of excess mucus in their lungs.

Treatment for cystic fibrosis currently includes physical therapy, medication, special diets, and the use of replacement digestive enzymes. Genetic tests are available to determine whether a person is a carrier, indicating they are carrying the recessive gene.

Albinism In humans, albinism is caused by altered genes, resulting in the absence of the skin pigment melanin in hair and eyes. Albinism is found in other animals as well. A person with albinism has white hair, very pale skin, and pink pupils. The absence of pigment in eyes can cause problems with vision. Although we all must protect our skin from the Sun's ultraviolet radiation, those with albinism need to be especially careful.

Tay-Sachs disease Tay-Sachs (TAY saks) disease is a recessive genetic disorder. Its gene is found on chromosome 15. Often identified by a cherry-red spot on the back of the eye, Tay-Sachs disease (TSD) seems to be predominant among some people of eastern European descent.

FOLDABLES
Incorporate information from this section into your Foldable.

Skill Practice

BL OL AL COOP LEARN

Visual Literacy Organize students into pairs. Have partners look over Tables 2 and 3 and decide whether dominant or recessive disorders are more common. recessive

ASK STUDENTS: ***Why are recessive disorders more common than dominant disorders?*** When a disorder is dominant, only one allele must be inherited for the person to be affected. If the dominant trait interferes with survival, the individual is less likely to pass the gene to the next generation. When the disorder is recessive, carriers do not display the disorder. Many people carry recessive alleles without being affected by the disorder.

Critical Thinking

BL OL AL **Predict** Draw a large Punnett square on the board. Perform a cross of two parents that are heterogenous for the gene.

ASK STUDENTS: ***What are the chances of two carriers of cystic fibrosis having a child with cystic fibrosis?*** one in four For caucasians, the odds of one carrier (1/23.6) marrying another carrier (1/23.6) is 1/500. The incidence of cystic fibrosis is about 1/2000 in Caucasians.

FOLDABLES

Going Further On the back of their Foldables, have students research and categorize the diseases investigated on the front tabs by dollar amounts spent to discover treatments or to find methods of prevention.

Content Background

Real-World Connection Singer Woodrow "Woody" Guthrie was born in Oklahoma in 1912. During the Dust Bowl of the 1930s, he gained fame singing on radio and writing political songs of protest. One of his most famous songs is "This Land Is Your Land." Later, the federal government paid him to compose songs. His health and behavior began to deteriorate, and he was misdiagnosed with such diseases as alcoholism and schizophrenia. In fact, he suffered from Huntington's disease, a dominant genetic disorder that had affected his mother. He died in October of 1967.

Writing Support

OL AL COOP LEARN

Summary Writing Have students work in small groups to research an inherited condition, such as sickle-cell disease or Tay-Sachs disease, that is more frequent in some populations than others. Have them write a summary of the condition and present it to the class.

Develop Concepts

BL OL AL COOP LEARN

Bulletin Board Have students collect articles from newspapers and magazines that relate to genetics. Have them work in groups to prepare a poster or a bulletin board covered with current articles about genetics.

Writing Support

OL AL COOP LEARN

Technical Writing Have students investigate other dominant or recessive disorders that are not mentioned in the chapter. Some examples of these disorders include polydactylism, Marfan syndrome, galactosemia, and muscular dystrophy. Have them design and write a technical pamphlet describing the genetic disorder. The pamphlet should include symptoms, genetic causes, frequencies of occurrence, treatments, and at least one graph. Students can research various disorders.

BL Supply students with appropriate research material and have them write a paragraph about a disorder.

VOCABULARY

ACADEMIC VOCABULARY

Decline
to gradually waste away; or a downward slope
His health declined because of the disease.

TSD is caused by the absence of the enzymes responsible for breaking down fatty acids called gangliosides. Normally, gangliosides are made and then dissolved as the brain develops. However, in a person affected by Tay-Sachs disease, the gangliosides accumulate in the brain, inflating brain nerve cells and causing mental deterioration.

Galactosemia Galactosemia (guh lak tuh SEE mee uh) is characterized by the inability of the body to digest galactose. During digestion, lactose from milk breaks down into galactose and glucose. Glucose is the sugar used by the body for energy and circulates in the blood. Galactose must be broken down into glucose by an enzyme named Galactose-1- phosphate uridyltransferase (GALT). Persons who lack or have defective GALT cannot digest galactose. Persons with galactosemia should avoid milk products.

Dominant Genetic Disorders

Not all genetic disorders are caused by recessive inheritance. As described in **Table 3,** some disorders, such as the rare disorder Huntington's disease, are caused by dominant alleles. That means those who do not have the disorder are homozygous recessive for the trait.

Huntington's disease The dominant genetic disorder Huntington's disease affects the nervous system and occurs in one out of 10,000 people in the U.S. The symptoms of this disorder first appear in affected individuals between the ages of 30 and 50 years old. The symptoms include a gradual loss of brain function, uncontrollable movements, and emotional disturbances. Genetic tests are available to detect this dominant allele. However, no preventive treatment or cure for this disease exists.

Achondroplasia An individual with achondroplasia (a kahn droh PLAY zhee uh) has a small body size and limbs that are comparatively short. Achondroplasia is the most common form of dwarfism. A person with achondroplasia will have an adult height of about 122 cm and will have a normal life expectancy.

Interestingly, 75 % of individuals with achondroplasia are born to parents of average size. When children with achondroplasia are born to parents of average size, the conclusion is that the condition occurred because of a new mutation or a genetic change.

Reading Check **Compare** the chances of inheriting a dominant disorder to the chances of inheriting a recessive disorder if you have one parent with the disease.

Table 3 **Dominant Genetic Disorders in Humans**

Disorder	Occurrence in the U.S.	Cause	Effect	Cure/Treatment
Huntington's disease	1 in 10,000	A gene affecting neurological function is defective.	• Decline of mental and neurological functions • Ability to move deteriorates	• No cure or treatment
Achondroplasia	1 in 25,000	A gene that affects bone growth is abnormal.	• Short arms and legs • Large head	• No cure or treatment

Differentiated Instruction

Physically Disabled When students with physical disabilities are in class, do not expect less of them because of their disability. The same academic and social standards should be set for every student so that students with disabilities are not viewed as less capable than their peers.

Reading Check Recessive: 50% chance if parent without the disease is heterozygous, 0% chance if parent without the disease is homozygous dominant. Dominant: 50% chance if the parent with the disease is heterozygous, 100% chance if the parent with the disease is homozygous dominant.

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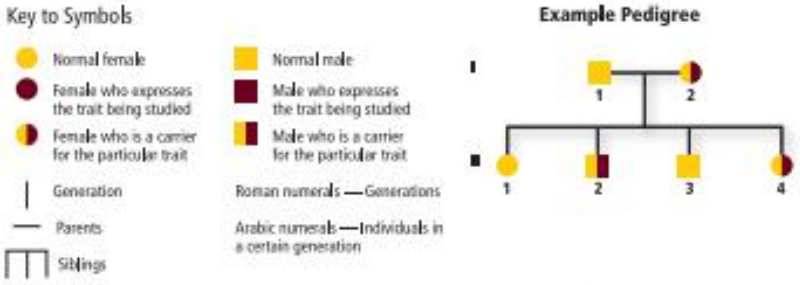


Figure 1 A pedigree uses standard symbols to indicate what is known about the trait being studied.

Pedigrees

In organisms such as peas and fruit flies, scientists can perform crosses to study genetic relationships. In the case of humans, a scientist studies a family history using a **pedigree,** a diagram that traces the inheritance of a particular trait through several generations. A pedigree uses symbols to illustrate inheritance of the trait. Males are represented by squares, and females are represented by circles, as shown in **Figure 1.** One who expresses the trait being studied is represented by a dark, or filled, square or circle, depending on their gender. One who does not express the trait is represented by an unfilled square or circle.

A horizontal line between two symbols shows that these individuals are the parents of the offspring listed below them. Offspring are listed in descending birth order from left to right and are connected to each other and their parents.

A pedigree uses a numbering system in which Roman numerals represent generations, and individuals are numbered by birth order using Arabic numbers. For example, in **Figure 1,** individual II1 is a female who is the firstborn in generation II.

Analyzing Pedigrees

A pedigree illustrating Tay-Sachs disease is shown in **Figure 2.** Recall from **Table 2** that Tay-Sachs disease is a recessive genetic disorder caused by the lack of an enzyme involved in lipid metabolism. The missing enzyme causes lipids to build up in the central nervous system, which can lead to death.

Examine the pedigree in **Figure 2.** Note that two unaffected parents, I1 and I2, have an affected child–II3, indicating that each parent has one recessive allele–they both are heterozygous and carriers for the trait. The half-filled square and circle show that both parents are carriers.

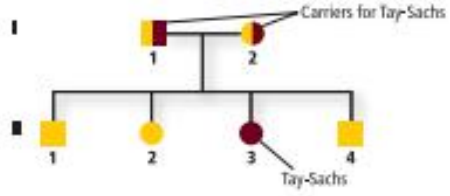


Figure 2 This pedigree illustrates the inheritance of the recessive disorder Tay-Sachs disease. Note that two unaffected parents (I1 and I2) can have an affected child (II3).

Critical Thinking

BL OL AL Differentiate On the board, place two or three pedigrees that illustrate dominant or recessive inheritance, such as pedigrees showing the inheritance of cystic fibrosis, Huntington's disease, and Tay-Sachs disease.

ASK STUDENTS: ***Which type of inheritance is shown in each pedigree?*** Have students write down how they determined which type of inheritance is demonstrated, then call on volunteers to share their answers orally.

D Develop Concepts

BL OL AL Scaffolding

ASK STUDENTS: ***What symbols are used to represent a male and a female in a pedigree?*** square for male; circle for female ***For what purpose is a genetic pedigree used?*** It shows the inheritance of a particular trait across several generations. ***Describe the pedigree of a boy who has galactosemia if his father has galactosemia, his paternal grandparents are phenotypically normal, his mother and maternal grandparents are both phenotypically normal.*** Paternal grandparents were both carriers of the recessive allele. Either or both maternal grandparents carried the recessive allele. ***What information might be added from the family ancestry that could possibly help determine the mother's parents' genotypes?*** By knowing more about the family ancestry of the mother's parents, one might be able to determine whether one or both of them are carriers of galactosemia.

Demonstration

BL OL AL Human Genetic Traits Show students pictures that demonstrate various human genetic traits. Contact a local hospital's education specialist about borrowing a slideshow presentation that would be appropriate for this demonstration.

ASK STUDENTS: ***Is this trait dominant or recessive?*** Discuss dominant and recessive traits such as: widow's peak (dominant), PTC tasting (dominant), earlobe shape (attached is recessive), bent little finger (dominant), dimples (dominant), hair whorl (clockwise is dominant), and mid-digital hair (hair is dominant).

Est. time: 10 min

Mini Lab 1

Est. Time 20 min

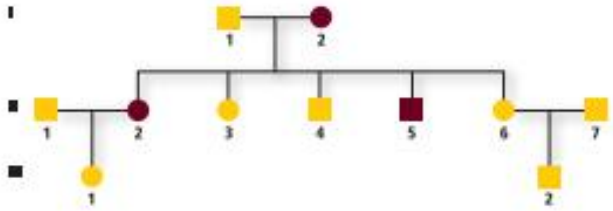
Safety Precaution Discuss the safety concerns of this lab before work begins.

Teaching Strategy Students could work individually or in small groups.

Analysis

1. With pedigrees, one can follow traits from one generaton to the next.
2. Families affected with unfavorable traits can be given advice about the chances of their future children possessing these traits. However, pedigree information obtained from only a few members of a family could be inaccurate, unreliable, or misleading.

Figure 3 This pedigree illustrates the inheritance of a dominant disorder. Note that affected parents can pass on their genes (II2, II5), but unaffected parents cannot have an affected child (III2).



The pedigree in **Figure 3** shows the inheritance of the dominant genetic disorder polydactyly (pah lee DAK tuh lee). People with this disorder have extra fingers and toes. Recall that with dominant inheritance the trait is expressed when at least one dominant allele is present.An individual with an unaffected parent and a parent with polydactyly could be either heterozygous or homozygous recessive for the trait. Each unaffected person would be homozygous recessive for the trait.

For example, in **Figure 3,** individual I2 has polydactyly, indicated by the dark circle. Because she shows the trait, she is either homozygous dominant or heterozygous. It can be inferred that she is heterozygous–having one dominant gene and one recessive gene–because offspring II3 and II4 do not have the disorder. Notice that II6 and II7, two unaffected parents, have an unaffected offspring–III2. What can be inferred about II2, based on the phenotype of her parents and her offspring?

Mini Lab 1

Investigate Human Pedigrees

Where are the branches on the family tree? Unlike some organisms, humans reproduce slowly and produce few offspring at one time. One method used to study human traits is pedigree analysis.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Imagine that you are a geneticist interviewing a person about his or her family concerning the hypothetical trait of hairy earlobes.
3. From the transcript below, construct a pedigree. Use appropriate symbols and format.

"My name is Scott. My great grandfather Walter had hairy earlobes (HEs), but great grandma Elsie did not. Walter and Elsie had three children: Lola, Leo, and Duane. Leo, the oldest, has HEs, as does the middle child, Lola; but the youngest child, Duane, does not. Duane never married and has no children. Leo married Bertie, and they have one daughter, Patty. In Leo's family, he is the only one with HEs. Lola married Omar, and they have two children: Carolina and Luetta. Omar does not have HEs, but both of his daughters do."

Analysis

1. **Assess** In what ways do pedigrees simplify the analysis of inheritance?
2. **Think Critically** Using this lab as a frame of reference, how can we put to practical use our understanding of constructing and analyzing human pedigrees?

Skill Practice

BL OL AL COOP LEARN

Visual Literacy Have students form groups of two or three and compare Figures 2 and 3.

ASK STUDENTS: ***What are the differences between the two types of inheritance?*** Dominant conditions often show up every generation. Individuals with one allele for a recessive condition would not be affected, but two individuals with one recessive allele each can have an affected child.

Content Background

Teacher FYI Tay Sachs disease is a fatal inherited disorder that most commonly affects infants. The babies appear healthy at birth but progressively deteriorate after a few months. They lack an enzyme (hexoaminindase A) to break down fatty substances that accumulate in nerve cells. Eventually these substances build up and destroy the nerve cells. Death usually occurs by the age of five.

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Inferring genotypes Pedigrees are used to infer genotypes from the observation of phenotypes. By knowing physical traits, genealogists can determine what genes an individual is most likely to have. Phenotypes of entire families are analyzed in order to determine family genotypes, as symbolized in **Figure 3.**

Pedigrees help genetic counselors determine whether inheritance patterns are dominant or recessive. Once the inheritance pattern is determined, the genotypes of the individuals can largely be resolved through pedigree analysis. To analyze pedigrees, one particular trait is studied, and a determination is made as to whether that trait is dominant or recessive. Dominant traits are easier to recognize than recessive traits because dominant traits are exhibited in the phenotype.

A recessive trait will not be expressed unless the person is homozygous recessive for the trait. That means that a recessive allele is passed on by each parent. When recessive traits are expressed, the ancestry of the person expressing the trait is followed for several generations to determine which parents and grandparents were carriers of the recessive allele.

Predicting disorders If good records have been kept within families, disorders in future offspring can be predicted. However, more accuracy can be expected if several individuals within the family can be evaluated. The study of human genetics is difficult, because scientists are limited by time, ethics, and circumstances. For example, it takes decades for each generation to mature and then to have offspring when the study involves humans. Therefore, good record keeping, where it exists, helps scientists use pedigree analysis to study inheritance patterns, to determine phenotypes, and to ascertain genotypes within a family.

CAREERS IN BIOLOGY

Genealogist A genealogist studies or traces the descent of individuals or families. Many professional genealogists are board-certified and accredited.

Section 1 Review

Section Summary

- Genetic disorders can be caused by dominant or recessive alleles.
- Cystic fibrosis is a genetic disorder that affects mucus and sweat secretions.
- Individuals with albinism do not have melanin in their skin, hair, and eyes.
- Huntington's disease affects the nervous system.
- Achondroplasia sometimes is called dwarfism.
- Pedigrees are used to study human inheritance patterns.

Understand Main Ideas

1. MAIN Ideas **Construct** a family pedigree of two unaffected parents with a child who suffers from cystic fibrosis.
2. **Explain** the type of inheritance associated with Huntington's disease and achondroplasia.
3. **Interpret** Can two parents with albinism have an unaffected child? Explain.
4. **Diagram** Suppose both parents can roll their tongues but their son cannot. Draw a pedigree showing this trait, and label each symbol with the appropriate genotype.

Think Critically

MATH in Biology

5. Phenylketonuria (PKU) is a recessive genetic disorder. If both parents are carriers, what is the probability of this couple having a child with PKU? What is the chance of this couple having two children with PKU?
6. **Determine** When a couple requests a test for the cystic fibrosis gene, what types of questions might the physician ask before ordering the tests?

C Critical Thinking

AL **Consider** Rare recessive disorders can occur in families after many generations.

ASK STUDENTS: ***How is this possible?*** The allele for a rare recessive disorder can remain hidden in the carrier state for many generations. Not until a family member with a recessive trait has offspring with another human who is a carrier will the recessive condition appear.

Formative Assessment

Evaluation

ASK STUDENTS: ***Name one type of condition that shows dominant inheritance and one that shows recessive inheritance.*** Answers will vary but should include examples from the chapter. ***List the effects (phenotypes) of each condition.***

Remediation Students having difficulty keeping track of the various types of genetic disorders can make flash cards for each disorder. Have them place the name of the disorder on one side and the type of inheritance and effects of the disorder on the other side. Students can use both sides of the card for studying.

Section 1 Review

1. The pedigree should show both parents as carriers (half-filled symbols) and the child infected with the disorder (a filled symbol).
2. dominant
3. Since albinism is recessive, the only type of offspring albino parents can have are albinos.
4. Both parents carry a recessive gene and have the genotype *Tt*. Their symbols should be half shaded. The boy is *tt*. His symbol should be shaded completely.
5. 1/4, 1/16 (1/4 × 1/4)
6. Answers may vary but might include: Why does the couple want to test for the cystic fibrosis gene? Is there a history of cystic fibrosis in either family?

Section 2

MAIN Idea

BL OL AL

Eye-Color Inheritance

ASK STUDENTS: ***What possible eye colors are there?*** Answers will likely include brown, green, and blue. Have students examine each other's eyes. ***What else do you notice about eye color?*** There are other shades, such as light blue, dark blue, and hazel; light, medium, and dark brown and black. Have students hypothesize whether eye color is inherited in a simple dominant/recessive manner. At this time the exact inheritance model of eye color has not been determined, but polygenic models have been made with a minimum of three pairs of genes.

R Reading Strategy

BL OL AL COOP LEARN

Brainstorm Have students read the new vocabulary terms on this page. Have students work in groups of three to brainstorm ways of remembering the definitions of these words.

C Critical Thinking

BL OL AL COOP LEARN

Compare Have students form pairs and examine Figure 4. **ASK STUDENTS:** ***Compare incomplete dominance and codominance to regular dominant/recessive inheritance.*** In codominance, each allele is expressed; in incomplete dominance, the resulting phenotype is an intermediate between the two homozygous phenotypes.

Caption Question **Fig. 4** The offspring would be 1/2 pink and 1/2 white.

Essential Questions

- What are the differences between various complex inheritance patterns?
- How can sex-linked inheritance patterns be analyzed?
- How can the environment influence the phenotype of an organism?

Review Vocabulary

gamete: a mature sex cell (sperm or egg) with a haploid number of chromosomes

New Vocabulary

incomplete dominance
codominance
multiple alleles
epistasis
sex chromosome
autosome
sex-linked trait
polygenic trait

Patterns for complex inheritance

MAIN Idea **Complex inheritance of traits does not follow inheritance patterns described by Mendel.**

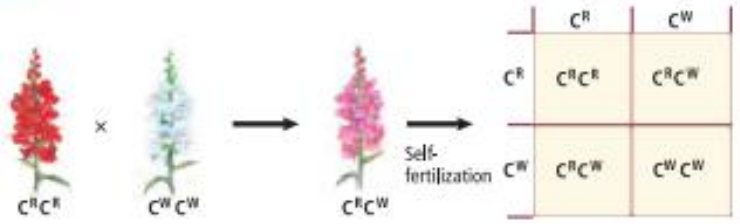
Real-World Reading Link Imagine that you have red-green color blindness. In bright light, red lights do not stand out against surroundings. At night, green lights look like white streetlights. To help those with red-green color blindness, traffic lights always follow the same pattern. Red-green color blindness, however, does not follow the same pattern of inheritance described by Mendel.

Incomplete Dominance

Recall that when an organism is heterozygous for a trait, its phenotype will be that of the dominant trait. For example, if the genotype of a pea plant is *Tt* and *T* is the genotype for the dominant trait *tall*, then its phenotype will be tall. When red-flowered snapdragons (C^RC^R) are crossed with white-flowered snapdragons (C^WC^W), the heterozygous offspring have pink flowers (C^RC^W), as shown in **Figure 4.** This is an example of **incomplete dominance,** in which the heterozygous phenotype is an intermediate phenotype between the two homozygous phenotypes. When the heterozygous F_1 generation snapdragon plants are allowed to self-fertilize, as in **Figure 4,** the flowers are red, pink, and white in a 1:2:1 ratio, respectively.

Sickle-cell disease. The altered form of hemoglobin that causes sickle-cell anemia is inherited as codominace trait yet individuals in heterozygous individuals express both normal and sickle hemoglobin as an incomplete dominance, so they have a mixture of normal and sickle red blood cells. Under these circumstances, Sickle-cell anemia affects red blood cells and their ability to transport oxygen. The most common type known as sickle cell anemia (SCA).

Figure 4 The color of snapdragon flowers is a result of incomplete dominance. When a plant with white flowers is crossed with a plant with red flowers, the offspring have pink flowers. Red, pink, and white offspring will result from self-fertilization of a plant with pink flowers.
Predict *what would happen if you crossed a pink flower with a white flower.*



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Changes in hemoglobin–the protein in red blood cells–cause those blood cells to change to a sickle, or C-shape. Sickle-shaped cells do not effectively transport oxygen because they block circulation in small blood vessels.

The allele responsible for sickle-cell disease is particularly common in people of African descent, with about 90% of African Americans having one form of the trait. **Figure 5** shows the blood cells of an individual who is heterozygous for the sickle-cell trait.

Sickle-cell disease and malaria **Figure 5** shows the distribution of both sickle-cell disease and malaria in Africa. Some areas with sickle-cell disease overlap areas of widespread malaria. Scientists have discovered that those who are heterozygous for the sickle-cell trait have a higher resistance to malaria as well. Consequently, sickle-cell disease continues to increase in Africa.

Key to alleles.
HB^{A} Normal Hb
HB^{S} Sickle cell

Figure 5 Left: Normal red blood cells are flat and disk-shaped. Sickle-shaped cells are elongated and C-shaped. They can clump, blocking circulation in small vessels.

Figure 5 Up: the sickle-cell allele increases resistance to malaria.

Codominance

Recall that when an organism is heterozygous for a particular trait, the dominant phenotype is expressed. In a complex inheritance pattern called **codominance,** both alleles are expressed in the heterozygous condition. the human Blood type provide case studies of codominant inheritance and multiple alleles **Figure 6**, as well as the hair color in horses.

DATA ANALYSIS LAB 1

Based on Real Data*

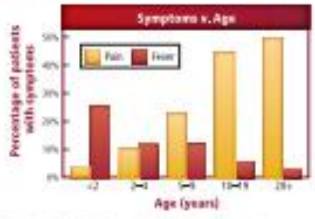
Interpret the Graph

What is the relationship between sickle-cell disease and other complications? Patients who have been diagnosed with sickle-cell disease face many symptoms, including anemia, respiratory failure and neurological problems. The graph shows the relationship between age and two different symptoms—pain and fever—during the two weeks preceding an episode of acute chest syndrome and hospitalization.

Think Critically

1. **State** which age group has the highest level of pain before being hospitalized.
2. **Describe** the relationship between age and fever before hospitalization.

Data and Observations



*Data obtained from: Walters, et al. 2002. Novel therapeutic approaches in sickle cell disease. Hematology 17: 10-34.

Demonstration

Sickle-Cell Disease Using a microprojector, scanned photos, or images from the Internet, prepare a slideshow presentation showing a blood smear from a person without sickled cells and one showing sickle-cell disease. Emphasize that the cells are sickled when they reach areas of low oxygen in the body, such as in the hands and feet. Est. time: 15 min

Develop Concepts

BL OL AL

Demonstrate Codominance

Display pictures of checkered chickens. Use the checkered chickens as another example of codominance. Black chickens breed with white chickens, resulting in chickens with both black and white feathers. Once you discuss this example, use a photo of a red shorthorn bull and a white shorthorn cow. When bred, they produce a both red and white hair mixed shorthorn offspring.

ASK STUDENTS: ***What type of inheritance does this demonstrate?*** codominance

DATA ANALYSIS LAB 1

About the Lab

- One of the main reasons people are hospitalized with sickle-cell disease is acute chest syndrome (ACS), characterized by fever, cough, chest pain, and shortness of breath. One study found that 29 % of people with sickle-cell disease had at least one episode of ACS.
- Also see Stuart, M.J. and B.N. Setty. 2001. Acute chest syndrome of sickle cell disease: new light on an old problem. *Current Opinions in Hematology;* 8(2): 111-122.

Think Critically

1. 20+
2. Fever is highest in those under two years of age and lowest in those over 20. Generally fever reduces with age.

Skill Practice

BL OL AL Visual Literacy

Have students make a table using information from Figure 6 and the text. They should label one column *Blood Type* and a second column *Possible Genotypes*.

Blood Type	Possible Genotypes
A	I^AI^A or I^Ai
B	I^BI^B or I^Bi
AB	I^AI^B
O	ii

Develop Concepts

BL OL AL

Clarify a Misconception

ASK STUDENTS: ***Is there such a thing as a universal blood donor?***

no Some students might think there is a universal donor for all blood groups. This is a misnomer. Because of complex immune reactions, researchers no longer use the term *universal donor*. Blood is typed and matched and given only to a matching blood type.

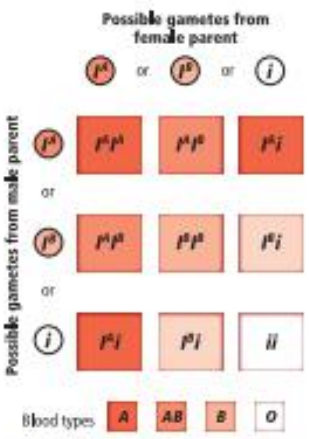


Figure 6 There are three forms of alleles in the ABO blood group—I^A, I^B, and i.

Multiple Alleles

Not all traits are determined by two alleles. Some forms of inheritance are determined by more than two alleles referred to as **multiple alleles.** An example of such a trait is human blood group is an example of codominance and multiple alleles.

Blood groups in humans The ABO blood group, shown in **Figure 6,** has three forms of alleles, sometimes called AB markers: I^A is blood type A; I^B is blood type B; and i is blood type O. Type O is the absence of AB markers. Note that allele i is recessive to I^A and I^B. However, I^A and I^B are codominant; blood type AB results from both I^A and I^B alleles. Therefore, the ABO blood group is an example of both multiple alleles and codominance.

The Rh blood group includes Rh factors, inherited from each parent. Rh factors are either positive or negative (Rh+ or Rh–); Rh+ is dominant. The Rh factor is a blood protein named after the rhesus monkey because studies of the rhesus monkey led to discovery of that blood protein.

Coat color of rabbits Multiple alleles can demonstrate a hierarchy of dominance. In rabbits, four alleles code for coat color: C, c^{ch}, c^h, and c. Allele C is dominant to the other alleles and results in a full color coat. Allele c is recessive and results in an albino phenotype when the genotype is homozygous recessive. Allele c^{ch} is dominant to c^h, and allele c^h is dominant to c and the hierarchy of dominance can be written as $C > c^{ch} > c^h > c$. **Figure 7** shows the genotypes and phenotypes possible for rabbit-coat color. Full color is dominant over not full color, which is dominant over Himalayan, which is dominant over albino.

The presence of multiple alleles increases the possible number of genotypes and phenotypes. Without multiple-allele dominance, two alleles, such as T and t, produce only three possible genotypes–in this example TT, Tt, and tt–and two possible phenotypes. However, the four alleles for rabbit-coat color produce ten possible genotypes and four phenotypes, as shown in **Figure 7.** More variation in rabbit coat color comes from the interaction of the color gene with other genes.

Figure 7 Rabbits have multiple alleles for coat color. The four alleles provide four basic variations in coat color.

Differentiated Instruction

Below Level When students are performing the critical thinking activities, pair students who perform below level with peer tutors. These students can help them to understand any concepts that are confusing and help them to reach acceptable conclusions.

Epistasis

Coat color in Labrador retrievers can vary from yellow to black. This variety is the result of one allele hiding the effects of another allele, an interaction called **epistasis** (ih PIHS tuh sus). A Labrador's coat color is controlled by two sets of alleles. The dominant allele *E* determines whether the fur will have dark pigment. The fur of a dog with genotype *ee* will not have any pigment. The dominant *B* allele determines how dark the pigment will be. Study **Figure 8.** If the dog's genotype is *EEbb* or *Eebb*, the dog's fur will be chocolate brown. Genotypes *eebb*, *eeBb*, and *eeBB* will produce a yellow coat, because the *e* allele masks the effects of the dominant *B* allele.

Figure 8 The results of epistasis in coat color in Labrador retrievers show an interaction of two genes, each with two alleles. Note that an underscore in the genotype allows for either a dominant or recessive gene.

Sex Determination

Each cell in your body, except for gametes, contains 46 chromosomes, or 23 pairs of chromosomes. One pair of these chromosomes, the **sex chromosomes,** determines an individual's gender. There are two types of sex chromosomes–X and Y. Individuals with two X chromosomes are female, and individuals with an X and a Y chromosome are male. The other 22 pairs of chromosomes are called **autosomes.** The offspring's gender is determined by the combination of sex chromosomes in the egg and sperm cell, as shown in **Figure 9.**

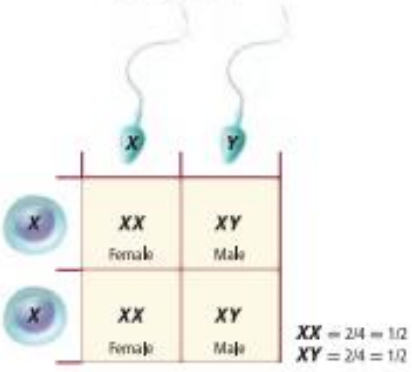


Figure 9
Left: The size and shape of the Y chromosome and the X chromosome are quite different from one another.
Right: The segregation of the sex chromosomes into gametes and the random combination of sperm and egg cells result in an approximately 1:1 ratio of males to females.

Develop Concepts

BL OL AL

Sex-Linked Inheritance

On the board, draw a Punnett square for a sex-linked inheritance such as color blindness. Be sure to stress the difference in writing these Punnett squares showing the X and Y chromosomes with linked genes. Emphasize to students that Punnett squares showing sex-linked inheritance must indicate both the X and the Y inheritance also.

Critical Thinking

BL OL AL **Evaluate**

ASK STUDENTS: ***During meiosis, what chromosome pairs up with the X chromosome?*** the Y or the X chromosome ***Why is there little crossover between the X and the Y when they are lined up?*** The X and the Y chromosome do not have the same alleles. Despite the fact that the X and Y chromosomes are different in size and the types of genes they contain, there is a small region where they match up during pairing in meiosis. Crossing over can occur only in this small region, and thus the frequency of crossover between the X and Y is lower than it is for other chromosome pairs.

Research Citation

Ample Practice Educational research indicates that students need to be provided with ample opportunities to practice a new skill in order to master the concept. When working with Punnett squares in this chapter, model how the charts are used, then provide time for students to practice using them individually so that you can assess their understanding. (Trafton, 1983)

D Develop Concepts

BL OL AL Scaffolding

ASK STUDENTS: ***How is gender determined genetically?*** by the father's sperm—whether it contributes an X or a Y chromosome ***Diagram the dosage difference between a female and male.*** Diagrams should show females have two large X chromosomes, males have one large X and one small Y chromosome. ***Explain how females compensate for the extra dosage of X chromosome compared to males.*** In females, one X chromosome randomly inactivates in every body cell. ***Infer how a calico cat inherits the colors of its coat.*** The coat color of a calico cat is the result of the random inactivation of one of the X chromosomes. In some cells, the X chromosome that was inherited from the mother is expressed, and in others, the X chromosome inherited from the father is expressed.

W Writing Support

AL Formal Writing Have students conduct research to find out about the life of Canadian biologist Murray Barr. Have them write a short biography of Barr and include his major scientific work.

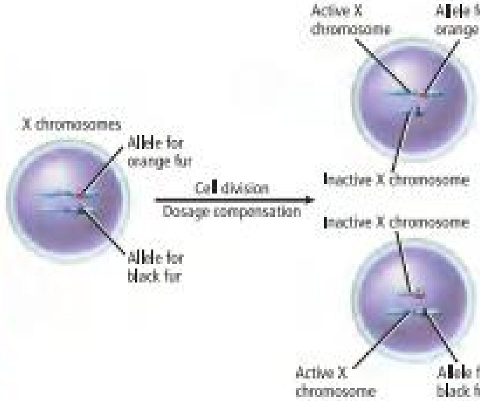


Figure 10 The calico coat of this cat results from the random inactivation of the X chromosomes in body cells. One X chromosome codes for orange fur, and one X chromosome codes for black fur, as illustrated on the right.

Dosage Compensation

Human females have 22 pairs of autosomes and one pair of X chromosomes. Males have 22 pairs of autosomes, along with one X and one Y chromosome. If you examine the X and Y chromosomes in **Figure 9,** you will notice that the X chromosome is larger than the Y chromosome. The X chromosome carries a variety of genes that are necessary for the development of both females and males. The Y chromosome mainly has genes that relate to the development of male characteristics.

Because females have two X chromosomes, it seems as though females get two doses of the X chromosome and males get only one dose. To balance the difference in the dose of X-related genes, one of the X chromosomes stops working in each of the female's body cells. This often is called dosage compensation or X-inactivation. Which X chromosome stops working in each body cell is a completely random event. Dosage compensation occurs in all mammals.

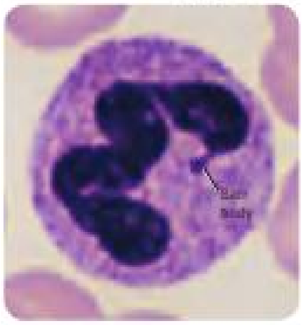
As a result of the Human Genome Project, the National Institutes of Health (NIH) has released new information on the sequence of the human X chromosome. Researchers now think that some genes on the inactivated X chromosome are more active than was previously thought.

Chromosome inactivation The coat colors of the calico cat shown in **Figure 10** are caused by the random inactivation of a particular X chromosome. The resulting colors depend on the X chromosome that is activated. The orange patches are formed by the inactivation of the X chromosome carrying the allele for black coat color. Similarly, the black patches are a result of the inactivation of the X chromosome carrying the allele for orange coat color.

Barr bodies The inactivated X chromosomes can be observed in cells. In 1949, Canadian scientist Murray Barr observed inactivated X chromosomes in female calico cats. He noticed a condensed, darkly stained structure in the nucleus. The darkly stained, inactivated X chromosomes, such as the one shown in **Figure 11,** are called Barr bodies. It was discovered later that only females, including human females, have Barr bodies in their cell nuclei.

Figure 11 An inactivated X chromosome in a female body cell is called a Barr body, a dark body usually found near the nucleus.

LM Magnification: 500×



Content Background

Teacher FYI Unlike the X chromosome, the Y chromosome is not "gene rich." Fewer than 100 genes have been mapped to the Y chromosome. Many of these genes contain instructions to make the baby a male. Without a functioning Y chromosome, the baby will develop similar to a female who has Turner syndrome (similar to an XO). In X inactivation, most of the X chromosome is inactivated in cells that have two X chromosomes. This occurs early in embryonic development. A gene called *XIST* produces RNA, which accumulates along the genes of one X chromosome, inactivating the majority of one X chromosome.

Sex-Linked Traits

Traits controlled by genes located on the X chromosome are called **sex-linked traits,** or X-linked traits. Because males have only one X chromosome, they are affected by recessive X-linked traits more often than are females. Females are less likely to express a recessive X-linked trait because the other X chromosome may mask the effect of the trait.

Some traits that are located on autosomes may appear to be sex-linked, even though they are not. This occurs when an allele appears to be dominant in one gender but recessive in the other. For example, the allele for baldness is recessive in females but dominant in males, causing hair loss that follows a typical pattern called male-pattern baldness. A male would be bald if he were heterozygous for the trait, while a female would be bald only if she were homozygous recessive.

Examples of Sex-Linked Traits

Red-green color blindness The trait for red-green color blindness is a recessive X-linked trait. About 8 percent of males in the United States have red-green color blindness. The photos in **Figure 12** show how a person with red-green color blindness might view colors compared to a person who does not have red-green color blindness.

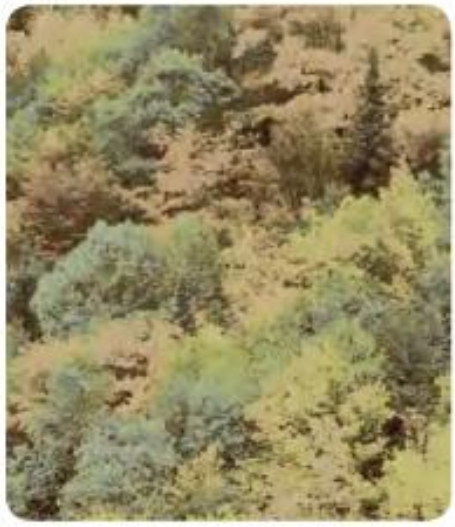
Study the Punnett square shown in **Figure 12.** The mother is a carrier for color blindness because she has the recessive allele for color blindness on one of her X chromosomes. The father is not color blind because he does not have the recessive allele. The sex-linked trait is represented by writing the allele on the X chromosome. Notice that the only offspring that can possibly have red-green color blindness is a male child. As a result of it being an X-linked trait, red-green color blindness is very rare in females.

Figure 12 People with red-green color blindness view red and green as shades of gray.
Explain *why there are fewer females who have red-green color blindness than males.*

X^B = Normal
X^b = Red-green color blind
Y = Y chromosome

	X^B	Y
X^B	X^BX^B	X^BY
X^b	X^BX^b	X^bY

Reading Check **compare and contrast sex-linked traits and sex-affected traits.**



Caption Question **Fig. 12** Since males have only one X chromosome, they are affected by recessive X-linked traits more often than females.

Demonstration

Color-Blind Test Children's color blindness tests are available from various companies. They are based on having the child match various colors and shades of yarn. Demonstrate this concept using one of the actual tests or using various shades of one color of yarn. Est. time: 10 min

Develop Concepts

BL OL AL **Activity** Have students gently scrape the inside of their cheek with a toothpick and rub the toothpick on a slide. Students should use caution with the sharp toothpicks. Add a drop of methylene blue and a coverslip. Female students should find a Barr body in their cells but males will not. Drop slides into a mild bleach solution before disposing of them.

Writing Support

OL AL **Informal Writing** Have students research congenital generalized hypertrichosis and write an essay describing this sex-linked disorder.

Critical Thinking

OL AL **Infer** The gene for male pattern baldness is on an autosome but is sex-influenced. The *B* allele is dominant in males but recessive in females.

ASK STUDENTS: ***What male genotypes will result in baldness?*** *BB or Bb* ***Will baldness result in a female with the genotype*** **Bb?** *No* ***What genotype will result in female baldness?*** *BB*

Writing Support

BL OL AL Persuasive Writing

Have students investigate the story of David, known as the "Boy in the Bubble." David, of Houston, Texas, suffered from the disorder called severe combined immunodeficiency (SCID). He lived the majority of his life in a sterile "bubble." Have students write a persuasive essay explaining whether they feel David's medical treatment was or was not ethical.

Skill Practice

BL OL Visual Literacy

Have students study Figure 13 and describe the passage of the hemophilia gene from Queen Victoria through the generations to Alexis. Queen Victoria to Alice to Alexandra to Alexis

AL Have students draw a pedigree that includes Alexis if he had married a noncarrier and had two boys and two girls. Both boys would be fine, but both girls would be carriers.

Develop Concepts

BL OL AL COOP LEARN

Activity In groups of three, have students draw an illustration that demonstrates the difference between autosomal and sex-linked inheritance. Diagrams should show dominant and recessive alleles in both types of inheritance and how X and Y chromosomes carry sex-linked traits and disorders.

Caption Question Fig. 13 Alexis inherited his mother's X chromosome and displayed the disorder. His sisters might have been carriers, but they did not display the disorder.

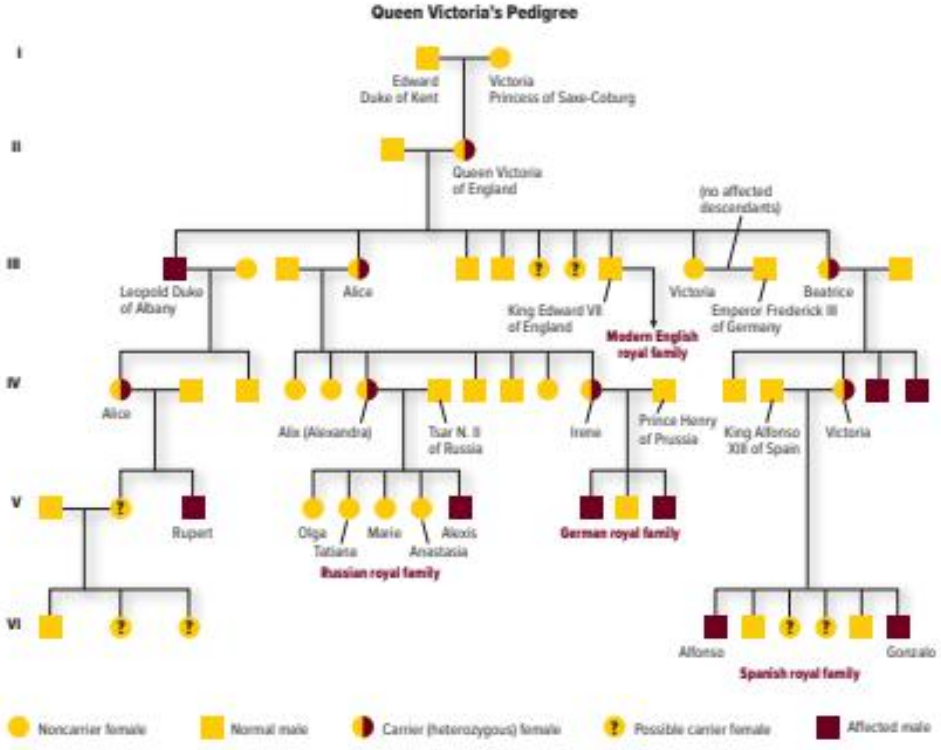


Figure 13 The pedigree above shows the inheritance of hemophilia in the royal families of England, Germany, Spain, and Russia, starting with the children of Queen Victoria.

Determine which of Alexandra's children inherited hemophilia.

Hemophilia Hemophilia, another recessive sex-linked disorder, is characterized by delayed clotting of the blood. Like red-green color blindness, this disorder is more common in males than in females.

A famous pedigree of hemophilia is one that arose in the family of Queen Victoria of England (1819-1901). Her son Leopold died of hemophilia, and her daughters Alice and Beatrice, as illustrated in the pedigree in **Figure 13,** were carriers for the disease. Alice and Beatrice passed on the hemophilia trait to the Russian, German, and Spanish royal families. Follow the generations in this pedigree to see how this trait was passed through Queen Victoria's family. Queen Victoria's granddaughter Alexandra, who was a carrier for this trait, married Tsar N. II of Russia. Irene, another granddaughter, passed the trait on to the German royal family. Hemophilia was passed to the Spanish royal family through a third granddaughter, whose name also was Victoria.

Men with hemophilia usually died at an early age until the twentieth century when clotting factors were discovered and given to hemophiliacs. However, blood-borne viruses such as Hepatitis C and HIV were often contracted by hemophiliacs until the 1990s, when safer methods of blood transfusion were discovered.

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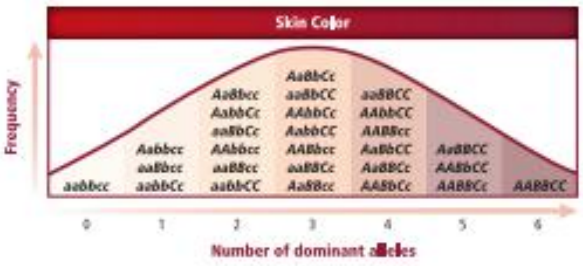


Figure 14 This graph shows possible shades of skin color from three sets of alleles, although the trait is thought to involve more than three sets of alleles.
Predict *Would more gene pairs increase or decrease the number of possible phenotypes?*

Polygenic Traits

You have examined traits determined by a pair of genes. Many phenotypic traits, however, arise from the interaction of multiple pairs of genes. Such traits are called **polygenic traits.** Traits such as skin color, height, eye color, and fingerprint pattern are polygenic traits. One characteristic of polygenic traits is that, when the frequency of the number of dominant alleles is graphed, as shown in **Figure 14,** the result is a bell-shaped curve. This shows that more of the intermediate phenotypes exist than do the extreme phenotypes.

Reading Check **Infer** Why would a graph showing the frequency of the number of dominant alleles for polygenic traits be a bell-shaped curve?

Environmental Influences

The environment also has an effect on phenotype. For example, the tendency to develop heart disease can be inherited. However, environmental factors such as diet and exercise also can contribute to the occurrence and seriousness of the disease. Other ways in which environment influences phenotype are very familiar to you. You may not have thought of them in terms of phenotype, however. Sunlight, water, and temperature are environmental influences that commonly affect an organism's phenotype.

Sunlight and water Without enough sunlight, most flowering plants do not bear flowers. Many plants lose their leaves in response to water deficiency.

Temperature Most organisms experience phenotypic changes from extreme temperature changes. In extreme heat, for example, many plants suffer. Their leaves droop, flower buds shrivel, chlorophyll disappears, and roots stop growing. These are examples that probably do not surprise you, although you may have never thought of them as phenotypic changes. What other environmental factors affect the phenotypes of organisms? Temperature also influences the expression of genes. Notice the fur of the Siamese cat shown in **Figure 15.** The cat's tail, feet, ears, and nose are dark. These areas of the cat's body are cooler than the rest. The gene that codes for production of the color pigment in the Siamese cat's body functions only under cooler conditions. Therefore, the cooler regions are darker; and the warmer regions, where pigment production is inhibited by temperature, are lighter.

Figure 15 Temperature affects the expression of color pigment in the fur of Siamese cats.

Develop Concepts

BL OL AL Activity Pass around a sheet of paper and have students write their height on it. Make copies of the list and distribute it to students. Have students make a line graph from the height data. The line graph should be close to a bell-shaped curve if enough students are included. Point out that this is the characteristic pattern of a polygenic inheritance.

Reading Check It would be bell shaped because there are more intermediate phenotypes than the extreme phenotypes.

Caption Question **Fig. 14** More gene pairs would increase the potential phenotypes.

Demonstration

Gene Expression Germinate 30 mustard seeds in petri dishes on moist paper towels. Germinate 15 in the dark and 15 with light exposure. Examine after seven days. *Brassica rapa* seeds, available from biological supply houses, will germinate in 24 h. The plants germinated in the dark will be white; those germinated in light will have green leaves. Set the plate germinated in the dark in the light for a few days to demonstrate the influence of environment on gene expression. Est. time: 5 min each day for 10 days

Assess Content Development

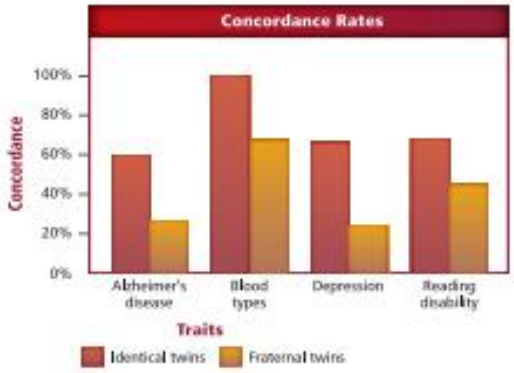
Assess how understanding has developed when students revisit the Launch Lab analysis questions.

Formative Assessment

Evaluation Have pairs of students prepare and solve several Punnett square or pedigree practice problems involving incomplete dominance, codominance, and sex-linked traits. Practice problems might include human blood groups and color blindness. Have the pairs exchange their problems and use each other's work to check the answers. If one pair produces an incorrect answer, have the other pair explain the correct answer.

Remediation Prepare a set of practice problems that illustrate each of the types of inheritance in this section. Have students who understand these complex patterns of inheritance work with students who are having difficulty understanding the concept.

Figure 16 When a trait is found more often in both members of identical twins than in fraternal twins, the trait is presumed to have a significant inherited component.



Review **Based on what you have read about human inheritance, how would you now answer the analysis questions?**

Twin Studies

Another way to study inheritance patterns is to focus on identical twins, which helps scientists separate genetic contributions from environmental contributions. Identical twins are genetically the same. If a trait is inherited, both identical twins will have the trait. Scientists conclude that traits that appear frequently in identical twins are at least partially controlled by heredity. Also, scientists presume that traits expressed differently in identical twins are strongly influenced by environment. The percentage of twins who both express a given trait is called a concordance rate. Examine **Figure 16** for some traits and their concordance rates. A large difference between fraternal twins and identical twins shows a strong genetic influence.

Section 2 Review

Section Summary

- Some traits are inherited through complex inheritance patterns, such as incomplete dominance, codominance, and multiple alleles.
- Gender is determined by X and Y chromosomes. Some traits are linked to the X chromosome.
- Polygenic traits involve more than one pair of alleles.
- Both genes and environment influence an organism's phenotype.
- Studies of inheritance patterns of large families and twins give insight into complex human inheritance.

Understand Main Ideas

1. MAIN Idea **Describe** two patterns of complex inheritance and explain how they are different from Mendelian patterns.
2. **Explain** What is epistasis, and how is it different from dominance?
3. **Determine** the genotypes of the parents if the father is blood type A, the mother is blood type B, the daughter is blood type O, one son is blood type AB, and the other son is blood type B.
4. **Analyze** how twin studies help to differentiate the effects of genetic and environmental influences.

Think Critically

5. **Evaluate** whether having sickle-cell disease would be advantageous or disadvantageous to a person living in central Africa.

MATH in Biology

6. What is the chance of producing a son with normal vision if the father is color-blind and the mother is homozygous normal for the trait? Explain.

Section 2 Review

1. incomplete dominance and codominance; Mendel described patterns of inheritance that were very simple.
2. Epistasis occurs when one allele masks or hides the expression of the other allele. It differs from dominance in that a recessive allele could potentially mask a dominant allele of another gene pair.
3. Both parents are heterozygous and carry a recessive type O (i) gene.
4. Identical twins are genetically alike, so traits that are alike are inherited and traits that are different are likely the result of environmental influences.
5. Sickle-cell disease can provide either an advantage and a disadvantage. In the heterozygous state, the person is resistant to malaria. In the homozygous sickle state, the person suffers from sickle-cell disease.
6. 100 % (the father donates a Y chromosome and the mother an X chromosome with a normal vision gene)

Essential Questions

- How are karyotypes used to study genetic disorders?
- What is the role of telomeres?
- How is nondisjunction related to Down syndrome and other abnormal chromosome numbers?
- What are the benefits and risks of diagnostic fetal testing?

Review Vocabulary

mitosis: a process in the nucleus of a dividing cell, including prophase, metaphase, anaphase, and telophase

New Vocabulary

karyotype
telomere
nondisjunction

Chromosomes and Human Heredity

MAIN Idea **Chromosomes can be studied using karyotypes.**

Real-World Reading Link Have you ever lost one of the playing pieces belonging to a game? You might not have been able to play the game because the missing piece was important. Just as a misplaced game piece affects a game, a missing chromosome has a significant impact on the organism.

Karyotype Studies

The study of genetic material does not involve the study of genes alone. Scientists also study whole chromosomes by using images of chromosomes stained during metaphase. The staining bands identify or mark identical places on homologous chromosomes. During metaphase of mitosis, each chromosome has condensed greatly and consists of two sister chromatids. The pairs of homologous chromosomes are arranged in decreasing size to produce a micrograph called a **karyotype** (KER ee uh tipe). Karyotypes of a human male and a human female, each with 23 pairs of chromosomes, are shown in **Figure 17.** Notice that the 22 autosomes are matched together with one pair of nonmatching sex chromosomes.

Telomeres

Scientists have found that chromosomes end in protective caps called **telomeres.** Telomere caps consist of DNA associated with proteins. The cap serves a protective function for the structure of the chromosome. Scientists have discovered that telomeres also might be involved in both aging and cancer.

Figure 17 Karyotypes arrange the pairs of homologous chromosomes from increasing to decreasing size.
Distinguish *which two chromosomes are arranged separately from the other pairs.*

Caption Question **Fig. 17** the X and Y chromosomes

Content Background

Teacher FYI Various stains, such as Giemsa dye, are used to band chromosomes. The staining results in dark and light regions. The number, intensity, and width of the band are reproducible characteristics and are used by geneticists to carefully prepare a medical karyotype. Computer programs can arrange the chromosomes into karyotypes.

Section 3

MAIN Idea

BL OL AL Karyotypes Show students a picture of a karyotype of a human male or female and one from another mammal.

ASK STUDENTS: ***What are the similarities and differences between the two karyotypes?*** Similarities: both show the chromosomes lined up in pairs, both show the chromosomes in a metaphase stage (consisting of two chromatids), and both are arranged from large to small chromosomes. Differences: the number of chromosomes; individuals of the two species may be different sexes.

D Develop Concepts

BL OL AL COOP LEARN

Activity Search the Internet for large copies of pictures of scattered male and female chromosomes. Give some pairs of students a male set and others a female set. Have students cut out the chromosomes and prepare a karyotype. They should be able to determine the sex of the individual.

W Writing Support

OL AL Formal Writing Have students research the hypothesized role of telomeres in cell aging and prepare a technical report on the possibility of telomeres being involved in aging that includes illustrations. Post the information on a bulletin board.

Section 3 • Chromosomes and Human Heredity 19

Visualizing Nondisjunction

Purpose

Students will illustrate how nondisjunction occurs either in meiosis I or meiosis II, causing Down syndrome.

Develop Concepts

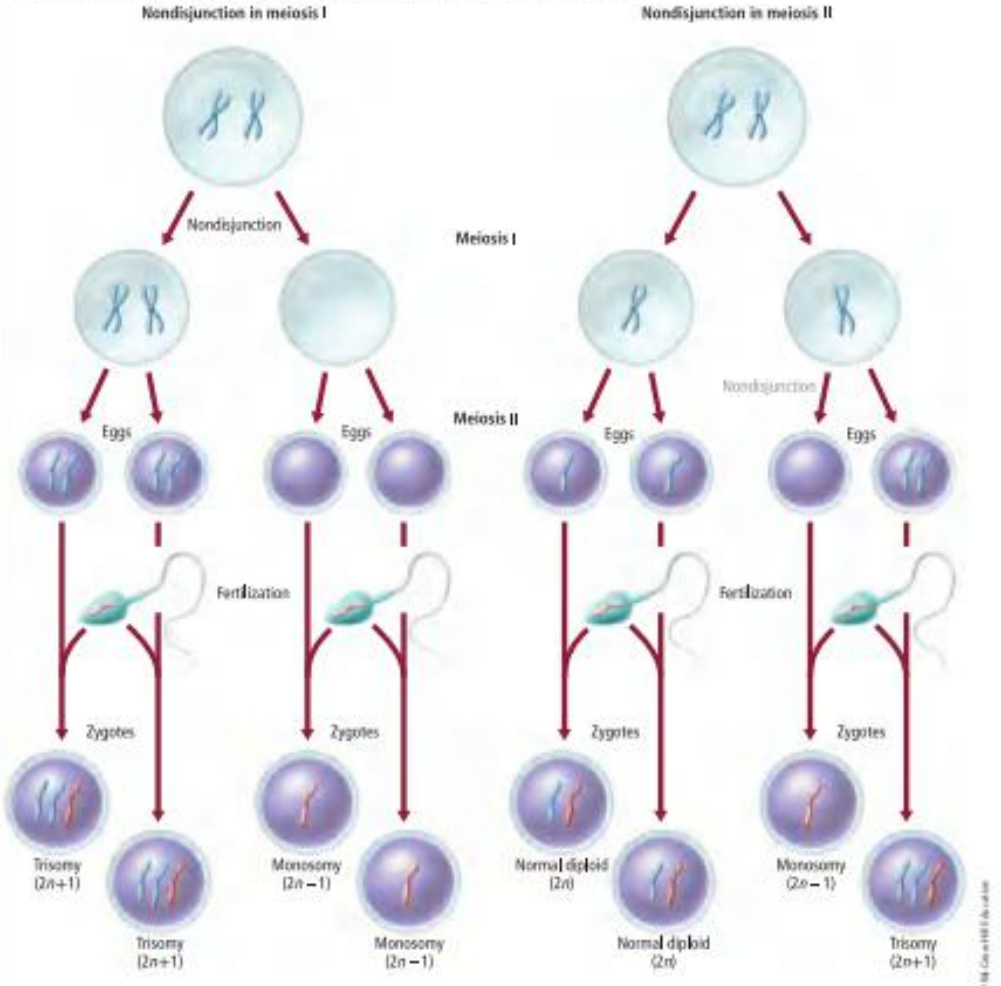
OL COOP LEARN **Research**

Organize students into groups of three and have them research tests for detecting chromosomal abnormalities associated with Down syndrome. Have them create a visual report on their findings, which should also include the use of genetic counseling.

Visualizing Nondisjunction

Figure 18

Gametes with abnormal numbers of chromosomes can result from nondisjunction during meiosis. The orange chromosomes come from one parent, and the blue chromosomes come from the other parent.



Demonstration

Sock Nondisjunction Use two pairs of socks to represent a pair of chromosomes (each consisting of two chromatids). Place a small piece of hook-and-loop tape on each sock to keep the pairs together as you hold them up to the class. The two pairs together represent a pair of chromosomes that line up during metaphase of meiosis I. Demonstrate nondisjunction during meiosis II as one of the pairs of socks fail to separate correctly. Two of the resulting four gametes have one sock chromatid each, one has two socks, and the fourth has none. Est. time: 15 min

Nondisjunction

During cell division, the chromosomes separate, with one of each of the sister chromatids going to opposite poles of the cell. Therefore, each new cell has the correct number of chromosomes. Cell division during which sister chromatids fail to separate properly, which does happen occasionally, is called **nondisjunction.**

If nondisjunction occurs during meiosis I or meiosis II, as shown in **Figure 18,** the resulting gametes will not have the correct number of chromosomes. When one of these gametes fertilizes another gamete, the resulting offspring will not have the correct number of chromosomes. Notice that nondisjunction can result in extra copies of a certain chromosome or only one copy of a particular chromosome in the offspring. Having a set of three chromosomes of one kind is called trisomy (TRI so me). Having only one of a particular type of chromosome is called monosomy (MAH nuh so me). Nondisjunction can occur in any organism in which gametes are produced through meiosis. In humans, alterations of chromosome numbers are associated with serious human disorders, which are often are fatal.

Down syndrome One of the earliest known human chromosomal disorders is Down syndrome. It is the result of an extra chromosome 21. Therefore, Down syndrome often is called trisomy 21. Examine the karyotype of a child with Down syndrome, shown in **Figure 19.** Notice that she has three copies of chromosome 21. The characteristics of Down syndrome include distinctive facial features, as shown in **Figure 19,** short stature, heart defects, and mental disability. The frequency of children born with Down syndrome in the United States is approximately one out of 800. The frequency of Down syndrome increases with the age of the mother. Studies have shown that the risk of having a child with Down syndrome is about six percent in mothers who are 45 and older.

CAREERS IN BIOLOGY

Research Scientist Research scientists know and research a particular field of science, such as genetic disorders. Most research scientists begin their work in their undergraduate studies and continue on to a Master's degree or Ph.D.

Figure 19 A person with Down syndrome has distinctive features and will have a karyotype that shows three copies of chromosome number 21.

False-Color LM Magnification: 1400×

R Reading Strategy

BL OL AL

Anticipation Guide
Before students read the text below the heading *Nondisjunction,* have the following discussion.
ASK STUDENTS: ***Do you know anyone with Down syndrome? What would you like to know about Down syndrome?*** Write the student questions on the board and then have students read the text. If any questions remain unanswered, have students research answers to those questions.

W Writing Support

BL OL AL **Informal Writing**
Give students the following scenario: A genetic test has just indicated that the child a couple is expecting will have Down syndrome. Have students write a letter from the physician explaining to the couple how Down syndrome occurred.

Critical Thinking

BL OL AL **Consider** The gametes from an individual with Klinefelter's syndrome are often sterile, but occasionally they can produce a functioning gamete.
ASK STUDENTS: ***What problem do the chromosomes have during meiosis in an individual with Kleinfelter's?*** The two X chromosomes and one Y chromosome line up together, so improper pairing occurs during meiosis, making the presence of abnormal gametes more likely.

"Knowledge exists to be imparted."
—Ralph Waldo Emerson

Differentiated Instruction

Visually Impaired If you will be using any special equipment such as a projector during class, warn students who are visually impaired of any changes to the layout of the classroom. This warning will allow students to make any needed adjustments as they move around the room.

MiniLab 2

Est. Time 30 min

Safety Precaution Discuss the safety concerns of this lab before work begins.

Teaching Strategies

- Prepare and distribute copies of a data table, such as this one, with rows for as many subjects as needed.

Survey Subject	Hitchhiker's thumb Y/N
1	
2	

Analysis

1. Answers will vary. Sample answer: we looked for the ratio of subjects with a hitchhiker's thumb to subjects without a hitchhiker's thumb.
2. Students might suggest DNA analysis or compiling pedigrees to determine dominance. In small populations, traits can be more common even though they are recessive, which might cause students to misidentify them as dominant.

Table 4 Nondisjunction in Sex Chromosomes

Genotype	XX	XO	XXX	XY	XXY	XYY	OY
Example							
Phenotype	Normal female	Female with Turner's syndrome	Nearly normal female	Normal male	Male with Klinefelter's syndrome	Normal or nearly normal male	Results in death

Sex chromosomes Nondisjunction occurs in both autosomes and sex chromosomes. Some of the results of nondisjunction in human sex chromosomes are listed in **Table 4.** Note that an individual with Turner's syndrome has only one sex chromosome. This condition results from fertilization with a gamete that had no sex chromosome.

Fetal Testing

Couples who suspect they might be carriers for certain genetic disorders might want to have a fetal test performed. Older couples also might wish to know the chromosomal status of their developing baby, called the fetus. Various types of tests for observing both the mother and the baby are available.

MiniLab 2

Explore the Methods of the Geneticist

How do geneticists learn about human heredity? Traditional methods used to investigate the genetics of plants, animals, and microbes are not suitable or possible to use on humans. A pedigree is one useful tool for investigating human inheritance. In this lab, you will explore yet another tool of the geneticist—population sampling.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Construct a data table as instructed by your teacher.
3. Survey your group for the hitchhiker's thumb trait.
4. Survey your group for other traits determined by your teacher.
5. Compile the class data, and analyze the traits that you investigated in the survey population. Determine which of the traits are dominant and which are recessive.

Analysis

1. **Interpret Data** What numerical clue did you look for to determine whether each trait surveyed was dominant or recessive?
2. **Think Critically** How could you check to see if you correctly identified dominant and recessive traits? Explain why you might have misidentified a trait.

Skill Practice

BL OL AL COOP LEARN

Visual Literacy Have students work in pairs to draw a series of meiosis stages illustrating one of the abnormal genotypes in Table 4. Have the groups exchange papers and infer which condition the meiosis pictures show.

Research Citation

Real-World Applications Research indicates that students gain a better understanding of concepts that are related to real-world problems. The MiniLab on this page demonstrates the relationship between pedigrees and inheritance, allowing students to relate this topic to the real world. (Steen and Forman, 1995)

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Table 5 Fetal Tests

Test	Benefit	Risk
Amniocentesis	• Diagnosis of chromosome abnormalities • Diagnosis of other defects	• Discomfort for expectant mother • Slight risk of infection • Risk of miscarriage
Chorionic villus sampling	• Diagnosis of chromosome abnormality • Diagnosis of certain genetic defects	• Risk of miscarriage • Risk of infection • Risk of newborn limb defects
Fetal blood sampling	• Diagnosis of genetic or chromosome abnormality • Checks for fetal blood problems and oxygen levels • Medications can be given to the fetus before birth	• Risk of bleeding from sample site • Risk of infection • Amniotic fluid might leak • Risk of fetal death

Connection Health Many fetal tests can provide important information to the parents and the physician. **Table 5** describes the risks and benefits of some of the fetal tests that are available. Physicians must consider many factors when advising parents about such examinations. At least a small degree of risk is possible in any test or procedure. A physician would not want to advise tests that would endanger the mother or the fetus; therefore, when considering whether to recommend fetal testing, a physician would need to consider previous health problems of the mother and also the health of the fetus. If the physician and parents determine that any fetal test is needed, the health of both the mother and the fetus is closely monitored throughout the testing.

Section 3 Review

Section Summary

- Karyotypes are micrographs of chromosomes.
- Chromosomes terminate in a cap called a telomere.
- Nondisjunction results in gametes with an abnormal number of chromosomes.
- Down syndrome is a result of nondisjunction.
- Tests for assessing the possibility of genetic and chromosomal disorders are available.

Understand Main Ideas

1. MAIN Idea Explain how a scientist might use a karyotype to study genetic disorders.
2. **Summarize** the role of telomeres.
3. **Illustrate** Draw a sketch to show how nondisjunction occurs during meiosis.
4. **Analyze** Why might missing sections of the X or Y chromosome be a bigger problem in males than deletions would be in one of the X chromosomes in females?

Think Critically

5. **Create** a karyotype of a female organism in which $2n = 8$, showing trisomy of chromosome 3.
6. **Discuss** the benefits and risks of fetal testing.

WRITING in Biology

7. Conduct research on the consequences of nondisjunction other than trisomy 21. Write a paragraph about your findings.

Develop Concepts

BL OL AL

Clarify A Misconception

ASK STUDENTS: ***If a rare disorder appeared only once in a couple's family–affecting the male's great uncle or a first cousin, for example– should the couple have their developing baby tested for the disorder?*** Yes, if they choose to do so, because recessive genes can be expressed after several generations. Students might think that problems affecting relatives in the distant past have little chance of showing up in their offspring.

Formative Assessment

Evaluation Prepare a picture presentation that shows karyotypes of various disorders and pictures of telomeres.

SAY TO STUDENTS: ***Identify the disorders represented by the presentation and explain how you identified the disorder.***

Remediation Have students write review questions from this section on note cards and write the answers on the backs of the cards. Students having difficulty with the ideas in this section can use the cards to review concepts.

Section 3 Review

1. to determine the sex of the individual, whether the proper number of chromosomes are there, whether there is extra or missing chromosomal material
2. Telomeres protect chromosomes.
3. Sketches should demonstrate an understanding of nondisjunction.
4. Males only receive one X and one Y, so missing sections could contain genes that are vital. With females who have two X's, deletion in one X could be made up for by the other.
5. Answer should show understanding of karyotype and show that the individual has three copies of chromosome 3.
6. benefits = discovery of genetic problem; risk = harm to fetus
7. Paragraphs should show understanding of nondisjunction. Paragraphs should not describe Down syndrome.

In the Field

Purpose

Students will understand that genetic counseling involves interpreting genetic tests and communicating the results to the client. Genetic counselors must have scientific and social skills.

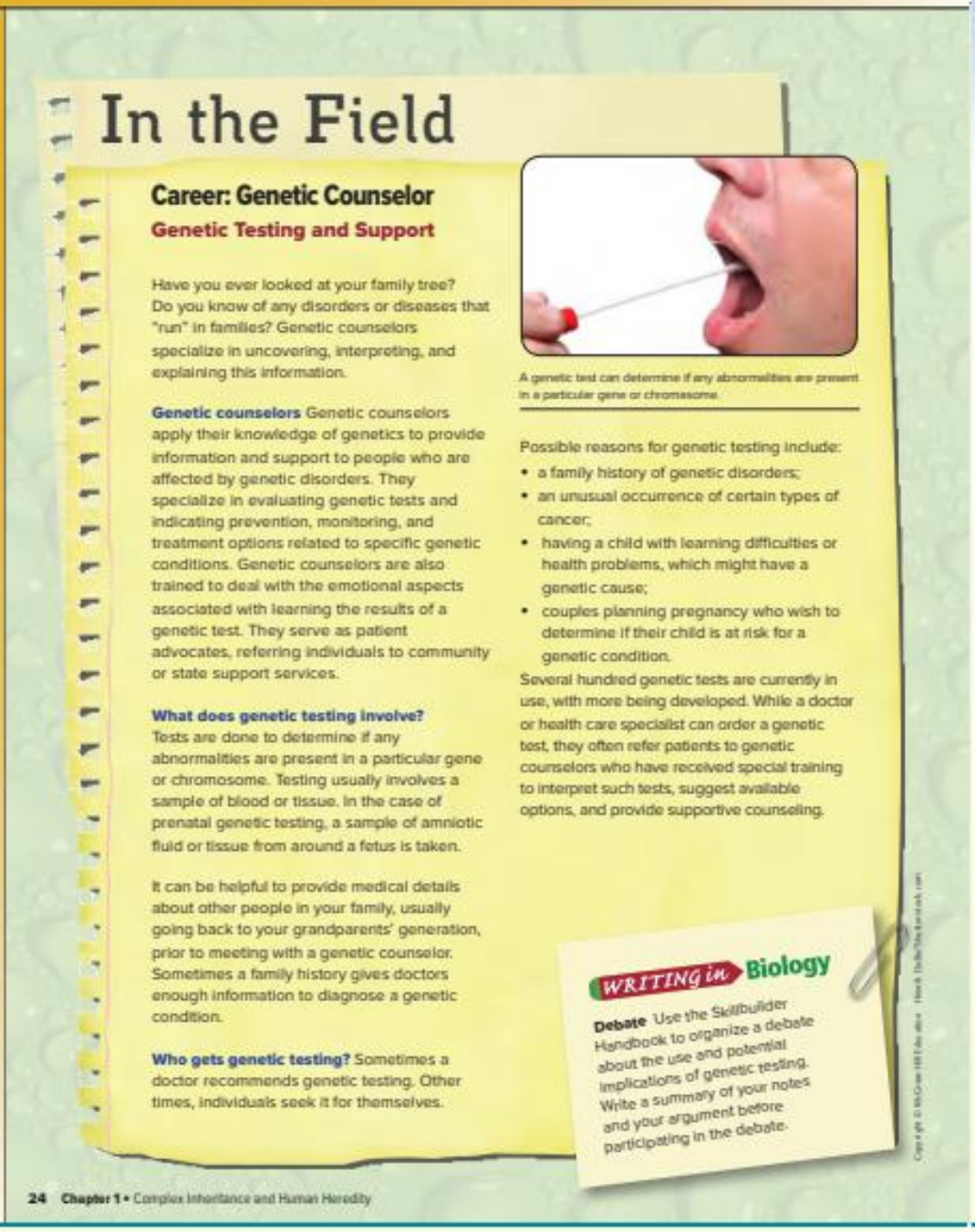
Anticipatory Guide

Engage students in a discussion of uses for genetic counseling.

ASK STUDENTS: ***What are some different reasons for genetic testing?*** Answers may include testing to see if a person is a carrier for a genetic disorder. ***Why do you think this type of test is important?*** Answers will vary, but might include helping a couple determine whether to have a child based on the chance of a genetic disorder in their offspring.

Background

Genetic counselors have changed our world immensely. Genetic testing has become an important vehicle for disseminating information about genetic disorders and has at times been the center of controversy. Ensuring genetic test information is correct and discussing the ways in which this information can be used are of critical importance in order to keep the public's trust.



In the Field

Career: Genetic Counselor

Genetic Testing and Support

Have you ever looked at your family tree? Do you know of any disorders or diseases that "run" in families? Genetic counselors specialize in uncovering, interpreting, and explaining this information.

Genetic counselors Genetic counselors apply their knowledge of genetics to provide information and support to people who are affected by genetic disorders. They specialize in evaluating genetic tests and indicating prevention, monitoring, and treatment options related to specific genetic conditions. Genetic counselors are also trained to deal with the emotional aspects associated with learning the results of a genetic test. They serve as patient advocates, referring individuals to community or state support services.

What does genetic testing involve? Tests are done to determine if any abnormalities are present in a particular gene or chromosome. Testing usually involves a sample of blood or tissue. In the case of prenatal genetic testing, a sample of amniotic fluid or tissue from around a fetus is taken.

It can be helpful to provide medical details about other people in your family, usually going back to your grandparents' generation, prior to meeting with a genetic counselor. Sometimes a family history gives doctors enough information to diagnose a genetic condition.

Who gets genetic testing? Sometimes a doctor recommends genetic testing. Other times, individuals seek it for themselves.

A genetic test can determine if any abnormalities are present in a particular gene or chromosome.

Possible reasons for genetic testing include:

- a family history of genetic disorders;
- an unusual occurrence of certain types of cancer;
- having a child with learning difficulties or health problems, which might have a genetic cause;
- couples planning pregnancy who wish to determine if their child is at risk for a genetic condition.

Several hundred genetic tests are currently in use, with more being developed. While a doctor or health care specialist can order a genetic test, they often refer patients to genetic counselors who have received special training to interpret such tests, suggest available options, and provide supportive counseling.

WRITING in Biology

Debate Use the Skillbuilder Handbook to organize a debate about the use and potential implications of genetic testing. Write a summary of your notes and your argument before participating in the debate.

Discussion

Organize students into groups. Present to them the following questions to discuss, and have one member in each group write down the group's responses.

ASK STUDENTS: ***How does genetic testing affect a person who has a parent with a genetic disorder? If you had a parent with a genetic disorder, would you want to be tested for the disorder?*** Have the class regroup and discuss their responses in the remaining time. Discussion points will vary but should include the importance of understanding uncertainties in test results, and implications of being a carrier for a recessive disorder. Students should also discuss the impact of changing science and technology on the field of genetic counseling.

BIOLAB

WHAT'S IN A FACE? INVESTIGATE INHERITED HUMAN FACIAL CHARACTERISTICS

Background: **Most people know that they inherit their hair color and their eye color from their parents. However, there are many other head and facial traits that humans inherit. In this lab, you will investigate a number of different inherited facial structures that combine to compose a human face.**

Question: *What structures that comprise the human face are actually determined genetically?*

Materials

coins, 2 per team: heads=dominant trait, tails=recessive trait
table of inherited human facial characteristics provided by the teacher

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Partner with a classmate.
3. One member of the team will represent the father, and one member will represent the mother. Decide which partner will represent the father and who will represent the mother.
4. Have the person representing the father flip a coin. If the coin lands *heads* facing up, the offspring is a female; if the coin lands *tails* facing up, the offspring is a male. Record the gender of the offspring.
5. Flip your coin at the same time as your partner. Flip the coins only once for each trait.
6. Continue to flip coins for each trait shown in the table. After each coin flip, record the trait of your offspring by placing a check in the appropriate box in the table.
7. Once the traits are determined, draw the offspring's facial features, give him or her a name, and be prepared to introduce the offspring to the rest of the class.

Analyze and Conclude

1. **Think Critically** Why did the partner representing the father flip the coin initially to determine the gender of the offspring?
2. **Calculate** What percent chance was there of producing male offspring? Female offspring? Explain.
3. **Recognize Cause and Effect** What are the possible genotypes of parents of the following three children: a boy with straight hair (hh), a daughter with wavy hair (Hh), and a son with curly hair (HH)?
4. **Observe and Infer** Which traits show codominance?
5. **Analyze and Conclude** Would you expect other student pairs in the class to have offspring exactly like yours? Explain.

WRITING in Biology

Research Imagine that you write a science column for a large newspaper. A reader has written to you asking for a job description for a genetic counselor. Research this question; then write a short newspaper column answering the question.

BIOLAB

Est. Time 35 min

Content Background
Humans inherit many traits other than just eye color and hair color.

Safety Precaution Discuss the safety concerns of this lab before work begins.

Teaching Strategies

- Have students compile their characteristics into a hand-drawn picture of their offspring, give the offspring a name, and introduce him/her to the class.
- Have students work in pairs.

Alternative Teaching Demo
Provide students with pictures of several members of a family. This may be members of a well-known family or your own family. Ask students to examine the pictures and determine why these people look related. What is similar about their faces?

Analyze and Conclude

1. The male determines the gender of the offspring in humans.
2. a 50 % chance in each situation
3. To achieve this outcome, both parents must have wavy hair *(Hh)*.
4. Answers will depend on the traits used.
5. The chances of two groups producing identical offspring are quite remote. It would require each coin flip for each group to be exactly the same for each trait.

Chapter 1 Assessment

THEME FOCUS **Diversity** Complex forms of inheritance, such as multiple alleles and codominance in the ABO blood group, result in a range of characteristics that contribute to the diversity and success of a species.

BIG Idea **Human inheritance does not always follow Mendel's laws.**

Section 1 Basic Patterns of Human Inheritance

carrier
pedigree

MAIN Idea **The inheritance of a trait over several generations can be shown in a pedigree.**

- Genetic disorders can be caused by dominant or recessive alleles.
- Cystic fibrosis is a genetic disorder that affects mucus and sweat secretions.
- Individuals with albinism do not have melanin in their skin, hair, and eyes.
- Huntington's disease affects the nervous system.
- Achondroplasia sometimes is called dwarfism.
- Pedigrees are used to study human inheritance patterns.

Section 2 Complex Patterns of Inheritance

incomplete dominance
codominance
multiple alleles
epistasis
sex chromosome
autosome
sex-linked trait
polygenic trait

MAIN Idea **Complex inheritance of traits does not follow inheritance patterns described by Mendel.**

- Some traits are inherited through complex inheritance patterns, such as incomplete dominance, codominance, and multiple alleles.
- Gender is determined by X and Y chromosomes. Some traits are linked to the X chromosome.
- Polygenic traits involve more than one pair of alleles.
- Both genes and environment influence an organism's phenotype.
- Studies of inheritance patterns of large families and twins give insight into complex human inheritance.

Section 3 Chromosomes and Human Heredity

karyotype
telomere
nondisjunction

MAIN Idea **Chromosomes can be studied using karyotypes.**

- Karyotypes are micrographs of chromosomes.
- Chromosomes terminate in a cap called a telomere.
- Nondisjunction results in gametes with an abnormal number of chromosomes.
- Down syndrome is a result of nondisjunction.
- Tests for assessing the possibility of genetic and chromosomal disorders are available.

26 Chapter 1 • Study Guide

Section 1

Vocabulary Review

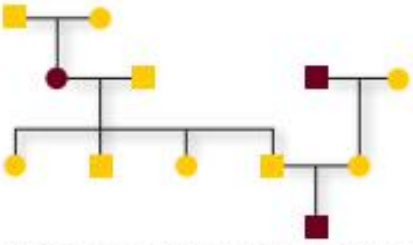
Use what you know about the vocabulary terms from the Study Guide page to answer the questions.

1. Which term describes a person who is heterozygous for a recessive disorder?
2. How is the inheritance pattern between parents and offspring represented diagrammatically?

Understand Main Ideas

3. Which condition is inherited as a dominant allele?
   - **A.** albinism
   - **B.** cystic fibrosis
   - **C.** Tay-Sachs disease
   - **D.** Huntington's disease
4. Which is not a characteristic of a person with cystic fibrosis?
   - **A.** chloride channel defect
   - **B.** digestive problems
   - **C.** lack of skin pigment
   - **D.** recurrent lung infections

Use the diagram below to answer questions 5 and 6.



5. Which disorder could not follow the inheritance pattern shown?
   - **A.** cystic fibrosis
   - **B.** albinism
   - **C.** Tay-Sachs disease
   - **D.** Huntington's disease
6. MAIN Idea How many affected males and females are in the pedigree?
   - **A.** 1 male, 2 females
   - **B.** 2 males, 1 female
   - **C.** 1 male, 1 female
   - **D.** 2 males, 2 females

Constructed Response

Use the photo below to answer question 7.

7. Imagine that all animals have the same genetic disorders that humans have. What is the biological name of the genetic disorder that this dwarf tree frog would have? Describe the inheritance pattern of the genetic disorder.
8. Predict the genotypes of the children of a father with Huntington's disease and an unaffected mother.

Think Critically

9. **Draw a conclusion** about the relationship of chloride ions to the excessively thick mucus in a patient suffering from cystic fibrosis.

Section 2

Vocabulary Review

Replace each underlined word with the correct vocabulary term from the Study Guide page.

10. Codominance is an inheritance pattern in which the heterozygous genotype results in an intermediate phenotype between the dominant and recessive phenotype.
11. A characteristic that has more than one pair of possible traits is said to be a(n) epistasis.
12. Genes found on the sex chromosomes are associated with multiple alleles.

Chapter 1 Assessment

Section 1

Vocabulary Review

1. carrier
2. pedigree

Understand Main Ideas

3. D
4. C
5. D
6. B

Constructed Response

7. achondroplasia, a dominant disorder caused by a mutation
8. Because Huntington's is a rare disorder, the male is likely Dd; the children each have a 50 percent chance of being *Dd* and a 50 percent chance of being *dd*.

Think Critically

9. Because chloride cannot leave the cell, water does not follow, so the mucus is thicker than normal.

Section 2

Vocabulary Review

10. Incomplete dominance
11. polygenic trait
12. sex-linked traits

Understand Main Ideas

13. What determines gender in humans?
    - **A.** the X and Y chromosomes
    - **B.** chromosome 21
    - **C.** codominance
    - **D.** epistasis

14. MAIN Idea Which two terms best describe the inheritance of human blood types?
    - **A.** incomplete dominance and codominance
    - **B.** codominance and multiple alleles
    - **C.** incomplete dominance and multiple alleles
    - **D.** codominance and epistasis

Use the photos below to answer question 15.

15. THEME FOCUS Diversity In radishes, color is controlled by incomplete dominance. The figure above shows the phenotype for each color. What phenotypic ratios would you expect from crossing two heterozygous plants?
    - **A.** 2: 2 red: white
    - **B.** 1: 1: 1 red: purple: white
    - **C.** 1: 2: 1 red: purple: white
    - **D.** 3: 1 red: white

Constructed Response

16. **Short Answer** How does epistasis explain the differences in coat color in Labrador retrievers?

17. **Short Answer** Explain whether a male could be heterozygous for red-green color blindness.

18. **Short Answer** What types of phenotypes would one look for if a phenotype were a result of polygenic inheritance?

Think Critically

19. **Evaluate** why it might be difficult to perform genetic analysis in humans.

20. **Summarize** the meaning of the following information regarding trait inheritance: For a certain trait, identical twins have a concordance rate of 54 percent and fraternal twins have a rate of less than five percent.

Section 3

Vocabulary Review

Identify the vocabulary term from the Study Guide page described by each definition.

21. the protective ends of the chromosome

22. an error that occurs during cell division

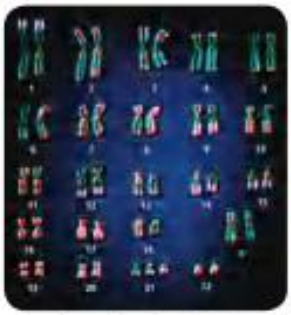
23. a micrograph of stained chromosomes

Understand Main Ideas

24. MAIN Idea What could explain a human karyotype showing 47 chromosomes?
    - **A.** monosomy
    - **B.** trisomy
    - **C.** codominance
    - **D.** dominant traits

25. Why does nondisjunction occur?
    - **A.** Cytokinesis does not occur properly.
    - **B.** The nucleoli do not disappear.
    - **C.** The sister chromatids do not separate.
    - **D.** The chromosomes do not condense properly.

Use the photo below to answer question 26.



26. What disorder can be identified in the karyotype?
    - **A.** Turner's syndrome
    - **B.** Klinefelter's syndrome
    - **C.** Down syndrome
    - **D.** The karyotype shows no disorder.

Understand Main Ideas

13. A
14. B
15. C

Constructed Response

16. The recessive alleles on the *E* gene for no pigment can hide the dominant allele on the *B* gene for dark pigment.
17. No, this is an X chromosome sex-linked trait and males only receive one X chromosome.
18. phenotypes showing continuous variation, that is small differences between each phenotype

Think Critically

19. Humans have small families, long generation time, and cannot be studied in controlled experiments for ethical reasons.
20. There is a fairly large genetic component to the trait.

Section 3

Vocabulary Review

21. telomere
22. nondisjunction
23. karyotype

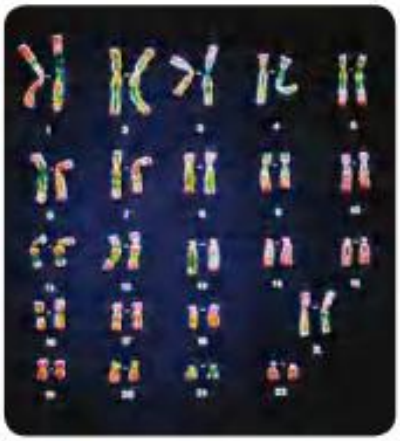
Understand Main Ideas

24. B
25. C
26. C

27. Which statement concerning telomeres is not true?
   A. They are found on the ends of chromosomes.
   B. They consist of DNA and sugars.
   C. They protect chromosomes.
   D. They are involved with aging.

Constructed Response

Use the photo below to answer question 28.



28. Describe a fetal test that results in the karyotype shown above.
29. What characteristics are associated with Down syndrome?
30. Most cases of trisomy and monosomy in humans are fatal. Why might this be?

Think Critically

31. **Hypothesize** why chromosomes need telomeres.
32. **Explain** why a girl who has Turner's syndrome has red-green color blindness even though both of her parents have normal vision.
33. **Illustrate** what might have occurred to result in an extra chromosome in the following example: A technician is constructing a karyotype from male fetal cells. The technician discovers that the cells have one extra X chromosome.

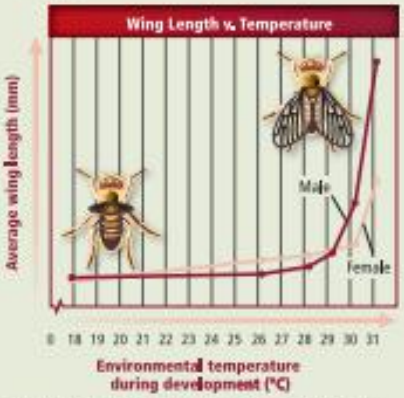
Summative Assessment

34. BIG Idea Give a specific example of an inheritable trait that does not follow Mendel's laws of inheritance. Apply Mendel's laws to that trait, and infer how the resulting genotypes and phenotypes would be different from what actually exists.
35. Describe how hemophilia is inherited.
36. Describe the cause of Down syndrome.
37. WRITING in Biology Write a scenario for one of the genetic disorders described in **Table 2.** Then create a pedigree illustrating the scenario.

Document-Based Questions

Answer the questions below concerning the effect of environment on phenotype.

Data obtained from: Hardy, M.H. 1936. Genetics. Journal of Experimental Zoology 56: 363-379.



38. At which temperature is wing length the greatest?
39. Is male or female wing length more influenced by temperature? Explain.
40. What is the relationship between temperature and wing length for all flies?

Document-Based Questions

Hardy, M.H. 1936. Genetics. *Journal of Experimental Zoology* 56: 363–379.

38. 31°C
39. Males, they have a larger average wing length at 31°C than female.
40. As temperature increases during development wing length increases.

27. D

Constructed Response

28. Both amniocentesis and chronic villus sampling can generate karyotypes.
29. distinctive facial features, short stature, heart defects, mental disability
30. Not having normal number of chromosomes causes serious disorders.

Think Critically

31. Answer may vary, but may include protection of the chromosomes during cell division and against cellular enzymes.
32. Because females normally inactivate one X chromosome, a female with Turner Syndrome only has one X chromosome, which has the allele for color blindness.
33. Illustrations should show nondisjunction during meiosis.

Summative Assessment

34. Possible answer: The ABO blood group is an example of multiple alleles and codominance, not two alleles, one of which is dominant over the other. If the ABO blood group followed Mendel's laws, there would only be two alleles (such as A and B) resulting in 3 genotypes (AA, AB, BB) and 2 phenotypes (type A blood, type B blood). Since the inheritance of blood type is complex, there are 3 alleles, 9 genotypes, and 4 phenotypes.
35. Hemophilia is inherited as a sex-linked recessive trait.
36. nondisjunction
37. The scenario and pedigree should demonstrate an understanding of the chosen disorder.

Standardized Test Practice

Multiple Choice Aligned with PISA

1. C **5.** D **9.** D
2. A **6.** B
3. B **7.** C
4. B **8.** B

Short Answer

Aligned with PISA & SAT

10. This Punnett square shows the outcome of the cross.

	Y	y
y	Yy	yy
y	Yy	yy

11. Homozygous plants make up 50% of the total. The plants with *yy* genotype are homozygous.

12. The onset of Huntington's disease is later than the age at which most people have children. So, although it is a fatal disease, it might not appear until after people have already reproduced.

13. When the cell cycle is disrupted, the amount of time spent in mitosis increases. Cells divide uncontrollably, and the resulting cancer cells accumulate to form a tumor.

14. The following steps are possible, but a student might answer in fewer steps by combining one or more of these listed.

A. During cell division in meiosis II, the sister chromatids start to separate.
B. The separation is not equal, causing a nondisjunction, in which one gamete gets an extra chromosome.
C. This gamete, with an extra chromosome in either the egg or sperm, is involved in fertilization.
D. The resulting embryo has three chromosomes in place of one of its chromosome pairs: a trisomy.

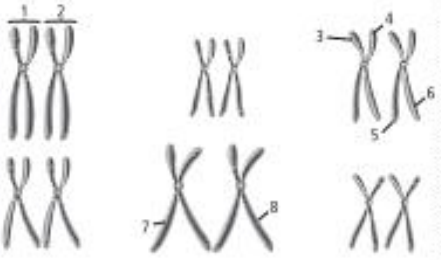
Standardized Test Practice

Cumulative

Multiple Choice Aligned with PISA

1. Which is affected when a cell has a low surface-area-to-volume ratio?
A. the ability of oxygen to diffuse into the cell
B. the amount of energy produced in the cell
C. the diffusion of proteins through the cells
D. the rate of protein synthesis in the cell

Use the diagram below to answer questions 2 to 4.



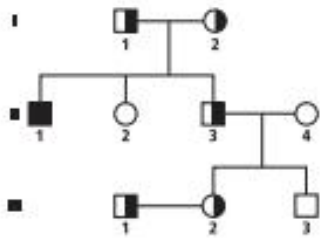
2. Which labeled structures represent a homologous pair?
A. 1 and 2
B. 3 and 4
C. 3 and 6
D. 7 and 8

3. Which parts of the chromosomes shown could appear together in a gamete of this organism?
A. 1 and 2
B. 3 and 6
C. 3 and 7
D. 5 and 6

4. If the diagram shows all the chromosomes from a body cell, how many chromosomes would be in a gamete of this organism at the end of meiosis I?
A. 3
B. 6
C. 9
D. 12

5. Which represents a polyploid organism?
A. 1/2 *n*
B. 1 1/2 *n*
C. 2 *n*
D. 3 *n*

Use the pedigree below to answer questions 6 and 7.



6. Which person could develop symptoms of the disease that is tracked in the pedigree?
A. I1
B. II1
C. II2
D. III2

7. According to the pedigree, who is a carrier and cannot have children with the disease?
A. I1
B. II1
C. II3
D. III1

8. Which condition would trigger mitosis?
A. Cells touch each other.
B. Cyclin builds up.
C. Environmental conditions are poor.
D. Growth factors are absent.

9. Shivering when you are cold raises your body temperature. This is an example of which characteristic of life?
A. Your body adapts over time.
B. Your body grows and develops.
C. Your body has one or more cells.
D. Your body maintains homeostasis.

Short Answer
Aligned with PISA & SAT

10. In pea plants, yellow seed color is the dominant trait, and green seed color is the recessive trait. Use a Punnett square to show the results of a cross between a heterozygous yellow-seed plant and a green-seed plant.

11. Based on your Punnett square from question 10, what percentage of the offspring would have a homozygous genotype? Explain your answer.

12. Because Huntington's disease is a dominant genetic disorder, it might seem that it would be selected out of a population naturally. Write a hypothesis that states why the disease continues to occur.

13. Explain how a cancerous tumor results from a disruption of the cell cycle.

14. Write, in order the steps that must occur for cell division to result in an organism with trisomy.

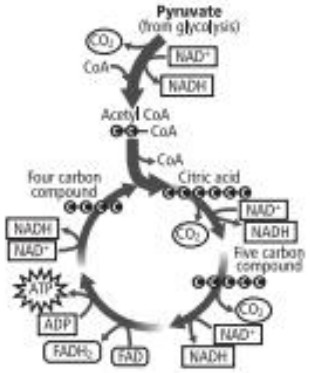
15. Which function in metabolism is performed by both the thylakoid membrane and the mitochondrial membrane? Give a reason why this function might or might not be important.

16. Suppose two parents have a mild form of a genetic disease, but their child is born with a very severe form of the same disease. What kind of inheritance pattern took place for this disease?

17. Describe an example of each of the following: species diversity, genetic diversity, and ecosystem diversity.

Extended Response
Aligned with PISA & SAT

Use the diagram below to answer question 18.



18. Identify the cycle in the figure and summarize the steps of the cycle.

19. Describe the function of microtubules, and predict what might happen if cells did NOT have microtubules.

Essay Question Aligned with PISA & SAT

The type of pea plants that Mendel investigated had either purple flowers or white flowers. One flower-color trait is dominant, and the other is recessive.

Using the information in the paragraph above, answer the following question in essay format.

20. Explain what crosses Mendel would have performed to determine which color is the dominant trait.

15. Electron transport is performed by both membranes. That fact might be important because it could give evidence for similarities of structure or origin. On the other hand, the fact that the two membranes perform the same function might be coincidental.

16. The simplest explanation is that the disease is due to incomplete dominance of a pair of alleles. For example, the disease might be caused by a recessive gene *h* that is partially expressed in the presence of the dominant gene *H*. The genotypes of the parents would be *Hh*, giving them a mild form of the disease. The genotype of the child would be *hh*, giving the child a severe form of the disease.

17. Examples can vary, but they should demonstrate an understanding of how the three kinds of diversity are different. For example: species diversity: in tropical rainforest region, there are a variety of populations of birds, flowering plants, etc; genetic diversity: among the crows in a population, there are genes for different kind of coloration; ecosystem diversity: as you move around Earth, you can find different types of ecosystems supporting different populations of living things

Extended Response
Aligned with PISA & SAT

18. The diagram represents the Krebs cycle or tricarboxylic acid cycle. Pyruvate is converted to acetyl CoA, releasing CO_2 and NADH. Acetyl CoA joins with a 4-carbon compound to form citric acid. Citric acid is further processed, releasing CO_2, NADH, and $FADH_2$, and producing ATP. Citric acid is eventually converted back to a 4-carbon compound which joins the next acetyl group.

19. Microtubules provide structural support and are involved in transportation within a cell. They also help separate chromosomes in mitosis. Cells without microtubules might have decreased ability to transport materials or perform mitosis.

Essay Question
Aligned with PISA & SAT

20. Mendel would have had to cross white and purple plants, then cross their offspring as well. Because either white or purple is recessive, it is possible to see which trait is least prevalent in the offspring of a cross of two heterozygous plants. The recessive trait would be least likely to show up in such a cross. Essay responses should explain these possible outcomes in detail to make clear how the recessive and dominant trait would be obvious.

CHAPTER 2

Launch Lab
Who discovered DNA?

Est. Time 20 min

Safety Precaution Discuss the safety concerns of this lab before work begins.

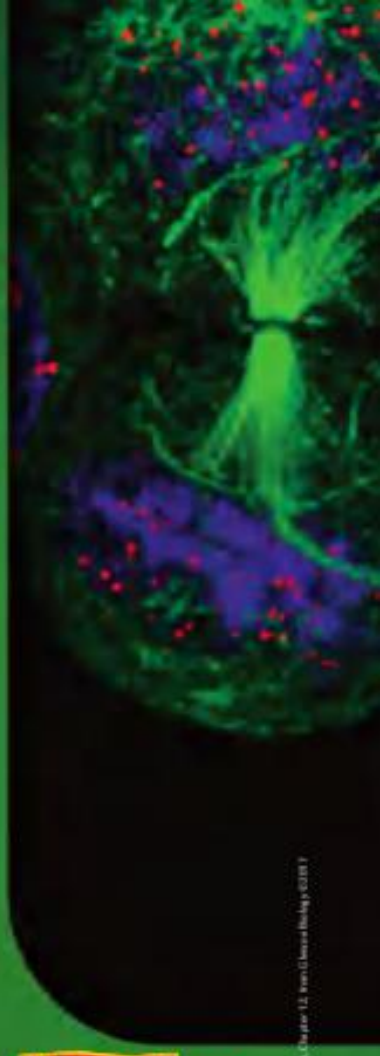
Teaching Strategies
- Have students work in small groups or pairs.
- Use the information and dates from student reports to prepare a class time line that can be displayed in the classroom.

Procedure
1. Identify the safety concerns of this lab before work begins.
2. Work in groups of 3-4 to identify scientists and experiments that made important contributions to the understanding of genetics and DNA.
3. Preview the chapter in this **textbook.**
4. Make a time line showing when each important discovery mentioned in the text was made.

Analysis
1. **Compare** and contrast your group's time line with the other time lines in the class.
Answers will vary, time lines should be similar because all students used the same source.
2. **Infer** how the results of the past experiments are important for each scientist that follows.
Answers will vary, but students should see that each scientist's work is dependent upon the work of other scientists.

CHAPTER 2

Molecular Genetics



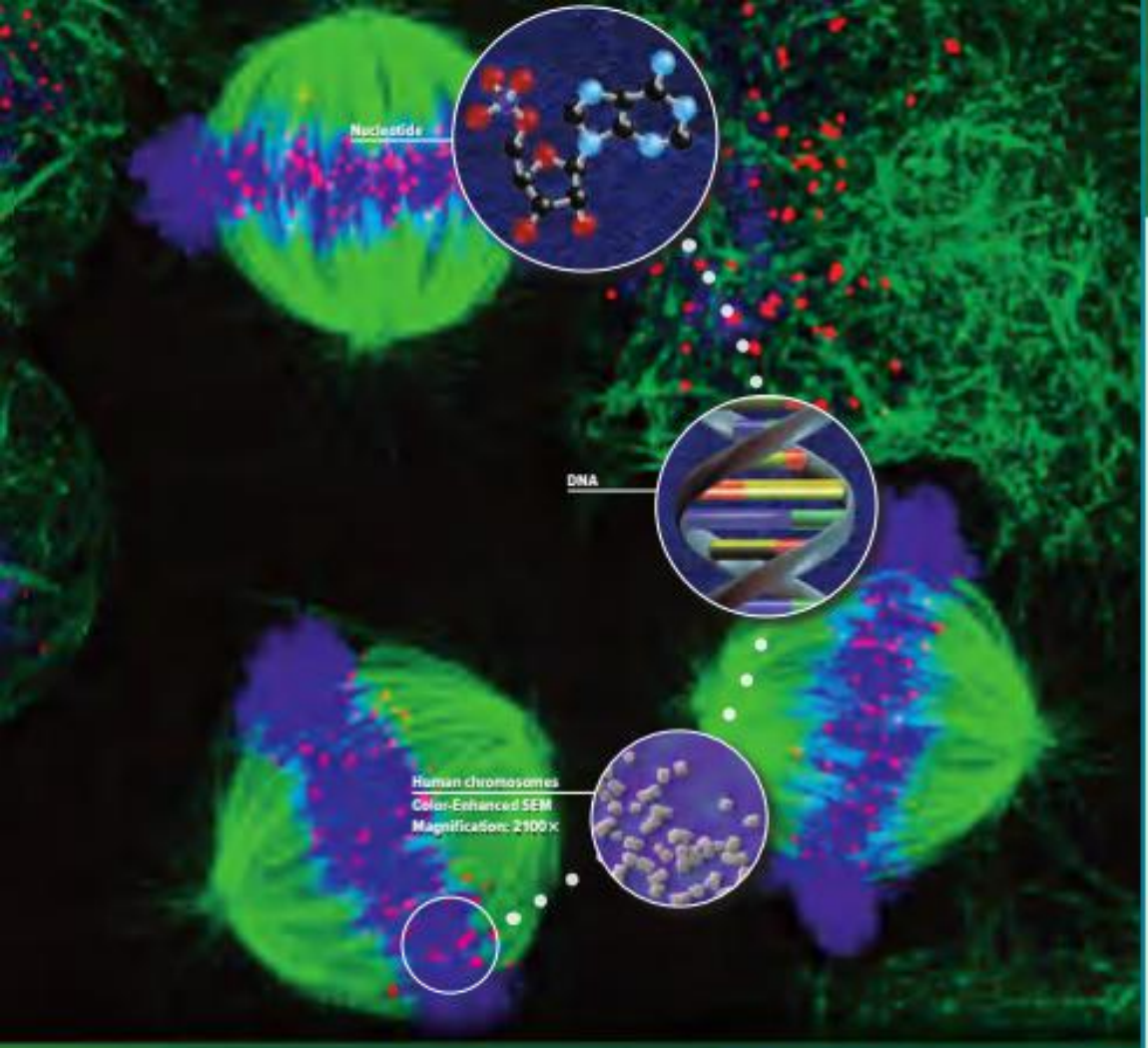
Launch Lab
Who discovered DNA?

The body of knowledge concerning genetics, DNA, and biotechnology has been accumulating for nearly one and a half centuries. In this lab you will make a time line of the discovery of DNA.

FOLDABLES

Make a two-tab book using the labels shown. Use it to organize your notes about transcription and translation.

32 **Chapter 2** • Molecular Genetics



THEME FOCUS Scientific Inquiry
The discovery of the structure of DNA dramatically changed the field of biology.

BIG Idea DNA is the genetic material that contains a code for proteins.

Section 1 • DNA: The Genetic Material
Section 2 • Replication of DNA
Section 3 • DNA, RNA, and Protein
Section 4 • Gene Regulation and Mutation

THEMES

Scientific Inquiry Many experiments led to the discovery of DNA as the genetic code.

Diversity Mutations in DNA provide the possibility of extensive variation.

Energy Replication of DNA requires energy, as do all biosynthetic actions.

Homeostasis Mistakes within DNA are usually fixed before replication occurs.

Change Mutations within DNA can be passed on to future generations.

Introduce the Chapter

Codes

ASK STUDENTS: ***Did you ever get a message from a friend that was in code?*** Some students will likely say yes. ***How did you figure out what the message said?*** Answers might include having a key or cracking the code to figure out the key. Use these questions to introduce how DNA serves as a code.

TELL STUDENTS: ***Like a secret code, DNA also involves the match of a code with a key, and the translation of the code results in something useful.***

BIG Idea

Outline Have students outline the chapter, writing first the Big Idea, then the Main Ideas and paragraph heads. Instruct students to continue the outline under the paragraph heads.

Sample outline:

I. Big Idea: DNA is the genetic material that contains a code for proteins.
  A. Main Idea: The discovery that DNA is the genetic code involved many experiments.
    1. Discovery of the Genetic Material
      a. Griffith
      b. Avery
      c. Hershey and Chase

Section 1

MAIN Idea

BL OL AL Genes and Traits

ASK STUDENTS: ***What features do human beings share?*** Answers might include two legs, two arms, two eyes, and general body shape. ***What features are different among people?*** Answers might include eye color, hair color, particular shapes of features like nose and lips. Tell students that this chapter will begin to explain the molecular basis of what makes each person unique.

Reading Strategy

BL OL AL Sequence Have students read about the experiments described in the text under the heading *Discovery of the Genetic Material*. Have them write a sequence of the experiments that led to the discovery of DNA on 3" x 5" cards, with the names of the people involved and a brief summary of what each experiment demonstrated.

Develop Concepts

BL OL Activity Have students begin collecting pictures of DNA and chromosomes in magazine and newspaper articles about genes to prepare a bulletin board on DNA.

Essential Questions

- Which experiments led to the discovery of DNA as the genetic material?
- What is the basic structure of DNA?
- What is the basic structure of eukaryotic chromosomes?

Review Vocabulary

nucleic acid: complex biomolecule that stores cellular information in the form of a code

New Vocabulary

double helix
nucleosome

DNA: The Genetic Material

MAIN Idea **The discovery that DNA is the genetic code involved many experiments.**

Real-World Reading Link Do you like to read mystery novels or watch people on television solve crimes? Detectives search for clues that will help them solve the mystery. Geneticists are detectives looking for clues in the mystery of inheritance.

Discovery of the Genetic Material

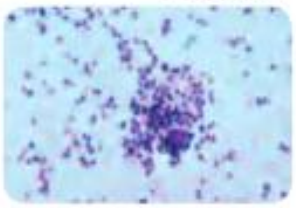
Once Mendel's work was rediscovered in the 1900s, scientists began to search for the molecule involved in inheritance. Scientists knew that genetic information was carried on the chromosomes in eukaryotic cells, and that the two main components of chromosomes are DNA and protein. For many years, scientists tried to determine which of these macromolecules–nucleic acid (DNA) or proteins–was the source of genetic information.

Griffith The first major experiment that led to the discovery of DNA as the genetic material was performed by Frederick Griffith in 1928. Griffith studied two strains of the bacteria *Streptococcus pneumoniae*, which causes pneumonia. He found that one strain could be transformed, or changed, into the other form.

Of the two strains he studied, one had a sugar coat and one did not. Both strains are shown in **Figure 1.** The coated strain causes pneumonia and is called the smooth (S) strain. The noncoated strain does not cause pneumonia and is called the rough (R) strain because, without the coat, the bacteria colonies have rough edges.

Follow Griffith's study described in **Figure 2.** Notice the live S cells killed the mouse in the study. The live R cells did not kill the mouse, and the killed S cells did not kill the mouse. However, when Griffith made a mixture of live R cells and killed S cells and injected the mixture into a mouse, the mouse died. Griffith isolated live bacteria from the dead mouse. When these isolated bacteria were cultured, the smooth trait was visible, suggesting that a disease-causing factor was passed from the killed S bacteria to the live R bacteria. Griffith concluded that there had been a transformation from live R bacteria to live S bacteria. This experiment set the stage for the search to identify the transforming substance.

Smooth strain—*S. pneumoniae*



Rough strain—*S. pneumoniae*

Figure 1 The smooth (S) strain of *S. pneumoniae* can cause pneumonia, though the rough (R) strain is not disease-causing. The strains can be identified by the appearance of the colonies.

Research Citation

Critical Thinking Educational research indicates that students should be challenged to think critically about the material they are reading. The Critical Thinking discussion on p. 327 will help them to develop the valuable skills of identifying similarities and differences between ideas. (Ross, 1987)

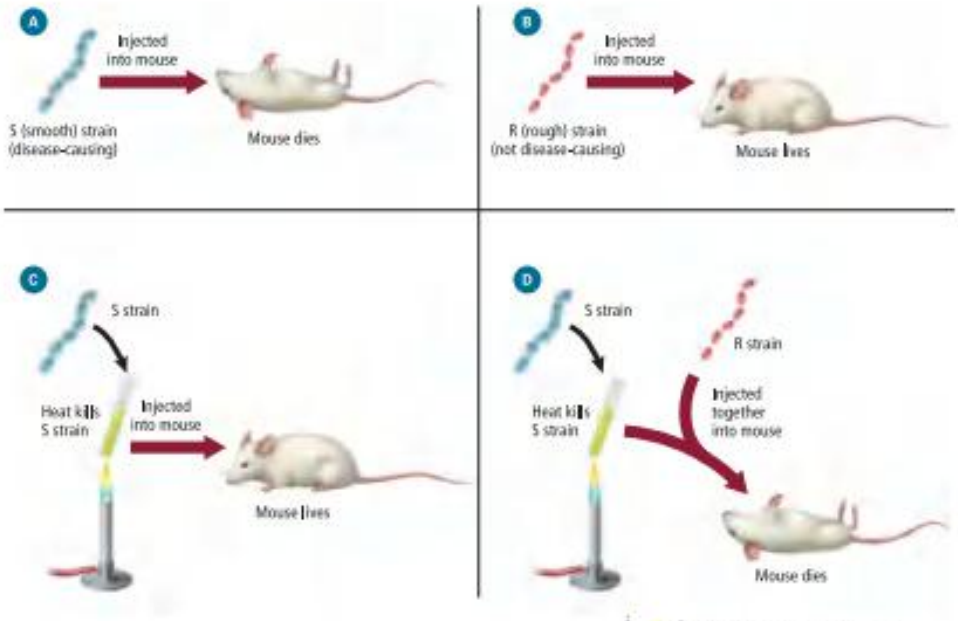


Figure 2 Griffith's transformation experiment demonstrates the change of rough bacteria into smooth bacteria.
Explain *why Griffith concluded there had been a change from live R bacteria to live S bacteria.*

Avery In 1944, Oswald Avery and his colleagues identified the molecule that transformed the R strain of bacteria into the S strain. Avery isolated different macromolecules, such as DNA, proteins, and lipids, from killed S cells. Then he exposed live R cells to the macromolecules separately. When the live R cells were exposed to the S strain DNA, they were transformed into S cells. Avery concluded that when the S cells in Griffith's experiments were killed, DNA was released. Some of the R bacteria incorporated this DNA into their cells, and this changed the bacteria into S cells. Avery's conclusions were not widely accepted by the scientific community, and many biologists continued to question and experiment to determine whether proteins or DNA were responsible for the transfer of genetic material.

Reading Check **Explain** how Avery discovered the transforming factor.

Hershey and Chase In 1952, Alfred Hershey and Martha Chase published results of experiments that provided definitive evidence that DNA was the transforming factor. These experiments involved a bacteriophage (bak TIHR ee uh fayj), a type of virus that attacks bacteria. Two components made the experiment ideal for confirming that DNA is the genetic material. **First** the bacteriophage used in the experiment was made of DNA and protein. **Second**, viruses cannot replicate themselves. They must inject their genetic material into a living cell to reproduce. Hershey and Chase labeled both parts of the virus to determine which part was injected into the bacteria and, thus, which part was the genetic material.

VOCABULARY
ACADEMIC VOCABULARY
Transform
to cause a change in type or kind
Avery used DNA to transform bacteria.

Content Background

Teacher FYI According to J. Watson, one of the scientists who discovered the structure of DNA, the race to find the genetic material was split into two groups: those who thought the genetic material was protein and those who thought the genetic material was DNA. One of the main protein proponents was Nobel Prize-winning chemist Linus Pauling. Watson's background in virology made him well aware of the Hershey-Chase experiment, which helped convince him that the genetic material was DNA.

Skill Practice
BL OL AL

Recognize Cause and Effect

ASK STUDENTS: ***What type of bacteria caused the mouse in Figure 2D to die?*** smooth bacteria ***Where did this type of bacteria come from?*** The bacteria were converted by a transforming substance from a rough to a smooth form of bacteria, which killed the mouse.

Writing Support
OL AL **Creative Writing**

Have students write a poem, story, or play about the Griffith experiment. Tell them that their creative work should demonstrate an understanding of the scientific process and the methods of the Griffith experiment.

Critical Thinking
OL AL **Differentiate**

ASK STUDENTS: ***How did Avery's experiment differ from Griffith's experiment?*** Griffith found that one strain of bacteria could be transformed to another and concluded that a transforming factor was involved. Avery tested to see which molecule changed the R strain into the S strain of bacteria. He found that DNA was the transforming molecule.

Caption Question **Fig. 2** The mouse died.

Reading Check When Avery exposed live R strain bacteria to DNA from killed S strain bacteria, the R cells were transformed to S cells.

Section 1 • DNA: The Genetic Material 35

Critical Thinking

BL OL AL **Conclude**

ASK STUDENTS: ***What was the purpose of using radioactive labeled sulfur and phosphorus?***

This allowed the experimenters to track what happened to the protein, which was labeled with radioactive sulfur, and the DNA, which was labeled with radioactive phosphorus, throughout the experiment.

Develop Concepts

BL OL AL COOP LEARN

Activity Organize students into groups of three or four and have them make a comic-style cartoon about the Hershey-Chase experiment. Text bubbles should contain conversations that explain the experimental procedure of radioactive labeling to trace molecules. Students can draw their final version of the cartoon in color on poster board or large sheets of paper. Hang cartoons around the classroom for other groups to examine.

Reading Check It showed that the genetic material in the form of DNA, not proteins, had entered the bacteria.

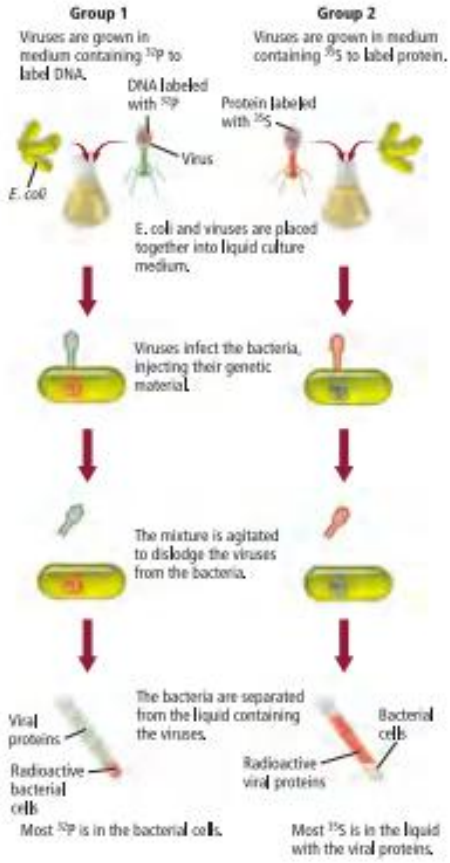


Figure 3 Hershey and Chase used radioactive labeling techniques to demonstrate that DNA is the genetic material in viruses.

Radioactive labeling Hershey and Chase used a technique called radioactive labeling to trace the fate of the DNA and protein as the bacteriophages infected bacteria and reproduced. Follow along in **Figure 3** as you continue learning about the Hershey-Chase experiment. They labeled one set of bacteriophages with radioactive phosphorus (^{32}P). Proteins do not contain phosphorous, so DNA and not protein in these viruses would be radioactive. Hershey and Chase labeled another set of bacteriophages with radioactive sulfur (^{35}S). Because proteins contain sulfur and DNA does not, proteins and not DNA would be radioactive.

Hershey and Chase infected bacteria with viruses from the two groups. When viruses infect bacteria, they attach to the outside of the bacteria and inject their genetic material. The infected bacteria then were separated from the viruses.

Tracking DNA Hershey and Chase examined Group 1 labeled with ^{32}P and found that the labeled viral DNA had been injected into the bacteria. Viruses later released from the infected bacteria contained ^{32}P, further indicating that DNA was the carrier of genetic information.

When examining Group 2 labeled with ^{35}S, Hershey and Chase observed that the labeled proteins were found outside of the bacterial cells. Viral replication had occurred in the bacterial cells, indicating that the viruses' genetic material had entered the bacteria, but no label (^{35}S) was found. **Table 1** summarizes the results of the Hershey-Chase experiment.

Based on their results, Hershey and Chase concluded that the viral DNA was injected into the cell and provided the genetic information needed to produce new viruses. This experiment provided powerful evidence that DNA, not protein, was the genetic material that could be passed from generation to generation in viruses.

Reading Check **Explain** why it is important that new viruses were produced in the bacteria.

Table 1 **Summary of Hershey-Chase Results**

Group 1 (Viruses labeled with ^{32}P)		Group 2 (Viruses labeled with ^{35}S)	
Infected Bacteria	**Liquid with Viruses**	**Infected Bacteria**	**Liquid with Viruses**
• Labeled viral DNA (^{32}P) found in the bacteria • Viral replication occurred • New viruses contained ^{32}P	• No labeled DNA • No viral replication	• No labeled viral proteins (^{35}S) • Viral replication occurred • New viruses did not have a label	• Labeled proteins found • No viral replication

36 Chapter 2 • Molecular Genetics

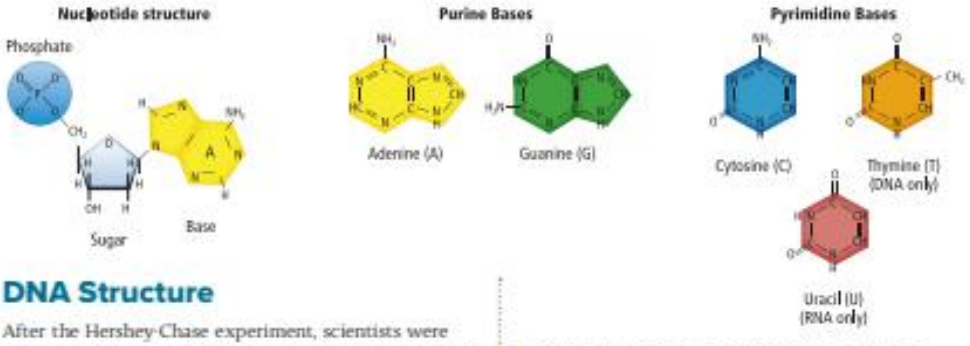


Figure 4 Nucleotides are made of a phosphate, sugar, and a base. There are five different bases found in nucleotide subunits that make up DNA and RNA.
Identify *the structural difference between purine and pyrimidine bases.*

DNA Structure

After the Hershey-Chase experiment, scientists were more confident that DNA was the genetic material. The clues had led to the identification of the genetic material, but the questions of how nucleotides came together to form DNA and how DNA could communicate information remained.

Nucleotides In the 1920s, the biochemist P. A. Levene determined the basic structure of nucleotides that make up DNA. Nucleotides are the subunits of nucleic acids and consist of a five-carbon sugar, a phosphate group, and a nitrogenous base. The two nucleic acids found in living cells are DNA and RNA. DNA nucleotides contain the sugar deoxyribose (dee ahk sih RI bos), a phosphate, and one of four nitrogenous bases: adenine (A duh neen), guanine (GWAH neen), cytosine (SI tuh seen), or thymine (THI meen). RNA nucleotides contain the sugar ribose, a phosphate, and one of four nitrogenous bases: adenine, guanine, cytosine, or uracil (YOO ruh sihl). Notice in **Figure 4** that guanine (G) and adenine (A) are double-ringed bases. This type of base is called a purine base. Thymine (T), cytosine (C), and uracil (U) are single-ringed bases called pyrimidine bases.

Chargaff Erwin Chargaff analyzed the amount of adenine, guanine, thymine, and cytosine in the DNA of various species. A portion of Chargaff's data, published in 1950, is shown in **Figure 5.** Chargaff found that the amount of guanine nearly equals the amount of cytosine, and the amount of adenine nearly equals the amount of thymine within a species. This finding is known as Chargaff's rule: C = G and T = A.

The structure question When four scientists joined the search for the DNA structure, the meaning and importance of Chargaff's data became clear. Rosalind Franklin, a British chemist; Maurice Wilkins, a British physicist; Francis Crick, a British physicist; and J. Watson, an American biologist, provided information that was pivotal in answering the DNA structure question.

Figure 5 Chargaff's data showed that though base composition varies from species to species, within a species C = G and A = T.

Chargaff's Data

	Base Composition (Mole Percent)			
Organism	A	T	G	C
Escherichia coli	26.0	23.9	24.9	25.2
Yeast	31.3	32.9	18.7	17.1
Herring	27.8	27.5	22.2	22.6
Rat	28.6	28.4	21.4	21.5
Human	30.9	29.4	19.9	19.8

Activity

BL OL AL Model DNA Have pairs of students make a candy model of DNA with three types of candies. One type of candy can represent the deoxyribose; another can represent phosphate groups. Small candies, such as jelly beans in four different colors, can represent A, T, C, or G. Have students attach their model to construction paper using glue and write a key to their candy representations. Est. time: 30 min

S Skill Practice

BL OL AL Visual Literacy

Before students read the text under the heading *Nucleotides*, have them examine Figure 5 and see if they can determine any type of ratio relationship among the base amounts found by Chargaff. The amount of guanine almost equals the amount of cytosine, and thymine almost equals adenine.

ASK STUDENTS: ***Why are the percentages not exactly the same?*** experimental error

D Develop Concepts

BL OL AL COOP LEARN

Activity Organize students into groups of three, and give each group 20 strips of paper of four distinct colors, such as red, green, yellow, and blue. Have them write *T* on one color, *G* on one color, *A* on one color, and *C* on one color. Ask them to tape the strips end to end in any order they wish. See if any group came up with the same sequence, which is unlikely. Point out that these represent nucleotide units, the building blocks of DNA, making a polymer. This activity emphasizes the wide variety of coding that is possible, even using only 20 nucleotides.

ASK STUDENTS: ***How many possible combinations can the 20 colored strips form?*** The possible combinations of 4 colors, 20 strips long is 4^{20} or 1×10^{12}. Use this activity to demonstrate the wide variety of proteins that can be synthesized from a short DNA sequence.

Caption Question **Fig. 4** Purine bases have two rings, and pyrimidine bases have one ring.

Writing Support

BL OL COOP LEARN

Creative Writing Organize students into groups of three, and have groups develop a poster about DNA. Poster topics may focus on such elements as the discovery of the structure of DNA in 1953, a biography of a key scientist and his or her contributions, or the importance of DNA to modern genetics, medicine, and biotechnology.

Assess Content Development

Assess how understanding has developed when students revisit the Launch Lab analysis questions.

D Develop Concepts

BL OL AL **Activity** Write the sequence of a strand of nucleotide bases on the board indicating the 3' and 5' ends. Have students write the complementary strand to go with this coding strand. Write the correct strand on the board aligned with the coding strand. C pairs with G and T pairs with A.

Reading Check Chargraff's data hinted that bases were specifically paired.

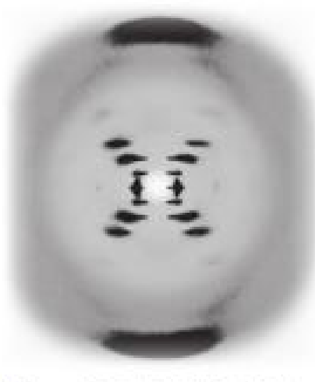


Figure 6 Rosalind Franklin's Photo 51 and X-ray diffraction data helped Watson and Crick solve the structure of DNA. When analyzed and measured carefully, the pattern shows the characteristics of helix structure.

Review Based on what you've read about the history of DNA experiments, how would you now answer the analysis questions?

X-ray diffraction Wilkins was working at King's College in London, England, with a technique called X-ray diffraction, a technique that involved aiming X rays at the DNA molecule. In 1951, Franklin joined the staff at King's College. There she took the now famous Photo 51 and collected data eventually used by Watson and Crick. Photo 51, shown in **Figure 6,** indicated that DNA was a **double helix,** or twisted ladder shape, formed by two strands of nucleotides twisted around each other. The specific structure of the DNA double helix was determined later by Watson and Crick when they used Franklin's data and other mathematical data. DNA is the genetic material of all organisms, composed of two complementary, precisely paired strands of nucleotides wound in a double helix.

Watson and Crick Watson and Crick were working at Cambridge University in Cambridge, England, when they saw Franklin's X-ray diffraction picture. Using Chargaff's data and Franklin's data, Watson and Crick measured the width of the helix and the spacing of the bases. Together, they built a model of the double helix that conformed to the others' research. The model that they built is shown in **Figure 7.** Some important features of their proposed molecule include the following:

1. Two outside strands consist of alternating deoxyribose and phosphate.
2. Cytosine and guanine bases pair to each other by three hydrogen bonds.
3. Thymine and adenine bases pair to each other by two hydrogen bonds.

DNA structure DNA often is compared to a twisted ladder, with the rails of the ladder represented by the alternating deoxyribose and phosphate. The pairs of bases (cytosine-guanine or thymine-adenine) form the steps, or rungs, of the ladder. A purine base always binds to a pyrimidine base, ensuring a consistent distance between the two rails of the ladder. This proposed bonding of the bases also explains Chargaff's data, which suggested that the number of purine bases equaled the number of pyrimidine bases in a sample of DNA. Remember, cytosine and thymine are pyrimidine bases, adenine and guanine are purines, and C = G and A = T. Therefore, C + T = G + A, or purine bases equal pyrimidine bases. Complementary base pairing is used to describe the precise pairing of purine and pyrimidine bases between strands of nucleic acids. It is the characteristic of DNA replication through which the parent strand can determine the sequence of a new strand.

Reading Check **Explain** why Chargaff's data was an important clue for putting together the structure of DNA.

Figure 7 Using Chargaff's and Franklin's data, Watson and Crick, shown here, solved the puzzle of the structure of DNA.

Demonstration

Double Helix Construct a DNA model that demonstrates the double helix. Link two chains of ten paper clips together, alternating small and large paper clips (phosphate = small paper clip, deoxyribose = large paper clip). Insert the ends of each strand of clips into a 4-cm × 8-cm polystyrene block, about 5 cm apart. Insert the other ends of the strands into a similar polystyrene block. Use four different colors of either twist ties or colored pipe cleaners to represent the bases and connect the two strands across at the large paper clips. Hold the structure up and twist one of the blocks to demonstrate the double helix. Est. time: 10 min

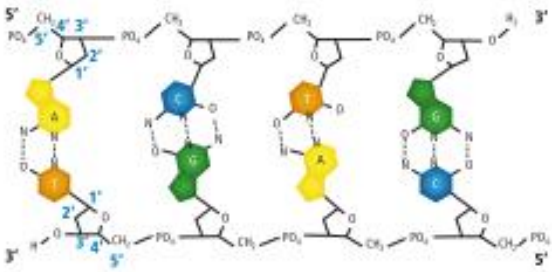


Figure 8 Two strands of DNA running antiparallel make up the DNA helix.
Explain *why the ends of the DNA strands are labeled 3′ and 5′.*

Orientation Another unique feature of the DNA molecule is the direction, or orientation, of the two strands. Carbon molecules can be numbered in organic molecules. **Figure 8** shows the orientation of the numbered carbons in the sugar molecules on each strand of DNA. On the top rail, the orientation of the sugar has the 5′ (read "five-prime") carbon on the left, and on the end of that rail, the 3′ (read "three-prime") carbon is on the right of the sugar-phosphate chain. The strand is said to be oriented 5′ to 3′. The strand on the bottom runs in the opposite direction and is oriented 3′ to 5′. This orientation of the two strands is called antiparallel. Another way to visualize antiparallel orientation is to take two pencils and position them so that the point of one pencil is next to the eraser of the other and vice versa.

The announcement In 1953, Watson and Crick surprised the scientific community by publishing a one-page letter in the journal *Nature* that suggested a structure for DNA and hypothesized a method of replication for the molecule deduced from the structure. In articles individually published in the same issue, Wilkins and Franklin presented evidence that supported the structure proposed by Watson and Crick. Still, the mysteries of how to prove DNA's replication and how it worked as a genetic code remained.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Prime

Science usage: a mark located above and to the right of a character, used to identify a number or variable
Carbon molecules in organic molecules are numbered and labeled with a prime.

Common usage: first in value, excellence, or quality
The student found the prime seats in the stadium for watching the game.

MiniLab 1

Model DNA Structure

What is the structure of the DNA molecule? Construct a model to better understand the structure of the DNA molecule.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Construct a model of a short segment of DNA using the materials provided by your teacher.
3. Identify which parts of the model correspond to the different parts of a DNA molecule.

Analysis

1. **Describe** the structure of your DNA molecule.
2. **Identify** the characteristics of DNA that you focused on when constructing your model.
3. **Infer** in what way your model is different from your classmates' models. How does this relate to differences in DNA among organisms?

Differentiated Instruction

Struggling Learners Before beginning the MiniLab on this page, model each step for Struggling learners. This reinforcement will reduce confusion.

Caption Question **Fig. 8** because of the orientation of the carbon atoms in the sugar

MiniLab 1

Est. Time 30 min

Safety Precaution Discuss the safety concerns of this lab before work begins.

Teaching Strategies

- Couple the model-building with appropriate A/V materials on DNA, if available.
- Have each lab team show you their finished model and explain the structure of DNA to you.
- A time-saving alternative is to buy one kit and conduct this lab as a teacher-led demonstration.

Analysis

1. It appears to have side rails with rungs between them, and the rungs twist like a spiral staircase.
2. The sugar and phosphate groups represent the handrails; the bases represent the steps or rungs.
3. The rungs in different models contain a variety of bases that represent the genetic code. With the exception of identical twins or triplets, each organism has a unique genetic code.

GOING GREEN Have students use items that would have normally become trash to build their models in MiniLab 1. These Items could include empty cereal boxes, clean plastic containers, paper towel rolls, and scrap paper.

Develop Concepts

BL OL

Clarify a Misconception

ASK STUDENTS: ***What is the relationship among genes, DNA, and chromosomes?*** Genes are specific sequences of DNA in a chromosome, and they code for a protein. Some students might have difficulty understanding the concept of a gene and a chromosome. They might have a basic understanding of the idea of inheritance being associated with a gene, but might have difficulty understanding the relationship between DNA and genes and between genes and chromosomes.

Formative Assessment

Evaluation

ASK STUDENTS: ***Which experiments first showed what molecule carries the genetic information?*** Griffith and Avery experiments ***Which experiment first showed that DNA enabled the replication of viruses?*** Hershey and Chase experiment ***Which experiment demonstrated the ratio of the nucleotides in DNA?*** Chargaff experiment ***Which four individuals were involved in solving the structure of DNA?*** Watson, Crick, Wilkins, and Franklin

Remediation Obtain and distribute blank diagrams representing the experiments above. Have students label and explain each experiment.

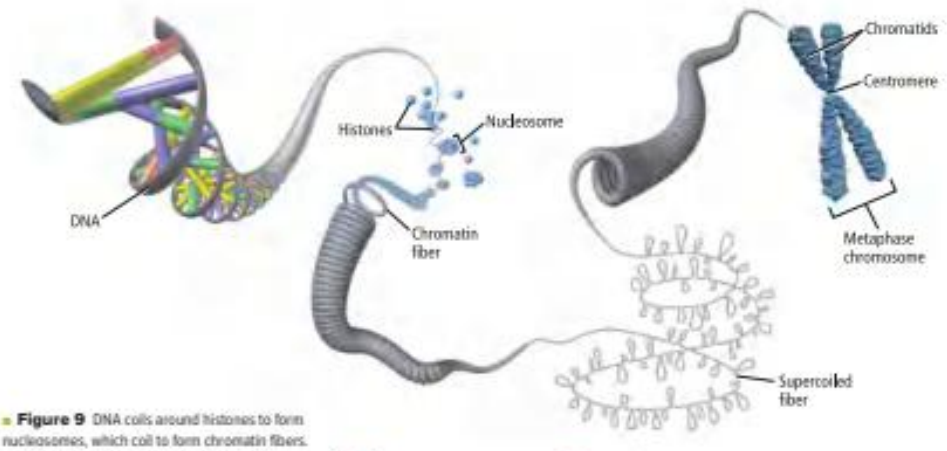


Figure 9 DNA coils around histones to form nucleosomes, which coil to form chromatin fibers. The chromatin fibers supercoil to form chromosomes that are visible in the metaphase stage of mitosis.

Chromosome Structure

In prokaryotes, the DNA molecule is contained in the cytoplasm and consists mainly of a ring of DNA and associated proteins. Eukaryotic DNA is organized into individual chromosomes. The length of a human chromosome ranges from 51 million to 245 million base pairs. If a DNA strand 140 million nucleotides long was laid out in a straight line, it would be about five centimeters long. How does all of this DNA fit into a microscopic cell? In order to fit into the nucleus of a eukaryotic cell, the DNA tightly coils around a group of beadlike proteins called histones, as shown in **Figure 9.** The phosphate groups in DNA create a negative charge, which attracts the DNA to the positively charged histone proteins and forms a **nucleosome.** The nucleosomes then group together into chromatin fibers, which supercoil to make up the DNA structure recognized as a chromosome.

Section 1 Review

Section Summary

- Griffith's bacterial experiment and Avery's explanation first indicated that DNA is the genetic material.
- The Hershey-Chase experiment provided evidence that DNA is the genetic material of viruses.
- Chargaff's rule states that in DNA the amount of cytosine equals the amount of guanine and the amount of thymine equals the amount of adenine.
- The work of Watson, Crick, Franklin, and Wilkins provided evidence of the double-helix structure of DNA.

Understand Main Ideas

1. MAIN Idea **Summarize** the experiments of Griffith and Avery that indicated that DNA is the genetic material.
2. **Describe** the data used by Watson and Crick to determine the structure of DNA.
3. **Draw** and label a segment of DNA showing its helix and complementary base pairing.
4. **Describe** the structure of eukaryotic chromosomes.

Think Critically

5. **Describe** two characteristics that DNA needs to fulfill its role as a genetic material.
6. **Evaluate** Hershey and Chase's decision to use radioactive phosphorus and sulfur for their experiments. Could they have used carbon or oxygen instead? Why or why not?

Section 1 Review

1. Griffith showed that bacteria could be transformed by the transfer of genetic material; Avery showed that DNA was the transforming factor.
2. Franklin's Photo 51 showed a helix shape. Her mathematical data showed distances between the strands. Chagraff's data suggested how bases pair.
3. Drawings should show C ≡ G and A = T base pairing and the antiparallel orientation of the strands.
4. DNA coils around histones to form nucleosomes, which group together to form chromatin fibers, which supercoil to make the chromosome.
5. DNA must code for proteins and be able to replicate.
6. They used radioactive sulfur because sulfur is found only in proteins, and radioactive phosphorus because phosphorus is found only in DNA. They could not have used carbon or oxygen because those elements are found in both DNA and proteins.

Essential Questions

- What is the role of enzymes in the replication of DNA?
- How are leading and lagging strands synthesized differently?
- How does DNA replication compare in eukaryotes and prokaryotes?

Review Vocabulary

template: a molecule of DNA that is a pattern for synthesis of a new DNA molecule

New Vocabulary

semiconservative replication
DNA polymerase
Okazaki fragment

Replication of DNA

MAIN Idea **DNA replicates by making a strand that is complementary to each original strand.**

Real-World Reading Link When copies are made using a photocopy machine, they are expected to be exact copies of the original. Making a copy would not be very efficient if it contained errors that were not in the original. Think about how your body might make copies of DNA.

Semiconservative Replication

When Watson and Crick presented their model of DNA to the science community, they also suggested a possible method of replication called semiconservative replication. During **semiconservative replication,** parental strands of DNA separate, serve as templates, and produce DNA molecules that have one strand of parental DNA and one strand of new DNA. Recall that DNA replication occurs during interphase of mitosis and meiosis. An overview of semiconservative replication is in **Figure 10.** The process of semiconservative replication occurs in three main stages: unwinding, base pairing, and joining.

Unwinding DNA helicase, an enzyme, is responsible for unwinding and unzipping the double helix. When the double helix is unzipped, the hydrogen bonds between the bases are broken, leaving single strands of DNA. Then, proteins called single-stranded binding proteins associate with the DNA to keep the strands separate during replication. As the helix unwinds, another enzyme, RNA primase, adds a short segment of RNA, called an RNA primer, on each DNA strand.

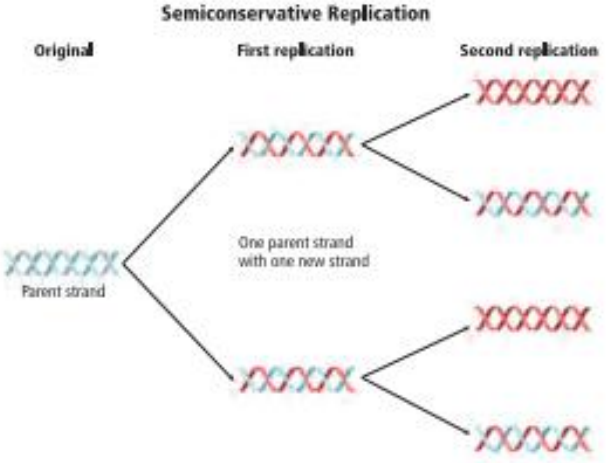


Figure 10 In semiconservative replication, the parental DNA separates and serves as templates to produce two daughter DNA, which then can separate to produce four DNA.

Differentiated Instruction

Gifted The SQ3R Reading Strategy on this page can be extended for students working above grade level. Develop open-ended questions that require students to think critically about the reading instead of just read for information. Sample question: ***What might happen if DNA replication was not semiconservative?*** If one strand of DNA was not available as a template for making a new strand, as occurs during semiconservative replication, many errors in the new DNA could occur.

Section 2

MAIN Idea

BL OL AL Making Copies

When Watson and Crick looked at the structure of DNA, they said, ". . . the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

ASK STUDENTS: ***What pairing were these scientists referring to?*** the hydrogen bonds between the nucleotides: adenine to thymine and guanine to cytosine

R Reading Strategy

BL OL SQ3R Have students **S**urvey the text under the heading *Semiconservative Replication*. Next, have students write **Q**uestions about key points made in this section. Then have students **R**ead the section and make notes related to the questions. Finally, have students **R**ecite vocabulary and **R**eview for meaning.

C Critical Thinking

OL Hypothesize

ASK STUDENTS: ***What would be the result if DNA replication took place after mitosis occurred?*** Some of the daughter cells might have no DNA, some might not have copies of all chromosomes, and some might have double the amount of DNA. Those cells without DNA, lacking copies of all chromosomes, and with double the DNA would likely die.

S Skill Practice

BL OL AL Visual Literacy

Have students study the information in Figure 10. Based on what students have learned about DNA so far, have them predict how the process of semiconservative replication works.

Writing Support

OL AL Narrative Writing

Have students write a paragraph explaining why the term *semiconservative* is a good name for the way by which DNA replicates. Paragraphs should describe how parent strands are used to build new DNA so that the new DNA is half "old" DNA.

MiniLab 2

Est. Time 30 min

Safety Precaution Discuss the safety concerns of this lab before work begins.

Teaching Strategy As an alternative, purchase a single kit and conduct this lab as a teacher-led demonstration.

Analysis

1. One strand (the parental strand) is from the original DNA molecule and makes up half of the new strand.
2. Nucleotides might not link up in the new strand. DNA ligase finishes the nucleotide-linking process.
3. during base pairing

The lab at the end of the chapter can be used at this point in the lesson.

Reading Check Each base binds only to its complement.

Caption Question Fig. 11
Because the lagging strand is in the opposite orientation (5' to 3') than the direction of replication, it must be synthesized in segments. Replication cannot occur in the lagging strand until the helix opens far enough to add another piece.

MiniLab 2

Model DNA Replication

How does the DNA molecule replicate? Use a model to better understand the replication of the DNA molecule.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Use your DNA model from **MiniLab 1** and extra pieces to model the replication of your segment of DNA.
3. Use your model to demonstrate DNA replication for a classmate, and identify the enzymes involved in each step.

Analysis

1. **Explain** how your model of DNA replication shows semiconservative replication.
2. **Infer** how DNA replication in a cell would be affected by an absence of DNA ligase.
3. **Identify** where errors could occur in the replication process.

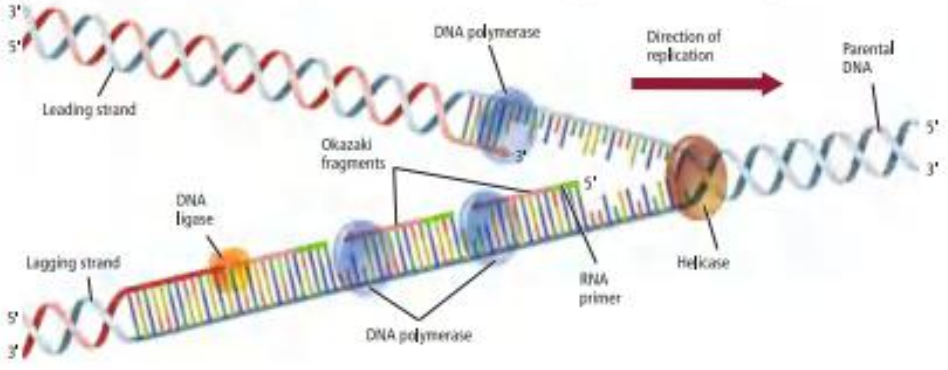
Base pairing The enzyme **DNA polymerase** catalyzes the addition of appropriate nucleotides to the new DNA strand. The nucleotides are added to the 3' end of the new strand, as illustrated in **Figure 11.** DNA polymerase continues adding new DNA nucleotides to the chain by adding to the 3' end of the new DNA strand. Recall that each base binds only to its complement–A binds to T and C binds to G. In this way, the templates allow identical copies of the original double-stranded DNA to be produced.

Notice in **Figure 11** that the two strands are made in a slightly different manner. One strand is called the leading strand and is elongated as the DNA unwinds. This strand is built continuously by the addition of nucleotides to the 3' end.

The other strand of DNA, called the lagging strand, elongates away from the replication fork. It is synthesized discontinuously into small segments, called **Okazaki fragments,** by the DNA polymerase in the 3' to 5' direction. These fragments are later connected by the enzyme DNA ligase. Each Okazaki fragment is about 100-200 nucleotides long in eukaryotes. Because one strand is synthesized continuously and the other is synthesized discontinuously, DNA replication is said to be semidiscontinuous as well as semiconservative.

Reading Check **Explain** how base pairing during replication ensures that the strands produced are identical to the original strand.

Figure 11 The DNA strands are separated during replication as each parent strand serves as a template for new strands.
Infer *why the lagging strand produces fragments instead of being synthesized continuously.*



Demonstration

BL OL Unzip DNA Hold up a zipper and unzip it.
ASK STUDENTS: ***How does this model represent the unzipping of DNA? Analyze where it fails.*** The zipper can unzip in small sections like DNA. Its sliding device is like the DNA polymerase, but polymerase does not go in both directions, and a zipper isn't replicated when the sliding device moves.
Est. time: 5 min

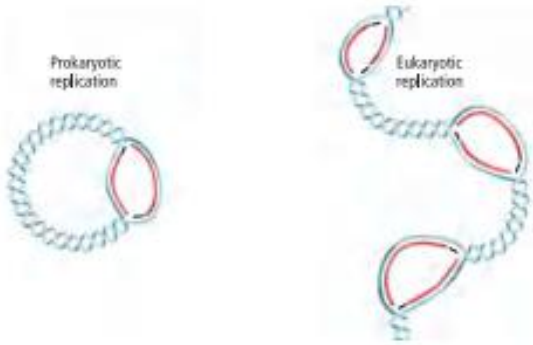


Figure 12 Eukaryotes have many origins of replication. Bacteria have one origin of replication, with the DNA replicating in both directions when it unzips.

Joining Even though the leading strand is synthesized continuously, in eukaryotic DNA replication there often are many areas along the chromosome where replication begins. When the DNA polymerase comes to an RNA primer on the DNA, it removes the primer and fills in the place with DNA nucleotides. When the RNA primer has been replaced, DNA ligase links the two sections.

Comparing DNA Replication in Eukaryotes and Prokaryotes

Eukaryotic DNA unwinds in multiple areas as DNA is replicated. Each individual area of a chromosome replicates as a section, which can vary in length from 10,000 to one million base pairs. As a result, multiple areas of replication are occurring along the large eukaryotic chromosome at the same time. Multiple replication origins look like bubbles in the DNA strand, as shown in **Figure 12.**

In prokaryotes, the circular DNA strand is opened at one origin of replication, as shown in **Figure 12.** Notice in the figure that DNA replication occurs in two directions, just as it does in eukaryotes. Remember that prokaryotic DNA is typically shorter than eukaryotic DNA and remains in the cytoplasm, not packaged in a nucleus.

Section 2 Review

Section Summary

- The enzymes DNA helicase, RNA primase, DNA polymerase, and DNA ligase are involved in DNA replication.
- The leading strand is synthesized continuously, but the lagging strand is synthesized discontinuously, forming Okazaki fragments.
- Prokaryotic DNA opens at a single origin of replication, whereas eukaryotic DNA has multiple areas of replication.

Understand Main Ideas

1. MAIN Idea **Indicate** the sequence of the template strand if a nontemplate strand has the sequence 5′ ATGGGGCGC 3′.
2. **Describe** the role of DNA helicase, DNA polymerase, and DNA ligase.
3. **Diagram** the way leading and lagging strands are synthesized.
4. **Explain** why DNA replication is more complex in eukaryotes than in bacteria.

Think Critically

MATH in Biology

5. If the bacteria *E. coli* synthesize DNA at a rate of 100,000 nucleotides per min and it takes 30 min to replicate the DNA, how many base pairs are in an *E. coli* chromosome?

Develop Concepts

BL OL **Clarify a Misconception**

ASK STUDENTS: ***Explain the relationship of DNA replication to mitosis, meiosis, and reproduction.*** DNA must be replicated before the other steps can take place. Students do not always tie DNA replication to mitosis, meiosis, and reproduction. Point out that these processes rely on prior DNA replication to duplicate the chromosomes so that genes are passed to offspring cells.

Develop Concepts

BL OL AL **Activity** On the board, write a DNA sequence about 20 nucleotides long and the same DNA sequence with a portion unzipped as replication begins. Have students copy this and finish the replication in a third drawing by writing the complementary strand.

Formative Assessment

Evaluation Have students write a step-by-step summary of the replication of DNA. Have them exchange papers with a partner and have the partners evaluate the summary to determine whether any of the steps or important information is missing.

Remediation Have students write questions that they have about DNA and replication. Collect student questions and read them aloud. Have a student volunteer read aloud the relevant text in the book.

Section 2 Review

1. 3′ TACCCCGCG 5′
2. DNA helicase is an enzyme that unwinds the DNA, DNA polymerase is an enzyme that builds the new DNA strand during replication, and DNA ligase hooks DNA Okazaki fragments together.
3. Diagrams should show that leading strands are synthesized continuously, while lagging strands are synthesized in fragments that are later connected.
4. The structure of the chromosome is much more complex and the chromosome is larger in eukaryotic cells. Eukaryotic cells have many origins of replication, whereas prokaryotes only have one.
5. 3,000,000 base pairs

Section 3

MAIN Idea

BL OL AL Protein Blueprint

ASK STUDENTS: ***Suppose you are going to build a house. What would you need to do first?*** An architect would first need to draw a house plan, or blueprint, that indicates the design of the house. Develop the analogy of an architect (cell) needing plans to build a house (a protein). ***Once the plans are drawn, what is next?*** The plans need to be read by the contractor and the area where the house is to be built needs to be staked out. Use this analogy with the mRNA (contractor) reading the plans of the DNA and carrying the message to the building site (ribosome). Materials (amino acids) will be brought in according to the plans by delivery trucks (tRNA). The whole process of building the house (protein) will cost a significant amount of money (energy) to the architect (cell).

W Writing Support

BL OL AL

Creative Writing As students read the text under the heading *Central Dogma*, have them think about the analogy of DNA as a cookbook recipe. Once they have read the text, organize students into pairs and have them write a recipe that develops this analogy further. One example might be making a cake (protein) with the recipe analogous to the DNA code, utensils analogous to RNAs, and ingredients analogous to amino acids. However, the difference is that recipes don't always have to follow the same sequence, whereas DNA, RNA, and protein must go in order.

Section 3

Essential Questions

- How are messenger RNA, ribosomal RNA, and transfer RNA involved in the transcription and translation of genes?
- What is the role of RNA polymerase in the synthesis of messenger RNA?
- How is the code of DNA translated into messenger RNA and utilized to synthesize a protein?

Review Vocabulary

synthesis: the composition or combination of parts to form a whole

New Vocabulary

RNA
messenger RNA
ribosomal RNA
transfer RNA
transcription
RNA polymerase
intron
exon
codon
translation

DNA, RNA, and Protein

MAIN Idea **DNA codes for RNA, which guides protein synthesis.**

Real-World Reading Link Computer programmers write their programs in a particular language, or code. The computer is designed to read the code and perform a function. Like the programming code, DNA contains a code that signals the cell to perform a function.

Central Dogma

One of the important features of DNA that remained unresolved beyond the work of Watson and Crick was how DNA served as a genetic code for the synthesis of proteins. Recall that proteins function as structural building blocks for the cells and as enzymes.

Geneticists now accept that the basic mechanism of reading and expressing genes is from DNA to RNA to protein. This chain of events occurs in all living things–from bacteria to humans. Scientists refer to this mechanism as the central dogma of biology: DNA codes for RNA, which guides the synthesis of proteins.

RNA RNA is a nucleic acid that is similar to DNA. However, **RNA** contains the sugar ribose, the base uracil replaces thymine, and usually is single stranded. Three major types of RNA are found in living cells. **Messenger RNA** (mRNA) molecules are long strands of RNA nucleotides that are formed complementary to one strand of DNA. They travel from the nucleus to the ribosome to direct the synthesis of a specific protein. **Ribosomal RNA** (rRNA) is the type of RNA that associates with proteins to form ribosomes in the cytoplasm. The third type of RNA, **transfer RNA** (tRNA) are smaller segments of RNA nucleotides that transport amino acids to the ribosome. **Table 2** compares the structures and functions of the three types of RNA.

Table 2 **Comparison of Three Types of RNA**

Name	mRNA	rRNA	tRNA
Function	Carries genetic information from DNA in the nucleus to direct protein synthesis in the cytoplasm	Associates with protein to form the ribosome	Transports amino acids to the ribosome
Example			

Content Background

Real-World Connection One exception to the central dogma is found in the enzyme reverse transcriptase, which was discovered in certain so-called retroviruses. These viruses include HIV, the virus that causes AIDS. The genetic material of a retrovirus is RNA rather than DNA. When a retrovirus invades a cell, the reverse transcriptase converts the RNA to DNA.

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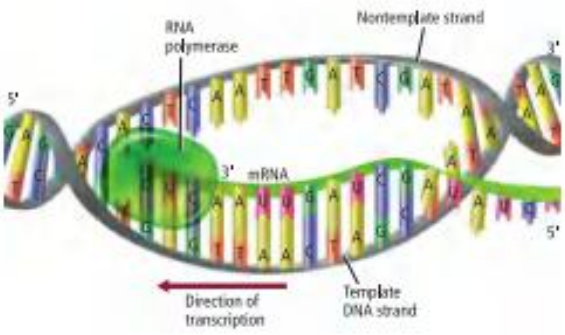


Figure 13 RNA is grown in the 5' to 3' direction.
Identify *which enzyme adds nucleotides to the growing RNA.*

Transcription The first step of the central dogma involves the synthesis of mRNA from DNA in a process called **transcription** (trans KRIHP shun). Through transcription, the DNA code is transferred to mRNA in the nucleus. The mRNA then can take the code into the cytoplasm for protein synthesis. Follow along with the process of transcription in **Figure 13.** The DNA is unzipped in the nucleus and **RNA polymerase,** an enzyme that regulates RNA synthesis, binds to a specific section where an mRNA will be synthesized. As the DNA strand unwinds, the RNA polymerase initiates mRNA synthesis and moves along one of the DNA strands in the 3' to 5' direction. The strand of DNA that is read by RNA polymerase is called the template strand, and mRNA is synthesized as a complement to the DNA nucleotides. The DNA strand not used as the template strand is called the nontemplate strand. The mRNA transcript is manufactured in a 5' to 3' direction, adding each new RNA nucleotide to the 3' end. Uracil is incorporated instead of thymine as the mRNA molecule is made. Eventually, the mRNA is released, and the RNA polymerase detaches from the DNA. The new mRNA then moves out of the nucleus through nuclear pores into the cytoplasm.

Reading check **Explain** the direction in which the mRNA transcript is manufactured.

RNA processing When scientists compared the coding region of the DNA with mRNA that ultimately coded for a protein, they found that the mRNA code is significantly shorter than the DNA code. Upon closer examination, they discovered that the code on the DNA is interrupted periodically by sequences that are not in the final mRNA. These sequences are called intervening sequences, or **introns.** The coding sequences that remain in the final mRNA are called **exons.** In eukaryotes, the original mRNA made in the nucleus is sometimes called pre-mRNA and contains all of the DNA code. Before the pre-mRNA leaves the nucleus, the introns are removed from it. Other processing of the pre-mRNA includes adding a protective cap on the 5' end and adding a tail of many adenine nucleotides, called the poly-A tail, to the 3' end of the mRNA. Research shows that the cap aids in ribosome recognition, though the significance of the poly-A tail remains unknown. The mRNA that reaches the ribosome has been processed.

FOLDABLES
Incorporate information from this section into your Foldable.

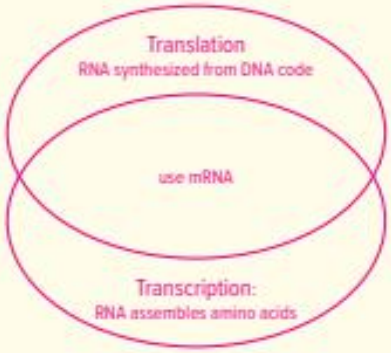
Develop Concepts
BL OL

Clarify a Misconception

ASK STUDENTS: ***Is mRNA made from both sides or one side of the DNA?*** one side: the template strand Students often have difficulty with the idea that mRNA is made only from one side of the DNA. Emphasize the difference between the template strand and the nontemplate strand each time you write or talk about the DNA strands in transcription. Students should be able to explain that one side of the DNA is the template strand and the other side is the nontemplate strand.

FOLDABLES

Going Further On the back of their Foldables, have students draw a Venn diagram to compare and contrast translation and transcription.



Caption Question **Fig. 13** RNA polymerase

Reading Check mRNA is built in a 5' to 3' direction.

Content Background

Teacher FYI RNA polymerase binds to an area of the DNA called the promoter, a sequence near the beginning of the gene. The area where the DNA is unwound by the RNA polymerase is called the transcription bubble. Within the bubble, the newly synthesized RNA remains paired with the DNA template. In those parts behind the bubble that have been transcribed, the DNA reforms a double helix and the RNA hangs out of the complex as a single strand.

Develop Concepts

BL OL

Clarify a Misconception

ASK STUDENTS: ***What accounts for the similarities among all human beings?*** Similar sequences of DNA make up genes. ***What accounts for individual differences?*** unique sequences of DNA that make up genes Students might understand that genetic differences account for individual traits but might not realize that genes also account for similarities among human beings. Common DNA sequences code for our general human features and differences in DNA sequences code for traits that make everyone unique.

Critical Thinking

BL OL **Compare**

ASK STUDENTS: ***How does decoding DNA compare to reading music?*** Musical notes represent a code for a particular sound. The musician reading the notes knows what sound to play. DNA code represents amino acids and RNA, and ribosomes translate the code and assemble the amino acids into proteins. Each codon is like a note and the notes add up to make music.

Skill Practice

BL OL AL **Visual Literacy**

Have students examine the code dictionary in Figure 14.

ASK STUDENTS: ***How many codons code for an amino acid?*** 61 ***How many codons code for "stop"?*** 3 ***What amino acid is coded by the codon AUG?*** methionine ***What is special about this particular codon (AUG)?*** It is the start codon (where the coding begins) for all mRNAs.

Caption Question Fig. 14 AUG—UCU/UCC/UCA/UCG/AGU/AGC—CAU/CAC—UGG—UAA/UAG/UGA

First Base	Second Base U	Second Base C	Second Base A	Second Base G	Third Base
U	UUU phenylalanine	UCU serine	UAU tyrosine	UGU cysteine	U
	UUC phenylalanine	UCC serine	UAC tyrosine	UGC cysteine	C
	UUA leucine	UCA serine	UAA stop	UGA stop	A
	UUG leucine	UCG serine	UAG stop	UGG tryptophan	G
C	CUU leucine	CCU proline	CAU histidine	CGU arginine	U
	CUC leucine	CCC proline	CAC histidine	CGC arginine	C
	CUA leucine	CCA proline	CAA glutamine	CGA arginine	A
	CUG leucine	CCG proline	CAG glutamine	CGG arginine	G
A	AUU isoleucine	ACU threonine	AAU asparagine	AGU serine	U
	AUC isoleucine	ACC threonine	AAC asparagine	AGC serine	C
	AUA isoleucine	ACA threonine	AAA lysine	AGA arginine	A
	AUG (start) methionine	ACG threonine	AAG lysine	AGG arginine	G
G	GUU valine	GCU alanine	GAU aspartate	GGU glycine	U
	GUC valine	GCC alanine	GAC aspartate	GGC glycine	C
	GUA valine	GCA alanine	GAA glutamate	GGA glycine	A
	GUG valine	GCG alanine	GAG glutamate	GGG glycine	G

Figure 14 This "dictionary" of the genetic code is helpful for knowing which codons code for which amino acids.

Determine ***the possible sequences that would produce the amino acid chain: start—serine—histidine—tryptophan—stop.***

The Code

Biologists began to hypothesize that the instructions for protein synthesis are encoded in the DNA. They recognized that the only way the DNA varied among organisms was in the sequence of the bases. Scientists knew that 20 amino acids were used to make proteins, so they knew that the DNA must provide at least 20 different codes.

Connection to Math The hypothesis for how the bases formed the code is based on math and logic. If each base coded for one amino acid, then the four bases could code for four amino acids. If each pair of bases coded for one amino acid, then the four bases could only code for 16 (4×4 or 4^2) amino acids. However, if a group of three bases coded for one amino acid, there would be 64 (4^3) possible codes. This provides more than the 20 codes needed for the 20 amino acids, but is the smallest possible combination of bases to provide enough codes for the amino acids.

This reasoning meant that the code was not contained in the base pairs themselves, but must run along a single strand of the DNA. Experiments during the 1960s demonstrated that the DNA code was indeed a three-base code. The three-base code in DNA or mRNA is called a **codon.** Each of the three bases of a codon in the DNA is transcribed into the mRNA code. **Figure 14** shows a "dictionary" of the genetic code. Notice that all but three codons are specific for an amino acid; these three are stop codons. Codon AUG codes for the amino acid methionine and also functions as the start codon.

Translation Once the mRNA is synthesized and processed, it moves to the ribosome. In eukaryotes, this means the mRNA must leave the nucleus and enter the cytoplasm. Once in the cytoplasm, the 5′ end of the mRNA connects to the ribosome. This is where the code is read and translated to make a protein through a process called **translation.** Follow along in **Figure 15** as you learn about translation.

In translation, tRNA molecules act as the interpreters of the mRNA codon sequence. The tRNA is folded into a cloverleaf shape and is activated by an enzyme that attaches a specific amino acid to the 3′ end. At the middle of the folded strand, there is a three-base coding sequence called the anticodon. Each anticodon is complementary to a codon on the mRNA. Though the code in DNA and RNA is read 5′ to 3′, the anticodon is read 3′ to 5′.

Research Citation

Visual Literacy Educational research indicates that using graphic organizers like the one described on page 337 can help students with higher-order thinking skills such as making comparisons. By providing a visual representation of the information, teachers can address a variety of learning styles and needs. (Horowitz, 1985)

Differentiated Instruction

Physically Disabled When working with students with physical disabilities, know their strengths and abilities. When students are working in groups, assign tasks so that physically disabled students are given responsibilities that utilize their abilities so they can contribute in a meaningful way to their group's task.

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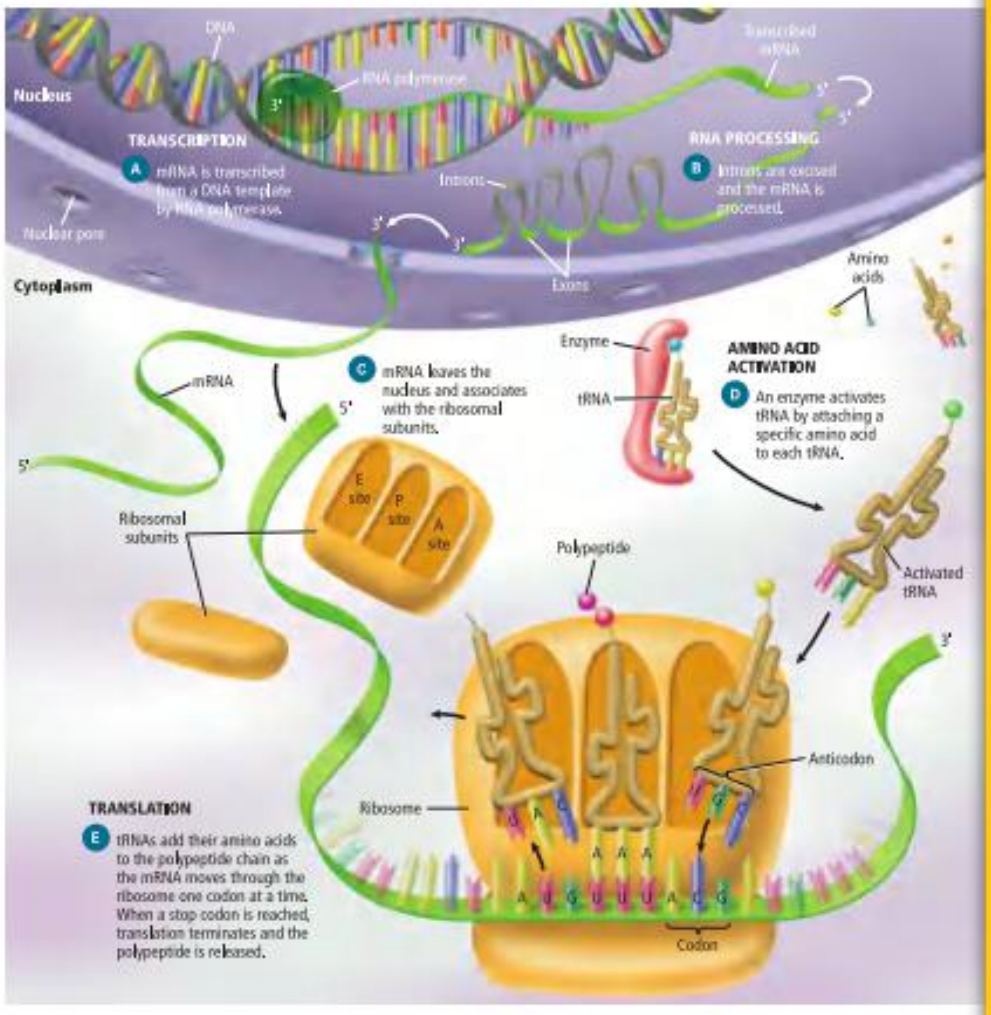
Visualizing Transcription and Translation

Figure 15

Transcription takes place in the nucleus. Translation occurs in the cytoplasm and results in the formation of polypeptides.



Demonstration

Transcription and Translation On the board, draw the letters of the nucleotides of a piece of two-stranded DNA. Erase a portion of one side and redraw part of one side spaced apart to indicate unzipping. Add the RNA polymerase and begin making an mRNA on one of the sides (template). Show the RNA leaving the nucleus with an arrow and have students decode the mRNA into an amino acid polypeptide. Est. time: 10 min

Purpose

Students will understand the process of DNA transcription and translation.

Develop Concepts

BL OL COOP LEARN Activity

Point out that the words *elm*, *elk*, and *eel* all differ by only one letter, yet their meanings are very different. In a similar manner, one letter in the DNA codon can make a major difference in the amino acid inserted into a protein. Have students form groups of three and come up with other similar word analogies for codons that differ by only one letter, similar to *elm*, *elk*, and *eel*.

Writing Support

BL OL Creative Writing Have students write a simple sentence in their notebooks. Then ask students to shift the letters. For example, "The fat cat ate the big rat" becomes "Hef atc ata tet heb igr att." Point out that the three-letter words model codons.

Develop Concepts

BL OL AL **Activity** Draw a short section of DNA on the board, labeling one side the coding or template strand and the other side the complementary or noncoding strand. Ask students to decipher the code into a segment of amino acids.

Develop Concepts

BL OL

Clarify a Misconception

ASK STUDENTS: ***Does protein synthesis "cost" the cell energy?***

yes Students may not understand that protein synthesis requires energy, as does all biosynthesis.

DATA ANALYSIS LAB 1

About the Lab

- Also see Liu, J., P. Feldman, and T. D. Chung. 2002. Real-time monitoring of *in vitro* transcription using molecular beacons. *Annals of Biochemistry* 300: 40–45.

Think Critically

1. Fluorescence levels increased the most over time in the bacterial and viral RNA not treated with rifampin.
2. RNA synthesis is inhibited.
3. *E. coli* and *M. smegmatis* are greatly affected by rifampin. Viral RNA is slightly affected.

Study Tip

Flowchart Draw a flowchart that connects the processes of DNA replication, transcription, and translation.

The role of the ribosome The ribosome consists of two subunits, as shown in **Figure 15.** These subunits are not associated when they are not involved in protein translation. When the mRNA leaves the nucleus, the two parts of the ribosome come together and attach to the mRNA to complete the ribosome. Once the mRNA is associated with the ribosome, a tRNA with the anticodon CAU carrying a methionine will move in and bind to the mRNA start codon–AUG–on the 5′ end of the mRNA. The ribosome structure has a groove, called the P site, where the tRNA that is complementary to the mRNA moves in.

A second tRNA moves into a second groove in the ribosome, called the A site, and corresponds to the next codon of the mRNA. The next codon is UUU, so a tRNA with the anticodon AAA moves in, carrying the amino acid phenylalanine.

Part of the rRNA in the ribosome now acts as an enzyme catalyzing the formation of a bond between the new amino acid in the A site and the amino acid in the P site. As the two amino acids join, the tRNA in the P site is released to the third site, called the E site, where it exits the ribosome. The ribosome then moves so the tRNA found in Groove A is shifted to Site P, as shown in **Figure 15.** Now a new tRNA will enter the A site, complementing the next codon on the mRNA. This process will continue adding and linking amino acids in the sequence determined by the mRNA.

The ribosome continues to move along until the A site contains a stop codon. The stop codon signals the end of protein synthesis and does not complement any tRNA. Proteins called release factors cause the mRNA to be released from the last tRNA and the ribosome subunits to disassemble, ending protein synthesis.

DATA ANALYSIS LAB 1

Based on Real Data*

Interpret the Data

How can a virus affect transcription? To study RNA synthesis, a group of scientists used a fluorescent molecular beacon to trace molecules. This beacon becomes fluorescent when it binds to newly synthesized RNA. The fluorescence increases as the RNA chain lengthens. Thus, the beacon can be used to follow RNA synthesis.

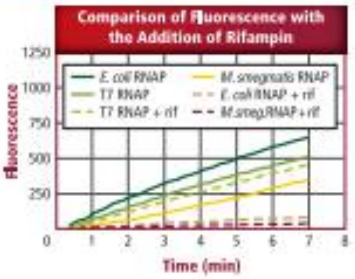
In this experiment, scientists added the antibiotic rifampin (rif) to RNA polymerase from a virus (T7 RNAP), *Escherchia coli (E. coli* RNAP), and *Mycobacterium smegmatis (M. smegmatis* RNAP) and followed RNA synthesis.

Think Critically

1. **Describe** the relationship between the fluorescence level and time in each experiment not exposed to rifampin.

*Data obtained from: Marras, Salvatore A.E., et al. 2004. Real-time measurement of in vitro transcription. *Nucleic Acids Research* 32.9:e 72.

Data and Observations



2. **Infer** what the relationship between fluorescence level and time indicates is happening in each case where rifampin was added.
3. **Interpret** which organism's RNA synthesis is affected most by the antibiotic rifampin.

Content Background

Cultural Diversity The discovery of the individual three-letter codes involved experiments by British scientists Francis Crick and Sydney Brenner, German plant physiologist Heinrich Matthaei and biochemist Marshall Nirenberg, and American geneticist Philip Leder. Crick and Brenner used mutants with deletions or additions of one, two, or three nucleotides to show that the code was a three-letter code. Nirenberg, Matthaei, and Leder used synthesis of mRNAs to solve the majority of the code charts. Nirenberg and Leder were able to synthesize short three-nucleotide mRNAs to finish solving the code chart in the 1960s.

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One Gene—One Enzyme

Once scientists learned how DNA works as a code, they needed to learn the relationships between the genes and the proteins for which they coded. Experiments on the mold *Neurospora* were the first to demonstrate the relationship between genes and enzymes. In the 1940s, George Beadle and Edward Tatum provided evidence that a gene can code for an enzyme. They studied mold spores that were mutated by exposure to X-rays. Examine **Figure 16** to follow along with their experiment.

Normally, *Neurospora* can grow on an artificial medium that provides no amino acids. This type of medium is called minimal medium. Complete medium provides all the amino acids that *Neurospora* needs to function. In Beadle and Tatum's experiment, the spores were exposed to X-rays and grown on a complete medium. To test for a mutated spore, the scientists grew spores on a minimal medium. When a spore was unable to grow on the minimal medium, the mutant was tested to see what amino acid it lacked. When the mold-spore type grew on a minimal medium with a supplement such as arginine, Beadle and Tatum hypothesized that the mutant was missing the enzyme needed to synthesize arginine.

Beadle and Tatum came up with what is known as the "one gene–one enzyme" hypothesis. Today, because we know that polypeptides make up enzymes, their hypothesis has been modified slightly to refer to the fact that one gene codes for one polypeptide.

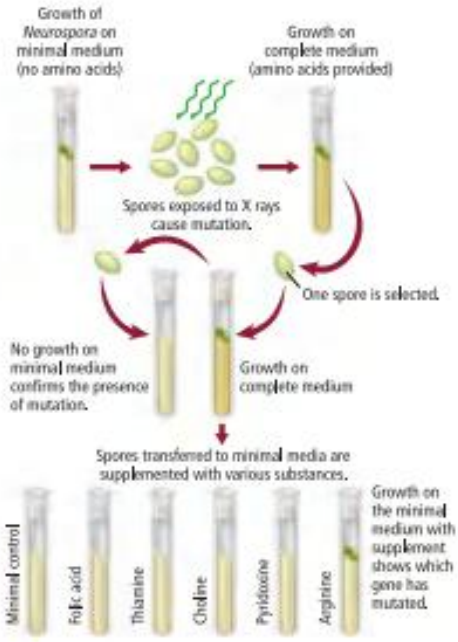


Figure 16 The Beadle and Tatum experiment showed that a gene codes for an enzyme. We now know that a gene codes for a polypeptide.

Section 3 Review

Section Summary

- Three major types of RNA are involved in protein synthesis: mRNA, tRNA, and rRNA.
- The synthesis of the mRNA from the template DNA is called transcription.
- Translation is the process through which the mRNA attaches to the ribosome and a protein is assembled.
- In eukaryotes, mRNA contains introns that are excised before leaving the nucleus. A cap and poly-A tail are added to the mRNA.
- One gene codes for one polypeptide.

Understand Main Ideas

1. MAIN Idea **Summarize** the process by which the DNA code is made into a protein.
2. **Describe** the function of each of the following in protein synthesis: rRNA, mRNA, and tRNA.
3. **Differentiate** between codons and anticodons.
4. **Explain** the role of RNA polymerase in mRNA sythesis.
5. **Conclude** why Beadle and Tatum's "one gene, one enzyme" hypothesis has been modified since they presented it in the 1940s.

Think Critically

MATH in Biology

6. If the genetic code used four bases as a code instead of three, how many code units could be encoded?

Develop Concepts

BL OL AL Scaffolding

ASK STUDENTS: ***Identify the experimental organism used by Beadle and Tatum.*** the mold *Neurospora* ***What was the purpose of growing the mutated mold spores on two different mediums?*** Mutants would grow only on the complete medium. In order to test if a mold spore was a mutant, it had to be shown that it could not grow on the minimal medium. ***Design and draw another set of results for a mold spore that is a niacin mutant.*** Drawings should be similar to Figure 16, but growth would occur only in the niacin tube.

Formative Assessment

Evaluation Write a single template strand sequence of DNA on the board. Have students write the complementary sequence, the mRNA sequence, the transfer RNAs, and the amino acid sequence of the polypeptide synthesized from this code.

Remediation Use interlocking toy building blocks with colors representing bases as follows: Red = A, Green = G, Yellow = C, Black = T, and Blue = U. Build a DNA template strand with the blocks. Have students build a complementary DNA strand, an mRNA strand, and tRNAs. Have students decipher the colors of the blocks to determine which amino acids are being coded.

Section 3 Review

1. RNA is synthesized from the template strand of DNA and used to assemble amino acids into proteins.
2. rRNA is a major component of the ribosome, mRNA carries a complementary code of the template strand of DNA to the ribosome for protein synthesis, and tRNA transports amino acids to the ribosome for protein synthesis.
3. Codons are the three-nucleotide code units on DNA or mRNA. Anticodons are the three-nucleotide code units on tRNA that complement the mRNA codon.
4. RNA polymerase initiates mRNA synthesis during transcription.
5. Further study and experimentation have allowed scientists to learn more information and further refine the hypothesis.
6. $4 \times 4 \times 4 \times 4 = 4^4 = 256$

Section 4

MAIN Idea

BL OL AL **Mutation**

ASK STUDENTS: ***What words and images come to mind when you hear the words* mutation *or* mutant?** Students might bring up stories or movies about science-fiction mutants. Allow an open discussion of what they associate with these words. Point out that in Latin the root *mutare* means "change." Lead students to see that certain things can change the DNA in the genotype, which can eventually cause changes in the phenotype of the organism. These changes can have a positive impact, negative impact, or no impact at all.

R Reading Strategy

BL OL AL

Directed Reading Have students make three columns on a sheet of paper. At the top of the left column, have them write *What I Know;* at the top of the middle column, *What I Want to Know,* and at the top of the third column *What I've Learned.* Have students fill in the left and middle columns before reading Section 4. After they read the text, have students fill in the right column.

Essential Questions

- How are bacteria able to regulate their genes by two types of operons?
- How do eukaryotes regulate the transcription of genes?
- What are the various types of mutations?

Review Vocabulary

prokaryote: organism that does not have membrane-bound organelles and DNA that is organized in chromosomes

New Vocabulary

gene regulation
operon
mutation
mutagen

Gene Regulation and Mutation

MAIN Idea **Gene expression is regulated by the cell, and mutations can affect this expression.**

Real-World Reading Link When you type a sentence on a keyboard, it is important that each letter is typed correctly. The sentence "The fat cat ate the rat" is quite different from "The fat cat ate the hat." Though there is a difference of only one letter between the two sentences, the meaning is changed.

Prokaryote Gene Regulation

How do prokaryotic cells regulate which genes will be transcribed at particular times in the lifetime of an organism? **Gene regulation** is the ability of an organism to control which genes are transcribed in response to the environment. In prokaryotes, an operon often controls the transcription of genes in response to changes in the environment. An **operon** is a section of DNA that contains the genes for the proteins needed for a specific metabolic pathway. The parts of an operon include an operator, promoter, regulatory gene, and the genes coding for proteins. The operator is a segment of DNA that acts as an on/off switch for transcription. A second segment of DNA, called the promoter, is where the RNA polymerase first binds to the DNA. The bacteria *Escherichia coli (E. coli)* respond to tryptophan, which is an amino acid, and lactose, which is a sugar, through two operons.

The *trp* operon In bacteria, tryptophan synthesis occurs in a series of five steps, and each step is catalyzed by a specific enzyme. The five genes coding for these enzymes are clustered together on the bacterial chromosome with a group of DNA that controls whether or not they are transcribed. This cluster of DNA is called the tryptophan *(trp)* operon and is illustrated in **Figure 17.**

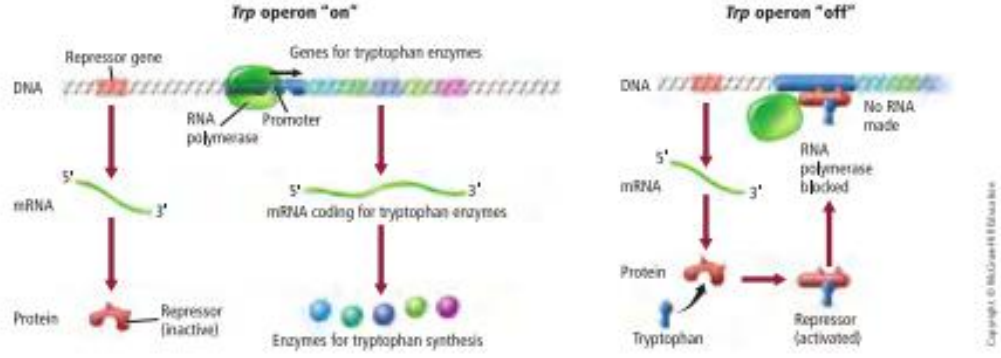


Figure 17 The *trp* operon is an example of the gene expression of repressible enzymes.

"Education is what remains after one has forgotten what one has learned in school."

—Albert Einstein

The *trp* operon is referred to as a repressible operon because transcription of the five enzyme genes normally is repressed, or turned off. When tryptophan is present in the cell's environment, the cell has no need to synthesize it and the *trp* repressor gene turns off, or represses, the transcription process by making a repressor protein. Tryptophan in *E. coli* combines with an inactive repressor protein to activate it, and the complex binds to the operator in the promoter sequence. If the repressor is bound to the operator, RNA polymerase cannot bind to it, which prevents the transcription of the enzyme genes. This prohibits the synthesis of tryptophan by the cell.

When tryptophan levels are low, the repressor is not bound to tryptophan and is inactive—it does not bind to the operator. The RNA polymerase is able to bind to the operator, turning on transcription of the five enzyme genes. This transcription enables the synthesis of tryptophan by the cell. Notice the location of the repressor protein in **Figure 17** when the operon is turned both off and on.

Reading Check **Summarize** the effect of tryptophan on the *trp* operon.

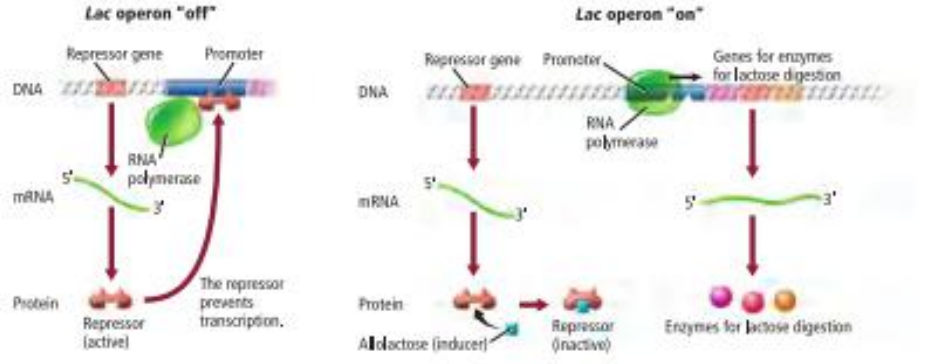
The *lac* operon When lactose is present in the cell, *E. coli* makes enzymes that enable it to use lactose as an energy source. The lactose (*lac*) operon, illustrated in **Figure 18,** contains a promoter, an operator, a regulatory gene, and three enzyme genes that control lactose digestion. In the *lac* operon, the regulatory gene makes a repressor protein that binds to the operator in the promoter sequence and prevents the transcription of the enzyme genes.

When a molecule called an inducer is present, the inducer binds to the repressor and inactivates it. In the *lac* operon, the inducer is allolactose, a molecule that is present in food that contains lactose. Thus, when lactose is present, the allolactose binds to the repressor and inactivates it. With the repressor inactivated, RNA polymerase then can bind to the promoter and begin transcription. The *lac* operon is called an inducible operon because transcription is turned on by an inducer.

CAREERS IN BIOLOGY

Microbiologist Scientists who study microbes, primarily prokaryotes, are called microbiologists. They might research to learn about which genes control the production of particular proteins or how a protein affects the life of a cell.

Figure 18 The lac operon is an example of the gene expression of inducible enzymes. ***Identify what the repressor is bound to when the lac operon is turned off.***



Caption Question **Fig. 18** The repressor is bound to the promoter.

Reading Check When tryptophan is present, the operon is off.

Skill Practice

OL AL Visual Literacy Have students carefully study Figures 17 and 18.

SAY TO STUDENTS: ***Compare the two types of prokaryotic genetic regulation pathways: the* lac *operon and* trp *operon.*** Have students make a table summarizing their comparison between the two types of regulation pathways.

Develop Concepts

BL OL AL Scaffolding

ASK STUDENTS: ***Which type of prokaryotic regulation pathway,* lac *or* trp *operon, works by preventing the transcription of genes?*** *trp* operon ***Explain the function of the five genes coding for proteins in the* trp *operon.*** These genes code for enzymes involved in the synthesis of tryptophan. ***Predict what will occur when tryptophan is added to the medium in which bacteria are growing.*** The tryptophan will combine with the inactive repressor and activate the repressor, turning off the *trp* operon.

Develop Concepts

BL OL

Clarify a Misconception

ASK STUDENTS: ***Do muscle cells and nerve cells contain the same genes?*** yes Students do not always understand that every cell in the body has the same DNA in it (exclusive of gametes). Every body cell contains the same genes. DNA regulation is very important in cell specialization. Cells of different types, such as neurons and muscle cells, have different types of genes turned on and turned off.

Writing Support

BL OL **Informal Writing**

Inform students that the regulation of the transcription of eukaryotic genes involves much more than turning them on and off. It also involves speeding up or slowing down their transcription.

SAY TO STUDENTS: ***Use the analogy of making a car go faster or slower to write a brief description on the role of activators and repressors.*** Activators can make transcription go faster, just as pushing on the gas pedal of a car makes it go faster. Repressors can slow transcription down in the same way a car can be slowed down by stepping on the brake pedal.

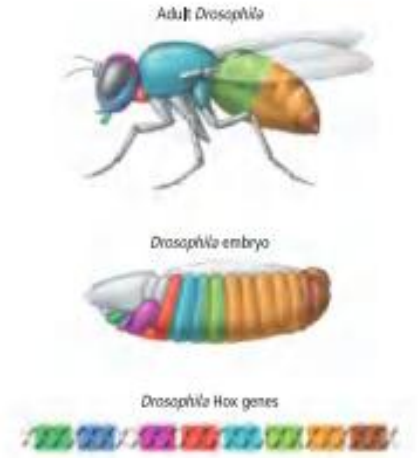


Figure 19 Hox genes are responsible for the general body pattern of most animals. Notice that the order of the genes is the same as the order of the body sections the genes control.

Eukaryote Gene Regulation

Eukaryotic cells also must control what genes are expressed at different times in the organism's lifetime. In eukaryotic cells, many genes interact with one another, requiring more elements than a single promoter and operator for a set of genes. The organization and structure of eukaryotic cells is more complex than in prokaryotic cells, increasing the complexity of the control system.

Controlling transcription One way that eukaryotes control gene expression is through proteins called transcription factors. Transcription factors ensure that a gene is used at the right time and that proteins are made in the right amounts. There are two main sets of transcription factors. One set of transcription factors forms complexes that guide and stabilize the binding of the RNA polymerase to a promoter. The other set includes regulatory proteins that help control the rate of transcription. For instance, proteins called activators fold DNA so that enhancer sites are close to the complex and increase the rate of gene transcription. Repressor proteins also bind to specific sites on the DNA and prevent the binding of activators.

The complex structure of eukaryotic DNA also regulates transcription. Recall that eukaryotic DNA is wrapped around histones to form nucleosomes. This structure provides some inhibition of transcription, although regulatory proteins and RNA polymerase still can activate specific genes even when they are packaged in the nucleosome.

Hox genes Gene regulation is crucial during development. Recall that multicellular eukaryotes develop from a single cell called a zygote. The zygote undergoes mitosis, producing all the different kinds of cells needed by the organism. Differentiation is the process through which the cells become specialized in structure and function. One group of genes that controls differentiation has been discovered. These genes are called homeobox (Hox) genes. Hox genes are important for determining the body plan of an organism. They code for transcription factors and are active in zones of the embryo that are in the same order as the genes on the chromosome. For example, the colored regions of the fly and fly embryo in **Figure 19** correspond to the colored genes on the piece of DNA in the figure. These genes, transcribed at specific times, and located in specific places on the genome, control what body part will develop in a given location. One mutation in the Hox genes of fruit flies has yielded flies with legs growing where their antennae should be. Studying these flies has helped scientists understand more about how genes control the body plan of an organism. Similar clusters of Hox genes that control body plans have been found in all animals.

Content Background

Teacher FYI Experiments with Hox genes in *Drosophila* have yielded a wealth of information about how development occurs in animals. The Hox gene clusters are located in the same order on the chromosome as the order of the body sections the genes control. The order of these genes is highly conserved in species, indicating an ancient origin. In fact, most variations between species are in the number of Hox gene clusters and in the number of genes in the clusters. Some evidence suggests that Hox genes are involved in human birth defects.

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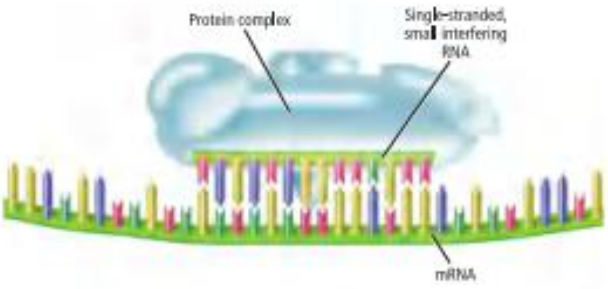

Figure 20 RNA interference can stop the mRNA from translating its message.
Describe *how the RNA-protein complex prevents the translation of the mRNA.*

RNA interference Another method of eukaryotic gene regulation is RNA interference (RNAi). Small pieces of double-stranded RNA in the cytoplasm of the cell are cut by an enzyme called dicer. The resulting double-stranded segments are called small interfering RNA. They bind to a protein complex that degrades one strand of the RNA. The resulting single-stranded small interfering RNA and protein complex bind to sequence-specific sections of mRNA in the cytoplasm, causing the mRNA in this region to be cut and thus preventing its translation. **Figure 20** shows the single-stranded small interfering RNA and protein complex binding to the mRNA. Research and clinical trials are being conducted to investigate the possibility of using RNAi to treat cancer, diabetes, and other diseases.

Reading Check **Explain** how RNA interference can regulate eukaryotic gene expression.

Mutations

Do you ever make mistakes when you are typing an assignment? When you type, sometimes you might strike the wrong key. Just as you might make a mistake when typing, cells sometimes make mistakes during replication. However, these mistakes are rare, and the cell has repair mechanisms that can repair some damage. Sometimes a permanent change occurs in a cell's DNA and this is called a **mutation.** Recall that one inheritance pattern that Mendel studied was round and wrinkled pea seeds. It is now known that the wrinkled phenotype is associated with the absence of an enzyme that influences the shape of starch molecules in the seeds. Because the mutation in the gene causes a change in the protein that is made, the enzyme is nonfunctional.

Types of mutations Mutations can range from changes in a single base pair in the coding sequence of DNA to the deletions of large pieces of chromosomes. Point mutations involve a chemical change in just one base pair and can be enough to cause a genetic disorder. A point mutation in which one base is exchanged for another is called a substitution. Most substitutions are missense mutations, where the DNA code is altered so that it codes for the wrong amino acid. Other substitutions, called nonsense mutations, change the codon for an amino acid to a stop codon. Nonsense mutations cause translation to terminate early. Nearly all nonsense mutations lead to proteins that cannot function normally.

Reading Strategy

BL OL Vocabulary Chart Have students make a three-column vocabulary chart. In the first column, have them write the new vocabulary terms for Section 4. In the second column, have them write the definition after reading the text. Then have them come up with a memory clue, such as a sketch or a word association, and have them write down their clue in the third column.

COOP LEARN Have students work in pairs.

AL Instead of a chart, have students write a paragraph describing the relationship between the vocabulary terms for this section.

Caption Question **Fig. 20** Small interfering RNA binds to a protein complex that degrades one strand of the RNA.

Reading Check It can prevent translation of sections of mRNA.

Differentiated Instruction

Below Level Alternative activities should be used to address the needs of students who are performing below grade level. The vocabulary chart described on this page is a valuable tool to use with students who struggle with reading, allowing them to develop visual clues they can use to recall the meanings of difficult vocabulary terms.

Content Background

Real-World Connection *Science* magazine called the discovery of RNAi the "Breakthrough of the Year 2002." The use of RNAi as a genetic therapy to silence a specific gene that has gone bad has entered human therapeutic clinical trials. One disease researchers are concentrating their efforts on is macrodegeneration of eyes.

VOCABULARY

ACADEMIC VOCABULARY

Substitution
the act of replacing one thing with another
The substitution of adenine for guanine in the DNA caused a dysfunctional protein.

Another type of mutation that can occur involves the gain or loss of a nucleotide in the DNA sequence. Insertions are additions of a nucleotide to the DNA sequence, and the loss of a nucleotide is called a deletion. Both of these mutations change the multiples of three, from the point of the insertion or deletion. These are called frameshift mutations because they change the "frame" of the amino acid sequence. **Table 3** illustrates various types of mutations and their effect on the DNA sequence.

Sometimes mutations are associated with diseases and disorders. One example is alkaptonuria. Patients with this disorder have a mutation in their DNA coding for an enzyme involved in digesting the amino acid phenylalanine. This mutation results in the black-colored homogentisic acid that discolors the urine. Studies have shown that patients with alkaptonuria have a high occurrence of frameshift and missense mutations in a specific region of their DNA. **Table 3** lists some more examples of diseases associated with different types of mutations.

Table 3 **Mutations**

Mutation Type	Analogy Sentence	Example of Associated Disease
Normal	THE BIG FAT CAT ATE THE WET RAT	
Missense (substitution)	THE BIZ FAT CAT ATE THE WET RAT	Achondroplasia: improper development of cartilage on the ends of the long bones of arms and legs resulting in a form of dwarfism
Nonsense (substitution)	THE BIG RAT	Muscular dystrophy: progressive muscle disorder characterized by the progressive weakening of many muscles in the body
Deletion (causing frameshift)	THB IGF ATC ATA TET HEW ETR AT	Cystic fibrosis: characterized by abnormally thick mucus in the lungs, intestines, and pancreas
Insertion (causing frameshift)	THE BIG ZFA TCA TAT ETH EWE TRA	Crohn's disease: chronic inflammation of the intestinal tract, producing frequent diarrhea, abdominal pain, nausea, fever, and weight loss
Duplication	THE BIG FAT FAT CAT ATE THE WET RAT	Charcot-Marie-Tooth disease (type 1A): damage to peripheral nerves leading to weakness and atrophy of muscles in hands and lower legs
Expanding mutation (tandem repeats)		Huntington's disease: a progressive disease in which brain cells waste away, producing uncontrolled movements, emotional disturbances, and mental deterioration
Generation 1	THE BIG FAT CAT ATE THE WET RAT	
Generation 2	THE BIG FAT CAT CAT CAT ATE THE WET RAT	
Generation 3	THE BIG FAT CAT CAT CAT CAT CAT CAT ATE THE WET RAT	

Writing Support

BL OL AL COOP LEARN

Creative Writing Have students work in pairs to research health issues related to mutations and then construct a poster on the topic. The purpose of the poster might be to educate people about the type of mutation involved, or to warn people about mutagenic agents that could increase the risk of developing a disease. Caution students to be sensitive in the way they approach their topic.

Skill Practice

BL OL AL **Visual Literacy**

Have students study Table 3. Write various normal and mutant sequences on the board or give them to students as a handout.

ASK STUDENTS: ***Identify the type of mutation that is demonstrated in each of the sequences.*** Encourage students to use the information in Table 3 to help them.

Research Citation

Formative Assessment Educational research indicates that assessment should be timely and ongoing. An evaluation of students' understanding throughout a lesson provides the teacher with valuable information to be used in planning remediation and future instruction. (Bransford, et al., 2000)

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Large portions of DNA can also be involved in a mutation. A piece of an individual chromosome containing one or more genes can be deleted or moved to a different location on the chromosome, or even to a different chromosome. Such rearrangements of the chromosome often have drastic effects on the expression of these genes.

Connection Health In 1991, a new kind of mutation was discovered that involves an increase in the number of copies of repeated codons, called tandem repeats. The increase in repeated sequences seems to be involved in a number of inherited disorders. The first known example was fragile X syndrome–a syndrome that results in a number of mental and behavioral impairments. Near the end of a normal X chromosome, there is a section of CGG codons that repeat about 30 times. Individuals with fragile X have CGG codons that repeat hundreds of times. The syndrome received its name because the repeated area on the tip of the X chromosomes appears as a fragile piece hanging off the X chromosome, as illustrated in **Figure 21.** Currently, the mechanism by which the repeats expand from generation to generation is not known.

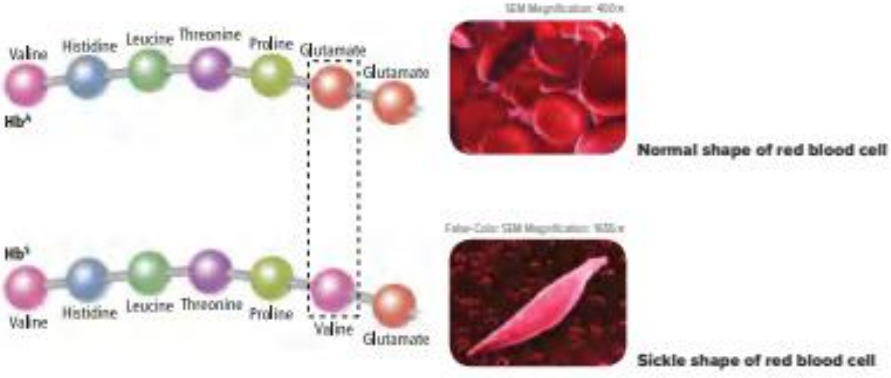
Reading Check **Describe** three types of mutations.

Protein folding and stability You might expect that large changes in the DNA code, such as frameshift mutations or changes in position, lead to genetic disorders. However, small changes like substitutions also can lead to genetic disorders. The change of one amino acid for another can change the sequence of amino acids in a protein enough to change both the folding and stability of the protein, as illustrated in **Figure 22.**

An example of a genetic disorder caused by a single point mutation is sickle-cell disease. In the case of sickle-cell disease, the codon for a glutamic acid (GAA) has been changed to a valine (GUA) in the protein. This change in composition changes the structure of hemoglobin and is the cause of this disorder.

Figure 21 Fragile X syndrome is due to many extra repeated CGG units near the end of the X chromosome, making the lower tip of the X chromosome appear fragile.

Figure 22 A single amino acid substitution can cause the genetic disorder sickle-cell disease. **Recall *what happens to the protein with the substituted amino acid.***



Normal shape of red blood cell

Sickle shape of red blood cell

Develop Concepts

AL Activity Use sickle-cell disease and cystic fibrosis as topics for a discussion about how a small change in a gene can cause major effects on the phenotype. Have students research how mutations result in each disorder.

ASK STUDENTS: ***What mutation causes sickle-cell disease?*** a point mutation in the gene that codes for the hemoglobin protein Review the quaternary structure with students: The hemoglobin molecule is made of four polypeptide chains, two identical alpha chains, and two identical beta chains. In the two beta chains, there is a single mutation in the sixth codon, which causes a glutamic acid to be replaced by a valine. These two changes (one in each beta chain) cause a misfolding of hemoglobin under low oxygen and lead to sickle-cell disease.

What mutation causes cystic fibrosis? a change in the gene that codes for a chloride channel The most common cause of this disorder is due to a deletion of three nucleotides of the 508th codon. The loss of the phenylalanine amino acid results in the disorder known as cystic fibrosis.

Reading Check Answers may include any three of the following: point mutation—involving a single base (substitution); insertion—addition of a base to the sequence; deletion—removing a base from a sequence; duplication—repetition of a gene or base; tandem repeats—multiple repetitions of a gene or base.

Caption Question **Fig. 22** The protein hemoglobin is defective and causes red blood cells to have a deformed, sickle shape.

Critical Thinking

BL OL AL **Theorize**

ASK STUDENTS: ***When you go to a dentist for X-rays, why do they cover you with a lead-filled blanket?*** X-rays are a mutagenic agent. The lead blanket protects your body, especially the reproductive glands (ovaries and testes), from exposure to X-rays, because X-rays cannot pass through lead. The X-ray technician will often leave the room to avoid exposure.

DATA ANALYSIS LAB 2

About the Lab

- The environment you live in contains many potential mutagens. The Ames test can screen many chemicals quickly and inexpensively.
- Also see Maron, Dorothy M. and Bruce N. Ames. 1983. Revised methods for the *Salmonella* mutagenicity test. *Mutation Research* 113: 173-215.

Think Critically

1. The greater the amount of compound in the culture, the greater the reversion rate.
2. A is the strongest mutagen, producing the most revertant colonies.

Hemoglobin is made of four polypeptide chains, which are two sets of two identical chains. The molecule also contains a large carbon-ring structure that binds iron called the heme group. The substituted glutamic acid is located near the start of one set of chains, as shown in **Figure 22.** Glutamic acid is a polar amino acid, but the valine that substitutes for it in sickle-cell disease is nonpolar. Because of the charge difference, the sickle-cell hemoglobin folds differently than normal hemoglobin. The abnormal folding of the protein caused by the mutation results in a change to the sickle shape of the red blood cell. Numerous other diseases involve problems with protein folding, including Alzheimer's disease, cystic fibrosis, diabetes, and cancer.

Causes of mutation Some mutations, especially point mutations, can occur spontaneously. During replication, DNA polymerase sometimes adds the wrong nucleotides. Because the DNA polymerase has a proofreading function, the wrong nucleotide gets added only for one in one hundred thousand bases; it goes unfixed in less than one in one billion.

Certain chemicals and radiation also can damage DNA. Substances which cause mutations are called **mutagens** (MYEW tuh junz). Many different chemicals have been classified as mutagens. Some of these chemicals affect DNA by changing the chemical structure of the bases. Often these changes cause bases to mispair, or bond, with the wrong base. Other chemical mutagens have chemical structures that resemble nucleotides so closely that they can substitute for them. Once these imposter bases are incorporated into the DNA, it can not replicate properly. This type of chemical has become useful medically, especially in the treatment of HIV–the virus that causes AIDS. Many drugs used to treat HIV and other viral infections mimic various nucleotides. Once the drug is incorporated in the viral DNA, the DNA cannot copy itself properly.

VOCABULARY

WORD ORIGIN

Mutagen
comes from the Latin word *mutare*, meaning *to change* and from the Greek word *genes*, meaning *born*

DATA ANALYSIS LAB 2

Based on Real Data*

Interpret the Graph

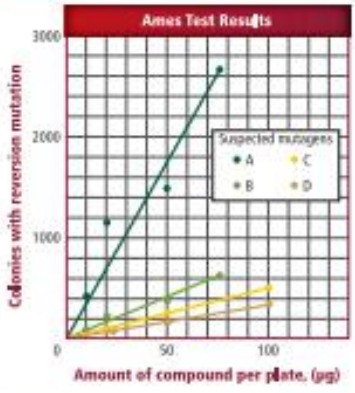
How can we know if a compound is a mutagen? The Ames test is used to identify mutagens. The test uses a strain of bacteria that cannot make the amino acid histidine. The bacteria are exposed to a suspected mutagen and grow on a medium without histidine. The bacteria that grow have a mutation called a reversion because they reverted to the natural condition of making histidine. The compounds in the graph were Ames tested.

Think Critically

1. **Describe** the relationship between the amount of the compound and the mutation.
2. **Analyze** which compound is the strongest mutagenic compound.

*Data obtained from: Ames, B.N. 1979. Identifying environmental chemicals causing mutations and cancer. Science. 204: 587-593

Data and Observations



Demonstration

Protein Folding Use both a coiled section and a straight section of telephone cord to demonstrate the shape of a protein. If telephone cords are not available, use straight and coiled shoelaces. Tell students the cord represents the chain of amino acids. Use a coiled telephone cord to demonstrate the helical structure, called an alpha helix, found in sections of a protein. Take the coiled cord and twist it into a ball shape. Some proteins, called globular proteins, consist of this type of structure. Take a section of straight telephone cord, and fold it back and forth on top of itself. Tell students this demonstrates the second most common type of structure of a protein, called a beta sheet. Point out that most proteins have sections of both alpha helixes and beta sheets. Est. time: 10 min

High-energy forms of radiation, such as X-rays and gamma rays, are highly mutagenic. When the radiation reaches the DNA, electrons absorb the energy. The electrons can escape their atom, leaving behind a free radical. Free radicals are charged atoms with unpaired electrons that react violently with other molecules, including DNA. Ultraviolet (UV) radiation from the Sun contains less energy than X-ray radiation and does not cause electrons to be ejected from the atoms. However, UV radiation can cause adjacent thymine bases to bind to each other, disrupting the structure of DNA, as shown in **Figure 23.** DNA with this structure disruption, or kink, are unable to replicate properly unless repaired.

Body-cell v. sex-cell mutation When a mutation in a body cell, also called a somatic cell, escapes the repair mechanism, it becomes part of the genetic sequence in that cell and in future daughter cells. Somatic cell mutations are not passed on to the next generation. In some cases, the mutations do not cause problems for the cell. They could be sequences not used by the adult cell when the mutation occurred, the mutation might have occurred in an exon, or the mutation might not have changed the amino acid for which it was coded. These mutations are called neutral mutations. When the mutation results in the production of an abnormal protein, the cell might not be able to perform its normal function, and cell death might occur. Recall that mutations in body cells that cause the cell cycle to be unregulated can lead to cancer. All of these effects are contained within the cells of the organism as long as only body cells are affected.

When mutations occur in sex cells, also called germ-line cells, the mutations are passed on to the organism's offspring and will be present in every cell of the offspring. In many cases, these mutations do not affect the function of cells in the organism, though they might affect the offspring drastically. When the mutations result in an abnormal protein in the sex cell, the offspring is impacted. However, the offspring is not impacted when an abnormal protein is produced in an isolated body cell.

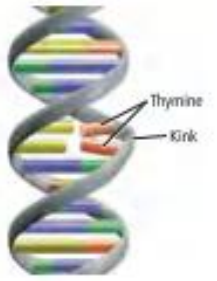


Figure 23 Ultraviolet radiation can cause adjacent thymines to bind to each other instead of to their complementary bases, making the DNA "kink" and preventing replication.

Section 4 Review

Section Summary

- Prokaryotic cells regulate their protein synthesis through a set of genes called operons.
- Eukaryotic cells regulate their protein synthesis using various transcription factors, eukaryotic nucleosome structures, and RNA interference.
- Mutations range from point mutations to the deletion or movement of large sections of the chromosome.
- Mutagens, such as chemicals and radiation, can cause mutations.

Understand Main Ideas

1. MAIN Idea **Relate** gene regulation and mutations.
2. **Identify** the two main types of mutagens.
3. **Diagram** how adding lactose to a culture affects the *lac* operon of *E. coli*.
4. **Analyze** how a point mutation can affect the overall protein shape and function, using hemoglobin as an example.
5. **Compare and contrast** prokaryotic and eukaryotic gene regulation.

Think Critically

6. **Explain** why most mutations in eukaryotes are recessive.
7. **Hypothesize** why DNA replication has such accuracy.

WRITING in Biology

8. Write an article describing how Hox genes regulate development in animals.

C Critical Thinking

BL OL AL **Infer**

ASK STUDENTS: ***Why is a mutation in a sex cell considered potentially more harmful than one in a body cell?*** Unlike a mutation in a body cell, a mutation in a sex cell could be passed on to the next generation.

Formative Assessment

Evaluation Prepare a quiz showing a normal section of DNA and a mutant section of DNA.

ASK STUDENTS: ***Identify the type of mutation that is shown.*** Answers will depend on the quiz material, but students should be able to identify mutations in particular codons.

Remediation Obtain a table similar to Table 3 but without the caption or labels. Distribute copies, and have students identify the types of mutations in the table. Write the correct mutations on the board so that students can compare their answers.

Section 4 Review

1. Gene regulation ordinarily ensures accurate replication of DNA, but occasionally a mutation occurs that has a significant effect on the phenotype.
2. radiation and chemicals that change the normal structure of DNA
3. Diagrams should show that milk turns on the production of lactose-digesting enzymes.
4. Point mutation in a hemoglobin gene causes the protein to fold abnormally.
5. In prokaryotes, gene regulation is usually controlled by an operon; regulation in eukaryotic cells involves many regulatory genes.
6. Individuals carry two alleles for each feature. It is unlikely that both will code for mutant proteins, so the normal allele is usually expressed and recessive genes will be passed on.
7. DNA polymerase "proofreads" the replication; repair systems fix the DNA.
8. Articles should indicate that Hox genes control cell differentiation in developing embryos.

Purpose

Students will describe the pros and cons of gene patenting.

Anticipatory Guide

ASK STUDENTS: *What is a gene?* Tell students that a gene is a functional unit that controls inherited trait expression that is passed on from one generation to another generation.

Where are genes located in the body? Tell students that genes are segments of DNA, which are found on chromosomes in the nucleus of every cell in the human body.

Background

Scientists have linked genes called connexin-26 and connexin-30 to hearing loss. Some have proposed that hospitals routinely test newborn infants for these genes if the newborns fail their initial hearing screening, much as babies are now routinely tested for other conditions. But because a company holds patents on the connexin-26 and connexin-30 genes, organizations such as the Association for Molecular Pathology worry that access to a test for the genes will be–and indeed, already has been–limited. "Thus, this particular patent threatens not just individual patient care and access, but public health for the entire population," the AMP wrote in a May 2009 letter to the chair of the Secretary's Advisory Committee on Genetics, Health and Society at the National Institutes of Health (NIH) Office of Biotechnology Activities.

Biology & Society

Who owns genes?

Can a company own parts of the human body? That is an ethical debate that has raged since 1977, when universities and private companies first started seeking patents on genes. To date, about 20 percent of all human genes have been patented. This issue has made headlines since a company patented the BRCA1 and BRCA2 genes, mutations of which have been linked to breast cancer and ovarian cancer.

Agricultural gene patents have also sparked fierce debate. In recent decades, companies have modified the genes in many plants to incorporate them with desirable traits, such as resistance to diseases and pests. Companies have received patents on these modified plant genes.

What is a patent? A patent grants the exclusive right to make a profit from the sale of an invention. Often, people or businesses have invested years and large amounts of money researching and developing an invention. The profits they receive from holding patents help them recoup their investments, as well as provide money for future research.

A patent on nature Opponents argue that patenting genes will hinder free and open scientific research and will harm patients seeking medical care. If companies own patents on genes, they can refuse to allow other scientists to use the genes in their work, possibly preventing important discoveries. The high cost of genetic testing and therapies related to patented genes can deter patients from receiving treatments.

Agricultural implications Agricultural gene patents pose an additional problem for farmers. If winds or animals bring seeds containing patented genes to the fields of a farmer who has not bought the rights to use those seeds, the company who holds the patent can sue the farmer.

Soybeans

Corn

Around the world, the amount of land devoted to the cultivation of genetically modified plants is rising. Soybeans and corn are two crops that are often genetically modified.

In the past, farmers have lost these court cases, even though it is impossible to stop natural forces from transferring seeds.

As companies continue to seek patents on genes, the debate is certain to continue. For now, the patenting of genes is legal. But in the future, ethical and practical considerations might swing the pendulum the other way.

DEBATE in Biology

Research Have students further research the issue of gene patenting. Divide the class into two teams, one for gene patenting and one against it and stage a debate.

DEBATE in Biology

Activity If students do not know how to begin their research on this topic, suggest that they type the keywords "gene patenting" into an online search engine. They also could search the database of the USPTO to find its ruling on gene patenting. (Check this citation: Federal Register: January 5, 2001, Volume 66, Number 4, Page 1092-1099.) Position statements on gene patenting can be found on the Web sites of various organizations, such as the American Medical Association, the Association for Molecular Pathology, and the American College of Medical Genetics.

58 Chapter 2 • Molecular Genetics

BIOLAB

FORENSICS: HOW IS DNA EXTRACTED?

Background: **DNA tests are important for biologists, doctors, and even detectives. Imagine that you are working in a lab where someone has brought a sample of corn from a crime scene to be analyzed. You decide to test the DNA of the corn to look for genes to identify the type of corn. Before the DNA sequence can be examined, the DNA must be extracted.**

Question: *How can DNA be extracted?*

Materials

corn kernels (50 g)
beakers (2)
blender
cheesecloth (4 squares–30 cm on each edge)
rubber band
glass spooling hook
homogenization medium (100–150 mL)
plastic centrifuge tube (30–50 mL)
contact lens cleaning tablet (containing papain)
95% ethanol (12 mL)
distilled water (3 mL)
test tube
container of ice
water bath at 60°C
stirring rod
timer or clock

Safety Precautions

Procedure

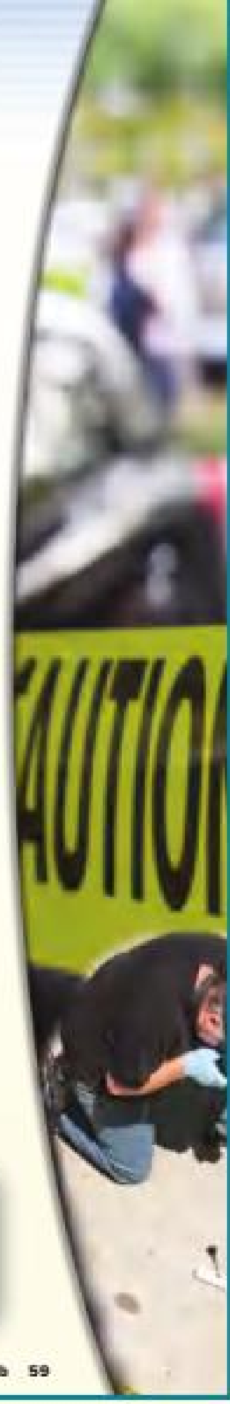
1. Identify the safety concerns of this lab before work begins.
2. Carefully weigh out 50 g of corn kernels.
3. Place the corn kernels into a beaker and cover with homogenization medium that has been warmed to 60°C. Place the beaker in a 60°C water bath for 10 min. Gently stir every 45 s.
4. Remove the beaker from the water bath and chill quickly in an ice bath for 5 min.
5. Pour the mixture into a blender and homogenize, or blend, to achieve a consistent texture.
6. Filter the homogenized mixture through four layers of cheesecloth into a clean large beaker on ice.
7. Pour 15 mL of the filtrate into a 30–50 mL plastic centrifuge tube.
8. Dissolve one contact lens cleaning tablet in 3 mL of distilled water in a test tube. Add this to the filtrate tube and mix gently.
9. Hold the filtrate tube at an angle and slowly pour 12 mL of cold 95% ethanol down the side of the tube.
10. Observe the DNA rising into the alcohol layer as a cloudy suspension of white strings. Use a hooked glass rod to spool the DNA, and allow it to dry.
11. **Cleanup and Disposal** Clean your lab area, disposing of chemicals and materials as directed by your teacher. Be sure to wash your hands when you are finished.

Analyze and Conclude

1. **Describe** the appearance of the DNA in suspension and once it has dried.
2. **Explain** why you put the corn kernels into the blender.
3. **Think Critically** Why is it important not to contaminate a sample of DNA that is to be sequenced? How would you know if you had contaminated your sample?

WRITING in Biology

Report Imagine you are the first researcher to extract DNA from corn. Write a report detailing your methods and possible applications of your discovery.



Analyze and Conclude

1. Answers will vary. It looks like white thread in suspension.
2. This physically breaks open the cells and releases their contents.
3. If the sample is contaminated, DNA from another substance might be present.

BIOLAB

Est. Time 50 min

Content Background

Extracting DNA from corn kernels and other plant tissues involves breaking the tissues apart and then breaking down the cell to release DNA from the nucleus. Heating and homogenizing break down tissue and cell walls. Detergents break down the outer cell and the nuclear membranes and release the DNA from the cell. Enzymes are added to degrade proteins and make the DNA molecules easier to spool. Finally, the DNA must be precipitated out of solution, using ethanol.

Alternative Materials

95% isopropyl alcohol can be substituted for ethanol; meat tenderizer can be substituted for the contact lens cleaning tablet.

Safety Precaution Discuss the safety concerns of this lab before work begins.

Teaching Strategy For homogenizing medium, mix 25 g SDS, 4.4 g NaCl, 2.2 g sodium citrate, and 0.15 g ETDA. Add distilled water to make 500 mL.

Alternative Teaching Demo

If you run out of time, show students the video lab as an alternative to performing it themselves.

Cleanup and Disposal Have students dispose of unused corn and husks and used cheesecloth in the regular trash. Dispose of liquid wastes down the drain to a sanitary sewer.

Chapter 2 Assessment

THEME FOCUS **Scientific Inquiry** Many different scientists and studies have contributed to our understanding of molecular genetics, and further studies are changing the way we practice science.

BIG Idea **DNA is the genetic material that contains a code for proteins.**

Section 1 DNA: The Genetic Material

double helix
nucleosome

MAIN Idea **The discovery that DNA is the genetic code involved many experiments.**

- Griffith's bacterial experiment and Avery's explanation first indicated that DNA is the genetic material.
- The Hershey-Chase experiment provided evidence that DNA is the genetic material of viruses.
- Chargaff's rule states that in DNA the amount of cytosine equals the amount of guanine and the amount of thymine equals the amount of adenine.
- The work of Watson, Crick, Franklin, and Wilkins provided evidence of the double-helix structure of DNA.

Section 2 Replication of DNA

semiconservative replication
DNA polymerase
Okazaki fragment

MAIN Idea **DNA replicates by making a strand that is complementary to each original strand.**

- The enzymes DNA helicase, RNA primase, DNA polymerase, and DNA ligase are involved in DNA replication.
- The leading strand is synthesized continuously, but the lagging strand is synthesized discontinously, forming Okazaki fragments.
- Prokaryotic DNA opens at a single origin of replication, whereas eukaryotic DNA has multiple areas of replication.

Section 3 DNA, RNA, and Protein

RNA
messenger RNA
ribosomal RNA
transfer RNA
transcription
RNA polymerase
intron
exon
codon
translation

MAIN Idea **DNA codes for RNA, which guides protein synthesis.**

- Three major types of RNA are involved in protein synthesis: mRNA, tRNA, and rRNA.
- The synthesis of the mRNA from the template DNA is called transcription.
- Translation is the process through which the mRNA attaches to the ribosome and a protein is assembled.
- In eukaryotes, mRNA contains introns that are excised before leaving the nucleus. A cap and poly-A tail are added to the mRNA.
- One gene codes for one polypeptide.

Section 4 Gene Regulation and Mutation

gene regulation
operon
mutation
mutagen

MAIN Idea **Gene expression is regulated by the cell, and mutations can affect this expression.**

- Prokaryotic cells regulate their protein synthesis through a set of genes called operons.
- Eukaryotic cells regulate their protein synthesis using various transcription factors, eukaryotic nucleosome structures, and RNA interference.
- Mutations range from point mutations to the deletion or movement of large sections of the chromosome.
- Mutagens, such as chemicals and radiation, can cause mutations.

60 Chapter 2 • Study Guide

Section 1

Vocabulary Review

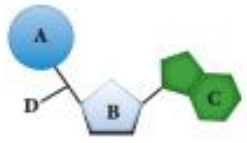
Each of the following sentences is false. Make the sentence true by replacing the underlined word with the correct vocabulary term from the Study Guide page.

1. The twisted ladder shape of DNA is called a nucleotide
2. A double helix consists of DNA wrapped around the histone proteins.

Understand Main Ideas

3. What are the basic building blocks of DNA and RNA?
   A. ribose **C.** nucleotides
   B. purines **D.** phosphorus
4. If a section of DNA has 27 percent thymine, how much cytosine will it have?
   A. 23 percent **C.** 46 percent
   B. 27 percent **D** 54 percent
5. Which was a conclusion of Griffith's work with *Streptococcus pneumoniae*?
   A. DNA is the genetic material in viruses.
   B. The structure of DNA is a double helix.
   C. Bacteria exposed to DNA can incorporate the DNA and change phenotype.
   D. The amount of thymine equals the amount of adenine in DNA.

Refer to the figure below to answer questions 6 and 7.



6. What is the entire labeled structure called?
   A. nucleotide **C.** base
   B. RNA **D.** phosphate
7. Which label represents the coding part of DNA?
   A. A **C.** C
   B. B **D.** D

Constructed Response

8. **Short Answer** Explain how DNA forms chromosomes in eukaryotic cells.

Use the figure below to answer question 9.

9. THEME FOCUS Scientific Inquiry Summarize the experiments and data shown in the photo that led to the discovery of DNA.

Think Critically

10. **Design** How might you use radioactive phosphorus to demonstrate that the transforming compound of bacteria in Griffith's experiment was DNA?
11. MAIN Idea How would the results of the Hershey-Chase experiment have been different if protein were the genetic material?

Section 2

Vocabulary Review

Write a sentence defining each of the following vocabulary terms.

12. DNA polymerase
13. semiconservative replication
14. Okazaki fragment

Understand Main Ideas

15. With what does the synthesis of a new strand of DNA begin?
   A. RNA primer
   B. nucleotide unit
   C. messenger RNA
   D. transfer RNA

Assessment

Section 1

Vocabulary Review

1. double helix
2. nucleosome

Understand Main Ideas

3. C
4. A
5. C
6. A
7. C

Constructed Response

8. DNA coils around histones to form nucleosomes, which coil to form chromatin fibers. The chromatin fibers supercoil to make chromosomes.
9. Franklin took the photo using the X-ray diffraction technique. The circle shows the twisted shape of the rails of the DNA "ladder." The X indicates where the bases cross, forming "rungs" of the twisted ladder.

Think Critically

10. By radioactively labeling the smooth bacteria DNA before they were killed, one could track the radioactive DNA as it was picked up and incorporated by the rough bacterial cells.
11. They would have found that it was radioactive sulfur that was passed from generation to generation in the virus rather than the radioactive phosphorus found in the DNA.

Section 2

Vocabulary Review

12. DNA polymerase is the enzyme that facilitates DNA replication.
13. Semiconservative replication is the method by which DNA makes copies of itself.
14. Okazaki fragments are short strands of new DNA produced during the replication of the lagging strand.

Understand Main Ideas

15. A

16. Which is true about the elongation of the lagging strand?
   A. does not require a template strand
   B. produces Okazaki fragments
   C. requires the action of RNA ligase
   D. proceeds by continually adding nucleotides to the 3' end

Constructed Response

17. **Short Answer** List the enzymes involved in replication and describe their functions.

18. MAIN Idea Summarize the process of DNA replication in a diagram. Add labels to explain what is happening.

Think Critically

Use the figure below to answer questions 19 and 20.

19. **Determine** Imagine that you are a scientist looking at a cell through a microscope. You see DNA replicating in several areas. Determine what type of cell you are looking at based on the origins of replication.

20. **Hypothesize** why it is important for the DNA in the figure to have multiple origins of replication.

21. **Infer** how complementary base pairing is responsible for semiconservative replication.

Section 3

Vocabulary Review

Write a sentence that connects the vocabulary terms in each pair.

22. mRNA – tRNA

23. codon – RNA polymerase

24. intron – exon

Understand Main Ideas

25. Which correctly lists the changes to eukaryotic pre-mRNA to form mRNA?
   A. cap added, introns excised, and poly T tail added
   B. cap added, exons excised, and poly T tail added
   C. cap added, introns excised, and poly A tail added
   D. cap added, exons excised, and poly A tail added

Use the figure below to answer questions 26 and 27.

26. What is the mRNA sequence for the template strand DNA sequence in the figure?
   A. 5' ATGTTTGATCTT 3'
   B. 5' AUGUUUGAUCUU 3'
   C. 5' TACAAACTAGAA 3'
   D. 5' UACAAACUAGAA 3'

27. What is the sequence for the nontemplate strand of the DNA in the figure?
   A. 5' ATGTTTGATCTT 3'
   B. 5' AUGUUUGAUCUU 3'
   C. 5' TACAAACTAGAA 3'
   D. 5' UACAAACUAGAA 3'

Constructed Response

28. **Short Answer** Compare and contrast transcription and translation. Indicate where they occur in prokaryotic cells and eukaryotic cells.

29. MAIN Idea Describe the experiment that led to the One Gene-One Enzyme hypothesis.

Think Critically

30. **Identify** the mRNA sequence and orientation if the nontemplate strand has the sequence 5' ATGCCAGTCATC 3'. Use **Figure 14** to determine the amino acid sequence coded by the mRNA.

Understand Main Ideas

16. B

Constructed Response

17. DNA helicase unzips the DNA, RNA primase adds a short RNA primer, DNA polymerase places the proper complementary nucleotide into place, and DNA ligase links the Okazaki fragments together.

18. Diagram should show the leading strand and the lagging strand and include labels for DNA polymerase, DNA helicase, Okazaki fragments, and DNA ligase.

Think Critically

19. In bacteria, there is one origin of replication, and replication proceeds in both directions. In eukaryotes, there are multiple origins of replication along the DNA strand, so this is a eukaryotic cell.

20. Eukaryotic chromosomes can be composed of up to one million base pairs. DNA replication can proceed at a faster rate with multiple areas of replication.

21. One strand of DNA serves as a template to make the matching strand. The matching strand is made of complementary bases.

Section 3

Vocabulary Review

22. mRNA contains the code from the DNA strand; tRNA has anticodons that correspond to the codons on the mRNA strand.

23. RNA polymerase catalyzes the transcription of mRNA, which contains the codons that are translated into amino acids during translation.

24. Introns are the parts of pre-mRNA that interrupt the code contained in the exons.

Understand Main Ideas

25. C

26. B

27. A

Constructed Response

28. Transcription involves the opening of the DNA and the synthesis of a complementary mRNA strand to the template strand of the DNA. Translation involves making a protein from the mRNA and occurs in the cytoplasm on a ribosome. In prokaryotes, both translation and transcription take place in the cytoplasm, since they have no nucleus. In eukaryotes, transcription takes place in the nucleus and translation takes place in the cytoplasm. In both, translation takes place on the ribosome.

29. Mold spores were mutated by exposing them to X rays. If the mutated spore could not grow on a minimal medium, it was tested to see what amino acid it lacked.

Think Critically

30. 5' AUGCCAGUCAUC 3'; amino acid sequence: methionine (start), proline, valine, isoleucine

Section 4

Vocabulary Review

Write the vocabulary term from the Study Guide page that describes each of the following processes.

31. regulation of a prokaryotic genome

32. control of the functional units of DNA

33. changes in DNA sequence

Understand Main Ideas

34. Which demonstrates an insertion mutation of the sequence 5' GGGCCCAAA 3'?
- **A.** 5' GGGGCCAAA 3'
- **B.** 5' GGGCCAAA 3'
- **C.** 5' GGGAAACCC 3'
- **D.** 5' GGGCCCAAAAAA 3'

35. Which is true about eukaryotic gene regulation?
- **A.** Eukaryotic gene regulation is exactly like prokaryotic gene regulation.
- **B.** Replication factors guide the binding of eukaryotic RNA polymerase to the promoter.
- **C.** Activator proteins fold DNA to enhancer sites that increase the rate of gene transmission.
- **D.** Repressor proteins bind to activators, preventing them from binding to the DNA.

36. Which is not a type of mutation?
- **A.** base substitutions
- **B.** insertions
- **C.** RNA interference
- **D.** translocation

Constructed Response

37. Short Answer Illustrate the effect of adding tryptophan to a culture of *E. coli*.

38. Short Answer Describe RNA interference.

Think Critically

39. Infer why base substitutions in the third position are least likely to cause a change in the amino acid for which it coded.

40. MAIN Idea Hypothesize how it might be possible for bacteria to respond to environmental stress by increasing the rate of mutations during cell division.

Summative Assessment

41. BIG Idea Explain the central dogma of protein synthesis.

42. WRITING in Biology The discovery of DNA and its structure required many scientists to research, conduct experiments, and publish their findings. Write about a scientific event that required scientists to build on others' findings to produce results.

43. WRITING in Biology The book *Jurassic Park* by Michael Crichton presents the idea of isolating DNA from extinct organisms and "resurrecting" them. If this were possible, should this be done? Defend your opinion in an essay.

DBQ Document-Based Questions

Data obtained from: Watson, J.D. and Crick, F.H.C. 1953. Molecular Structure of Nucleic Acids. *Nature* 171: 737-738.

The following excerpts are from Watson and Crick's description of the structure of DNA.

"The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain so that the two lie side by side with identical z-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur."

"It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

44. Draw a diagram of DNA structure based on the description above.

45. According to the description, how are the bases joined together?

46. What did Watson and Crick see as a possible copying mechanism?

Section 4

Vocabulary

31. operon

32. gene regulation

33. mutation

Understand Main Ideas

34. D

35. C

36. C

Constructed Response

37. Tryptophan acts as a corepressor, binding to the inactive repressor, activating it, and shutting off the enzymes needed to synthesize tryptophan.

38. RNA interference involves small pieces of RNA that bind to mRNA and interfere with its expression.

Think Critically

39. The third position for many amino acids could be any of the DNA codes, and a change in the third position will not change the amino acid for which it coded.

40. Accept any logical hypothesis. Answers might include reduction in the amount of checking enzymes produced. Increased mutations might lead to an adaptation that increases chances of survival under changing environmental conditions.

Summative Assessment

41. The central dogma of protein synthesis is DNA codes for RNA and RNA guides the synthesis of proteins.

42. Answers will vary, but should involve a situation where people used teamwork to determine or answer a common question, problem, or activity.

43. Answers will vary. Students should defend their opinions.

DBQ Document-Based Questions

Watson, J. D. and Crick, F. H. 1953. Molecular structure of nucleic acids. *Nature* 171: 737–738.

44. The diagram should show the side rails of sugar bonded to phosphate. The steps of the ladder are thymine double bonded (hydrogen bonds) to adenine and cytosine triple bonded (hydrogen bonds) to guanine.

45. Cytosine bonds to guanine and thymine bonds to adenine.

46. The hydrogen bonds could break and the parental strands serve as a template for the synthesis of new strands.

Standardized Test Practice

Multiple Choice Aligned with PISA & SAT

1. A 5. D
2. A 6. A
3. C 7. C
4. A 8. C

Short Answer Aligned with PISA & SAT

9. The law of independent assortment states that a random distribution of alleles occurs during gamete formation. Therefore, a dihibrid cross of YyRr would

	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

produce a phenotype ratio of 9:3:3:1.

10. Answers can vary, but should show the link between technology and new understandings of DNA. For example: X-ray diffraction was a technique for taking pictures of molecular structures. Franklin used this technique to find that the DNA molecule had a double helix shape.
11. Coat variations that occur only in females are likely caused by dosage compensation. The degree of expression would depend on the number of alleles present in the females. Sex-linked genes do not likely cause the effects, unless the genes are not expressed or are lethal in males.
12. The genotypes homozygous for both traits are *RRYY, RRyy, rrYY,* and *rryy.* The homozygous genotypes are 25% of the total. The easiest way to determine the percent of offspring homozygous for both traits would be to use a Punnett square.
13. Mendel's work showed that there are very regular patterns for inheritance, so it opened up questions about what causes these patterns.
14. The organism would have five chromosomes in its karyotype. Monosomy is the absence of one chromosome from a pair. The organism has a chromosome number of $2n = 6$, or six chromo-

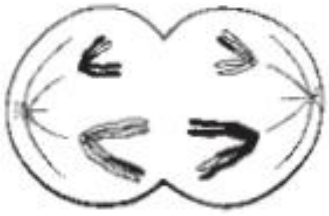
Standardized Test Practice

Cumulative

Multiple Choice Aligned with PISA & SAT

1. Which macromolecule can be formed using the sugars produced by plants during photosynthesis?
   - A. cellulose
   - B. DNA
   - C. lipid
   - D. protein

Use the diagram below to answer questions 2 and 3.

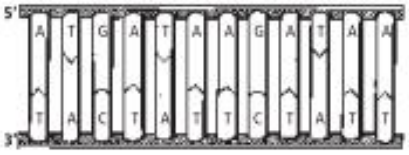


2. Which stage of meiosis is represented in the diagram?
   - A. anaphase I
   - B. anaphase II
   - C. metaphase I
   - D. metaphase II

3. Which process can take place during the stage of meiosis that follows the stage in the diagram?
   - A. change to diploid
   - B. crossing over
   - C. cytokinesis
   - D. DNA replication

4. What enzyme is responsible for "unzipping" the DNA strand during replication?
   - A. DNA helicase
   - B. DNA ligase
   - C. DNA polymerase
   - D. RNA primase

Use the illustration below to answer question 5.



5. Which sequence is possible for mRNA formed from the DNA strand shown in the illustration?
   - A. 5'AATAGAATAGTA3'
   - B. 5'AAUAGAAUAGUA3'
   - C. 5'ATGATAAGATAA3'
   - D. 5'AUGAUAAGAUAA3'

6. Which cells would likely undergo apoptosis?
   - A. cells between fingers
   - B. cells reproducing normally
   - C. cells reproducing slowly
   - D. cells surrounding the heart

7. Which genotype could be the one of a person whose blood type is A?
   - A. I^BI^B
   - B. ii
   - C. I^Ai
   - D. I^AI^B

8. Which sex chromosomes are present in a person with Kleinfelter Syndrome?
   - A. OY
   - B. XO
   - C. XXY
   - D. XYY

64 Chapter 2 • Assessment

Short Answer
Aligned with PISA & SAT

9. Using the law of independent assortment, describe a dihybrid cross of heterozygous yellow, round-seed pea plants (YyRr). Include a Punnett square and phenotype ratios in your response.

10. Give an example of a technological development, and explain how it contributed to scientists' understanding of the structure of DNA.

11. Which probably causes the coat color variations that occur only in the females of a certain animal? Give a reason to support your conclusion.

12. Suppose you perform a dihybrid cross between two organisms with the genotype RrYy. What percentage of the offspring would be homozygous for both traits? Explain how you determined the answer.

13. Why do you think Mendel's work preceded the search for molecules involved in inheritance?

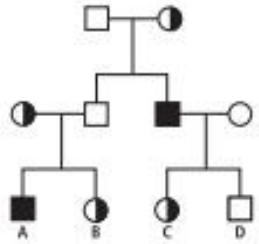
14. Suppose an organism (with a chromosome number of $2n = 6$) has mo nosomy of chromosome 3. How many chromosomes are in the organism's karyotype? Explain your answer.

15. Explain why the number of bases in a strand of mRNA can be different from the number in the DNA from which it was synthesized.

16. Explain why a hypothesis must be testable.

Extended Response
Aligned with PISA

Use the figure below to answer question 17.



17. Describe the pattern of inheritance of the disease tracked in the pedigree above.

18. Human nerve cells seldom divide after they are formed. Evaluate how this might affect a person with a spinal cord injury.

19. Explain the role that publication of findings had in the discovery of DNA's structure.

Essay Question
Aligned with PISA

For certain kinds of research studies, scientists recruit pairs of twins to be participants or subjects of the research. They might recruit identical or fraternal twins, depending on the focus of the study. Twins can be particularly helpful in studies about genetics and heredity.

Using the information in the paragraph above, answer the following question in essay format.

20. Imagine you are a research scientist. Write a plan for a research study that would require participants to be twins. Explain what you are trying to learn, whether you are looking for identical or fraternal twins, and why it is important to have twins as subjects for your study.

Essay Question Aligned with PISA

20. Answers can vary. Students should clearly state the purpose of the study and the reason for having twins involved. For instance, students might propose doing research about a health issue. They could propose doing research on a disease that is caused by both genetic and environmental factors, such as heart disease or diabetes. The study could also pertain to other health issues, such as the development of behavioral characteristics or complex physical characteristics such as height and weight. Identical twins could be useful for the study because they are genetically the same. Differences between identical twins presumably come from environmental factors, because there are no genetic differences between the twins. On the other hand, fraternal twins can be included in a study to show which traits are affected by genetic factors. Fraternal twins are genetically different but can have similar environmental factors in their upbringing. Consequently fraternal twins can also be useful in a twin study.

somes. The loss of one chromosome would give a total of five.

15. Introns that are not needed for coding of proteins are taken out of the mRNA sequence. Also, a chain of adenine nucleotides might be added to the 3' end of the chain.

16. A hypothesis is a tentative explanation for a specific research question about a phenomenon. A hypothesis must be testable in order to determine if it is a valid explanation for the phenomenon. If a hypothesis is not testable, it cannot be supported by evidence.

Extended Response Aligned with PISA

17. This is a sex-linked disease and the gene causing the disease is recessive. It is sex-linked because the disease itself appears much more frequently in males, while females are usually just carriers of the gene for the disease, indicating that they have another gene on their second X-chromosome that is dominant and covers the gene of the disease tracked in the pedigree. The gene causing the disease tracked in the pedigree is recessive because it can occur only in females who receive the gene for this disease from both parents.

18. The damaged nerves in the spinal cord would not be able to repair themselves by dividing and making new nerve cells. This means that a spinal cord injury is usually permanent.

19. Answers can vary, but should describe how the publication of Watson and Crick's ideas about structure, in addition to Franklin's publication about her findings about the shape of DNA, made the double helix public knowledge in the scientific community. This, in turn, made it possible for others to try replicating their findings, or to determine whether the findings agreed with other evidence about DNA's structure.

Student Resources

For students and parents/guardians

Investigation and experimentation are key components of your biology class. Use this reference to learn lab techniques that will enhance your lab experience. Laboratory safety is vital to a successful investigation and experiment; we've outlined basic laboratory safety principles here.

The skillbuilder handbook helps you sharpen your problem-solving skills so you can get the most out of reading and understanding scientific writing and data. Improving skills such as making comparisons, analyzing information, reading time lines, and using graphic organizers also can help you boost your test scores.

The reference handbook is another tool that will assist you. The classification tables, word origins, and the periodic table of the elements are resources that will help increase your comprehension.

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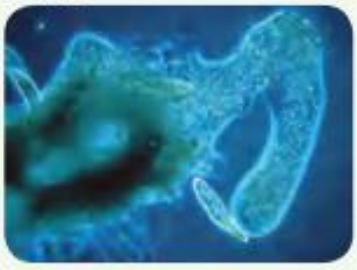
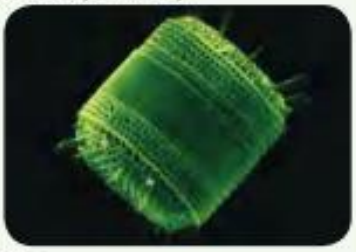
Six-Kingdom Classification

The classification used in this text combines information gathered from the systems of many different fields of biology. For example, phycologists–biologists who study algae–have developed their own system of classification, as have mycologists–biologists who study fungi. The naming of animals and plants is controlled by two completely different sets of rules. The six-kingdom system, although not ideal for reflecting the phylogeny of all life, is useful for showing relationships. Taxonomy is an area of biology that evolves just like the species it studies. In **Table 1,** only the major phyla are listed, and one genus is named as an example. For more information about each taxon, refer to the chapter in the text in which the group is described.

Table 1 Six-Kingdom Classification

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Bacteria  *Salmonella*	Actinobacteria	*Mycobacterium*	• unicellular • most absorb food from surroundings • some are photosynthetic • some are chemosynthetic • many are parasites • many are round, spiral, or rod-shaped • some form colonies
	Omnibacteria	*Salmonella* (salmonella)	
	Spirochaetae (spirochetes)	*Treponema*	
	Chloroxybacteria	*Prochloron*	
	Cyanobacteria (blue green algae)	*Nostoc* (nostoc)	
Archaea  *Methanococcus jannaschii*	Aphragmabacteria	*Mycoplasma*	• unicellular • some absorb food from surroundings • some are photosynthetic • some are chemosynthetic • many are found in extremely harsh environments including salt ponds, hot springs, swamps, and deep-sea hydrothermal vents
	Halobacteria	*Halobacterium*	
	Methanocreatrices	*Methanobacillus*	
Protista  *Amoeba*	Sarcodina (amoeba)	*Amoeba* (amoeba)	• unicellular • take in food • free-living or parasitic • move by means of pseudopods
	Ciliophora (ciliates)	*Paramecium* (paramecium)	• unicellular • take in food • have large numbers of cilia
	Apicomplexa (apicomplexan)	*Plasmodium* (plasmodium)	• unicellular • take in food • no means of movement • are parasites in animals

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Protista *(continued)*  Diatom	Zoomastigina (zooflagellates)	*Trypanosoma*	• unicellular • take in food • free-living or parasitic • have one or more flagella
	Euglenophyta (euglenoids)	*Euglena* (euglena)	• unicellular • photosynthetic or take in food • most have one flagellum
	Bacillariophyta (diatoms)	*Navicula*	• unicellular • photosynthetic • have unique double shells made of silica
	Pyrrophyta (dinoflagellates)	*Gonyaulax*	• unicellular • photosynthetic • contain red pigments • have two flagella
 Red algae	Rhodophyta (red algae)	*Chondrus*	• most are multicellular • photosynthetic • contain red pigments • most live in deep, salt water
	Phaeophyta (brown algae)	*Laminaria*	• most are multicellular • photosynthetic • contain brown pigments • most live in salt water
	Chlorophyta (green algae)	*Ulva*	• unicellular, multicellular, or colonies • photosynthetic • contain chlorophyll • live on land, in freshwater, or salt water
 Slime mold	Acrasiomycota (cellular slime mold)	*Dictyostelium*	• unicellular or multicellular • absorb food • change form during life cycle • cellular and plasmodial slime molds
	Myxomycota (acellular slime mold)	*Physarum*	
	Oomycota (water mold/ downy mildew	*Phytophthora*	• multicellular • are either parasites or decomposers • live in freshwater or salt water

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Fungi  Bread mold	Zygomycota (common mold)	*Rhizopus* (bread mold)	• multicellular • absorb food • spores are produced in sporangia
	Ascomycota (sac fungi)	*Saccharomyces* (yeast)	• unicellular and multicellular • absorb food • spores produced in asci
	Basidiomycota (club fungi)	*Crucibulum* (bird's nest fungus)	• multicellular • absorb food • spores produced in basidia
	Deuteromycota (imperfect fungi)	*Penicillium* (penicillum)	• members with unknown reproductive structures • imperfect fungi
	Chytridiomycota	*Chytridium* (chrytid)	• some are saprobes • some parasitize protists, plants, and animals
Plantae  Liverwort	Hepaticophyta (liverworts)	*Monosolenium* (Pellia)	• multicellular nonvascular plants • reproduce by spores produced in capsules • green • grow in moist, land environments
	Anthocerophyta (hornworts)	*Anthoceros*	
	Bryophyta (moss)	*Polytrichum* (haircap moss)	
	Lycophyta (club moss)	*Lycopodium* (wolf's claw)	• multicellular vascular plants • spores are produced in cone-like structures • live on land • photosynthetic
	Arthrophyta	*Equisetum* (horsetails)	• vascular plants • ribbed and jointed stems • scale-like leaves • spores produced in cone-like structures
 Wood fern	Pterophyta (ferns)	*Polypodium* (ferns)	• vascular plants • leaves called fronds • spores produce in clusters or sporangia called sori • live on land or in water
	Ginkgophyta (ginko)	*Ginkgo* (ginko)	• deciduous trees • only one living species • have fan-shaped leaves with branching veins and fleshy cones with seeds

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Plantae *(continued)*  Welwitschia	Cycadophyta (cycad)	*Cyas* (palm tree)	• palm-like plants • have large, feather-like leaves • produce seeds in cones
	Coniferophyta (conifer)	*Pinus* (pine tree)	• deciduous or evergreen • trees or shrubs • needle-like or scale-like leaves • seeds produced in cones
	Gnetophyta (gnetophyte)	*Welwitschia* (welwitschia)	• shrubs or woody vines • seeds produced in cones • division contains only three genera
	Anthophyta (flowering plant)	*Rhododendron* (rhododendron)	• dominant group of plants • flowering plants • have fruit with seeds
Animalia  Sponge	Porifera (sponges)	*Spongilla* (sponge)	• aquatic organisms that lack true tissues and organs • asymmetrical and sessile
	Cnidaria (cnidarians)	*Hydra* (hydra)	• radially symmetrical • digestive cavity with one opening • most have tentacles armed with stinging cells • live in aquatic environments singly or in colonies
	Platyhelminthes (flatworms)	*Dugesia* (planaria)	• unsegmented, bilaterally symmetrical • no body cavity • digestive cavity, if present, has only one opening • parasitic and free-living species
	Nematoda (roundworms)	*Trichinella* (trichinella)	• pseudocoelomate, unsegmented, bilaterally symmetrical • tubular digestive tract • without cilia • live in great numbers in soil and aquatic sediments
Abalone	Mollusca (mollusks)	*Nautilus* (nautilus)	• soft-bodied coelomates • bodies are divided into three parts: head-foot, visceral mass, and mantle • many have shells • almost all have a radula • aquatic and terrestrial species

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Animalia *(continued)*  Sand dollar	Annelida (segmented worms)	*Hirudo* (leech)	• coelomate, serially segmented, bilaterally symmetrical • complete digestive tract • most have setae on each segment that anchor them during crawling • terrestrial and aquatic species
	Arthropoda (arthropods)	*Colias* (butterflies)	• chitinous exoskeleton covering segmented bodies • paired, jointed appendages • many have wings • land and aquatic species
	Echinodermata (echinoderm)	*Cucumaria* (sea cucumber)	• marine organisms • have spiny or leathery skin and a water-vascular system with tube feet • radially symmetrical
 Sea otter	Chordata (chordates)		• segmented coelomates with a notochord • possess a dorsal nerve cord, pharyngeal slits, and a tail at some stage of life • most have paired appendages
	Chordata Subphylum: Urochordata	*Polycarpa* (sea squirt)	• young have all of the main chordate features; adults have only pharyngeal gill slits
	Chordata Subphylum: Cephalochordata	*Branchiostoma* (amphioxus)	• adults have all of the main features of chordates
	Chordata Subphylum: Vertebrata	*Panthera* (panther)	• the hallmark feature of all vertebrates is a spinal column

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Three-Domain Classification

Increasingly, biologists are classifying organisms into categories larger than kingdoms called domains. The three domains are: Domain Bacteria, Domain Archaea, and Domain Eukarya. With future discoveries, this classification system might change to incorporate new information.

DOMAIN	Bacteria	Archaea	Eukarya			
KINGDOM	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia

Scientific Word Origins

This list of prefixes, suffixes, and roots is provided to help you understand science terms used throughout this biology textbook. The list identifies whether the prefix, suffix, or root is of Greek *(G)* or Latin *(L)* origin. Also listed is the meaning of the prefix, suffix, or root and a science word in which it is used.

Origin	Meaning	Example
A		
ad *(L)*	to, toward	adaxial
aero *(G)*	air	aerobic
an *(G)*	without	anaerobic
ana *(G)*	up	anaphase
andro *(G)*	male	androceium
angio *(G)*	of seed	angiosperm
anth/o *(G)*	flower	anthophyte
anti *(G)*	against	antibody
aqu/a *(L)*	of water	aquatic
archae *(G)*	ancient	archaeologist
arthro, artio *(G)*	jointed	arthropod
askos *(G)*	bag	ascospore
aster *(G)*	star	Asteroidea
autos *(G)*	self	autoimmune
B		
bi *(L)*	two	bipedal
bio *(G)*	life	biosphere
C		
carn *(L)*	flesh	carnivore
ceph *(G)*	head	cephalopod
chloros *(G)*	light green	chlorophyll
chroma *(G)*	pigmented	chromosome
cide *(L)*	to kill	insecticide
circ *(L)*	circular	circadian
cocc/coccus *(G)*	small and round	streptococcus
con *(L)*	together	convergent
cyte *(G)*	cell	cytoplasm
D		
de *(L)*	remove	decompose
dendron *(G)*	tree	dendrite
dent *(L)*	tooth	edentate
derm *(G)*	skin	epidermis
di *(G)*	two	disaccharide
dia *(G)*	apart	diaphragm
dorm *(L)*	sleep	dormancy

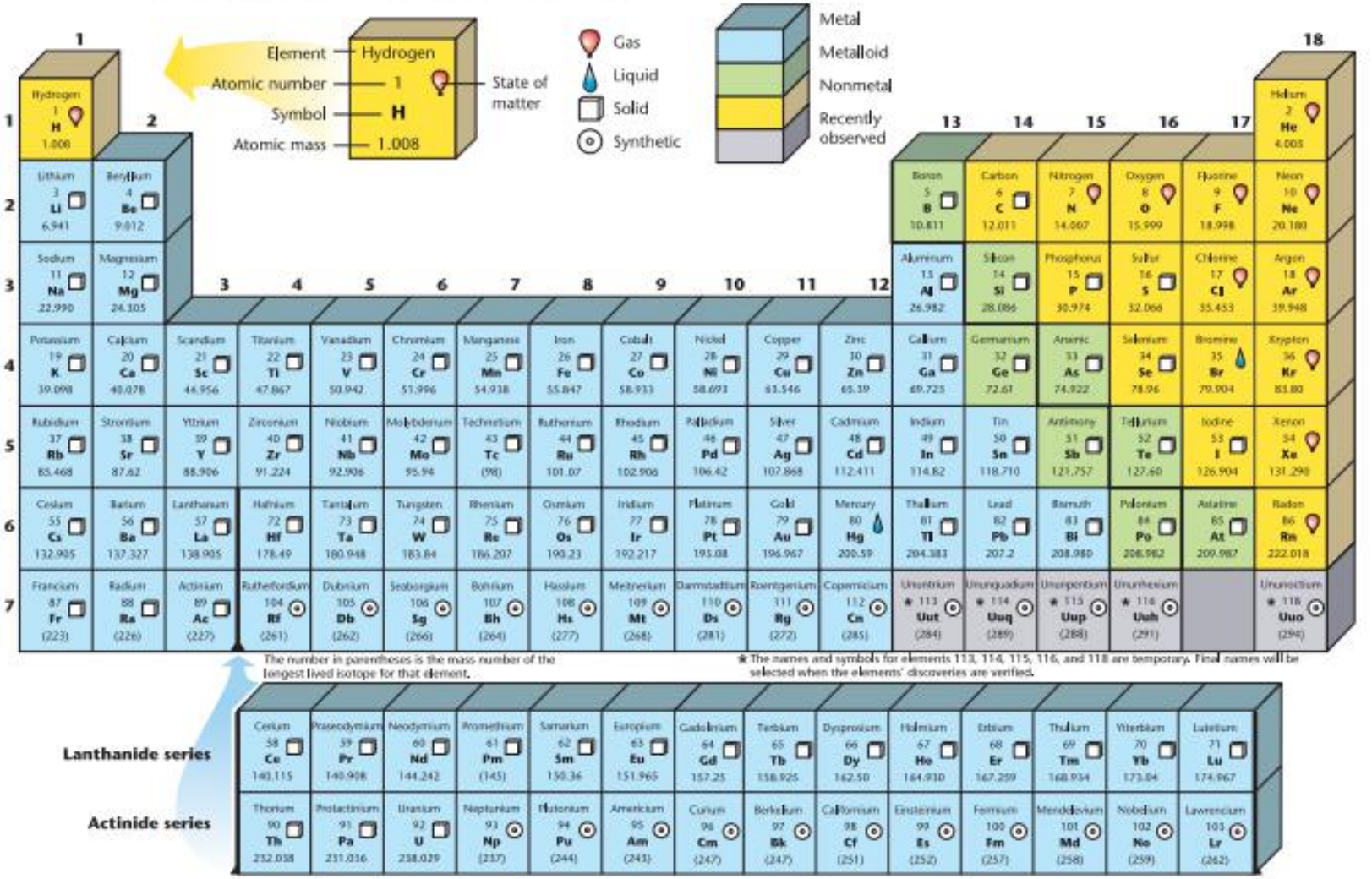
Origin	Meaning	Example
E		
echino *(G)*	spiny	echinoderm
ec *(G)*	outer	ecosystem
ella(e) *(L)*	small	organelle
endo *(G)*	within	endosperm
epi *(G)*	upon	epidermis
eu *(G)*	true	eukaryote
exo *(G)*	outside	exoskeleton
F		
fer *(L)*	to carry	conifer
G		
gastro *(G)*	stomach	gastropod
genesis *(G)*	to originate	oogenesis
gen/(e)(o) *(G)*	kind	genotype
gon *(G)*	reproductive	archegonium
gravi *(L)*	heavy	gravitropism
gymn/o *(G)*	naked	gymnosperm
gyn/e *(G)*	female	gynecium
H		
hal(o) *(G)*	salt	halophyte
hapl(o) *(G)*	single	haploid
hemi *(G)*	half	hemisphere
hem(o) *(G)*	blood	hemoglobin
herb/a(i) *(L)*	vegetation	herbivore
heter/o *(G)*	different	heterotrophic
hom(e)/o *(G)*	same	homeostasis
hom *(L)*	human	hominid
hydr/o *(G)*	water	hydrolysis
I		
inter *(L)*	between	internode
intra *(L)*	within	intracellular
is/o *(G)*	equal	isotonic
J		
jug *(L)*	to join	jugular

Origin	Meaning	Example
K		
kary *(G)*	nucleus	eukaryote
kera *(G)*	hornlike	keratin
L		
leuc/o *(G)*	white	leukocyte
logy *(G)*	study of	biology
lymph/o *(L)*	water	lymphocyte
lysis *(G)*	break up	dialysis
M		
macr/o *(G)*	large	macromolecule
meg/a *(G)*	great	megaspore
meso *(L)*	in the middle	mesophyll
meta *(G)*	after	metaphase
micr/o *(G)*	small	microscope
mon/o *(G)*	only one	monocotyledon
morph/o *(G)*	form	morphology
N		
nema *(G)*	a thread	nematode
neuro *(G)*	nerve	neuron
nod *(L)*	knot	nodule
nomy(e) *(G)*	system of laws	taxonomy
O		
olig/o *(G)*	small, few	oligochaete
omn *(L)*	all	omnivore
orni(s) *(G)*	bird	ornithology
oste/o *(G)*	bone formation	osteocyte
ov *(L)*	an egg	oviduct
P		
pal(a)e/o *(G)*	ancient	paleontology
para *(G)*	beside	parathyroid
path/o *(G)*	suffering	pathogen
ped *(L)*	foot	centipede
per *(L)*	through	permeable
peri *(G)*	around, about	peristalsis
phag/o *(G)*	eating	phagocyte
phot/o *(G)*	light	photosynthesis
phyl *(G)*	race, class	phylogeny
phyll *(G)*	leaf	chlorophyll
phyte *(G)*	plant	epiphyte
pinna *(L)*	feather	pinnate

Origin	Meaning	Example
P (continued)		
plasm/o *(G)*	to form	plasmodium
pod *(G)*	foot	gastropod
poly *(G)*	many	polymer
post *(L)*	after	posterior
pro *(G) (L)*	before	prokaryote
prot/o *(G)*	first	protocells
pseud/o *(G)*	false	pseudopodium
R		
re *(L)*	back to original	reproduce
rhiz/o *(L)*	root	rhizoid
S		
scope *(G)*	to look	microscope
some *(G)*	body	lysome
sperm *(G)*	seed	gymnosperm
stasis *(G)*	remain constant	homeostasis
stom *(G)*	mouthlike opening	stomata
syn *(G)*	together	synapse
T		
tel/o *(G)*	end	telophase
terr *(L)*	of Earth	terrestrial
therm *(G)*	heat	endotherm
thylak *(G)*	sack	thylakoid
trans *(L)*	across	transpiration
trich *(G)*	hair	trichome
trop/o *(G)*	a change	gravitropism
trophic *(G)*	nourishment	heterotrophic
U		
uni *(L)*	one	unicellular
V		
vacc/a *(L)*	cow	vaccine
vore *(L)*	eat greedily	omnivore
X		
xer/o *(G)*	dry	xerophye
Z		
zo/o *(G)*	living being	zoology
zygous *(G)*	two joined	homozygous

Reference Handbook

PERIODIC TABLE OF THE ELEMENTS



The number in parentheses is the mass number of the longest lived isotope for that element.

★ The names and symbols for elements 113, 114, 115, 116, and 118 are temporary. Final names will be selected when the elements' discoveries are verified.

Safety Symbols

These safety symbols are used in laboratory and field investigations in this book to indicate possible hazards. Learn the meaning of each symbol and refer to this page often. *Remember to wash your hands thoroughly after completing lab procedures.*

SAFETY SYMBOLS	HAZARD	EXAMPLES	PRECAUTION	REMEDY
DISPOSAL 	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
BIOLOGICAL 	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
EXTREME TEMPERATURE 	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
SHARP OBJECT 	Use of tools or glassware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
FUME 	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
ELECTRICAL 	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus. Use GFI-protected outlets.	Do not attempt to fix electrical problems. Notify your teacher immediately.
IRRITANT 	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
CHEMICAL 	Chemicals that can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
TOXIC 	Substance may be poisonous if touched, inhaled, or swallowed.	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
FLAMMABLE 	Open flame may ignite flammable chemicals, loose clothing, or hair.	alcohol, kerosene, potassium permanganate, hair, clothing	Avoid open flames and heat when using flammable chemicals.	Notify your teacher immediately. Use fire safety equipment if applicable.
OPEN FLAME 	Open flame in use, may cause fire.	hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instructions on lighting and extinguishing flames.	Always wash hands thoroughly after use. Go to your teacher for first aid.

Eye Safety
Proper eye protection must be worn at all times by anyone performing or observing science activities.

Clothing Protection
This symbol appears when substances could stain or burn clothing.

Animal Safety
This symbol appears when safety of animals must be ensured.

Radioactivity
This symbol appears when radioactive materials are used.

Handwashing
After the lab, wash hands with soap and water before removing goggles.

A Biologist's Guide To The Periodic Table