Teacher's Edition

IQWST

Life Science

Why Do Organisms Look the Way They Do?

Second Edition

WHY DO ORGANISMS LOOK THE WAY THEY DO?

Heredity and Natural Selection

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Investigating and Questioning Our
World through Science
and Technology
(IQWST)

WHY DO ORGANISMS LOOK THE WAY THEY DO?

Heredity and Natural Selection

LIFE SCIENCE

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Heredity and Natural Selection

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ART

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LS3 CONTENTS

IQWST OVERVIEW

IQWST is a carefully sequenced, 12-unit middle school science curriculum, developed with support from the National Science Foundation. As designed, each academic year includes four units, one in each discipline: Physics, Chemistry, Life Science, and Earth Science. IQWST's foundation is the latest research on how students learn and how they learn science in particular. At its core, IQWST engages students in scientific practices as they experience, investigate, and explain phenomena while learning core ideas of science. Rather than memorizing facts, students build understanding by connecting ideas across disciplines and across the middle grades. The following are key components of IQWST, important whether following NGSS, the Framework, or individual state standards.

Core Ideas: Focus on a limited number of core science ideas, aiming for depth of understanding rather than the superficial coverage inherent when aiming for breadth.

Scientific Practices: Engage meaningfully in science and the work of scientists through eight practices, used singly or in combination to explore and learn core ideas *in each lesson*.

Crosscutting Concepts: Thread throughout the curriculum the seven cross-disciplinary concepts, repeatedly revisited such that students construct deep understanding of the ideas as they apply to each science discipline.

Coherence: Build understanding through a progression within each grade level and across grade levels. Learning critical concepts and practices across content areas and grades provides students with opportunities to develop, reinforce, and use their understandings on an ongoing basis throughout their middle school years.

Performance Expectations: Identify *how* students engage with a specific practice in order to learn a specific core idea and to build increasing understanding of a broader crosscutting concept.

THE IQWST UNIT SEQUENCE: BUILDING COHERENCE

Although IQWST units can be enacted in a manner that meets district needs, they are designed based on research that shows the importance of coherent curriculum, structured such that students build understanding as they revisit ideas across disciplinary strands, content, and grade levels and deepen their understanding across time. The *Framework* indicates, "Standards should be organized as progressions that support students' learning over multiple grades. They should take into account how students' command of concepts, core ideas, and practices becomes more sophisticated over time with appropriate instructional experiences" (NRC 2011).

The role of coherence in materials and instruction is well documented: Most science programs (textbooks and instruction) do not support deep, integrated student learning because they lack coherence (Kesidou & Roseman, 2002; National Research Council, 2007). Yet presenting interrelated ideas and making connections between and among them explicit (Roseman, Linn, & Koppal, 2008) was found to be the strongest predictor of student outcomes in the Trends in International Mathematics and Science Study (TIMSS) (Schmidt, Wang, & McKnight, 2005).

Curricular coherence is best accomplished through teaching the ideas in IQWST units in a recommended sequence. That sequence aligns with NGSS, which treats a core idea such as "energy," for example, as both a Crosscutting Concept and a Core Idea. In IQWST, students engage with ideas about energy in the first physical science unit of the sequence and then revisit energy concepts in life science, chemistry, and Earth science—and in later physical science units—so that as students apply energy ideas to new content and contexts, their understanding of one of the most challenging concepts in science education deepens across middle school.

The following chart illustrates the recommended sequence for optimum curriculum coherence, enabling students to build on and revise their understanding of core content and to strengthen their ability to successfully engage in scientific practices over multiple years.

IQWST MIDDLE SCHOOL CURRICULUM

Level 1	Physical Science	Introduction to Chemistry	Life Science	Earth Science
	Can I Believe My Eyes? Light Waves, Their Role in Sight, and Interaction with Matter	*How Can I Smell Things from a Distance?* Particle Nature of Matter, Phase Changes	*Where Have All the Creatures Gone?* Organisms and Ecosystems	*How Does Water Shape Our World?* Water and Rock Cycles
Level 2	Introduction to Chemistry	Physical Science	Earth Science	Life Science
	How Can I Make New Stuff from Old Stuff? Chemical Reactions, Conservation of Matter	*Why Do Some Things Stop While Others Keep Going?* Transformation and Conservation of Energy	*What Makes the Weather Change?* Atmospheric Processes in Weather and Climate	*What Is Going on Inside Me?* Body Systems and Cellular Processes
Level 3	Earth Science	Life Science	Physical Science	Introduction to Chemistry
	How Is the Earth Changing? Geological Processes, Plate Tectonics	*Why Do Organisms Look the Way They Do?* Heredity and Natural Selection	*How Will It Move?* Force and Motion	*How Does Food Provide My Body with Energy?* Chemical Reactions in Living Things

UNIT STRUCTURE

Driving Questions

Each IQWST unit focuses on a Driving Question, which is also the unit's title. A Driving Question is a rich, open-ended question that uses everyday language to situate science content in contexts that are meaningful to middle school students. As each unit progresses, the phenomena, investigations, discussions, readings, and writing activities support students in learning content that moves them closer to being able to answer the Driving Question in a grade-appropriate manner.

Learning Sets

IQWST lessons are grouped into three to five learning sets per unit, each guided by a subquestion that addresses content essential to answer the Driving Question. This structure unifies lessons and enables students to meet larger learning goals by first addressing constituent pieces of which they are comprised.

IQWST lessons support research-based instructional routines with several components designed and structured to meet teacher needs. Each lesson comprises multiple activities (i.e., Activity 1.1, Activity 1.2) that altogether address one to four Performance Expectations (as described in NGSS). Each lesson is preceded by lesson preparation pages, Preparing the Lesson, as described in the following Lesson Structure section.

LESSON STRUCTURE

Each IQWST lesson contains common components to support teachers as they progress through the unit's activities.

Preparing the Lesson

The information on the first pages of each lesson supports the teacher in previewing and preparing for the lesson.

Teacher Background Knowledge

This section describes content to be addressed in the lesson, specifics about use of language or measurement tools, and prerequisite knowledge students are expected to have. If IQWST units are taught in the designed sequence, prerequisite knowledge is that which is expected from elementary school. If IQWST units are taught in an alternative sequence, this section alerts teachers about what students will need to understand in order to make sense of activities in a unit and to achieve its learning goals. This section also addresses content that may lie outside of teacher expertise in order to support teachers in working with content with which they are less familiar.

Sometimes, a Common Student Ideas heading describes ideas from research on misconceptions or describes other difficulties students have been shown to have with the content of a particular lesson. The section may describe prior knowledge that does not align with accepted science and that may be a stumbling block to understanding.

Setup

Setup is noted on the preparation page when the teacher needs to prepare materials ahead of time, such as mixing solutions, premeasuring materials for student groups, or setting up stations.

Safety Guidelines

A section on safety is included in the IQWST Overview. Within units, safety guidelines specific to a lesson are sometimes described separately so as to call attention to them. Examples include how chemicals should be handled and disposed of or when wafting is necessary rather than inhaling substances.

Differentiation Opportunities

Differentiation ideas highlighted prior to a lesson specify ways to either go beyond the performance expectations for the lesson or to support students who need additional help with content. Differentiation strategies that can be applied across lessons are described elsewhere in this Overview.

Building Coherence

This section briefly situates the lesson in those that precede and follow it and often references content students will have encountered in previous IQWST units, if units have been enacted in the recommended sequence.

Timeframe (Pacing)

This note estimates the number of class periods the lesson will take to complete based on widespread classroom experience. Richer discussions, more time spent on reading or writing skills, enacting demonstrations as group activities or vice versa, and other teacher-chosen adaptations require adjusting the timeframe. Most lessons require two or more class periods, as most are composed of multiple activities. Pacing is based on 50-minute class periods. Longer or shorter periods, or block schedules, require adjustment so that each class session is a coherent whole. Suggested pacing is also noted on the Unit Calendar located in the front matter.

Overview

A succinct list provides a snapshot of primary activities within a lesson, identified by activity number (i.e., Activity 1.1, Activity 1.2).

Performance Expectations

Performance Expectations describe what students should *know* and *be able to do* in a given lesson. Performance expectations describe one or more scientific practices in which students will engage in order to learn a disciplinary core idea, often also addressing a crosscutting concept, such that teachers can effectively plan, focus, and assess students' understanding.

Materials

These sections list the supplies required to carry out each activity within a lesson. They are quantified and grouped based on teacher needs, group needs, and individual needs.

Introducing the Lesson

This feature is included when activities are specifically designed to launch a lesson, often including integration of the previous reading or homework assignment.

Discussion Types

Types of discussion are described elsewhere in this Overview and are identified within each activity: Brainstorming, Synthesizing, or Pressing for Understanding. Each discussion has a stated purpose, followed by suggested prompts to guide conversation. Prompts are not intended as a script but provide teachers with alternatives they can use or from which they can shape their own questions—both factual/close ended and open ended to encourage thinking, challenging, explaining, and arguing from evidence.

Reading Follow Up and Introducing Reading

Suggestions for introducing and following up reading aid comprehension, retention, and integration of reading into science lessons. Readings are designed to be done independently, as homework, providing students with opportunities to revisit class activities, to connect science to their everyday lives, to deepen their understanding of content, and to apply their understanding to new examples and contexts. The pacing of lessons, as described, presumes that reading is not an in-class activity but is an at-home activity to extend student learning. Reading is addressed more fully elsewhere in this Overview.

Teacher Supports

Icons


Apple – Signals an "aside" to the teacher, often a strategy or a hint about student thinking likely to arise during an activity. Strategies and hints are embedded at points in the lessons that are most helpful to the teacher.


Checkmark – Signals a point at which the teacher should stop and check students' understanding before moving forward in the lesson or unit. Often, the ideas accompanied by this icon can be used as assessment opportunities.


Open Book – Signals either a reading assignment or a follow-up homework activity at the point in a lesson that it is best assigned. Typically the book icon is at the end of an activity and indicates work that is to be done in preparation for the activity that follows.


Safety – Signals precautions important to ensure safety in a lesson. Many lessons do not have specific safety precautions; instead, the lesson directs the teacher to the Overview, where general precautions, to be followed across IQWST lessons, are outlined.


Key – Signals smaller-scale learning goals that may be components of a larger disciplinary core idea. Key ideas might also include scientific principles derived from class activities, important definitions, or a new type of X to be added to a list of "types of X" students have been compiling in the unit. Key ideas might include main ideas at which students should arrive after an activity, reading, or class discussion.


Probe – Signals that technology is used in a particular lesson either for modeling (e.g., a computer simulation) or for quantitative measurement (e.g., probes and data loggers).


Pencil (only in Student Edition) – Signals places in which a written response is expected. Because questions are used as headers and are also woven throughout readings to engage students as active readers, an icon is used to indicate when a written response, rather than simply "thinking about," is required.

Projected Images (PI)

The value for students of seeing images in science cannot be overestimated. Projected Images (PI) are to be displayed for the class. Selected images may be printed for display on the Driving Question Board and perhaps laminated for reuse.

Each IQWST lesson includes projected images, charts, and graphs to expand students' understanding of science concepts. These colorful images are most effective for instruction if they are displayed in the front of the room on the white board. The images are located on the IQWST Portal in each unit folder, and all are named clearly.

The IQWST Portal

The IQWST Portal is an online resource for educators and students to access IQWST curriculum resources, including teacher editions of IQWST textbooks, student lab books, unit materials lists, assessments, and more. The IQWST Portal also provides access to digital resources including lesson-specific videos and audio files with narration of every student reading. Interactive resources and simulations like NetLogo are also located on the IQWST Portal.

The IQWST Portal is organized with each of the 12 units listed as a course. Within each course the content is divided into learning sets that are composed of multiple lessons. Within the lessons, educators can access digital versions of IQWST print materials, digital resources, and interactive resources. Each unit also contains a news section with up-to-date links to articles and research relevant to physical science, chemistry, life science, and Earth science.

DIFFERENTIATION IN IQWST

Range of Student Learners

Strategies built into IQWST lessons acknowledge students' differing capabilities, expectations, experiences, preferred learning styles, language proficiency, reading strategy use, and science background knowledge, among others. Materials address diverse needs by connecting classroom science to students' everyday, real-world interests and experiences. Each activity provides opportunities for teacher guidance, for independent work as well as small-group and whole-group interaction, for investigation, for discussion, and for reading, writing, and talking science. Opportunities for differentiation abound in each of these areas and in each lesson, so all students can work at their appropriate level of challenge.

Activity-based experiences enable students to share common experiences from which to build understanding. Students with kinesthetic preferences can use their strengths as doers and problem solvers. Those with verbal preferences can talk and write about processes and practices and can contribute ideas from readings to the discussion. Those with tactile preferences can manipulate materials. Those with visual preferences observe rather than only read about science. IQWST does not require memorizing definitions, writing paragraphs using vocabulary, or writing lab reports. Students with a range of learning preferences, language abilities, and other strengths and weak areas as learners can contribute to, engage in, and learn from each investigation—independently and collaboratively.

Specific differentiation opportunities are described in the Preparing the Lesson pages that precede each lesson. The following general strategies apply across IQWST.

General Differentiation Strategies

- Students begin each unit with an activity to generate original questions that will form the Driving Question Board (DQB) for the unit. Some of their questions will not fit into any of the categories used to organize the DQB and will not be addressed in the unit. Such questions may be assigned to students as an ongoing, individual project that they complete using various resources.

    - Such projects enable students who benefit from "going beyond" the unit to do so independently. With the teacher's discretion, projects for advanced students might come from such work, requiring use of multiple resources with varied text complexity.
    - Passionate interest has been shown to motivate students who struggle with reading to nonetheless read texts well beyond their Lexile level or presumed "ability" in a quest to learn more about something they are invested in. English Learners, students with learning disabilities, and struggling readers should thus be encouraged to investigate topics in which they are keenly interested. Some students will need support with resources (e.g., Internet search terms or suggested websites), but it is important to encourage all students to pursue areas of interest.

- Two follow-up questions that students cannot get wrong, simply by virtue of having read are (1) What did you find most interesting about last night's reading? and (2) What is one new thing you learned as you read last night's assignment? Some variation of either of these questions can be used for accountability purposes (i.e., Did the student read?) and for encouragement purposes (i.e., There are no wrong answers).

- Discussion is important to allow exchange of ideas and examination of one's own ideas. Many students, especially English-language learners, students with learning disabilities, or students with auditory processing difficulties, struggle to make sense of a question and formulate a response in time to raise their hands and articulate their ideas orally. For such students, consider a think-pair-share strategy. Pose a question and provide students with time to *think* about their response (or to write their ideas). Then, *pair* students with partners to *share* ideas. The teacher can then call on a pair, who can give a response they have had time to rehearse. This activity can be taken a step further to *square* the response by having two pairs talk together.

- Some students participate more fluently and comfortably if they are sometimes told ahead of time which question they are going to be asked to share their ideas about. Preparation time allows them to jot notes, to practice orally, or to reread a written response and be confident about sharing aloud. A teacher can prepare a sticky note such as "Be ready to talk about your answer to Question 3," and can place that note on a student's book in the course of teaching a lesson. This enables students with a range of language proficiencies, background knowledge, memory, or ability to process information time to think through their ideas and thus to be more confident and successful sharing in whole-class contexts.

Reading Differentiation Strategies

- Readings are designed based on research indicating that when students are passionate about a topic they often read well beyond their determined "reading level." Thus, IQWST readings emphasize engaging students in science. In many programs, reading level is simplified by shortening sentences and using easier vocabulary. However, doing so shortchanges students in two ways. First, shorter sentences require removal of connecting words (therefore, so, then) that actually support comprehension. Second, simplifying text by limiting multisyllabic words shortchanges students by ensuring that weaker readers remain unable to engage with texts that use the vocabulary of science. Therefore, IQWST does not differentiate with simplified materials but with strategies that support readers to learn all they can from the texts provided.

- IQWST lessons provide strategies for introducing reading, monitoring student comprehension, and following up on reading assignments. A Getting Ready section begins each reading as a research-based strategy for improving comprehension—the sections generate interest and engage students, activate prior knowledge, and provide a purpose for reading. Although these strategies support all students, struggling readers can be explicitly taught the value of each of these components as strategies successful readers use to improve comprehension. Strong readers, often unknowingly, "wonder" about what they are about to read, thus providing a purpose for reading that improves their comprehension and retention.

- Reading in science contains both main ideas and important details. Some IQWST readings employ methods for students who need to continue to work on reading strategies with built-in prereading strategies and advance organizers to help students with both text structure and content. Teachers may create additional advance organizers, as desired for particular readings.

- Encourage students to read all of the written material, as it is designed to support learning of key concepts, and to extend the application of key ideas into the real world thus to generate interest in science. However, many options enable the teacher to support struggling readers, students with learning disabilities, English Language Learners, and advanced students.

    - If students find an assignment overwhelming, let them know what to focus on as they read, perhaps indicating (or marking) two or three sections of the reading that they should read carefully. Doing so gives them freedom to read all of the material but focuses their reading so that they are more likely to experience success when they can participate in follow-up class discussion because they focused on the "right" section of the reading.
    - When a reading has multiple examples (e.g., a reading about how the eyes of three types of animals work), invite students to prepare to talk about any one of the three. Doing so does not erase the opportunity to read all but enables students to make choices and to focus their reading, providing encouragement and small steps toward success.
    - Many opportunities exist for advanced students to conduct Internet searches and read more complex texts as they either pursue areas of interest or are assigned such work by the teacher.

- Support readers by pre-identifying challenging language in the readings. On the board, write 2-3 words likely to be stumbling blocks, pronounce them, and provide connections (if possible) to everyday use of such words or to cognates for English-language learners (e.g., consulting an English/Spanish science glossary). IQWST is built on a strong research base showing that the best way to learn vocabulary is to encounter and use words in context. Use an interactive Word Wall to display words so that they may be referred to often. Pre-identifying and pronouncing words that might cause difficulty is not meant as a strategy for teaching vocabulary but only as a way to ensure that when students encounter Leonardo da Vinci's name or see "optical illusion" in print, they will not experience unfamiliar words as roadblocks.

- Readings should be previewed and followed up in class, and soon most students, even struggling readers, will attempt at least portions of the reading. Even if they do not read the entire assignment, or do not read well, students will make sense of whatever they do accomplish in ways that will help them learn. IQWST is not a textbook-driven curriculum, so using class time to read the materials does not align with a project- and inquiry-based philosophy in which students experience phenomena and then think about, write about, talk about, and read about science to learn content in meaningful ways. Encourage reluctant readers by asking follow-up questions that draw on examples from the reading, making the focus not on details, but on sense making, so that all can feel successful and encouraged to read.

Writing Differentiation Strategies

- Writing in science must be clear and accurate. For students with motor skills difficulties, provide ample writing space by using the margins, the back of the page in the student book, or additional paper. Students can also write on a computer, print, and paste the page into the student book.

- To support students with learning disabilities, who may omit words in writing, suggest that they read their own writing aloud, as they can often "hear" omissions when they do so. Alternatively, a peer or family member can read a written response aloud to allow students to self-correct as they hear errors in their writing. Another person may also scribe while students who struggle with writing provide oral responses, allowing students to express their understanding of science ideas and to communicate more successfully.

Mathematics Differentiation Strategies

- Measurements in science are precise, and measuring using science equipment can be difficult. Collaborative investigations enable students with varied strengths to work together. Although all students should learn how to use the tools of science, students who have difficulties with motor skills or vision impairments, for example, do not need to physically measure or be the person solely responsible for reading the thermometer. Instead, students work together to carry out investigations.

- Procedures in science require a sequencing of steps that can be difficult for some students if instructions are given only orally or only in print. To support all students, review written instructions orally, step-by-step, as needed. Have students reread procedures even after they have been reviewed. Demonstrate procedures for investigations that are anticipated to cause confusion or frustration. Many students are more successful if they check off steps as each is completed.

SCIENTIFIC AND ENGINEERING PRACTICES

The *Framework* and NGSS identify eight practices that build and refine scientific knowledge and thus are central to the scientific enterprise. Rather than separate content knowledge and inquiry skills, as in previous versions of national standards newer standards move toward combining core content and scientific practices in tandem. IQWST is based on the same extensive research that forms the foundation of science education for the 21st century and the basis for the *Framework* and NGSS. Thus, IQWST lessons integrate and continually reinforce practices such that students develop greater facility with and deeper understanding of these practices and of the content they address, whether NGSS, the Framework, or state standards guide learning.

Engaging in scientific practices enables students to experience how it is that scientists come to particular understandings rather than to experience science as a set of complete, discrete, isolated facts. In addition, a focus on practices, as an extension of previous approaches to inquiry, expands students' understanding of science beyond viewing it as a limited set of procedures or as a single approach typically characterized as "the scientific method."

Scientific practices require both knowledge and skill, and IQWST approaches scientific practices in that manner; they are always contextualized. Rather than a lesson about "how to construct a good scientific explanation," explanations are taught in the context of a lesson about core content using the construction of an evidence-based explanation as a way to think about, make sense of, and communicate one's understanding of phenomena. All eight practices are reflected throughout IQWST. However, each unit's learning goals emphasize particular practices, emphasizing those best taught (and practiced) in the context of a given unit's learning goals and investigative activities.

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics, Information and Computer Technology, and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Each of these is addressed individually in sections that follow.

Scientific Practice 1: Asking Questions and Defining Problems

A key IQWST instructional component is each unit's Driving Question. A driving question is a rich, open-ended question that uses everyday language to situate scientific principles in contexts that are meaningful to middle school students. The discussions, investigations, science readings, and writing activities all relate to the Driving Question. IQWST involves students in constructing, evaluating, communicating, and reaching consensus on scientific explanations of how and why phenomena happen. In order to engage in this practice, students must make sense of phenomena they study and then articulate and defend their understandings to themselves, each other, the teacher, and other audiences. As each unit progresses, students learn content that moves them closer to being able to answer the Driving Question in a grade-appropriate manner. As important, each unit purposefully solicits students' original questions and provides the teacher with guidance about posting those questions on a Driving Question Board in the classroom and integrates them into the lessons. Thus science becomes "what I wonder about" rather than only "what I am told I should think about."

In addition, in the process of exploring phenomena and wondering how and why things happen, students question one another about what they observe and the conclusions they draw. They question one another about the texts they read. They learn about questioning in this manner, as well as asking testable questions that students can answer by designing, planning, and carrying out an investigation. In some IQWST units, students work together to define a problem, determine how to find a solution, and compare ideas with others in the process of solving the problem.

Driving Question Board

To organize each IQWST unit, the Driving Question is displayed on a Driving Question Board (a bulletin board or large area on a wall). The Driving Question Board (DQB) is a tool used throughout IQWST to focus students' attention, record what they have learned, and show students where they have been and the direction they are going. The DQB serves as a visual reference that remains in place throughout a unit. Lesson plans typically guide the teacher in their use. Although the teacher maintains the DQB, because it functions as a shared space to represent learning, students might also contribute regularly to the display.

Each IQWST lesson addresses a component of the unit's Driving Question, supporting students in making sense of science content and determining which part of a question they can answer and which they still need to investigate. Thus, new lessons are motivated, in part, by what questions still need to be addressed. The visual display supports teachers and students in tracking and organizing ideas along the way.

Each unit invites students to post their own original questions on the DQB to encourage active engagement in a participatory classroom culture. As they think of new questions at any time during the unit, students write those questions on sticky notes and add them to the class DQB. Across a unit, the Driving Question Board will come to include the unit-specified question and subquestions, as well as student questions, drawings, photographs, artifacts, objects, and sample student work. The DQB will serve as a focal reference helpful to all but especially important for students for whom visual representations aid in their learning, such as connecting new ideas to previous understandings. Revisit the DQB with students in each lesson. Refer to it often. Point to artifacts displayed on it as a reminder of previous activities or understandings. Post on it summaries of scientific principles, as well as artifacts students create that relate to specific questions. Any projected image used in IQWST could be printed, laminated, or inserted into a plastic sleeve and displayed on the Driving Question Board. This includes models or data tables developed as a class or any other visual representation of concepts students have studied.

Space on the Driving Question Board may be limited, but it is important that aesthetics and the neatness of the DQB do not outweigh the support provided to students when they can frequently refer to the visual representations as a reminder of activities done and content learned throughout a unit.

Scientific Practice 2: Developing and Using Models

The *Framework* describes the central role of constructing and using models to explain: "Science often involves the construction and use of a wide variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond observations and imagine a world not yet seen. Models enable predictions . . . to be made in order to test hypothetical explanations." NGSS specifies that models can include "diagrams, physical replicas, mathematical representations, analogies, and computer simulations," all of which contain "approximations and assumptions" that students need to learn to recognize as a given model's limitations. In science, models are used to help people understand, describe, predict, and explain phenomena in the real world.

Scientific modeling consists of several core practices: constructing models, using models to explain or predict, evaluating models, and revising models. IQWST engages students in all of these, supporting learners as they develop models, use models to explain, use models to predict, critique one another's models, and revise models as they learn new information—engaging in modeling as real scientists do. Because modeling is often connected with other aspects of scientific practice, students' experiences with modeling are embedded in the broader context of investigating, understanding, and explaining phenomena. Students create and use models to understand and apply scientific ideas, to illustrate and defend ideas, and to evaluate interpretations.

Engaging Students in Modeling

Students need to understand the purpose of models and modeling in science in order to effectively engage in the practice of developing and using models. Initially, it may be useful to have students think about other models they know, such as models of weather phenomena that scientists use to explain and predict the path of hurricanes, tornadoes, thunderstorms, or snowstorms.

Before Students Develop Models

1. It is helpful to emphasize that the point of developing models is to try to explain the phenomenon just investigated in class. Students' models should demonstrate their best ideas about how to show how and why X happened, so that the model can be used to explain what happened to someone else.

2. Begin to develop criteria for good models, which can be posted in the classroom and used throughout IQWST as students develop their own models and critique one another's models. These ideas should come from class discussion and should be written in students' own language. Important ideas include the following:
   a. Models need to explain. Does the model show *how* and *why* the phenomena happened the way they did? Is there anything in the model that does not need to be here? Are there steps we are leaving out?
   b. Models need to fit the evidence. Does this model fit what was seen about the phenomenon?
   c. Models need to help others understand a phenomenon. Is the model easy to understand? Are there ways to clarify what it shows?
   d. As lessons lead to the need for model revision to account for a new phenomenon, address the idea that models also can be used to predict. Probe students with the following questions: What does our model predict about what will happen in situation X? Was that what actually happened? What does that mean about our model? What do we need to revise based on our new evidence?

Before Students Share Models

It is helpful to give students guidance about how they should listen to each other as they present their models. Eventually students will ask critical questions and make constructive suggestions to each other. Be sure to support that process until they understand this kind of classroom discourse. The following are ideas to address:

1. Different ideas will arise as we try to figure things out. This is our chance to put our heads together and come up with the best model we can come up with, as a group. But we need to agree on what we are looking for. As we listen to each other explain our models, remember what we created these models to try to do. Let's talk about what is important.
2. All scientific models have limitations. Not every aspect of a phenomenon can be explained using a single model. Models often simplify as they illustrate things that are too small, too large, too fast, or too slow to observe without a model as a representation. A static model cannot show movement. No model can sufficiently illustrate the number of molecules involved in a phenomenon nor the time required for others to take place.
3. More than one model can be used to explain the same phenomenon. Scientists judge how good a model is based on how well it helps to explain or predict phenomena—not by how similar it looks to the thing it aims to explain or describe. For example, a good model of gases can be used to explain all the behaviors of gases observed in the real world (e.g., what happens when air is cooled, heated, or compressed), but it will not be used to explain the behavior of solids. Different models have different advantages and disadvantages.

Constructing Models Depends on Scientific Argumentation

The practice of constructing models in IQWST draws critically on another scientific practice, Engaging in Argument from Evidence. In the practice of constructing models in IQWST, argumentation occurs when students defend their proposed models, showing how the model fits evidence and explains the phenomena. Argumentation occurs in classroom discourse when comparing and discussing competing models. IQWST lessons contain support for students to critique one another's models and ultimately to reach consensus, both critical parts of the argumentation practice.

Scientific Practice 3: Planning and Carrying Out Investigations

IQWST is an activity-based, phenomena-rich, investigative curriculum. Students plan investigations that address the Driving Question for each unit and carry out investigations in each lesson. The investigations build understanding of core ideas throughout each unit, always directed at gaining more understanding toward being able to answer the Driving Question. In addition, students' original questions not answered in the unit can be used as a springboard for additional investigation. Some investigations arise out of previous ones in a process of figuring out "what we know as a class" and "what we need to figure out next," typically in learning the how and why of a process. Any such questions can motivate further investigation. Thus, besides those opportunities provided by the curriculum itself, the teacher can require or encourage the planning and carrying out of investigations that extend student learning beyond the performance expectations of a given unit.

Carrying out a multistep procedure is an important science literacy skill; thus teachers might have students plan investigations, write procedures, and share plans and procedures with other groups to read and critique.

Scientific Practice 4: Analyzing and Interpreting Data

IQWST units engage students in observation, data collection and organization, interpretation, and using data to make sense of phenomena they investigate. All lessons regularly use the language of "observation," "data," and "evidence." Teachers are encouraged to ask students to support their ideas with evidence (e.g., Why do you think that? How could that happen? What if . . . ? What evidence do you/we have for that?), requiring students to consider their data carefully. Teachers encourage students to question data provided by others. This creates a situation in which using data as evidence to defend a claim makes sense—students need evidence because they will be questioned about their data in discussion.

Students analyze both qualitative and quantitative data in IQWST. They learn that both are important and while observation with the unaided eye enables them to make some significant claims, instrumentation and scientific tools enable them to be much more precise. Students analyze data they have collected themselves as well as data collected by others (e.g., changes in a population over time, melting points of substances they are unable to investigate in the classroom). Charts and graphs require understanding of independent and dependent variables, and investigations require understanding of what it means to control variables. Throughout the units, IQWST provides students with multiple opportunities to analyze and interpret data through classroom discourse as a whole class, in small groups, in pairs, and independently, providing practice in multiple contexts that reinforce the development of this scientific practice.

Scientific Practice 5: Using Mathematics, Information and Technology, and Computational Thinking

NGSS specifies within this practice ideas such as "using digital tools," for example, "to analyze very large data sets for patterns and trends" and "to test and compare solutions to an engineering design problem." In addition, this practice specifies a need for students to "measure and compare quantitative attributes of different objects and display the data using simple graphs." Therefore, IQWST units include lessons that include probes, sensors, data loggers, and a sensor interface as digital tools that enable quantitative measurement and graphic display in a manner in which real scientists do their work.

IQWST uses the language of *probes*, *sensors*, *data loggers*, and *sensor interface* for illustrative purposes, given rapid changes and advancements in technology and the attempt to use generic terms where possible. IQWST materials show photographs of and reference Pasco brand probes for several activities, as Pasco makes high-quality equipment for middle school use. If your school uses another brand of technology, adjustments may be required in the instructions to students. If your school does not have probeware, and you elect not to purchase such equipment, then more significant adjustment to activities will be necessary, especially where measurements may not be made quantitatively without similar devices. It is recommended, in keeping with the NGSS call for the types of scientific practices considered integral to science education, that probeware be used as recommended in IQWST. More specific guidelines and instructions specific to brands of probeware may be found on the Teacher Portal with updates available to teachers in a timely manner.

Mathematics is used throughout the IQWST program as students take measurements using the tools of science, collect data, plot data on graphs or create data tables, and come to understand and work with dependent and independent variables. Students use scientific probes to calculate in the manner of scientists. Computers are used for simulations of models of phenomena, such as predator/prey relationships, or for observing a phenomenon in slow motion so that it can be more carefully examined.

Scientific Practice 6: Constructing Explanations and Designing Solutions

The *Framework* defines explanations as "accounts that link scientific theory with scientific observations or phenomena" and identifies the related engineering practice of designing solutions, in which students construct and defend solutions to problems that draw on scientific ideas. In IQWST, these two aspects of the practice are combined as constructing, evaluating, and defending evidence-based scientific explanations. The scientific practice of explanation goes beyond asking students to describe what they know about a particular idea. Instead, students develop a chain of reasoning that shows why the phenomenon occurs as it does.

For example, rather than asking students simply to "explain the process of cellular respiration," an IQWST Life Science Unit asks students to "explain why the air a human breathes out contains less oxygen than the air breathed in." Students not only describe the process of respiration but also construct a causal chain that fits the evidence. Drawing on prior ideas from chemistry and physical science, such a chain should specify where glucose goes in the body, what materials can get into and out of cells, and conclude that a chemical reaction requiring both glucose and oxygen must be taking place in cells to convert energy to a form the organism can use.

What Does It Mean to Construct an Explanation?

In the practice of constructing explanations in IQWST, students make claims, use data as evidence to support their claims, and engage in reasoning that draws on scientific principles, or the "what we know" in science, to explain the "how" and "why" of phenomena they investigate in the classroom. Teachers pose questions that push students to think more deeply about what they have observed, read, and experienced, modeling this practice so that students learn to question one another. IQWST lessons support students in critiquing one another's explanations, providing students with opportunities to talk, to write, to discuss, to give and receive feedback, and to revise the explanations they have constructed. Many literacy standards are addressed as students cite evidence from sources; integrate information from observations and from text; write arguments that use a claim, use data as evidence, and use logical reasoning in an explanatory text; and engage in revision focused on writing clearly and coherently for a specific purpose and audience.

Supports are designed around a framework that divides scientific explanations into three smaller, manageable, and teachable components for middle school students: claim, evidence, and reasoning (referred to as the C,E,R framework). IQWST identifies these components in order to support students as they learn to write in a new way.

Claim

A claim is a statement of one's understanding about a phenomenon or about the results of an investigation. The claim is a testable statement about what happened. The claim expresses what the author is trying to help the audience understand and believe.

Claims may be made about data that students have been given or they have gathered themselves. If an investigation has independent and dependent variables, the claim describes the relationship between them.

In practice, teachers have found it useful to teach that a claim must be a complete sentence, cannot begin with "yes" or "no," and is typically the first sentence of an explanation. Although it is not necessary that a claim be the first sentence, experience has shown that freedom to vary the guidelines is best managed *after* the guidelines and their purpose have been learned.

The claim is often the part of an explanation that students find easiest to include and to identify as they critique others' explanations. One of the purposes of focusing on evidence-based scientific explanations is to help students include more than a claim (or "simple" answer to a question) in their writing.

Evidence

The evidence consists of the data used to support the claim. The evidence tells the audience the support the author has collected that makes the claim convincing.

An explanation must contain accurate and sufficient evidence in support of the claim. Evidence makes claims understandable and convincing. While "data" can refer to all the observations that students have collected or analyzed, data become "evidence" when used to support a claim. The evidence for explanations can come from investigations students conduct, from observations they make, or from reports of empirical research others have done. Where possible, explanations incorporate more than one piece of data as evidence.

A goal in IQWST is to help students understand that data must be marshaled as evidence in support of a particular claim. In complex situations, more than one claim might be made about a single data set. It might also be that more data are available than are necessary to support a particular claim. Students must determine which are the appropriate data to use in support of a claim they have made and what are sufficient data to support that claim. The idea that multiple claims might be made using the same data develops across the curriculum as the inquiry activities become more complex, and students' options for research questions (and resulting claims and evidence) become increasingly open ended.

Reasoning

Students learn that the accepted scientific understanding or principles that underlie the explanation must be made explicit in a process IQWST calls reasoning. The reasoning presents the logic that leads from the evidence to the claim and, if possible, connects it with a scientific principle. The reasoning says why the claim makes sense, given what is understood so far about the phenomena. Reasoning ties in the scientific knowledge or theory that justifies the claim and helps determine the appropriate evidence. The reasoning may include a scientific principle that reflects the consensus students have developed so far about the phenomena they are investigating. It may also require a logical chain that shows how the principle and evidence work together to support the claim. For example, the reasoning for the effects of a competitor X on population Y may refer to a series of connected steps that start with the increase in population size of the competing species X, decrease of available food sources needed by both X and Y, and then drop in population size of Y due to lack of food.

The reasoning connects to the general knowledge of the scientific community and a chain of logic to explain how particular data support a claim, given what scientists know about the world. Reasoning is the most difficult aspect of explanation writing for students to understand and is the most difficult aspect for teachers to teach. Reasoning requires relating general scientific principles—what is already known in science—to the specific question being investigated and requires students to make explicit the steps of their thinking.

Scientific Practice 7: Engaging in Argument from Evidence

The *Framework* defines the central role of scientific argumentation in building scientific knowledge as "a process of reasoning that requires a scientist to make a justified claim about the world. In response, other scientists attempt to identify the claim's weaknesses and limitations." In the practice of constructing explanations in IQWST, argumentation occurs when students defend their explanations both in written form, by providing supporting evidence and reasoning, and in classroom discourse, when comparing and discussing competing explanations. IQWST lessons contain support for students to critique one another's explanations and to reach consensus, both critical parts of argumentation. Students learn about criteria for critiquing explanations that also apply to arguments: both must fit the evidence, be logically coherent, fit what is known in science, and include important steps in reasoning.

Argumentation is key in IQWST thus significant attention is paid to evidence-based explanation and argumentation, and students engage in this practice in every IQWST unit.

Scientific Practice 8: Obtaining, Evaluating, and Communicating Information

Student readings provide additional information to support students' in-class investigations. Readings are designed to be integrated into each lesson such that students obtain, evaluate, and communicate information from multiple sources—their own work, others' work, and the science they read about—in all that they do. In addition, opportunities abound for additional research using the Internet, for example, so that students can pursue areas of individual interest that go beyond the performance expectations and grade-level standards. That is, a student who reads about solar sails, described in an IQWST reading as an example of the use of solar power, might wish to learn more about what solar sails are and how they work. Such reading might also trigger interest in alternative forms of energy and their advantages and disadvantages and lead to a written project as situated in the context of the science being studied. This can enable a student to apply his or her understanding to global concerns or to issues in the local community. Such projects, models, and written products that result can interest and motivate students, deepen content understanding, encourage engagement in scientific practices and literacy practices related to science, and provide application and extension opportunities beyond the classroom. In addition, deeper understanding will likely be fostered as the student encounters new ideas in science that fit with the knowledge gleaned from such a project as the core of learning—connecting new understandings with prior knowledge—is strengthened. IQWST does not require research paper types of projects; however, opportunities for teachers to collaborate across content areas such that students might explore science topics as a way to meet literacy learning goals is an option, given that students are likely to encounter many topics they wish to explore further as they investigate phenomenon and read, write, and talk science in every lesson.

INSTRUCTIONAL SUPPORT FOR SCIENTIFIC PRACTICES

The following strategies support students in developing experience with scientific practices.

Use Data to Build Understanding

As designed, earlier IQWST units help students become familiar with observation and data collection and with using data to make sense of phenomena. Teachers are encouraged to ask students to support ideas with evidence (e.g., Why do you think that? How could that happen? What if . . . ? What evidence do you/we have for that?). Teachers allow students to question evidence provided by others. This creates a situation in which using data as evidence to defend a claim makes sense—students need evidence because they will be questioned about it in discussion.

Model the Practice

The teacher uses a think-aloud process to make thinking visible to students. This highlights the underlying aspects of scientific practices, making them explicit as the teacher "talks through" his or her thinking, modeling how good writers, modelers, thinkers, observers, or questioners think as they engage in the practice.

Identify the Audience

All written tasks should be constructed with an audience in mind. This helps students shape their writing, so that the audience can make sense of a written explanation, a model, or a representation of data. In IQWST, students may be asked to think about convincing someone from another class of the validity of the claim in an explanation, to share with someone at home and get feedback, or to explain to an absentee student, someone new the school, or an elementary student.

Motivate the Practice

As teachers incorporate explanation construction and modeling into lessons, they must help students move back and forth between the components of the practice (e.g., claim, evidence, reasoning) and the overall purpose of the practice. Otherwise, focusing on the components becomes formulaic, and students lose sight of the purpose of explanations and modeling in science. To help students see a need for this work, they are placed in situations in which they must engage in argumentation as a way to "convince" someone that their conclusions make sense and can be supported with data.

Generate Criteria

When students are asked to convince one another and to determine whether they are convinced by someone's claim, they need criteria on which to base decisions. Although teachers begin with criteria in mind (described in each unit), they guide students to develop criteria in their own words. The framework can be given to students at the outset; however, students have a deeper understanding of the components and more buy-in when they work cooperatively as a class to generate criteria or the framework for an explanation.

Critique Examples

Students are accustomed to process writing in ELA, but they tend to think that once something is written in other content areas it is finished. Whole-class, teacher-led, and small-group critique of explanations and models helps students see that explanations can be revisited, rethought, and revised. A teacher can create sample explanations for critique purposes. Once students have written explanations, their work can be used anonymously for whole-class critique. Teacher-guided critique, in which the teacher asks probing questions in a discussion, is a useful next step. Once students have practiced in teacher-led sessions, they are ready to critique one another's work. In any critique, strengths and weaknesses should be highlighted and suggestions for improvement offered. It is small-group or paired sharing, in which students compare ideas and justify their use of evidence, that IQWST emphasizes. It is in those comparison and justification activities that deep conceptual understanding takes place, and it is these activities that motivate the use of explanations and models in science.

LITERACY IN THE IQWST CLASSROOM

IQWST supports literacy for diverse learners as students transition from *learning to read and write* in elementary school to *reading and writing to learn* in middle school. Lessons draw on the most recent research in literacy learning, with emphasis on reading comprehension and on the role that reading and writing—in tandem—play in learning. In IQWST, students learn by engaging with the tools, materials, ideas, and principles of science and by thinking, reading, writing, and talking science.

Literacy practices are integrated into every IQWST lesson. The curriculum encourages students to be reflective and critical thinkers, to ask questions of the teacher and each other, to share in small- and whole-group discussion, to read texts that connect science to their everyday lives and prior knowledge, to write responses to embedded questions, to construct models and written explanations and to revise them, to engage in argumentation to defend their ideas and to challenge one another's thinking.

Student books are consumable, functioning as portfolios; the lab activity pages, models and diagrams students draw, readings, and all writing are in one place. Books can be used to teach additional skills by a specialist, support person, or teacher who chooses to teach annotation or highlighting, for example, as students write directly in their books.

Reading in Science

IQWST materials are designed to meet expectations for reading and include strategies to guide teachers in addressing literacy requirements with additional depth or to differentiate for diverse students.

LITERACY GOALS	AS ADDRESSED IN IQWST
Cite specific textual evidence to support analysis of science and technical texts.	Discussion prompts and strategies for teachers and responses to questions embedded in readings ask students to refer to text for evidence.
Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.	Summarizing or referencing central ideas from text in discussion is often done in the "Reading Follow Up" section that begins most lessons.
Follow precisely a multistep procedure when carrying out an experiment taking measurements or performing technical tasks.	Activity sheets that accompany investigations and homework activities provide extensive practice in reading and following procedures.
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to Grades 6–8 texts and topics.	The language of science is key to science learning. Thus readings address vocabulary in a manner that is context rich, and use of an interactive Word Wall reinforces the reading and the use of science language.

Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.	Readings provide opportunities for teacher-led analysis of structure.
Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.	Readings provide an opportunity for teacher-led analysis of purpose.
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).	Readings support students in moving back and forth between text and visual information (e.g., "notice the shaded area in the diagram"), and some readings suggest that teachers reinforce this practice when previewing or reviewing readings.
Distinguish among facts, reasoned judgment based on research findings and speculation in a text.	This is best accomplished through suggested projects in which students pursue individual interests or go into more depth studying a topic related to class.
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	Questions such as "How does what you read help you think about yesterday's investigation?" support students in integrating multiple sources of information. Videos and simulations, as well, are interwoven with reading and with hands-on investigations.
RANGE OF READING IN IQWST	
As students transition from learning-to-read to reading-to-learn, IQWST supports them with built-in strategies for students and teachers. IQWST does not provide texts at multiple Lexile levels, based on research that indicates (1) that students who are interested in a topic will choose to read well beyond their test-determined reading level, and (2) that reducing word length and shortening sentences (key strategies for decreasing reading level) can impair comprehension.	Rather than confine students who read below level to reading lesser content, materials suggest strategies for teachers to differentiate instruction so all students have opportunities to use the materials to develop as readers capable of using a range of written materials. Suggestions for students at the top of the grade level reading band encourage independent reading of texts beyond curriculum requirements, so no ceiling suppresses what IQWST students can achieve as readers and critical thinkers.

IQWST readings are integral to students' understanding of science concepts and enable teachers to simultaneously address reading- and writing-related concepts.

Readings

- Extend classroom learning by providing additional examples of principles and concepts encountered in class
- Review in-class activities to help students understand and retain main ideas and to support absent students with content they missed
- Elicit students' prior knowledge and draw on it in engaging ways
- Provide real-world connections that illustrate the value of science outside the classroom
- Use examples with which middle school students are likely to have personal experience or at least be familiar
- Embed questions, to which students write responses, supporting integration of reading and writing in the service of learning, as well as support students' active engagement as readers

Given that the ability to "read and comprehend complex informational texts independently and proficiently" is a lifelong literacy skill, IQWST materials are designed such that readings are intended to be done independently, outside of class time. The few exceptions, in which class time is specifically devoted to addressing some portion of a reading assignment, are clearly indicated in the materials.

Introducing Reading sections in the teacher materials often suggest that the teacher review the Getting Ready section of the student materials as a whole-class, oral activity, thus eliciting whole-class prior knowledge, engaging students in brief discussion, and setting a purpose for the homework reading. Reading setup could take as few as 2 to 3 minutes of class time, or as much as 10, depending on the teacher's purpose, students' abilities, and the nature of the individual activity, but in general, teachers should plan on three to five minutes to introduce the reading.

The Student Edition

Annotated versions of the student pages—in the Teacher Resource Book—provide the teacher with likely student responses or expected responses (including correct answers, where appropriate) as well as ideas for using those responses as formative or summative assessments.

Driving Question Notes and Scientific Principles Pages

The first few pages of every student edition are provided as note-taking space in which students can record both their own individual ideas that connect with the Driving Question, and those big ideas generated by the class. Students should record their own original questions and can add information about those as they progress through the unit. Scientific principles are big ideas that the entire class "arrives at" by the end of many lessons and that students record for ongoing reference. The teacher materials often suggest ideas to be recorded on these pages, but they can be used to record any information the teacher or students deem appropriate. Tracking of scientific principles is a way to ensure that the class articulates "what we know so far" as students progress through the unit; it has common language to draw on when constructing explanations or arguments that draw on these big ideas.

Activity Sheets

IQWST students experience phenomena in a problem-based, investigative context, typically guided by activity sheets for each lesson. These pages support students as they plan and carry out investigations, follow procedures, make predictions and compare them with what happened, organize and analyze data, and make sense of science. Activity sheets often include an opportunity for students to explain the *how* or *why* of a phenomenon, deepening students' understanding as they engage in scientific practices.

Having a student read the "What will we do?" section aloud is one strategy to provide students with an overview of activities in which they are about to engage. Read through the procedure with students, demonstrate it, highlight key components, or summarize briefly so that students conceptualize the big picture of what they are going to do. For example, tell students "You are going to observe two materials separately, and then observe them again after you put them together. It is important that you describe your observations in the table on your activity sheet. Then, you will write some questions about what you observed." Such review frames the activity for all students but is especially important for students who need to hear and not just read the procedure or who need to understand the big picture before making sense of the individual steps.

Homework

Some take-home assignments are designed as extension activities, typically requiring students to apply what they have learned to new contexts. These assignments reinforce in-class activities, providing independent practice focused on key ideas in each unit.

Using IQWST Readings Effectively

The Teacher Edition provides two primary ways of supporting students as readers in science by taking a brief amount of time to introduce the readings and consistently following up on readings in class discussion, as bell work at the beginning of class, or in a quiz-type format.

Introducing Reading

The best way to introduce readings is for the teacher to take the first few minutes of class time to generate interest. Materials typically include an Introducing Reading section with ideas. While spending a few minutes can have tremendous payoff for students, sometimes the teacher will be pressed to do something quick. Most important is that something is done to introduce the reading in order to engage interest, elicit prior knowledge, and set a purpose for reading.

Reading Follow Up

It is important to follow up the readings or other homework. Use the embedded assessments for grades or points or use them to generate follow-up discussion to begin a class period. Students held accountable for reading either through assessments or through in-class questions that require having read the materials in order to participate in discussion are more likely to read as homework. As they enter class, a simple way to do this is to have on the board an opening question that draws on what they read.

Writing in Science

LITERACY GOALS	AS ADDRESSED IN IQWST
Write arguments focused on discipline-specific content. (a) Introduce claims, distinguish from opposing claims, and organize reasons and evidence logically. (b) Support claims with logical reasoning and relevant, accurate data, and evidence. (c) Clarify relationships among claims, counterclaims, reasons, and evidence. (d) Maintain a formal style. (e) Provide a concluding statement that supports the argument.	One pervasive opportunity in IQWST is for students to construct evidence-based explanations of phenomena they investigate and to analyze and give feedback on the written explanations of their peers. In some units, this is taken a step further into argumentation, with written and oral defense of arguments: a key scientific practice supported when the unit content is conducive to argumentation. Reading and discussing writing can help students deepen their own understanding, hone their critical thinking skills, and support consensus-building or argumentation skills in a group.
Write informative/explanatory texts, including scientific procedures/experiments. (a) Introduce the topic clearly and organize ideas, concepts, and information as appropriate to achieving purpose. (b) Develop the topic with relevant facts, details, or other information. (c) Clarify the relationships among ideas and concepts. (d) Use precise language and domain-specific vocabulary to explain the topic. (e) Maintain a formal style and objective tone. (f) Provide a concluding statement that supports the explanation presented.	In addition to the information in the previous box, students write explanations in response to questions embedded in their reading materials and on activity sheets to conclude and make sense of investigations. Additional opportunities to write explanatory texts are often provided in the Differentiation Opportunities sections that precede each lesson.
Narrative skills—for example, write precise enough descriptions of step-by-step procedures they use in investigations that others can replicate them and (possibly) reach the same results.	Students write step-by-step procedures when they design investigations, engaging in an important scientific practice.
Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.	All explanations and arguments in IQWST are designed for a specific purpose and audience, and many other writing tasks define a purpose and audience so that students learn to write for different purposes.
With some guidance and support from peers and adults, students develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.	Process writing, as learned in ELA, is used throughout IQWST as students compose evidence-based scientific explanations and arguments, share them with peers, give and receive feedback, and revise.

Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.	Opportunities to use the Internet to search for information and to inform writing are provided as Differentiation Opportunities to enable students to pursue curriculum-related topics in which they are keenly interested or for the teacher to assign topics to advanced students so that they might "go beyond" the curriculum's learning goals.
Conduct short research projects to answer a question (including a self-generation question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	Self-generated questions are at the core of IQWST, generated in the initial lesson in each unit, and then questions are continually encouraged throughout. Students write their questions on sticky notes, post them on a Driving Question Board, and are advised (or can be required) to investigate them independently.
Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.	In order to engage in the previously mentioned activity, students draw on multiple resources, including in-class activities and readings and Internet searches for other resources.
Draw evidence from informational texts to support analysis, reflection, and research.	Students draw on multiple resources including in-class activities and readings and Internet searches for other resources.

Summarizing is another valuable way to use writing. Summarizing requires determining and restating main ideas and findings. To support students in summarizing key ideas, provide practice for them to verbalize their thinking before writing or time to write about their ideas before sharing orally. For instance, before writing a summary of a reading, students could be asked the following: *How would you summarize this reading for students who were absent yesterday? What did they miss that they need to know?* After discussing, students will be better prepared to write summaries. Writing before sharing orally enables students to think and to process what they have learned before they are called upon to share ideas in class. These and other strategies support students as readers, writers, speakers, and listeners in the context of the science classroom.

In addition to the multiple opportunities provided for students to write to learn in IQWST lessons, activity sheets, readings, and home assignments, teachers can provide additional opportunities to meet the needs of individual students, many of which are suggested in the Differentiation Opportunities section that precedes each lesson.

Speaking and Listening

LITERACY GOALS	AS ADDRESSED IN IQWST
Engage effectively in a range of collaborative discussions (one-on-one, in-group, and teacher-led) with diverse partners . . . building on others' ideas and expressing their own clearly, (a) come to discussions prepared, having read required material, (b) follow rules for collegial discussions, (c) pose and respond to questions with elaboration and detail . . . connect the ideas of several speakers and respond to others' questions and comments with relevant evidence, observations, and ideas; and (d) acknowledge new information expressed by others and, when warranted, qualify, justify, or modify their own views in light of the evidence presented.	These behaviors are addressed in daily discussion, often as a follow-up to reading, to make sense of science during and after investigations and as a precursor to writing. Students given opportunities to talk about their ideas and those of others; to use talk as a way to think more deeply; and to critique claims, evidence, and reasoning orally are then better positioned to be able to write convincingly about their ideas. In addition, talking through ideas in this manner enables students to make sense of reading they have done or can set up reading as students read purposefully to determine whether their ideas were right, wrong, or somewhere in between.
Interpret and analyze information, main ideas, and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue.	As students engage with phenomena during investigations, their work requires interpreting and analyzing information that is visual/observational, verbal as expressed in both oral and written texts, and both qualitative and quantitative, requiring students to synthesize information from multiple sources.
Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.	Activities throughout IQWST that call for explanation or argumentation also call for students to share and to critique one another's ideas.
Present claims and findings, sequencing ideas logically and emphasizing salient points in a focused, coherent manner; use appropriate eye contact, adequate volume, and clear pronunciation.	Activities throughout IQWST that call for explanation or argumentation, as well as modeling, also call for students to present their ideas to a partner, a small group, or to the whole class.
Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.	Visual displays, especially models that accompany explanations and arguments, are constructed and shared in every IQWST unit.
Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.	The primary manner of speaking and listening in IQWST is presenting ideas for comparison with others' ideas and both giving and receiving oral feedback.

Classroom Culture

Establishing a culture in which students actively participate in "talking science" is at the core of IQWST, but it is challenging for both teachers and students. By the time students have reached the middle grades, they know a great deal about what it means to "do school." They raise their hands, do so only when they think they have the right answer, and respond to teacher-posed questions rather than to peers' ideas. In an IQWST classroom, students ask questions that arise out of individual interests or concepts about which they are confused. They ask questions of other students, as well as the teacher. Science discussions promote active engagement in science learning such that everybody expresses their understanding and learns from each other. The goal is for students to develop as thinkers and problem solvers through participating in thoughtful talk about core content.

Sharing ideas openly, asking questions of one another, defending one's ideas, and not having right answers challenges many students, as well. Students who are successful when reading and answering questions may not be comfortable discussing and exploring alternative ways to explore concepts. Students may be uncomfortable participating in discussions if they are unsure of the correct answer or may be uncomfortable with the idea that multiple responses may be considered correct at a given time in the process of learning. Students who are successful doing activities and discussing their reasoning may struggle when they are required to write about their ideas. Students who have looked to the teacher for answers and guidance may find it unusual that they need to question another student or provide rationale for their responses.

Establishing a classroom culture wherein students feel comfortable sharing and discussing with each other and feel confident about participating actively begins on the first day of class. Since IQWST may introduce a new manner of discussion for students, the teacher will need to model sharing, listening, and learning with students by demonstrating the value of contributions, not just correct answers. The primary goal of oral discourse is for students to articulate their own understanding and to listen and respond to each other. This goal is assisted when the following occurs:

- All students are provided opportunities to participate.
- All students are encouraged to participate.
- Students are encouraged to think together, rather than only speak, if they think they have the correct answer.
- Students see the value in wrong answers for figuring things out.
- Students are provided opportunities to write their responses before sharing aloud.
- Students use information in readings as a springboard for discussion.
- Students listen carefully to others and respond to others' ideas.

Small-group discussions are an integral part of the inquiry process in IQWST. They provide the best opportunity for students to learn from each other and interact with their peers as well as with the teacher. It is important that all students have an opportunity to participate, express their ideas, listen to one another, and respect others' ideas. Developing a classroom culture in which this is the norm may take time, especially if this is not what students are accustomed to in other classroom settings.

Teacher Supports

IQWST lessons support teachers by providing scaffolding to help facilitate conversation. Teacher supports include a list of possible questions or prompts a teacher may use or adapt, as needed, possible student responses, information about what student responses might suggest about their understanding, and ideas about how to address those ideas. The lessons support the teacher in creating a culture of science discourse by providing question stems such as these:

- What can you add to make this idea clearer?
- How does this idea compare to the idea of the previous speaker?
- What can you add to expand on what was just said?
- How can you summarize our conclusions?

Three Types of Discussion

IQWST lessons identify discussions by type to assist teachers in recognizing the structure of the discussion and conducting the discussion according to the guidelines for each.

In IQWST, brainstorming is any discussion with the purpose of generating and sharing ideas without evaluating their validity. Prompts provided for all brainstorming discussions are suggestions meant to encourage students to express their ideas. It may be useful to record ideas on the board, on a computer, or on a transparency so that students can see what has been said and can build on others' ideas. A photograph of notes recorded on the board, a printout, or a transparency can be attached to the Driving Question Board as a reminder of the activity.

1. Discussion: Brainstorming
   Purpose: To articulate and share ideas without evaluating their validity.
   - All ideas are accepted in brainstorming.
   - Ideas are captured and recorded as they are generated.
   - Brainstorming prompts include the following:
     - What have you observed or experienced?
     - What do you think about when you hear the word . . . ?
     - What do you know about . . . ?
     - Who has a different way of thinking about this topic?
   - Follow-up can include, as appropriate, such questions as the following: Where does that idea come from? How do you know? Where have you heard/seen/experienced that before?
2. Discussion: Synthesizing
   Purpose: To put ideas together or assemble them from multiple activities into a coherent whole.
   - Discussions may include making connections to personal experiences, to the Driving Question, and to other lessons or content areas.
   - Synthesizing prompts include the following ones:
     - How does this connect to . . . ?

- How does this support the Driving Question?
- How does this help us think about the activity we did yesterday?
- What do we know about this topic so far?

In IQWST, the purpose of a Pressing for Understanding discussion is to get students to think more deeply and to make sense of their experiences. Some questions can lead to a simple answer, others to a deeper, more thoughtful answer. Learning through inquiry encourages students to think more deeply but only if their thinking is scaffolded until they learn to think in terms of how and why, to make connections, to analyze, and to synthesize. Probing questions such as *Why do you say that?, What makes you think that?,* and *How do you think that works?* invite students to think more deeply and, over time, establish a culture in which doing so is the norm in science class.

3. Discussion: Pressing for Understanding

   Purpose: To figure things out or make sense of readings or activities while going deeper and beyond surface answers.

   - Discussions may involve respectful challenge, debate, or arguments in which students justify their ideas.
   - When pressed, students may revise their previous ideas as they learn new information that shows the limitations of their previous understandings.
   - Pressing for Understanding prompts include the following:
     - How do you know? What evidence supports that idea?
     - Why does our old model not work to explain this new phenomenon?
     - How could we figure this out?
     - How does . . . compare to . . . ?
     - What new questions do you have?

THE LANGUAGE OF SCIENCE: VOCABULARY

New Meanings, Familiar Words

Science as a discipline is known for its challenging vocabulary; thus IQWST lessons contain supports to help students develop deeper understanding of science concepts, including how, when, and why particular language is used. Students are engaged in thinking about the language of science in multiple ways.

IQWST takes a research-based, contextual approach to science language, stressing the repeated, ongoing, pervasive use of new words in oral and written discourse, acknowledging that language and conceptual understanding develop hand-in-hand. Science words are taught as they are needed. Typically, after a concept has been encountered, it is then given a label (the vocabulary word). A primary support for students occurs when teachers use science vocabulary frequently and appropriately and guide students to do so as well.

One of the hallmarks of successful readers is their ability to understand word meanings as they occur in varied contexts. When the teacher uses science vocabulary in context and calls attention to similarities and distinctions between words, all students are supported in building their science vocabularies. Students' everyday understanding can help or hinder their understanding of the uses of many words in science. Words like *absorb* and *reflect* have everyday uses that are consistent with their meanings in science, so linking the everyday to the scientific is likely to be helpful. However, words like *volume* and *mass* or words that name scientific practices such as *modeling* or *explanation,* have everyday meanings that may not help students understand the meaning in science. In those cases, making differences explicit supports students in learning multiple uses of words, including specific uses in science.

Simple routines used before students read new text can help students recognize and use science language as they read, write, and discuss their developing understandings.

Prereading

Before asking students to read independently, the teacher can identify words that will be difficult for the class. Words the teacher anticipates will be difficult can be rehearsed by displaying them (on the board or on a Word Wall), pronouncing them, and providing a snapshot definitions aimed only to help students recognize the words when they encounter them in the context of written text. This scaffolding helps students move words from listening and speaking vocabulary to their reading and writing vocabulary.

Building Vocabulary

Many science words have common prefixes, suffixes, or root words. Building a list of words with similar word parts allows students to see, define, and make connections between words such as *biology* and *ecology*, especially when connected to biosphere, ecosystem, eco-friendly, biochemical, and biography, among others.

For teachers required to do more intense vocabulary study at the middle school level, strategies should support students in developing deeper understanding of science concepts, rather than simply memorizing textbook-style definitions. Although writing vocabulary words in sentences is common school practice, it has not been shown to promote science vocabulary learning. Thus time is better spent engaged in tasks that use science vocabulary: constructing oral and written explanations and arguments, composing brief summaries, and answering questions that require both critical thinking and the use of appropriate vocabulary.

Interactive Word Wall

Keeping a space in the classroom to post new science language, as new words are encountered, provides students with multiple exposures to new words and allows them to refer to the Word Wall when communicating ideas, formulating questions, or writing (and learning to spell science vocabulary). Having words posted allows the teacher to gesture to the Word Wall during discussion to support students in using science language in their talk. Words written on sentence strips can easily be moved to increase opportunities for connecting words in various ways, grouping them or creating concept maps. Word Walls may be enhanced by short definitions or by visual representations, as well. Students with artistic ability or who like to draw, or who learn by the act of creating representations may create visuals to post on the Word Wall along with new words. Most important is that the classroom is language rich, providing students with ongoing exposure to discipline-specific vocabulary, which supports them as readers, writers, and critical thinkers in science.

ASSESSMENTS

Embedded/Formative Assessments

Formative assessment opportunities are embedded within IQWST lessons. They occur during discussions, activities, and readings and can be used to gauge students' understandings and developing science ideas in the moment. Formative assessments used regularly during the learning process enable the teacher to determine whether concepts need to be revisited, whether an optional activity would be beneficial for student learning, whether discussion should be extended or guided differently in order to support student learning, or whether some or all students would benefit from additional support. Formative assessments also enable teachers to provide explicit feedback to students on their ideas, so students can know in what ways they are on track toward meeting learning goals. Formative assessments also enable teachers to differentiate instruction in response to students' current understandings. Questions embedded in readings and as suggested prompts for discussion include possible student responses and, where appropriate, correct answers. When using embedded assessments to gauge students' understanding, analyze responses by listening for students'

- the ability to connect previous ideas with new content;
- the ability to summarize ideas accurately;
- current content understanding, as it will lead to meeting learning goals; and
- developing use of appropriate science language.

Summative Assessments

Many of the embedded assessments, while designed for formative use, may be assigned points or letter grades. Any written response in the student books may be seen as a summative opportunity. An option is to invite students to submit their one "best response" to questions in a lesson or their best evidence-based explanation or other revised response for a grade. This practice acknowledges that motivation, interest, and understanding vary from day to day and recognizes that assessing one's best work helps students be more aware of their own performance and what constitutes "good work" in science. IQWST also provides a bank of questions, available electronically, and in Word format, that teachers may draw from to customize quizzes and tests. Questions may be used as they are or adapted to best match instruction or to meet students' needs (i.e., differentiation).

SAFETY PRACTICES

Laboratory investigations excite students about the practice of science and lead to reflective discussions about investigation design and the real work of scientists. With investigations comes the need to teach laboratory safety and practice safety precautions with middle school students who may be new to lab experiences.

Science teachers are expected to take all possible actions to avoid accidents in the laboratory setting and to monitor labs for hazardous chemicals or flammable materials. This includes standard safety practices that include housekeeping to keep the laboratory areas clear of clutter and prohibiting unsupervised access to areas where electricity, chemicals, or heat sources are used.

Teachers should provide information about, and practice, laboratory evacuation drills. Gas and electricity should be shut off during any drills or whenever the class is leaving the lab. All exits must be kept free from obstructions, and no materials should be stored outside of the lab storage room. Safety rules should be posted in the room and reviewed with students prior to lab work. If the teacher, school, or district has specific science rules, those should be posted.

IQWST lessons contain specific safety information at the start of each lesson and throughout the lessons for easy reference for teacher and student. MSDS sheets should be consulted for appropriate use of all chemicals.

Science Lab Rules

There are many science rules to ensure safety in the laboratory. IQWST lessons have specific science cautions through each lesson to guide teachers and students, but middle school students, because of their inexperience with science labs, may need to be aware of certain safety procedures that include the following:

1. Clothing and Hair—Loose or baggy clothing, dangling jewelry, and long hair are safety hazards in the laboratory.
2. Cold and Heat Protection—Cold or hot materials should only be touched with hands protected by items such as safety tongs, safety mittens, or rubber gloves. In some instances, only the teacher should handle materials at extreme temperatures (e.g., dry ice).
3. Food—No eating, drinking, or use of cosmetics should occur during lab time. Even familiar substances used in activities (e.g., marshmallows for molecules) should not be consumed, as they may be contaminated in the lab setting.
4. Glass Caution—Glass should be used cautiously, and students should report any chipped, cracked, or scratched glassware should such occur during a lab activity.
5. Housekeeping—Work areas should be kept clean at all times, with backpacks, books, purses, and jackets placed away from lab tables.
6. Washup—Hands should be washed with soap and water before and after laboratory work. Students should not touch their faces or hair with either bare or gloved hands that have handled lab materials.

7. Safety Equipment—Personal protective equipment such as goggles, gloves, and aprons should be used as appropriate for the activity.
8. Allergies—All allergies should be noted for students and a plan put in place if peanuts, peanut oil, latex, or other known allergenic items are used in the lab. For example, although gloves and goggles provided in IQWST materials are latex-free, some units use balloons, which students with latex allergies should not handle.
9. Sniffing—When directed to "sniff" in the lab, students should be taught to follow the teacher's directions for "wafting" odor to the nose.

These rules are general and should always be followed in a lab situation. IQWST provides a letter to parents that discusses science safety rules. If a school or district has another science letter, and/or additional safety rules, teachers should use the district letter and follow all school or district guidelines for safety in the science lab. For additional safety information, consult the NSTA safety portal at http://www.nsta.org/portals/safety.aspx.

SAFETY LETTER

Dear Students, Parents, and Guardians:

Middle school science consists of engaging topics for students to investigate in a lab setting. However, any science activity may have potential safety issues if not conducted properly. Safety in the science classroom is an important part of the scientific process. To ensure a safe learning environment, a list of rules has been developed and discussed with all students because science rules must be followed at all times. Additional safety instructions will be given for each activity. Please discuss the safety rules with your child and return the bottom of this letter.

No science student will be allowed to participate in science activities until the student and a parent or guardian have acknowledged their understanding of these safety rules by signing this document.

Science Safety Rules

1. Conduct yourself in a responsible manner at all times in the science room.
2. Follow instructions carefully. Ask questions if you do not understand the instructions.
3. Use equipment (e.g., scissors and sharp items) only as directed by the teacher.
4. Perform only approved experiments.
5. Never eat, drink, chew gum, or taste anything in the science lab.
6. Keep hands away from face, eyes, and mouth while using science materials. Wash your hands with soap and water after the activity.
7. Wear safety goggles when instructed. Never remove safety goggles during an experiment. There are no exceptions to this rule!
8. Clean all work areas and equipment, and dispose properly of any waste materials.
9. Report any accident (spill, breakage, and so on), injury, or broken equipment to the teacher immediately.
10. If you have allergies, it is important that your teacher knows about them and that you avoid handling materials that could cause problems. For example, if you are allergic to latex, you can participate in activities that use balloons, but you should not be the one to handle the balloons.

SAFETY AGREEMENT

Dear Students, Parents, and Guardians:

We are providing the Science Safety Rules to keep you informed of the school's effort to create and maintain a safe science classroom/laboratory environment for all students.

Your signature on this letter indicates that you have read the Science Safety Rules, have reviewed them with your child, and are aware of the measures taken to ensure the safety of your son/daughter in the science classroom.

Parent/Guardian Signature: ____

Student Signature: ____

Date: ____

Important question – Does your child have any health issues or allergies? If yes, please list them here.

UNIT OVERVIEW

Why Do Organisms Look the Way They Do? is a seven-week Life Science unit organized around three clusters of ideas: heredity, variation within and between species, and natural selection. These three clusters of ideas focus on different levels of organization: the individual, species, and populations. The organizing theme is focused on the similarities and differences between organisms. What makes them similar or different and how does that happen?

DRIVING QUESTION

The unit's Driving Question is its title: Why Do Organisms Look the Way They Do? A Driving Question is a rich and open-ended question that uses everyday language to connect with authentic interests and curiosities students have about the world. In order to answer this question, students need to gain expertise in the target learning outcomes. Performance Expectations blend the content and scientific practices through which students will come to learn the science ideas necessary to answer the Driving Question in a grade-level-appropriate manner. As in all IQWST units, the Driving Question is displayed on a Driving Question Board (DQB), which serves as a road map for teachers and students. Newly learned ideas and original student questions are posted on the DQB and revisited in each lesson of the unit.

LEARNING SET 1: WHY DO I LOOK THE WAY I DO?

The first learning set, composed of four lessons, focuses on the similarities and differences in traits. In Lesson 1, students first identify similarities and differences between organisms. These traits are then classified as inherited, acquired, or both. In the last activity, students are introduced to the idea that bodies carry *instructions* for specific traits, and DNA is identified as the molecule that carries these instructions. In Lesson 2, students investigate the distinction between inherited and acquired traits. They also start the first of two experiments using Wisconsin Fast Plants® in order to collect data about how traits are inherited in plants. In Lesson 3, students examine human pedigrees in order to determine patterns in how traits are inherited. They also collect the data from the plants and set up seeds in order to observe another generation of plants. Students use multiple generations of data for both humans and plants in Lesson 4 in order to support the patterns they have identified with data they have collected.

LEARNING SET 2: HOW DOES THE INSIDE AFFECT THE OUTSIDE?

The observations students made and the data they collected in the first Learning Set raised the question of how the DNA that carries instructions for traits can be passed from one generation to another. In Lesson 5, students compare cell division in somatic cells in order to understand the differences and how those differences serve specific functions. In the second activity, they investigate how instructions from the same set of parents can lead to different combinations of instructions in the offspring. In Lesson 6, students construct a model of inheritance in order to explain how genetic information gets passed from parents to offspring. Students use their model to explain the data they have collected on humans in Lesson 7.

LEARNING SET 3: WHY DOES VARIATION MATTER?

This learning set shifts the focus from individuals, and how genetic information gets passed on, to species and populations and variation within them. In Lesson 8, students investigate traits with multiple variations and analyze data about the distribution of those variations from three different populations. They also engage in an activity about how to best represent those data. The lesson concludes with a teacher-led exercise in order to develop the concept of a gene pool. Lesson 9 focuses on whether the variation of a trait within a population can affect the survival of individuals in that population. Using multiple sources of data, students investigate the story of the peppered moth and write an evidence-based explanation to account for the change in the frequency of color of the moths. In Lesson 10, students are engaged in an investigation of the finches on the Galapagos Island of Daphne Major. Using software that contains data collected by scientists, students try to discover why many finches died and why some were able to survive. Students use the learned conceptual and mathematical knowledge to analyze the data and construct an evidence-based explanation to answer the questions. In the final lesson of the unit, students construct a consensus model of population change and are introduced to the concept of natural selection. They then apply that model to two cases. In the final activity, students return to the Driving Question and work in groups, choosing an organism to describe. They create a poster or storyboard that has designated areas for each of the four quadrants from the Driving Question Board. For each trait, students will indicate which of the four quadrants influenced the trait—is this a species characteristic? Environmental influence on individuals? Hereditary trait? Both heredity and environment? Environmental influence on population? The groups include the trait and the reasoning. After presenting their organism and its traits to the class, students engage in a final discussion to answer the Driving Question: Why Do Organisms Look the Way They Do?

UNIT CALENDAR

Unit Driving Question – Why Do Organisms Look the Way They Do?

Learning Set 1: Why Do I Look the Way I Do?

2–3 Class Periods	**Lesson 1 – The Same and Different You and Me**
	Activity 1.1: What Traits Do Humans Have?
	Activity 1.2: Traits of You and Me
	Activity 1.3: Baby, Where Did You Get Those Eyes?
	Reading 1.3: Where Did You Get Those Eyes?
2 Class Periods	**Lesson 2 – What Traits Get Passed On?**
	Activity 2.1: Are Traits Connected?
	Reading 2.1: Do the Traits I Inherited Affect My Sense of Taste or Smell?
	Activity 2.2: How Do Plants Reproduce?
	Reading 2.2: What Is the Buzz About?
	Activity 2.3: Is There a Pattern to How Traits Get Passed On?
2–3 Class Periods	**Lesson 3 – Can We Determine Patterns in Traits?**
	Activity 3.1: What Are the Patterns in How Traits Are Inherited?
	Activity 3.2: Are There Patterns in Plant Traits?
	Activity 3.3: What Seed Patterns Are There in a Future Generation?
	Reading 3.3: Heredity Patterns – A Key to Diagnosis
	Homework 3.3: Heredity Patterns – A Key to Diagnosis
2–3 Class Periods	**Lesson 4 – Do Traits Show Patterns over Multiple Generations?**
	Activity 4.1: How Do Traits Get Passed On?
	Activity 4.2: What about the Next Generation of Seeds?
	Activity 4.3: Synthesizing the Data
	Reading 4.3: Why Are Patterns Important?

Learning Set 2: How Does the Inside Affect the Outside?	
2 Class Periods	**Lesson 5 – How Do Instructions from Our Parents Get inside Us?**
	Activity 5.1: How Do I Get New Cells?
	Activity 5.2: How Can Parents Produce Offspring with Different Traits?
	Reading 5.2: Discovering the Source
2–3 Class Periods	**Lesson 6 – Constructing a Model of Inheritance**
	Activity 6.1: Constructing a Model of Inheritance
	Activity 6.2: Testing the Model
	Reading 6.2: Models: Using Models to Decide between Possible Explanations
2 Class Periods	**Lesson 7 – Extending and Applying the Model of Inheritance**
	Activity 7.1: Extending and Applying the Model of Inheritance
	Activity 7.2: Introducing Albinism
	Reading 7.2: Which Instructions Get Followed?
Learning Set 3: Why Does Variation Matter?	
3–4 Class Periods	**Lesson 8 – Variations, Variations, and More Variations**
	Activity 8.1: What Do I Do with All This Data?
	Activity 8.2: How Can We Show Ranges of Variation?
	Homework 8.2: Who Uses Social Networks More?
	Activity 8.3: Variation Everywhere, So What?
	Activity 8.4: How Do Genes Work for Continuous Traits?
	Reading 8.4: Height – Unraveling a Genetic Puzzle
2 Class Periods	**Lesson 9 – Do Variations between Individuals Matter?**
	Activity 9.1: The Case of the Peppered Moth
	Activity 9.2: How Does Variation Matter?
	Reading 9.2: How Does Variation Matter?
	Activity 9.3: Explaining the Change in the Peppered Moth Population

7–8 Class Periods

Lesson 10 – The Finch Investigation

Activity 10.1: Background to the Mystery

Activity 10.2: Introducing Data Comparisons and Individual Finch Data

Activity 10.3: Investigating the Finches

Reading 10.3: Where Did the Data Come From?

Activity 10.4: Midpoint Sharing

Activity 10.5: Explaining the Mystery

Homework 10.5: What Happens Next?

1–2 Class Periods

Lesson 11 – Constructing a General Model of Population Change

Activity 11.1: Constructing a General Model of How Populations Can Change

Reading 11.1: Does Selection Always Occur Naturally?

Activity 11.2: Does the Consensus Model Work?

Activity 11.3: Putting It All Together – Why Do Organisms Look the Way They Do?

LS3 SCIENTIFIC PRINCIPLES

A list of Scientific Principles is provided for consistency with other IQWST units, but students will be drawing on a "Pattern and Evidence Chart" (see Lesson 3).

1. Offspring can get instructions for a trait from either parent.
2. Different offspring of the same two parents can inherit different traits from each parent.
3. For some traits, when parents have the same trait, the offspring always have the same trait as the parents (e.g., two nontaster parents can only have nontaster offspring).
4. For some traits, one variation is more likely to be passed on from the parents (e.g., one blue-eyed and one brown-eyed parent usually have brown-eyed children).
5. It is possible for offspring to have a trait that neither parent shows (e.g., a redheaded child of two brown-haired parents).
6. Two organisms can express the same trait but carry different genetic information.
7. Each trait is determined by two copies of instructions: one inherited from the mother and one from the father.
8. When two copies of information for a trait are not the same, one variation determines the expressed trait (phenotype).
9. Two parents can pass on a trait neither expresses if both parents contain one copy of each variation and the offspring happens to get both nonexpressed alleles.
10. Some traits (e.g., PTC [phenylthiocarbamide] tasting, tongue rolling) have only two variations. Other traits have a continuous range of variations (e.g., height, eye color, skin color).
11. Changes in a population can occur when a population of organisms varies on an inherited trait; there is a change in the environment that affects the organism's survival; one variation of the trait has an advantage for survival; individuals with that variation are more likely to survive and reproduce; or the proportion of individuals with that variation increase in the next generations.

Lesson 1

The Same and Different You and Me

PREPARATION

Teacher Background Knowledge

Defining Species

Currently, a generally accepted definition is based on Ernst Mayr's *biological species* concept. Mayr wrote: "I define biological species as groups of interbreeding natural populations that are reproductively (genetically) isolated from other such groups" (Mayr, E. [2004]. *What Makes Biology Unique? Considerations on the Autonomy of a Scientific Discipline*).

- While this is a very useful definition, it is limited in its application. For example, it cannot be applied to those organisms that reproduce asexually.
- Although limited, this is the basis of the definition of *species* used in this unit.

The definition of species—For sexually reproducing organisms, species comprises all organisms that can mate with one another to produce viable offspring.

Taxonomy of Organisms

This unit does not deal with levels of taxonomy (kingdom, phylum, class, order, family, genus, and species). Although these ideas are often taught in middle-school textbooks, learning these levels of taxonomy does not help students explain any of the scientific phenomena about heredity and natural selection that form the basis of this unit, nor does it connect well to questions students have about their experiences with the natural world. However, in order to fully define *species*, students need a sense of the similarities between the organisms, which are higher levels of taxonomy.

Heredity and Environment

Although some examples seem relatively simple, other examples are more complex, with the environment triggering certain genetic reactions.

- Siamese cats' coloring depends on the temperature in which they live. All of these cats are born with fur that is all white. As it grows, dark pigments appear on the nose, ears, tail, and feet. These areas are known as points. In cold environments, the pale fur darkens until it becomes dark all over, sometimes making the points indiscernible from the other areas of fur. This is caused by a gene that produces melanin, the pigment involved in darkened fur. In Siamese cats, this is a mutated enzyme that only operates at below-average body temperature. Extremities (paws, feet, and so on) are usually below the body temperature.
- A particular plant found in Sweden has a phenotype that is determined by the environment. One habitat is rocky, seaside cliffs, where the plants are bushy with broad leaves and flowers spread out on the stalk. The other environment is among sand dunes, where the plants grow stretched out along the ground with narrow leaves and flowers compacted on the stalk.

Vulcan Greeting

- The tendons that allow each finger joint to straighten are called the extensor tendons. They are connected to the extensor muscles in the mid-forearm. When the extensor muscles contract, they tug on the extensor tendon and straighten the finger.
- The Vulcan greeting is difficult for most people to do because the ring finger lacks a separate extensor tendon. This makes moving the ring finger alone impossible for most people without help from their other hand.
    - o There are some people who do have independent extensor tendons for the ring finger.
    - o Independent movement of the ring finger can be developed (acquired). For example, guitar players through practice develop the independent movement ability.

DNA

This information is not instructional material for students.

- DNA is a molecule called deoxyribonucleic acid.
- DNA in the nucleus is nuclear DNA. An organism's complete set of nuclear DNA is called a *genome.*
- In humans and other complex organisms, small amounts of DNA are found in the cells' mitochondria, the energy-generating organelle.
- Red blood cells do not have a nucleus and therefore do not carry chromosomes (compressed DNA). Platelets also do not have a nucleus. The third component of blood, white blood cells, has a nucleus and therefore holds the genetic information.
- During cell division, the tightly wound DNA in chromosome form unwinds. This allows its instructions to be copied into the new cells. The unwinding also lets the instructions be used for protein synthesis.
- Half of DNA is inherited from one parent and half from the other parent. The mitochondrial DNA, however, only comes from the female parent because egg cells—not sperm cells—keep their mitochondria during fertilization.

Setup

Specific instructions for activity setup are embedded within the lesson.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 1

The Same and Different You and Me

TEACHING THE LESSON

Performance Expectations

Students will

- identify the traits of an organism.
- identify the distinction between inherited and acquired traits.
- analyze data about the traits of an organism.

Overview

Introduction
- Observe images to identify similarities and differences.
- Identify the difference between trait and variation.

Activity 1.1
Brainstorm traits that differentiate humans from other organisms and one human from another.

Activity 1.2
- Identify variation in selected traits.
- Survey the class for selected traits.
- Create graphs that show the frequency of the occurrence of those traits.

Activity 1.3
Identify questions about heredity, traits, and genes.

Students begin by looking at pictures of familiar organisms and identifying the similarities and differences in their traits. Next, they work in groups to brainstorm a list of traits that differentiate humans from other organisms and one human from another. In the second activity, based on the list that the class creates and two additional variation traits, students survey the class for selected traits and create graphs that show the frequency of occurrence of those traits. This leads to the Driving Question of the unit—Why Do Organisms Look the Way They Do?—and the initiation of the Driving Question Board. In the final activity, students are introduced to the idea that bodies carry instructions for specific traits. DNA is identified as the physical molecule that carries those instructions.

Building Coherence

This lesson introduces the Driving Question and the concept of DNA as a molecule that carries instructions for traits. Students may have studied (IQWST LS2) structure and function in organisms, and now they will investigate where similarities and differences in structures come from.

Timeframe

2–3 Class Periods

Materials – Introduction

For the Class

- Projected Image (PI): Trout and Lamprey
- PI: Fish and Plants
- PI: Desert Plant and Rainforest Plant
- PI: Birds

Introducing the Unit

Students may have learned about how organisms interact, and about how one population can affect another in the same ecosystem (IQWST LS1). They may also have learned that both plants and animals need food, and that chemical reactions are the process by which they get energy from food (LS2, IC2, IC3). Students should know that all organisms have cells, but cells in plants and animals carry out different chemical reactions. Review these ideas as a starting point for this unit.

Structure/function is another idea that may emerge, along with the idea that different organisms solve the same problem in different ways. Organisms have different structures for eating, moving, and getting food. Show students the pictures of three pairs of organisms (PI: Fish and Plants; PI: Birds). Each pair has some similarities and some differences.

Suggested Prompts

- What characteristics or structures do any of these organisms have in common? *(Birds have wings; plants have leaves; birds and fish have mouths; birds have beaks; and so on.)*
- What structures do they have that allow them to get what they need to survive? (*Fish and birds have mouths that they use to take in food. Birds have wings they can use to fly to get food or get away from predators. Plants have leaves so that they can make their own food.*)
- How are the birds' mouths different? Why? (*The hummingbird has a long, very thin, curved beak so that it can get nectar from flowers. The pelican has a large beak with a pouch for catching fish.*)
- How are the plants similar or different? (*Plants both have leaves, but one is very large and one is small.*)
- If all of these organisms have different characteristics, how do they get the structures they need? (*It has to do with the organs and cells they have; it has to do with genes from their parents; and it comes from their DNA.*)

Students may use words like *genes* or *DNA*. Elicit their knowledge.

Suggested Prompts

- What is DNA?
- How does it work?
- How do they get the DNA?
- How does the DNA lead to different beaks, mouths, or types of leaves?

In this unit, students will try to figure out the answers to these questions. Put the Driving Question for the unit at the top of the Driving Question Board: Why Do Organisms Look the Way They Do?

Introducing the Lesson

In order to figure out why organisms look the way they do, we need to keep track of what things we are trying to explain about each organism.

Suggested Prompts

- How were you able to distinguish the birds from the fish? The plants from the birds? (*You can tell the difference by their characteristics or structures.*)
- By looking at the projected images again, what could you predict about other plants? Other fish? (*Other plants would have the same characteristics as the plants in the picture—for example, leaves, stems, and so on. The same is true for other fish.)*
- How do you know they will be the same? (*Responses should suggest that fish produce other fish, and plants produce other plants.*)
- How could you distinguish a human from these other organisms? (*Humans have different characteristics.*)

- Biology started with scientists trying to categorize living things—for example, how they are similar and how they are different.
- They also considered relationships. For example, fish mate with other fish and produce fish; humans mate with other humans and produce humans.
- They began with large categories, such as plants and animals, and then broke those groups down into smaller groups based on characteristics.
- An important level of this organization was *species*. Birds, fish, and humans all belong to the large group called animals, but they are different species. A species is
    - o all organisms that can mate with one another.
    - o a group in which mating can produce viable (fertile) offspring.

When scientists talk about the characteristics of an organism, they use the word *trait*. This difference in a trait is called a *variation*.

Put the following graphic on the board:

trait = number of legs
variations = 2 (humans); 4 (dogs)

Another example of a trait and a variation is the following:

trait = number of permanent teeth
variations = 32 (humans); 42 (dogs)

Variations are not always in the number of the trait.

trait = type of foot
variation = paw (dog); hoof (cow)

These example variations are across species.

Suggested Prompts

- How can you tell two dogs apart from each other? *(You can tell them apart by color, spots, size, types of fur, and so on.)*
- How can you tell one friend from another friend?
- How can you tell your brother from your sister? Your one sister from the other sister?
- How can you tell yourself from your parent? *(Students should answer all of these questions by giving examples of traits and variations for each question.)*
- How are these traits different from those that let you identify the differences between species? (*These traits are all differences within individuals in one species.*)

Summarize the discussion with the idea that there are variations of traits between species and within individuals in a species. Focus attention on the Driving Question.

Suggested Prompts

- If traits vary between and within species, where do these traits come from?
- If you are brother and sister, why do you look different?
- If humans and birds are different species, what makes some traits similar (*two legs*), and what makes some different (*wings vs. arms*)?

To begin to answer the Driving Question, students will explore the question "Why do I have the traits I have?" Place a circle with *My Traits* below the Driving Question on the DQB. (See last page of Lesson 1 for sample DQB.)

Materials – Activity 1.1

For Each Student

- Activity Sheet 1.1
- PI: Fish and Plants
- PI: Birds

Activity 1.1 – What Traits Do Humans Have?

Suggested Prompts

- How do you know that an organism belongs to a certain species? (*There are traits that are common to all of the organisms in the species.*)
- What traits do humans have in common? (*Students may say things like arms, legs, eyes, and so on. They may also describe more abstract characteristics, such as humans have two legs and walk upright on them; they have a large, complex brain; they communicate through language; they have the ability to express themselves symbolically through art and music; and so on.*)

Guide students to state that one reason they look the way they do is that they are human—the same species—so there are common traits. Draw an arrow from the *My Traits* circle and label a section of the Driving Question Board *Species Traits: All Humans Have in Common*. Why do you not look like everyone else in the class if you are all one species? (*There are variations in traits within species.*)

Draw an arrow to the second section of the Driving Question Board and label it *Individual Traits: Variation of Traits within Humans*. Leave a section of the right-hand side of the board empty; this will be filled in later.

Surveying Traits

Students will focus on the second column for this activity, which are traits that vary within the human species. Allow students about 5 minutes to brainstorm and refine a list of observable human traits and the possible variations that they observe or recall. Students will record them in Part 1 of Activity Sheet 1.1. Allow another 5 or 10 minutes for students to identify possible individual variations of each trait. On the board or projector, make a chart with two columns: *Trait* and *Individual Variation*. Have each group share their list of traits. Ask students for possible variations of that trait, and record several in the variation column. All groups should add additional traits to their list.

It is important to distinguish between the trait and its variation. Students may say that two arms is a trait. Remind them of the chart on the board. The trait is arms, and the variation could be number of arms or length of arms. The following chart shows possible responses. It is not necessary to use these particular traits if students do not come up with them.

HUMAN TRAIT	INDIVIDUAL VARIATIONS
Eyes	Blue, brown; two; big, small (color, number, size)
Legs	Long, short
Freckles	Yes/no
Hair	Black, brown, blond; long, short (color, length)
Fingers	Five on each hand (10)
Arms	Two; long, short (number, length)

When all groups have reported, focus on the list of traits.

Suggested Prompts

- Are any of these traits something that humans can change or learn?
- Are any of these traits something that humans are born with?
- Can any of these traits humans are born with be changed? Write the words *inherited* and *acquired* on the board.
- What does it mean when something is inherited?
- What do you think an inherited trait is?
- What does it mean to acquire something?
- What do you think an acquired trait is?

Guide students to a common understanding that acquired traits are ones that can be learned or changed depending on an organism's interaction with its environment. Inherited traits are somehow passed from parent to child. Have students complete Part 2 on Activity Sheet 1.1 by grouping their human traits list into three groups: acquired, inherited, and both. When completed, bring the class together.

Suggested Prompts

- Which traits are inherited? (*Two arms, two legs, hair color, leg length, and so on are inherited.*)
- Are there any traits that someone can change during their life? (*Building muscles, dyeing hair, wearing colored contacts, and getting a suntan are traits that someone can change.*)
- Are there traits on the list that might be the same for other members of your family?
- Were there any traits that could be both inherited and acquired?
- How can a trait be both? (*Traits like big muscles or jumping ability could be both inherited and acquired. Jumping ability could improve with training but would also depend on leg length. You have muscles when you are born, but you can work out and make those muscles stronger and bigger.*)

At the beginning of this activity, students had a working definition of *trait* that defined it as a characteristic of an organism. How can we make our definition more precise?

A trait is a characteristic of an organism that can be inherited, or acquired, or inherited and affected by the environment.

Suggested Prompts

- You look the way you do mainly because you are part of the human species. What else influences the traits that you have?
- How can you tell one cousin from another? (*You can tell by variation in traits.*)
- Where do inherited traits come from? (*Most students will answer "parents."*)

Ask students to take five minutes in their groups to generate some questions they have so far. Have them record their questions on a sticky note and post it on the Driving Question Board. On the DQB, the second section is *Individual Variations: Traits I Get from My Parents.*

On the Driving Question Board, label the third section *Environmental Influences: Interactions That Influence My Traits*. Add any questions that arise.

Have students copy the headings from the Driving Question Board (species traits; individual variations; environmental influences) at the top of each section of the Driving Question Notes. Relevant questions or information from the lesson should be recorded. In the next activity, students will focus on traits that are inherited.

Students should know the following:

- A characteristic of an organism is a trait.
- Traits can be inherited from parents.
- Many traits can be both inherited and influenced by the environment.

Materials – Activity 1.2

For the Class
- PI: Inherited Traits
- PI: Class Data Table

For Each Student
- Activity Sheet 1.2

Activity 1.2 – Traits of You and Me

Ask: "Why do you think you need to focus on inherited traits?" *(In order to figure out why I look the way I do, identifying the traits that we are born with and where they come from is important.)* Students will identify certain inheritable traits within the class and create graphs of those traits.

Tell students that you have decided that the class should begin with a friendly greeting. You want to make sure that everyone will be able to give the greeting so that the class will collect data on the number of students who can do it. Since you are a *Star Trek* fan, you are going to use the Vulcan greeting used by Spock. (See photograph.) Raise your hand in the "V" greeting and say, "Live long and prosper." Ask students to quickly return the greeting. The class should find that some students can easily make the sign and others will find it difficult.

Lead In
- Why do you think some people are able to do this quickly and others cannot? (*Some students may suggest that they have learned how to do this by practicing.*)
- What have you learned about traits that helps explain what is happening? (*Maybe it is an inherited trait, since some people could do it right away, some had practiced so they could do it, and some could not do it at all.*)

Explain that this is an inherited trait. Although people can usually improve with practice, some people can spread their hands this way with no effort at all. Ask: "What is the trait?" *(can spread fingers)* "What is the variation?" (*yes or no*) Take a count of how many students could do it and how many could not. Record it in a data table on the projector. A sample table may look similar to this.

VULCAN GREETING	
Able to do it	Not able to do it
8	24

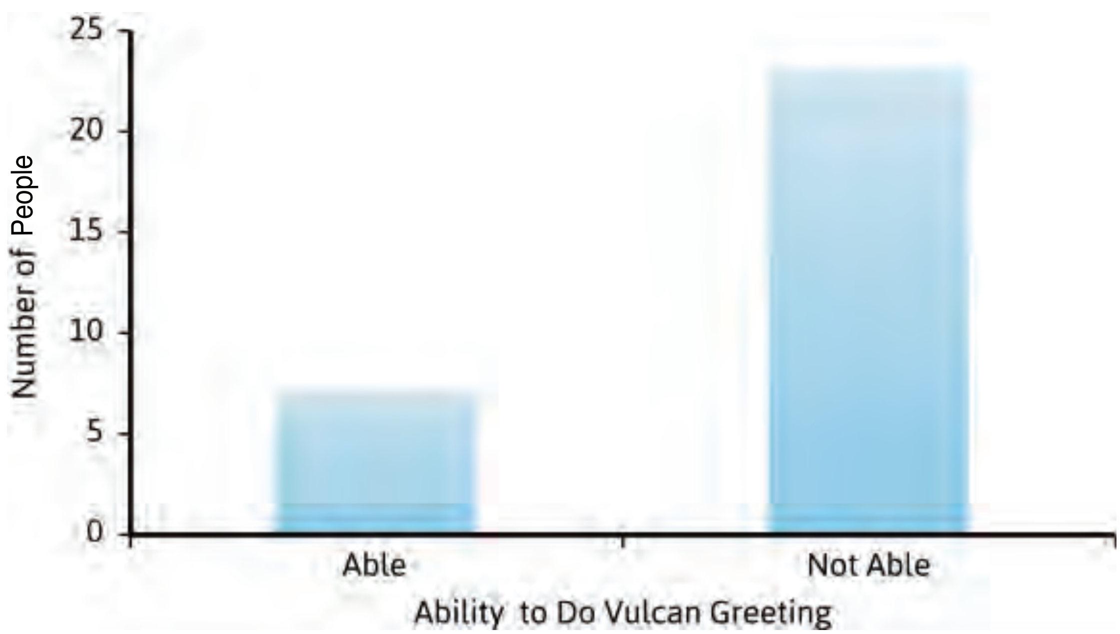
This is the first trait students have observed. They will be examining several more to try to answer the Driving Question about how humans get their traits. Since they will need to collect and analyze data, this activity will allow them to practice how to record and display data with this simple set.

Suggested Prompts

- What is the best way to represent these data?
- What do we want to be able to show? (*Compare the number of people who are able to do the greeting and those who are not.*)
- What is a good way to quickly show that? (*Lead students to recognize that a bar graph would be the best representation.*)

Lead students to recognize that a bar graph would be the best representation.

- What label and data should be on the x-axis? (*the ability to do the Vulcan greeting; able/not able*)
- What label and data should be on the y-axis? (*number of people; 1, 2, 3 . . .*)



Suggested Prompts

- Which variation occurs more frequently?
- What is the ratio of students who can do the Vulcan salute to those who cannot? (*for example, 8:24*)
- If 8 out of 32 people can do the salute, what percentage of students are able to do the Vulcan salute? (*25%*)

In order to answer the Driving Question, students need to figure out how humans get their traits. They will need to collect data on traits and keep track of those data. In this activity, they will organize and analyze some trait data from the class using a data table and graphs.

Collecting and Organizing Class Data

Now that students have collected and displayed one simple set of data, the activity asks them to collect class data on several inherited traits and look for patterns. Use PI: Inherited Traits. Ask students what kind of variations these traits have. (*This shows traits that are inherited and have only two variations: detached ear lobe, overlapping thumbs, widow's peak, and hitchhiker's thumb. Humans either have these traits, or they do not.*)

Ask: "Do you think we can capture all the ways that people differ using traits like these?" In this activity, students will use some of these simple traits along with two traits from Activity 1.1 in order to see what traits the class has and if there are any patterns in those traits.

Suggested Prompts

- What kinds of patterns do you think you will see?
- Do you think there will be equal numbers of each variation? Why?
- Do you think some variations will be more common? Why?

Return to the list of traits from Activity 1.1 and choose two traits that have more than two variations. Class data will be collected on these traits. Two likely choices are (1) hair color and (2) eye color. These traits need some clarification, such as natural color, since each of these traits can be altered. In classrooms where students all have similar color hair or eyes, use shades of that color (such as light blond, strawberry blond, dark blond; light blue, deep blue) as the variations.

In small groups, students will fill out the data table on Activity Sheet 1.2. When they have finished, bring the class back together to assemble the class data. Use PI: Class Data Table to tally each trait. Students should copy the tallied numbers into the fourth column on the activity sheet. They will create a graph for each trait and complete the activity sheet.

Discussion – Making Sense

Purpose

Draw conclusions about patterns in traits based on students' observations.

Suggested Prompts

- What do you notice about the patterns on these graphs?
- How does your data relate to the similarities and differences you saw in the pictures in the first activity? (*Students should see that, like the dogs, while they share traits, there are also differences.*)
- Looking at the graphs, were some variations of traits more common than others? (*Class data should show that there are some variations of traits that seem to be more common.*)
- Were there any traits where everyone in the class had the same variation of the trait?
- If humans are all the same species, and we all have the same traits, how can there be so many variations?
- Why do you get the variations that you have?

It is unlikely that this will occur. The point of this question is to help students arrive at the idea that there are similarities and differences within a group of the same organism.

In the next activity, students will try to determine where the information for these variations comes from.

Students should understand the following:

- Humans share the same traits, but there are variations in some of the traits that they share.
- Some human traits have only two variations (e.g., gender, overlapping fingers, widow's peak, and hitch-hiker's thumb).
- Some human traits have many variations (e.g., hair color and eye color).

Record these ideas in Driving Question Notes and on the Driving Question Board.

Materials – Activity 1.3

For the Class

- PI: Human Cheek Cells
- PI: From Cell to DNA

For Each Student

- Reading 1.3

Activity 1.3 – Baby, Where Did You Get Those Eyes?

Discussion – Synthesizing

Purpose

Develop questions about traits that will drive the unit's investigations.

Suggested Prompts

- Where do you think you get inherited traits? (*You get them from your parents.*)
- How does this happen?
- Why does a baby get a nose like his or her father?
- Why does a baby get red hair like his or her grandmother?
- Why does a baby get two legs instead of four legs?
- Why do you get some traits, but your sister got different ones? (*Some students may say something about genes or DNA. If so, ask what that means; push them to be specific. They may have some idea that genes are what produce certain traits, but they will be unclear on how this happens. Other students may say that you get them from your parents when you are born. With either idea, they will most likely be thinking that all traits are set at birth.*)
- If identical twins that have dimples are separated at birth, will they still have dimples 20 years later? (*yes*)

There are three important questions that should come out of the discussion:

- Are there instructions in the body for traits?
- What would these instructions be like?
- Where would these instructions be?

Record these questions on the Driving Question Board and in the Driving Question Notes.

- If you were going to look inside the body for something that makes traits show up like they do, where would you look? (*Some students may suggest the cell. If not, prompt with the following question.*)
- What do you know about what is inside our bodies that lets us do the things we do? (*Students may say organs, organ or body systems, and so on.*)
- What do those structures do?

Continue prompting students until the discussion arrives at the idea that all of the organs and systems in the body function to get the cells what they need to survive. If students studied the IQWST LS2 unit, they learned the following information.

- The important work of the body takes place in the cells.
- All body systems are made up of cells.
- Body systems function and interact to provide the cells with what they need to do the work of the body.

Given what we know about what cells do to keep our bodies running, what do you think about looking inside of cells for the instructions that determine our traits?

Use the following prompts to get students to realize that the instructions must be made of matter in the cells.

- What have you learned about the "stuff" that all things—including cells—are made of? (from IQWST IC1: matter, atoms, and molecules)
- What evidence have you seen that cells are matter? (from IQWST LS2: skin, onion, and amoebae under microscope, all cells with mass and volume)
- What happens when you have different arrangement of the atoms in a molecule or a different arrangement of the molecules? (different arrangements mean different substances with different properties)

Display PI: Human Cheek Cells. Ask the following questions.

- What is the dark structure in the cell? (*The nucleus is the dark structure.*)
- What do you understand about the nucleus? (*The nucleus is like the brain of the cell. It controls everything happening in the cell.*)
- Would this be a logical location for something that tells the body how to make traits?

The nucleus is the location of the stuff that makes the instructions.

- What do you think cells are made of? (*molecules*)
- How can there be different structures in the cell? (*Molecules that make up the cell structures may be different atoms or the molecules may be arranged differently.*)

If students have already brought up DNA as somehow connected to inheritance, ask them if they know what DNA is. Most students will have heard of DNA but will not know where it is found in the body or what type of matter DNA is. Explain that when scientists were able to observe cells closely, they noticed stringy "stuff" inside the nucleus. Regardless of what kind of cell it was, it was always there. This stuff was DNA. If we could zoom in on a cell, this is what DNA would look like. Display PI: From Cells to DNA. Using this as a visual guide, engage students in a brief discussion about DNA.

Suggested Prompts

- Do you notice that the strand of DNA seems to stretch out from a strand in the nucleus? Explain that this strand is called a chromosome. A chromosome is a compressed package of DNA.
- Where are the chromosomes located? (*They are located in the cell's nucleus.*)
- Could DNA be a molecule? (*Yes, because it is part of the cell.*)
- Why would you think that DNA has anything to do with traits? (*Students most likely will talk about DNA being connected to forensics. It is something that is used to identify a person, so it may have something to do with traits.*)

Ask students if they have heard any other terms that relate to what we are studying that might help us figure out what is happening with traits. (*Students may suggest words like* genetics, gene, *or* heredity.) At this point, defining genetics—the study of how heredity happens—will be useful going forward.

While this clearly has something to do with genes, that word is not added to the Word Wall here because students do not know what it means based on their activities.

Review the questions from the beginning of the activity. Prompt discussion with the following questions.

- Do you have any evidence that there are instructions from somewhere in the body for traits? (*no*)
- If there were instructions, where might they be found? (*We have a hypothesis that they might be in the cell somewhere, like in DNA.*)

Students should know the following:

- DNA is a molecule, so it is something physical.
- Compressed DNA in the cell is a chromosome.
- Every cell of the body that has a nucleus contains DNA.

Students now have a strong hypothesis that there are molecules in cells that may lead to traits.

Wrapping Up the Lesson

Students may have learned about similarities and differences between organisms in how they did things like obtain food, reproduce, and move (IQWST LS1). How can traits be used to describe similarities and differences? (*Traits are used to identify species with two arms, two legs, and so on; to distinguish between species with two or four legs, wings, and fins; and to distinguish among species such as the Chihuahua, Great Dane, and people with red hair and people with brown hair.)*

By the end of this lesson students should understand:

- Cells are made of molecules that can be arranged in different ways.
- DNA is a molecule, so it is something physical.
- Compressed DNA in the cell is a chromosome.
- Every cell of the body that has a nucleus contains DNA.

If you are going to find out where traits come from, what would we have to do next? (*Students will have various ideas. Someone will probably suggest that they should investigate traits more closely. If not, suggest it.*)

By the end of Lesson 1, the DQB might look like the following diagram.

WHY DO I LOOK THE WAY I DO?

My Traits

SPECIES TRAITS
All Humans Have in Common

Why do I look like other humans?

- Species have common traits.
- There are variations of common traits: sometimes only two and sometimes more.

Where do traits come from?

- Traits are acquired from parents and others come from interactions with the environment.

INDIVIDUAL VARIATIONS
Traits I Inherit from My Parents

How do I get traits from my parents?

- How can I get my parents' traits?
- How does a body know which traits it has?
- Is there something in a body that gives instructions for traits?

ENVIRONMENTAL INFLUENCE
Interactions that Influence My Traits

How do interactions in my environment affect my traits?

- working out with weights to change how my muscles look
- lying out in the sun to change skin color

In the next lesson, students will explore patterns in inherited traits.

Introducing Reading 1.3 – Where Did You Get Those Eyes?

During this unit, students will be looking at the broader Driving Question of the unit: Why Do Organisms Look the Way They Do? Students will look at variations among and within species. They will work like scientists who investigate genetics—the study of how traits are passed down. Ask students why scientists would want to study genetics. As they read, ask students to see if they can determine why it would be important to study genetics.

LESSON 2

What Traits Get Passed On?

PREPARATION

Teacher Background Knowledge

Wisconsin Fast Plants®

The plants used in this unit are Wisconsin Fast Plants® because of their fast growth and easy-to-see variation. Students will look at the trait of stem color with two variations.

- Variation 1: Purple-stemmed plants produce a purple pigment (anthocyanin) that is visible on the stems and hypocotyls (stems), under cotyledons (leaves), and at the leaf tips. The presence or absence of anthocyanin is controlled by a single gene (anl); in the homozygous recessive condition (anl/anl), no anthocyanin is expressed. If the genotype is anl/ANL or ANL/ANL, then anthocyanin is expressed in varying levels. Plants with these genotypes both appear purple. However, the plants with the ANL/ANL genotype have more purple pigment than the anl/ANL. Plants of the seeds used in this unit have been selected for high levels of purple.
- The purple color is best observed on the hypocotyls (stems) or under the cotyledons (leaves) when the plants are between four and seven days old. The intensity of the purple color is affected by the environment. More light yields a deeper purple color. Petri-plate germination yields a deeper purple color than pot-grown plants.
- Variation 2: Non-purple stemmed plants do not produce anthocyanin. The lack of anthocyanin causes the plants to appear a brilliant green color. The non-purple phenotype is conditioned by a single, recessive gene (anl). In the homozygous condition (anl/anl), no anthocyanin is produced.
- When germinating the seeds, be sure to keep them moist. Covering the dishes with plastic wrap will slow down the evaporation rate. If the seeds are not kept moist, they will not germinate. Do not put the lid on the Petri dishes, as this will hinder growth.

Taste Receptors

In the IQWST IC1 Unit, students learn that there are receptors in the nose that detect the particles in the air so they can smell. In the IQWST PS1 Unit, students learn that there are sensors in the eye that detect the light that reaches them. Those sensors send a signal to the brain through the optic nerve. In the IQWST LS2 Unit, students learn about receptors that detect pressure and send a signal to the brain that they are touching something. A person is able to taste because of receptors on the tongue, which detect certain chemicals and send signals to the brain about what is being tasted. Let students know that these tastes are the following:

- sweet (like sugar)
- sour (like lemons)
- bitter (like unsweetened chocolate or coffee)
- salty (like potato chips)
- umami (like the savory taste of meats and cheeses)

Scientists used to believe that different parts of the tongue had receptors that responded to different tastes. This is often represented by a tongue map showing where each of the taste receptors is located on the tongue. More recent research has revealed that taste buds seem to contain 50 to 100 receptors for each taste. The degree of variation is still debated, but in general, all parts of the tongue can taste all five tastes, although some areas may be more sensitive than others.

In 2002, a fifth taste was added. It is called umami and refers to taste like that of meat or cheese. It is a taste that has been recognized in many parts of the world, particularly Japan and China, for a long time. Scientists now believe they have found the receptors on the tongue that detect the chemical (monosodium glutamate). This chemical occurs naturally in some foods, like soy sauce, parmesan cheese, crab, shrimp, and lobster.

Plant Reproduction

Plants reproduce in one of two ways: sexually or asexually.

Asexual reproduction in plants does not involve meiosis, chromosome reduction, or fertilization.

Vegetative reproduction is a type of asexual reproduction. Some examples of vegetative reproduction are bulbs (onions, tulips); tubers (potatoes, Dahlias); adventitious buds that develop on stems (rather than the tip), leaves, and roots of plants (can be seen on tree stumps, old roots); and runners (strawberries, some ferns, and grasses).

Asexual plant reproduction will not be studied in this unit.

Sexual reproduction in plants, like other organisms, involves the combining of two cells each with half of the genetic information (DNA) to create other living plants.

Flowering-plant sexual reproduction involves special structures within the flower: the stamen and the pistil.

The main male part is called the stamen. Two parts of the stamen are anthers, which carry the pollen, and filaments, which are threadlike structures that hold up the anthers.

The main female part is called the pistil. Three parts of the pistil are the stigma, which is the sticky surface at the top of the pistil that captures and holds the pollen; the style, which holds up the stigma; and the ovary, which holds the ovules (eggs) that become the seeds.

The Wisconsin Fast Plants® used in this unit are flowering, sexually reproducing plants.

Pollen from the stamen fertilizes the ovule. Pollination happens when bees and other insects, birds, wind, and so on help move the pollen from the stamen to the pistil. Once on the pistil, the pollen forms a pollen tube and the pollen grain moves through it to fertilize the ovule in the ovary. The fertilized ovary grows into a fruit around the seeds.

Tasting Brussels Sprouts

Brussels sprouts, broccoli, and cauliflower all belong to the same family of vegetables called the Brassicaceae family. Many people do not like broccoli and Brussels sprouts because of their bitter taste. The bitter taste that some people associate with these vegetables has been linked to a specific gene that also controls the ability to taste a substance called PTC (phenylthiocarbamide). The ability to taste PTC is a genetically inherited trait and runs in families.

Students should taste the Brussels sprouts before doing the PTC tasting. Many students may not have tasted them before and therefore cannot answer the question about liking or disliking them. Students should not be forced to taste the Brussels sprouts. If they have already tasted them and know whether they like them or not, they do not need to taste them again.

Tasting PTC

There is great variability in the taste threshold or the concentration at which a person can taste PTC. It is possible for a person to be considered a nontaster in one test, but if given a higher concentration of PTC, he or she is a taster. The concentration of PTC on these test papers is extremely low, and it is likely that only those students who have a high sensitivity to PTC will be able to taste it. Therefore, students who report tasting nothing as well as students who are unsure should be scored as nontasters. When counted this way, about 70% of students will be tasters and 30% will be nontasters. Values from any given class may show variation from these percentages due to the small size of the sample. Combining results from several classes may yield a more typical distribution. (Source: Carolina Biological Supply Co., Carolina™ Test Papers)

When tasting the PTC paper, the students who are able to taste the chemical will have a strong reaction to the bitter taste, and it can leave a bitter taste in the mouth. To get rid of the taste, students should drink water and rinse out their mouths or eat a piece of hard candy, if possible.

Scientific Language

This is a good opportunity to talk about how the same word or symbol can be used in different situations and have different meanings.

If students struggle with the *purple × purple* language, discuss the idea of scientific language. Scientists use special ways to talk about phenomena that may be confusing for students. They have learned in mathematics that the × means "multiply." In the language of genetics, it represents a cross or fertilization of one organism by another to produce offspring.

In this activity, students will also see the terms F_1 and F_2 on their activity sheets. F stands for *filial,* which comes from the Latin word for son or daughter. F_1 and F_2 represent the first- and second-generation offspring of the P (parent) generation.

GROUPS	SEEDS FROM PACKET	
	L2 Experiment Setup	L3 Experiment Setup
A1 and A2	A	D
B1 and B2	B	E
C1 and C2	C	F

Seed Packets for Activity 2.2

PACKET	STUDENT GROUP	OFFSPRING (F_1 GENERATION)	CAROLINA BIOLOGICAL SUPPLY CATALOGUE #
A	Purple/Purple (Both parent plants are ANL/ANL.)	Purple	158810 *Brassica rapa*, Hairy Purple Stem Seed, Pkg.g. 50 158811 *Brassica rapa*, Hairy Purple Stem Seed, Pkg.g. 200
B	Non-purple/ non-purple (Both parent plants are anl/anl.)	Non-purple	158812 *Brassica rapa*, Hairless Non-purple Stem Seed, Pk 50 158813 *Brassica rapa*, Hairless Non-purple Stem Seed, Pk 200
C	Non-purple/ Purple (Non-purple parent is anl/anl; purple parent is ANL/ ANL.)	Purple	158880 *Brassica rapa*, F_1 Hairless Non-purple Stem, Pkg. 50 158881 *Brassica rapa*, F_1 Hairless Non-purple Stem, Pkg. 200

Seed Packets for Activity 3.2

PACKET	STUDENT GROUP	OFFSPRING (F_2 GENERATION)	CAROLINA BIOLOGICAL SUPPLY CATALOGUE #
D	Purple/Purple Seeds are F_2 generation cross. Both parent plants are ANL/ANL.	Purple	See packet A.
E	Non-purple/ Non-purple Seeds are F_2 generation cross. Both parent plants are anl/anl.	Non-purple	See packet B.
F	Purple/Purple Seeds are F_2 generation cross. Both parent plants are anl/ANL.	Mixed (approx. a 3:1 ratio of purple to non-purple)	158886 *Brassica rapa*, F_2 Hairless Non-purple Stem Seed, Pkg. 250

Setup

Groups and Seed Packets

In Lesson 3, students will set up a second experiment. Group members will remain the same for each experiment. The following table indicates which packet the seeds come from for each group.

Setting Up Petri Dishes

- The seeds take two to three days to germinate and for students to be able to see the stem color.
- It is important to ensure that students place their seeds in the top half of the Petri dish and keep that side of the dish out of the water. The paper towel in the Petri dish will wick water from the container it is in and keep the seeds moist. The seeds only need a moist environment and should not be floating in water.
- Groups should place their Petri dishes in a larger container with water. Next, cover the container with plastic wrap to prevent the water from evaporating.

- Students should check the water level in the class container daily. If the seeds are not kept moist, they will not sprout.
- See the picture on the student activity sheet for the setup of class seeds.

Setup for Activity 2.2: Purchase the flowers before this activity. Lilies are suggested because of their large size and ease of dissection. Tulips will also work. It is important that the reproductive parts of the flowers can be observed easily.

Safety Guidelines

Activity 2.2

In this lab, students will be using sharp instruments (forceps and probes). Caution students to handle these instruments carefully.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 2

What Traits Get Passed On?

TEACHING THE LESSON

Performance Expectations

Students will

- analyze data about inherited traits to determine if two traits are related.
- provide evidence to distinguish between the influence of inheritance and environment on traits.

Overview

Activity 2.1

- Conduct a class survey about liking/disliking Brussels sprouts.
- Compare PTC tasting data to Brussels sprouts data to determine if there is a link between the two.

Activity 2.2

Dissect a flower to observe parts involved in sexual reproduction.

Activity 2.3

Prepare seeds for exploring how different traits are passed down.

Introducing the Lesson

Reading Follow Up

The last reading asks the question "Are athletes born or built?" How important are genetics in athletic success? Use an example of a familiar athlete and ask students if they think the person was born with the ability to do X or learned to do it through training. Ask: "Did the person inherent the ability or was it acquired?" Students should support their thinking with textual evidence from the reading.

Building Coherence

The purpose of this lesson is for students to further develop their understanding of a trait and the distinction between traits that are inherited and those that are acquired. They expand their investigation to include plants as well as humans. This lesson connects to the IQWST IC1 unit, in which students learn that odors are chemicals that can be detected by the nose. Here students investigate the connection between chemicals and the ability to taste. It also connects to the IQWST LS2 unit, in which students learn that receptors located throughout the body send impulses to the brain. The questions generated in this lesson will help to drive the investigations of later lessons.

Timeframe

2 Class Periods

Lead In

- Do you think that heredity could influence other things besides athletic ability and certain physical traits, like hair color or a widow's peak?
- Could heredity play a role in the foods you like? Engage students in a brief discussion about this question. Try to get support from the students for both sides of the argument.

Suggested Prompts

- Does everyone in your family like all of the same foods?
- Do you think this is heredity or common experience?
- Is there a food you eat now that you would not eat when you were younger? (*Students may claim that food preferences are learned. For example, you are given certain foods by your parents, and certain cultures like certain types of food that are different from other cultures. Some students may claim food preferences are inherited because they like what their mothers or fathers like.*)

After students have shared their ideas, ask them how they could figure out if what they like to eat is inherited or acquired.

Materials – Activity 2.1

For the Class

- samples of Brussels sprouts for tasting*
- PTC taste paper
- PI: Data Table for Comparing Two Traits

For Each Student

- Activity Sheet 2.1
- Reading 2.1

* This item is not included in the kit.

Activity 2.1 – Are Traits Connected?

Doing this activity in groups gives students the opportunity to discuss their findings as they happen. Students will need Activity Sheet 2.1 to record their individual findings and their group results. Before beginning the activity, have students fill in the prediction on their activity sheets. The question asks if they think that a preference for a certain food is inherited or acquired. Students should check their choice on their sheets and then explain why they chose that response. Ask students how they are able to taste things. Students may use words like *taste buds* or *tongue*.

There are taste receptors all over the tongue. They are not just yes/no sensors, but they are able to sense whether something is very bitter or only slightly bitter.

Suggested Prompts

- Do we all have the same kinds of receptors on our tongues? (*yes*)
- Do you think things taste exactly the same to each of us? (*Students may disagree about this answer. At this point, they have only their experiences on which to base a response. Press students to give reasons for their answers.*)

If there is disagreement on this question, ask how students think they could determine if things taste the same to everyone. (*The idea of having everyone taste the same thing and then describe how it tastes will most likely come from students. If it does not, suggest it.)*

Ask if any students in the class ever tasted Brussels sprouts. In the first part of this activity, students will taste Brussels sprouts and record their reactions on the activity sheet. Distribute the Brussels sprouts to the groups and have students taste them and answer Question 1 on Activity Sheet 2.1.

Suggested Prompts

- What trait are you studying? (*the taste of Brussels sprouts*)
- What are the variations of the trait? What were the two choices you were given on the activity sheet? (*The two choices were liking the taste of Brussels sprouts and not liking the taste of Brussels sprouts.*)

Have the students who liked the taste of the Brussels sprouts describe how they tasted to them. Follow up with students who disliked them. Encourage students to use the five tastes that scientists use to describe how the Brussels sprouts taste to them. This information helps students begin to see that all people do not perceive the taste of food in the same way. There seems to be variation in the ability to taste.

Suggested Prompts

- Do students think that whether or not they liked Brussels sprouts is an inherited or acquired taste and why?
- Is there any way they could try to figure that out?

If students do not suggest it, propose the idea that they could taste something no one in the class had tasted before. Students may suggest that it would be hard to find a food that no one in the class has ever tasted. Show students the PTC strips and explain that this paper has been treated with a chemical called PTC. Ask if anyone has ever heard of this before. Assure students that the chemical on the paper is not harmful. Each student will get two strips of paper: one that has been treated with PTC and one that has not. Distribute PTC tasting papers to each group. Have each student taste both strips and record his or her reaction on the activity sheet. After students have finished tasting the PTC paper, have them complete the questions on the activity sheet. When all groups are finished, discuss the activity.

Suggested Prompts

- Did everyone have the same experience when they tasted the PTC paper?
- What trait did we just test for? (*the ability to taste PTC)*
- What are the variations of the trait? (*Taste or nontaste are the variations.*)
- Do you think that you learned to dislike the taste of PTC? Why? (*Students should be able to state that since it is a chemical they have never seen or tasted before, they probably did not learn to dislike it.*)

Using PI: Data Table for Comparing Two Traits, compare the results of the two tests. Sample results for a class of 30 students are included in the following chart.

Keep the bottom half of the image covered. You will complete that portion after the next section of the lesson. Students have completed the same chart for their group on the activity sheet. Combine data from the groups to construct class totals, and fill in the quadrants of the table.

- number of students who could taste PTC and liked Brussels sprouts
- number of students who could not taste PTC and liked Brussels sprouts
- number of students who could taste PTC and disliked Brussels sprouts
- number of students who could not taste PTC and disliked Brussels sprouts

There should be a strong correlation between the number of students who could taste PTC and those who disliked Brussels sprouts. The two PTC-tasting columns have different patterns depending on whether or not you like Brussels sprouts. (See sample data.)

Ask students if this is evidence that these two traits are related and why. (*The pattern of liking Brussels sprouts is reversed in the two columns. There is a very large proportion—17 out of 20 students—that dislike Brussels sprouts and can taste PTC. It is more evenly split in the nontaste group.*)

Now that students have seen the connection between two traits, ask if they think other traits could be connected. Suggest they try something that only some people can do: rolling their tongues. Take a minute to have students see if they can roll their tongues or not. Ask if anyone taught them how to roll their tongues. Explain that just like PTC tasting, this trait also has only two variations. Either you can roll your tongue into a *U* or you cannot. Using a show of hands, fill in the table on the bottom of PI: Data Table for Comparing Two Traits with the class data. Place the total number of students that fall into each category into the appropriate box.

Suggested Prompts

	TASTE PTC	NON-TASTE PTC
Liked Brussels Sprouts	3	6
Disliked Brussels Sprouts	17	4

- Look at the class data for tongue rolling. Do you see any patterns?
- What does the evidence show about the connection between tasting PTC and rolling your tongue? (*Students should see that there does not seem to be any relationship between tongue rolling and tasting PTC. Whether a person can taste PTC or not does not seem to influence the relative proportion of tongue rolling or not.*)

Have students return to Activity Sheet 2.1 and answer Question 2 in the Making Sense section.

Looking for a Pattern in the Data

Have a few students share their answers to the Making Sense question about whether or not the ability to taste PTC and disliking Brussels sprouts are connected. For those that changed their minds after seeing the class data, be sure to have them share their reasoning for why they changed their minds. Explain that scientists know that the ability to taste PTC is an inherited trait. Ask students if the data they have collected, combined with knowing that PTC tasting is an inherited trait, helps answer the question about whether or not what we like to eat is inherited.

There may not be a one-to-one match between the tasters and the people who disliked the vegetable, but there should be a positive correlation between the two.

Suggested Prompts

- Does everyone who dislikes Brussels sprouts taste PTC? (*no*)
- Do all nontasters like Brussels sprouts? (*no*)

	TASTE PTC	**NON-TASTE PTC**
Tongue Rolling		
Non-tongue Rolling		

- Is there a pattern in our data? (*The data should show that many of the tasters also dislike Brussels sprouts. There seems to be a pattern that these two things are connected.*)
- Do the data help us answer our question about whether food preferences are inherited or acquired? (*The data seem to indicate that at least some of the foods we dislike could be influenced by inherited traits. However, the data also raise a question, because not everyone who disliked Brussels sprouts could taste the PTC. That means that some people learned or acquired the dislike of Brussels sprouts.)*
- How many students had ever tasted PTC paper before tasting it in class? (*It is unlikely that any will have done this before.*)
- How did you know to react to the bitter taste of the chemical? (*It may take some probing to get students to understand that they inherited the ability to taste the PTC and that their reaction to it was not learned.*)
- If you could taste the PTC, do you think you could ever learn to like the taste of it? What if you could not taste it? Do you think you could learn to taste it? (*Students should be able to state that it is possible they could learn to like the taste of it but that there is no way they could learn to taste it. If they could not taste it, they cannot be taught how to taste it.*)
- What other factors could influence whether or not a person likes certain foods? (*Food preferences can be influenced by culture, availability, and family.*)
- If you were able to taste the PTC and dislike Brussels sprouts, do you think that it would be possible to learn to like them? (*Some students may argue that if they have*

an inherited trait [tasting of PTC] and it is linked to the taste in Brussels sprouts, then there is no way to learn to like them.)

- If tasting the PTC is inherited, just what is it you got from your parents? (*Students will not know the exact answer to this question but may offer some ideas based on what they have heard.*)

Note: At this point, accept all students' responses, since the purpose of this lesson is to raise questions and not necessarily answer them.

Explain that while their parents did not give them their actual taste buds, they somehow gave the instructions to taste PTC or not. In Lesson 1, students developed the hypothesis that the instructions may be in the DNA in the nucleus of a cell. It is fine that this remains an open question at this point. Right now, students only need to have the idea that somehow instructions are passed from parent to child. Have a brief discussion about tongue rolling and its connection to the ability to taste PTC.

Suggested Prompts

- Does there seem to be a connection between tongue rolling and the ability to taste PTC? (*no*)
- How are the data different?

All four combinations should be more equally represented in the table. Students should notice that there is no relationship between tongue rolling and PTC tasting. They seem to be two completely separate traits, unlike the PTC and Brussels sprouts comparison that students did. Students leave this activity with an open question about whether the ability to taste is a trait that is inherited, acquired, or both. It seems likely that it is inherited, but students do not have enough data to support that claim. Some traits seem to be independent, like PTC tasting and tongue rolling.

Suggested Prompts

- What evidence would help to convince you that taste is inherited?
- What would you need to know that you do not know now?

In this activity, students have looked at data from themselves, but they do not have any information about their parents' ability to taste PTC, so they cannot make the connection to how the instructions are passed on.

Introducing Reading 2.1 – Do the Traits I Inherited Affect My Sense of Taste or Smell?

Use the Getting Ready section to introduce the reading to students. Have them think about other vegetables they like or dislike. Have them fill in that section of the reading and talk about why they like or dislike certain vegetables.

Materials – Activity 2.2

For the Class
- PI: Flower Parts
- dissection tools: scalpel, scissors, forceps, and probe

For Each Group
- (1) flower* (lily)
- (1) white paper plate*
- (1) sheet white construction paper (12 × 18)

For Each Student
- Activity Sheet 2.2
- Reading 2.2

* This item is not included in the kit.

Activity 2.2 – How Do Plants Reproduce?

Reading Follow Up

Ask: "Do you think that whether or not you like a certain vegetable is inherited, acquired (learned), or both? What information from the reading would help you decide the answer?"

Dissecting a Flower

In the first activity, students saw evidence that it seems likely that the ability to taste is inherited based on the data they collected. The data showed that some could taste PTC and some could not and that it was not likely that they learned to taste the PTC, since no one had ever tasted it before. Students still could not determine if taste is inherited because they did not have data about their parents.

If students had life science, it is sometimes difficult to easily observe things in humans. Ask: "Can you think of other examples in scientific investigations where you investigated things you could not directly observe?" If students had the IQWST LS1 Unit, they observed interactions in ecosystems by manipulating a computer simulation. In the IQWST LS2 Unit, they looked at amoebae, bacteria, and yeast. They also observed osmosis in an onion cell.

Suggested Prompts
- What could you do in this activity to observe how traits are passed from parent to offspring? (*Look at other organisms to observe how traits are passed on.*)
- Do you think that plants might be a good choice for modeling how traits are passed from parents to offspring? Why? (*Students may respond that plants are not like humans and do not reproduce in the same way, so maybe they pass on traits differently. Some students may not think of plants as having traits.*)
- Are there any ways that plant reproduction is similar to human reproduction? (*Students may not have many ideas about how plants reproduce. They may offer ideas like the following:*
  1. *Plants are not like humans because there are not male and female plants.*
  2. *You do not need two plants to make a new plant.*
  3. *Plants reproduce from seeds, humans do not.)*

Suggested Prompts

- How could it take two plants to produce a new plant, especially if plants do not move?
- Can plants reproduce in the wild, where there are no farmers or gardeners to plant seeds?
- How do you think they do that?
- What could you do to figure out how plants are able to reproduce?

Students will dissect a flower in order to investigate how plants reproduce. This will help the class figure out whether they can use plants as organisms to study what may be happening in people. In order to examine the different structures of a plant, it would be useful for students to be able to refer to the parts by their names. Using PI: Flower Parts, guide students through a brief explanation of plant reproduction.

Student groups will then dissect a flower in order to better understand this process. They will need to be familiar with the following terms in order to complete the activity:

- stamen
- pistil
- pollen
- anther
- filament
- stigma
- ovary
- ovule

Display PI: Flower Parts during the activity so that students may refer to it as they dissect their flowers. Each student should complete his or her own activity sheet and the group will complete a composite, labeled diagram of the dissected flower. Each student will need Activity Sheet 2.2, and the group will need a sample flower to dissect, as well as a sheet of white paper for their diagram. Cover the tables with newspaper, as the pollen can be messy. You may want to have microscopes available for students who want to observe flower parts more closely (e.g., pollen).

Remind students that they are each responsible for completing their activity sheets and the group is responsible for completing a labeled flower diagram using the parts from their dissected flower.

Discussion – Making Sense

Purpose

Make sense of sexual reproduction in plants and compare it to human reproduction.

Now that students have investigated flower reproduction, return to the question that began the activity: Are there any ways human reproduction and plant reproduction are similar?

Suggested Prompts

- Have you changed your answer to that question?
- How do you compare the way flowers and humans reproduce? (*Similar: Both plants and animals have male and female parts. They both have eggs [in ovaries]. Plants have pollen and humans have sperm that fertilize the egg. Both produce offspring that have traits similar to the parents. Different: Plants have both male and female parts in a single flower; humans have separate males and females.*) Students should understand that the way plants and humans reproduce is more similar than different because they both reproduce sexually.
- If the way plants and humans reproduce is similar, would plants make a good organism to study in order to determine how traits are inherited? Why? (*Plants would make good organisms to study because they can be grown in the lab. It takes humans a long time to reproduce, and they cannot be studied in school.*)

  Note: In the next activity, students will be setting up an experiment to look at how traits are passed down from parent plants to their offspring.

Introducing Reading 2.2 – What Is the Buzz About?

This reading is about pollination of plants and bees. It reinforces the ideas learned in this activity about how plants are pollinated and reproduce. Ask: "How do you think pollen gets from the anther to the stigma on a plant?"

At the end of the reading, there are fun facts about honeybees that could be used as an introduction to the reading.

Given that interest plays a key role in students' motivation to read, these can be used to draw students into the reading. These facts are not intended to become quiz questions or even extra-credit points on quizzes. They are just for fun.

Materials – Activity 2.3

For the Class

- grow light for germinating seeds

For Each Student

- Activity Sheet 2.3

For Each Group

- (1) Petri dish
- (1) piece of paper towel*
- (20) seeds from Wisconsin Fast Plants® (see Preparation section for directions)

* This item is not included in the kit.

Activity 2.3 – Is There a Pattern to How Traits Get Passed On?

Reading Follow Up

Ask students what they have learned about bees that make them such important insects.

Looking at the Seeds

For this activity, the teacher will need the two Petri dishes of germinated seeds that were set up at the beginning of the lesson. Students identified the need to know about parents and their offspring in order to decide if a trait was inherited.

Suggested Prompts

- Based on what you learned about plant reproduction, can they be used to test ideas about heredity?
- What could you do in class to test your ideas?
- Show students two small pots of growing Wisconsin Fast Plants®, one purple and one non-purple. The photograph shows plants that were grown from seeds in about one week. Point out that these are the same kinds of plants but that they have variations in some traits.

Since many plants reproduce sexually, they can be used to study how traits are passed on from parent to offspring. The plants used in this unit are Wisconsin Fast Plants®. In this activity, students will germinate seeds to see if the plants that come from those seeds have traits similar to the plants that produced the seeds. Discuss the trait students will be observing.

Suggested Prompts

- What are the similarities and differences you notice? (*The stems are different colors.*)
- How many variations do you see in this trait? (*Students will see only two: purple and non-purple.*)
- Is this similar or different from the traits you observed in Lesson 1 and in Activity 2.1? (*Students should note that these are similar to those traits because there are only two variations. Here the stems are either purple or non-purple. In the other lessons, people could either roll their tongues or not or could taste PTC or not.*)
- In this activity, students will observe a single trait—stem color—to look for patterns of how traits are passed on from one generation to the next.

Setting Up the Seed Samples

Students will work in groups for this activity and need Activity Sheet 2.3. Ask students if they can give you a definition of *generation*. Students should be able to say that it represents an age group and give examples such as parents, grandparents, and children being different generations. Explain to students that they will be able to see the stem color of the plants as soon as the seeds start to sprout. Explain to students that the Petri dishes of purple and non-purple sprouted seeds represent a generation of plants.

The purple plants come from a long line of purple plants. This means that they have never reproduced with a non-purple plant. The non-purple plants come from a long line of non-purple plants. Ask students what they could test to figure out what traits the offspring of these plants would have. (*Students should suggest the idea of having different parent plants reproduce to see what variations of the stem trait occur*.)

Ask students what possible combinations we could try, and record these on the board. You should have the following combinations listed, suggesting them if students do not produce them.

- plants that have non-purple stems with other plants with non-purple stems (NON-PURPLE × NON-PURPLE)
- plants that have purple stems with other plants with purple stems (PURPLE × PURPLE)
- plants with non-purple stems with plants with purple stems (NON-PURPLE × PURPLE)

Explain to students that they could take the pollen from a non-purple stem plant and use it to fertilize a purple-stemmed plant, but they would first have to wait for these seedlings to grow. That would take 45 days. So instead of waiting to do that, they are going to use some seeds that come from the three combinations listed on the board. The company that produces these seeds made sure that they came from those combinations.

Divide the class into six groups and distribute the seeds and parent plants as follows:

- Two groups (A1 and A2) will be germinating seeds that resulted from the cross of two plants with purple stems. They should receive these seeds (20) and two Petri dishes with purple-stemmed plants to observe so they can see what the parent plants that produced these seeds look like. (This corresponds to the seeds in Packet A.)
- Two groups (B1 and B2) will be germinating seeds that resulted from the cross of two plants with non-purple stems. They should receive these seeds (20) and two Petri dishes with non–purple stemmed plants to observe. (This corresponds to the seeds in Packet B.)
- Two groups (C1 and C2) will be germinating seeds that resulted from the cross of a plant with a purple stem and a plant with a non-purple stem. They should receive these seeds (20) and one dish of non–purple stemmed plants and one dish of purple-stemmed plants to observe. The two Petri dishes represent the parent plants that produced the seeds they have. (This corresponds to the seeds in Packet C.)

Students should record the cross for their group and make their predictions about the offspring on the activity sheet. Next, students should follow the directions for setting up their

Petri dishes and seeds. Be sure that students label their dishes with their group name or number, as well as with F_1 and the type of cross they used. Explain that F_1 is used to indicate the first generation of offspring (or first filial generation). This is the way scientists keep track of generations so they know the order of offspring.

After students have set up their seeds, explain that it will take two or three days for the seeds to sprout. They will return to check the seeds in the next lesson. Be sure to have students check each day to make sure that there is enough water to keep the seeds moist.

Wrapping Up the Lesson

In order to decide if traits are inherited, we need to know about both parents and their offspring.

In the plant experiment that students just set up, they will be able to compare the stem color of the parents and offspring. In the next lesson, students will use human data to compare parent and offspring traits.

LESSON 3

Can We Determine Patterns in Traits?

PREPARATION

Teacher Background Knowledge

All Traits Come from the Mother

It is a common student misconception that offspring only inherit traits from the mother because she gives birth to them. It is important that students are able to identify that traits can come from either parent.

Jigsaw Groups

Jigsaw is a strategy where students begin the activity working in one group and then recombine for the second part of the activity. The new groups contain a mix of the first groups. One way to do this is to have students in the original group count off (1, 2, 3, and 4). Then have all the ones form a new group, all the twos form a new group, and so on. This strategy helps students become more responsible for participating in the group work because they have to explain the data collected by their original group.

Creating a Pattern and Evidence Chart

A completed copy of this chart is found at the end of the Preparation section.

- This Sense-Making discussion is key to establishing the questions about patterns students have seen in the pedigrees in this activity. By developing questions around those patterns, students will return to this chart later in Lesson 3 and in Lesson 4 when they look at plants to see if they find more evidence to support those patterns or if they need to revise their ideas.
- There are many possible pieces of evidence that students can give for each of the patterns on the chart. It is not necessary that all pieces of evidence are listed. Students should be able to explain why the evidence fits the pattern.
- The claims are based only on the data students have collected so far. When more evidence is collected, some claims may change.

Setup

Groups

Students will set up a second experiment. In this setup, the groups will have the same members as the original experiment; however, the label on their seed packet will change. The setup for each group is as follows. (See Lesson 2 Preparation section for more details)

GROUPS	SEEDS FROM PACKET	
	L2 Experiment Setup	L3 Experiment Setup
A1 and A2	A	D
B1 and B2	B	E
C1 and C2	C	F

Pattern and Evidence Chart
(completed chart as of L3)

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
1. Can offspring get instructions for the variation of a trait from either parent?	*Offspring can get instructions for a trait from either parent.*	*Mom has blue eyes and Dad brown. My brother has blue eyes and mine are brown.*	**Activity 3.1:** • Pedigrees A1, Cases 3 & 4 • Pedigrees A2, Cases 10, 11, 13, & 14 • Pedigrees B1, Cases 2, 4, & 5	No evidence
2. Do all offspring from the same parents inherit identical variations of traits?	*Sometimes offspring inherit identical traits and sometimes they don't.*	*There are three kids in our family and we all have different colored hair. Two of us have brown eyes and one has green.*	**Activity 3.1:** • Pedigrees A1, Cases 3, 4, & 5 • Pedigrees A2, Cases 9, 10,11, 13, & 14 • Pedigrees B1, Cases 2, 3, & 5 • Pedigrees B2, Cases 9, 10, 11, 13, & 14	No evidence

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
3a. Can offspring show a variation of a trait that neither parent shows?	*Offspring can show a variation of a trait that neither parent shows.*	*My parents both have brown hair, but mine is red.*	**Activity 3.1:** • Pedigrees A1, Case 5 • Pedigrees A2, Case 9 • Pedigrees B1, Case 5 • Pedigrees B2, Case 9	No evidence
3b. Do certain combinations of parents always have offspring that look like them?	*Certain combinations of parents always have offspring that look like them.*	*In our family, my grandparents on both sides have brown eyes, my parents have brown eyes, and my brother and I have brown eyes.*	**Activity 3.1:** • Two nontasters always have nontaster children (zero cell) • Two non–tongue rollers always have non–tongue rolling children.	**Activity 3.2:** • Purple × purple always gave us purple. (This will change in L4.) • Non-purple × non-purple always gave us non-purple.
4. If parents have different variations of a trait, does it seem that one is more likely to be passed on?	*When parents have different variations of a trait, one is more likely to be passed on.*	*Mom has blue eyes and Dad has brown. All siblings have brown eyes.*		**Activity 3.2** • Non-purple and purple always gave us purple.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 3

Can We Determine Patterns in Traits?

TEACHING THE LESSON

Performance Expectations

Students will

- use evidence to support claims about patterns in heredity data.
- analyze data to compare patterns between plant and human data.

Overview

Activity 3.1
Examine human pedigree data to determine patterns in how traits are inherited.

Activity 3.2
Determine patterns in the way plant traits are passed from one generation to the next.

Activity 3.3
Predict what traits will appear in the second generation of plants.

Building Coherence

This lesson examines additional organisms to determine patterns in the appearance of different traits over multiple generations in order to determine how traits are inherited. Students may have had experience in the IQWST LS1 unit in using sample organisms in order to study phenomena that they could not easily observe in humans. In Lesson 2, students determined that they needed information about both parents' traits in order to determine if traits are inherited. In this lesson, they analyze data of plants and human pedigrees to see if there are patterns of inherited traits.

Timeframe

2–3 Class Periods

Materials – Activity 3.1	
For Each Group	***For Each Student***
• copy of Pedigree A1, A2, B1, or B2	• Activity Sheet 3.1

Activity 3.1 – What Are the Patterns in How Traits Are Inherited?

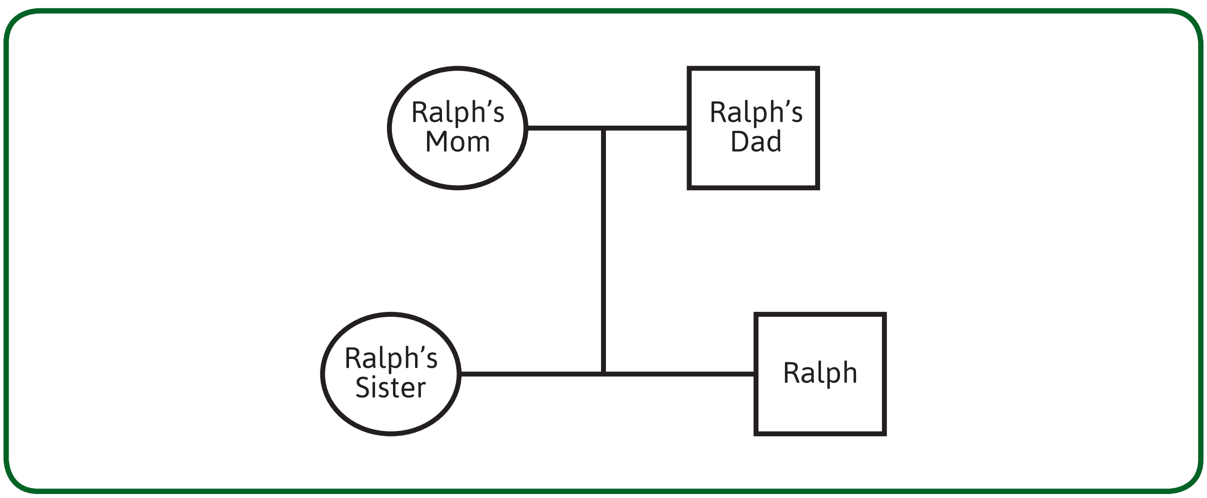
In Lesson 2, students determined that they would need to know the traits of both parents and their offspring in order to find the patterns in how traits are inherited. In this activity, they will be examining data to see what patterns they can find.

Introducing Pedigrees

- How are you going to know if a trait is passed on? (*Allow students to suggest their ideas. Point out the following: We need to keep track of which traits each individual has and keep track of who the parents are of each individual. We also need to know the traits of the parents. Then we could see which traits are passed from parents to child.*)
- Do you think keeping track of two generations is enough? (*Students may suggest that knowing the parent and offspring is enough. Suggest that whatever they use should be set up in a way so that they could look at more generations if they think they need to.*)

Explain that scientists use something called a pedigree to keep track of family relationships and traits. A pedigree is a graphic organizer or diagram that keeps track of that information. Ask if students have heard the term *pedigree* before. Some may be familiar with the term as it relates to dogs. What information about a dog does a pedigree keep track of? (*family relationships like parents, grandparents, sisters, and brothers*)

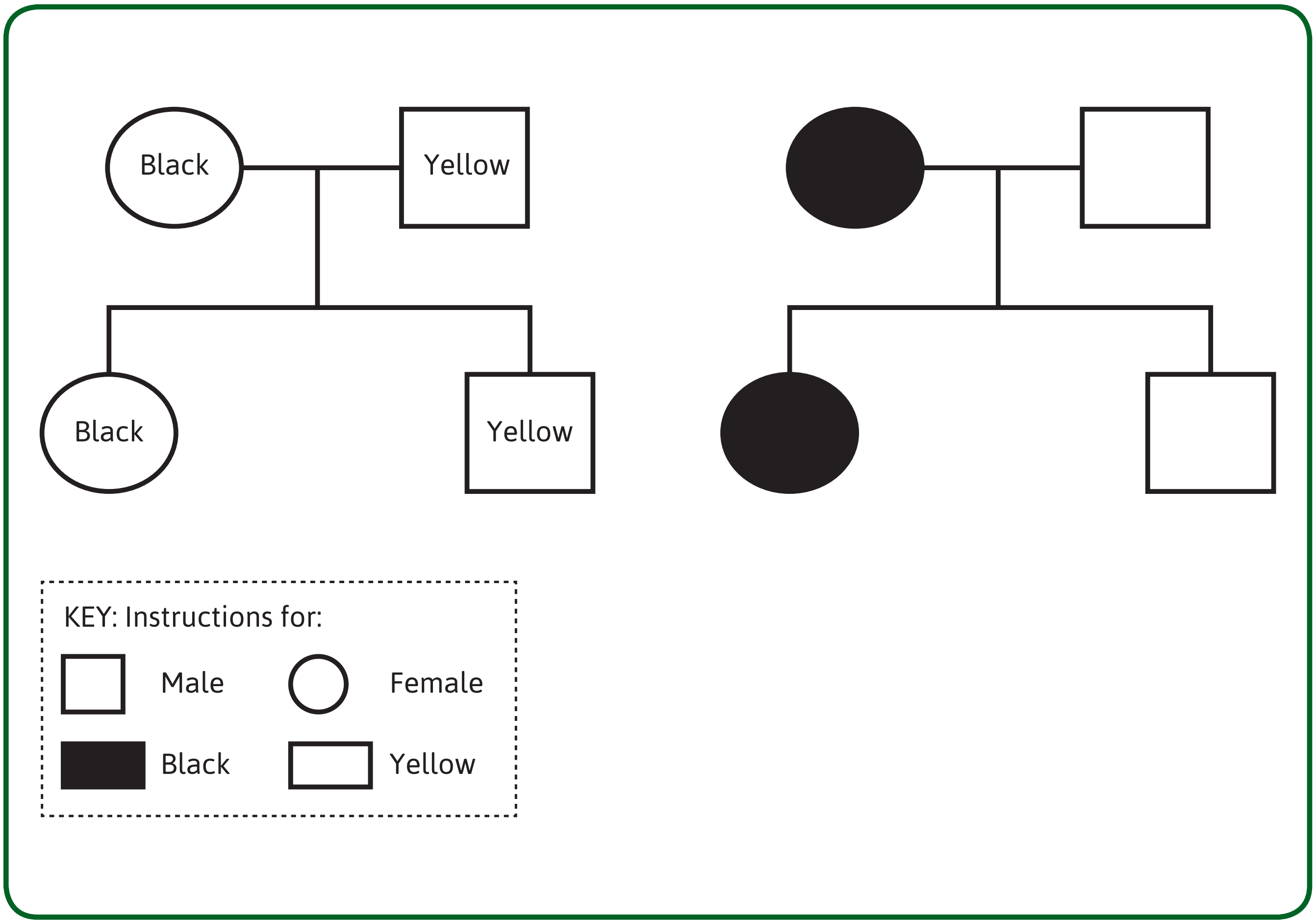
Draw a sample pedigree for Ralph the dog on the board or projector.



- How are the differences between the males and the females shown? (*Squares show males and circles show females.*)
- How are the relationships shown? (*Lines show relationships.*)
- How are the parents shown? (*A horizontal line between them shows parents.)*
- How are the offspring shown? (*Vertical lines extending downward from the parents show offspring.*)
- How are generations shown?
- Where is the oldest generation located? (*It is located at the top of the pedigree.*)

- Where is the youngest generation located? (*It is located at the bottom of the pedigree.*)
- How could a pedigree help us observe traits that are inherited?

Guide students to the idea that instead of names, traits could be listed in the pedigree. Remind students that traits result from instructions that are carried in DNA. Explain that Ralph and his family are Labrador retrievers. Common colors are black and yellow. Using the example of Ralph, erase the name identifiers and replace them with the trait variation or a color to represent the trait variation.



Ask students what kind of results they might see in a pedigree that could tell them something about the trait of color. (*Students might say something like "Black dogs always have black puppies." Accept any answer that draws on the data that can be observed by using pedigrees like this.*)

Interpreting Human Pedigrees

Students will use pedigrees to determine if there are any patterns for how traits are inherited. Have students take out Activity Sheet 3.1 and fill in the prediction tables for both tongue rolling and PTC tasting. They will check cells to indicate their predictions. For example, if students believe that a mom and dad who are both PTC tasters will have a child who tastes PTC but none who are nontasters, they would check the cell in that column across from *Child*

Tastes PTC and leave the cell under that column for *Child Is a Nontaster* blank. If they predict they will have both kinds of offspring, they would fill in both offspring cells. Before passing out the pedigrees, discuss their predictions.

Suggested Prompts

- Does everyone agree? Disagree?
- Which cases are more difficult to predict? Why?

Arrange students in groups of four. Distribute the pedigrees to the groups:

For PTC Tasting

- A quarter of the groups receive Pedigree A1.
- A quarter of the groups receive Pedigree A2.

For Tongue Rolling

- A quarter of the groups receive Pedigree B1.
- A quarter of the groups receive Pedigree B2.

After completing Part 1, direct students to Part 2, and jigsaw groups so that the new groups comprise at least four students, each representing one of the pedigree sheets (A1, A2, B1, and B2). In the new group, they will share data and complete the charts in Part 1 of the activity sheets. As groups record data, check that they have identified the patterns correctly. Completed charts follow. Have students complete the Making Sense questions.

	Mom and Dad both are PTC tasters	Mom and Dad both are Non–PTC tasters	Dad tastes PTC; Mom is a Non–PTC taster	Dad is a Non–PTC taster; Mom is a PTC taster
CHILD TASTES PTC	A1 = 8 A2 = 5 Total = 13	A1 = 0 A2 = 0 Total = 0	A1 = 2 A2 = 2 Total = 4	A1 = 2 A2 = 3 Total = 5
CHILD IS PTC NON-TASTER	A1 = 1 A2 = 1 Total = 2	A1 = 4 A2 = 3 Total = 7	A1 = 1 A2 = 3 Total = 4	A1 = 2 A2 = 3 Total = 5

	Mom and Dad Both are Tongue Rollers	Mom and Dad Both are Non–Tongue Rollers	Dad is a Tongue Roller; Mom is a Non–Tongue Roller	Dad is a Non–Tongue Roller; Mom is a Tongue Roller
CHILD IS A TONGUE ROLLER	B1 = 5 B2 = 5 Total = 10	B1 = 0 B2 = 0 Total = 0	B1 = 2 B2 = 2 Total = 4	B1 = 4 B2 = 4 Total = 8
CHILD IS A NON–TONGUE ROLLER	B1 = 1 B2 = 1 Total = 2	B1 = 4 B2 = 3 Total = 7	B1 = 1 B2 = 3 Total = 4	B1 = 3 B2 = 2 Total = 5

Bring the class together.

Suggested Prompts

- What combinations behaved like you expected?
- What surprised you?
- What do you think this indicates? (*Students should notice that zeroes only occur when both parents are nontasters or non–tongue rollers. There are no offspring that are tasters or tongue rollers. Offspring of certain combinations of parents always have parents that look like them.*)

Students now have some evidence for formulating questions and claims about inheritance patterns. To help organize these data, tell students that the class will create a Pattern and Evidence Chart based on the patterns they observed. Record the chart on the board or projector. This list should be posted on the Driving Question Board and will become part of the model students develop in Lesson 6. Point out the Pattern and Evidence Notes in student books. As observations and questions are articulated, have students record each one on a separate Pattern and Evidence Note. Use the Sense-Making discussion to formulate questions. The questions on the class chart should be in the students' own language.

The goal of the chart is to keep track of what students have seen in order to combine what they see in the human data and what they see when their plants grow. In IQWST, investigations always begin with a question. Students have to figure out what the evidence is and what they think it means—their claim. Students have already gathered a lot of evidence. Suggest that they set up their class chart using the following headings.

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS

Discussion – Making Sense

Purpose

Identify questions arising from observations.

Begin to fill out rows of the Pattern and Evidence Chart with questions. Ask the class the question and then ask for evidence. Evidence can come from their own experience (column 3) or from human data that they have seen (column 4).

> Note: At this point in the lesson, students have no evidence from plants. At the end of Activity 3.2, they will add evidence from plants.

Suggested Prompts

- Can offspring get instructions for the variation of a trait from either parent? Write this question in the first row of the chart.
- For example, when parents were a non-tongue roller and a tongue roller, which variation did the offspring have?
- What claim would you make to answer that question?
- What evidence do you have that supports your claim? (*Students should be able to cite evidence from their own experience and from the human pedigrees.*)

Continue the discussion in the same way until questions, claims, and evidence similar to the four important types of evidence are listed on the chart. The wording of these questions should be the students'. These suggested questions can be useful in getting to the four important ideas that should be on the chart. If students have additional questions, it is fine to add them. Remind students that each one of these questions will go at the top of separate pages in their Pattern and Evidence Notes.

- Can offspring get instructions for the variation of a trait from either parent? (1)
- Do offspring from the same parents always inherit identical variations of traits? (2)
- Can offspring show a variation of a trait that neither parent shows? (3)

There are two parts to this question that are important for students to see: (a) Sometimes offspring show traits that neither parent does. You can see this in the pedigrees where two tongue rollers or two PTC tasters can have a child that does not share that trait. (b) There are situations in the pedigrees where if two parents match, their children always show the same trait as the parents. Call students' attention to the results in the tables with zeroes. When both parents are nontasters or non-rollers, their offspring never show the opposite trait.

If students generate other ideas, ask them for evidence from the pedigrees to support their pattern. If their idea can be supported with evidence, add it to the chart. However, it is important that the aforementioned three questions are on the list. A fourth type of evidence will be added in Activity 3.2. When recording evidence, it is helpful for students to have an example pedigree, along with the number of the case for reference. Students can record their evidence by using pedigrees or describing it in words. See the following example.

Can offspring get instructions for the variation of a trait from either parent?

- On class chart: Drawing of Pedigree A1 Case
- Students' Pattern and Evidence Sheet: Two offspring, one boy and one girl, inherited the tasting instructions from the dad. One girl inherited the nontasting instructions from the mother.
- On class chart: Drawing of Pedigree B1 Case 4
- Students' Pattern and Evidence Sheet: Two girls and one boy inherited non–tongue rolling instructions from their father, and the other girl inherited instructions for tongue rolling from the mother.

Here is an example of how the Pattern and Evidence Chart might appear before adding evidence from plants and human pedigrees.

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
1. Can offspring get instructions for the variation of a trait from either parent?	*Offspring can get instructions for a trait from either parent.*	*Mom has blue eyes and Dad brown. My brother has blue eyes and mine are brown.*		
2. Do all offspring from the same parents inherit identical variations of traits?	*Sometimes offspring inherit identical traits and sometimes they don't.*	*There are three kids in our family and we all have different colored hair. Two of us have brown eyes and one has green.*		
3. Can offspring show a variation of a trait that neither parent shows?	*Offspring can show a variation of a trait that neither parent shows.* *Certain combinations of parents always have offspring that look like them.*	*My parents both have brown hair, but mine is red.* *In our family, my grandparents on both sides have brown eyes, my parents have brown eyes, and my brother and I have brown eyes.*		

Here is how one teacher organized the Pattern and Evidence Chart in his classroom.

Remind students of the question they asked in Lesson 2: Are there patterns in the way traits are passed from parent to offspring?

- Based on the evidence you have collected so far, how would you answer this question?
- What other data can you test? (*Test it with data from the plants.*)

Introducing Homework 3.3 – Heredity Patterns – A Key to Diagnosis

Students will use the data for PTC-tasting and tongue-rolling pedigrees on Activity Sheet 3.1. From their jigsaw group, they should have data in all cells (including a zero in those cells with the non/non combinations). They will look for other evidence that applies to any of the four questions and record it in the appropriate place on their Pattern and Evidence Sheets. The assignment should require them to find at least one additional piece of evidence that applies to each question.

Materials – Activity 3.2

For the Class

- Activity Sheet 2.3
- Activity Sheet 3.1
- Activity Sheet 3.2
- PI: Class Seed Data

Activity 3.2 – Are There Patterns in Plant Traits?

Homework Follow Up

Use students' responses to insert additional evidence in the class Pattern and Evidence Chart based on homework responses. At end of the homework review, the chart may look similar to the following example.

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
1. Can offspring get instructions for the variation of a trait from either parent?	*Offspring can get instructions for a trait from either parent.*	*Mom has blue eyes and Dad brown. My brother has blue eyes and mine are brown.*	**Activity 3.1:** • Pedigrees A1, Cases 3 & 4 • Pedigrees A2, Cases 10, 11, 13, & 14 • Pedigrees B1, Cases 2, 4, & 5	
2. Do all offspring from the same parents inherit identical variations of traits?	*Sometimes offspring inherit identical traits and sometimes they don't.*	*There are three kids in our family and we all have different colored hair. Two of us have brown eyes and one has green.*	**Activity 3.1:** • Pedigrees A1, Cases 3, 4, & 5 • Pedigrees A2, Cases 9, 10,11, 13, & 14 • Pedigrees B1, Cases 2, 3, & 5 • Pedigrees B2, Cases 9, 10, 11, 13, & 14	
3. Can offspring show a variation of a trait that neither parent shows?	*Offspring can show a variation of a trait that neither parent shows.* *Certain combinations of parents always have offspring that look like them.*	*My parents both have brown hair, but mine is red.* *In our family, my grandparents on both sides have brown eyes, my parents have brown eyes, and my brother and I have brown eyes.*	**Activity 3.1:** • Pedigrees A1, Case 5 • Pedigrees A2, Case 9 • Pedigrees B1, Case 5 • Pedigrees B2, Case 9 **Activity 3.1:** • Two nontasters always have nontaster children (zero cell) • Two non–tongue rollers always have non–tongue rolling children.	

Collecting Plant Data

In this activity, students will observe their seedlings for evidence of inherited trait variation patterns for plants. Activity Sheet 3.2 will be used in this lesson and in Lesson 4, so some parts will be left blank until they get to Lesson 4. Refer students to Activity Sheet 2.3 and have them review their predictions for the F_1 generation.

Have each group retrieve the Petri dishes that they set up in Activity 2.3. (Each group will be collecting data only on their setup.) Students check their results by counting the number of purple stems and non-purple stems, and they record results in the group data table on Activity Sheet 3.2. After recording their results, have each group report their results to the class. Record the class results on PI: Class Seed Data. (You will return to this chart in Lesson 4 and add the data from the next generation of seeds.) Each group should fill in data from the other groups on their Class Data Table on Activity Sheet 3.2.

Summarize the results.

- Non-purple offspring only came from non-purple/non-purple crosses. Purple offspring came from both purple/purple crosses and purple/non-purple crosses.
- Were there any surprises? Differences from what was seen in the human pedigree data? (*Only purple stems came from purple × non-purple. In human data, some offspring of tongue rollers/non–tongue rollers and PTC tasters/non–PTC tasters were non–tongue rollers/tasters.*)

Discussion – Making Sense

Purpose

Make sense of the human and plant data.

- What does your new evidence mean for each of the questions and claims on the Pattern and Evidence Chart? Refer to the Pattern and Evidence Chart and Pattern and Evidence Notes. Ask if students found evidence to support the claims on the Pattern and Evidence Chart.
    - Row 1: Can offspring get instructions for a trait from either parent? (*No evidence—There was only one case where the parents differed, and in that case, all of the offspring were purple. None showed the non-purple trait. Therefore, we did not see any evidence in plants.*)
    - Row 2: Do all offspring from the same parents always inherit identical variation of traits? (*No evidence—Unlike the human data, purple × non-purple showed only one variation—purple.*)
    - Row 3a: Can offspring show a variation of a trait that neither parent shows? (*We saw some children inherit a trait different from their parents; we have no evidence.*)
    - Row 3b: *(There are situations where if two parents match, their children always inherit the same trait as the parents; we have some evidence.*)

Note: These two questions should be recorded as one. It will be adjusted in Lesson 4 when students observe the F_2 generation.

- Did your group's prediction match what actually happened?
- Did your group's results surprise you?
- What was surprising? (*Students should be surprised that, unlike the human pedigrees, purple plants crossed with purple plants only give purple offspring, unlike the pedigree data, where taster/tongue-roller crosses showed a variation of traits in the offspring.*)
- Ask students to describe the evidence and a question it raises for the Pattern and Evidence Chart. In a fourth row on the Pattern and Evidence Chart, add a question similar to the following: When two parents have different variations, does one variation matter more for what the offspring inherit? Have students add the question to another page of their Pattern and Evidence Notes. Develop a claim similar to the following: Sometimes a particular variation of a trait seems to be the only one that gets passed on. Add this claim to the chart and notes.
- What evidence supports this claim? (*Activity 3.2—non-purple and purple always produced purple.*)

Note: Students will be able to test this claim with human data in Lesson 4.

Assign Questions 1–4 in the Making Sense section. Students will refer to both Activity Sheet 3.1 and Activity 2.3 in order to compare the plant data to the human data from previous activities. Have students complete Question 5, the prediction for the F_2 generation.

Note: The next Making Sense section will be completed in Lesson 4.

Discussion – Pressing for Understanding

Purpose

Compare the patterns in the human and plant pedigrees.

Review the plant combinations that students used (purple × purple, non-purple × non-purple, and purple × non-purple). Refer to Pedigrees A and B in Activity 3.1.

Summarize

- What happened when non-purple was crossed with non-purple?
- What happened when purple was crossed with purple?
- What happened when a purple and non-purple were crossed?

Analyze

- How do the human data compare with the plant data?
- Which plant crosses were always the same as the human crosses? (*Non-purple crossed with non-purple always produced non-purple. Non–tongue rolling crossed with non–tongue rolling [nontasting × nontasting] always produced non–tongue rolling [nontasting] offspring.*)
- Which plant and human data were different? (*Students should have found that the pattern is more complicated in the human data than the plants.*
    - o *In plants, purple-stemmed plants crossed with other purple-stemmed plants always had purple-stemmed offspring. But two tongue-rolling (PTC-tasting) parents could occasionally have a non–tongue rolling child.*

- o *Purple-stemmed plants crossed with non-purple stemmed plants always made purple-stemmed seedlings. But, there was a mixture of tongue-rolling/non–tongue rolling [tasting/nontasting] offspring in the human data.)*
- How could two tongue-rolling (tasting) parents produce a non–tongue rolling (non-tasting) offspring when you did not see that in the purple-stemmed plants?
- What do you know about the parent generation of the purple-stemmed seedlings that you germinated? (*The purple-stemmed seedlings were from a long line of purple-stemmed plants.*)
  (Students may not remember this from Lesson 2 and may need to be reminded.)
- Do you know the same thing about the human parents? (*Students do not know anything about the previous generations of the humans they examined.*)
- Do you think the difference in the plant and human data could be related to what you know about the parent generations?

Refer to the Pattern and Evidence Chart. Students will test each of these claims by identifying any evidence from the plant data that supports the claim. For 1–3, students will find no evidence to support the claim. At the end of the Wrapping Up the Lesson section, the chart will be similar to the following chart.

Pattern and Evidence Chart
(completed chart as of the end of Activity 3.2)

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
1. Can offspring get instructions for the variation of a trait from either parent?	*Offspring can get instructions for a trait from either parent.*	*Mom has blue eyes and Dad brown. My brother has blue eyes and mine are brown.*	**Activity 3.1:** • Pedigrees A1, Cases 3 & 4 • Pedigrees A2, Cases 10, 11, 13, & 14 • Pedigrees B1, Cases 2, 4, & 5	No evidence
2. Do all offspring from the same parents inherit identical variations of traits?	*Sometimes offspring inherit identical traits and sometimes they don't.*	*There are three kids in our family and we all have different colored hair. Two of us have brown eyes and one has green.*	**Activity 3.1:** • Pedigrees A1, Cases 3, 4, & 5 • Pedigrees A2, Cases 9, 10,11, 13, & 14 • Pedigrees B1, Cases 2, 3, & 5 • Pedigrees B2, Cases 9, 10, 11, 13, & 14	No evidence

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
3a. Can offspring show a variation of a trait that neither parent shows?	*Offspring can show a variation of a trait that neither parent shows.*	*My parents both have brown hair, but mine is red.*	**Activity 3.1:** • Pedigrees A1, Case 5 • Pedigrees A2, Case 9 • Pedigrees B1, Case 5 • Pedigrees B2, Case 9	No evidence
3b. Do certain combinations of parents always have offspring that look like them?	*Certain combinations of parents always have offspring that look like them.*	*In our family, my grandparents on both sides have brown eyes, my parents have brown eyes, and my brother and I have brown eyes.*	**Activity 3.1:** • Two nontasters always have nontaster children (zero cell) • Two non–tongue rollers always have non–tongue rolling children.	**Activity 3.2:** • Purple × purple always gave us purple. (This will change in L4.) • Non-purple × non-purple always gave us non-purple.
4. If parents have different variations of a trait, does it seem that one is more likely to be passed on?	*When parents have different variations of a trait, one is more likely to be passed on.*	*Mom has blue eyes and Dad has brown. All siblings have brown eyes.*		**Activity 3.2** • Non-purple and purple always gave us purple.

Materials – Activity 3.3

For the Class
- Activity Sheet 2.3

For Each Group
- (1) Petri dish* (and paper towel to line it; do not use the same one as from Lesson 2)
- (20) seeds for germinating the F_2 generation (see Setting up Seeds for F_2 Generation section within this lesson)

For Each Student
- Activity Sheet 3.2
- Reading 3.3

* This item is not included in the kit.

Activity 3.3 – What Seed Patterns Are There in a Future Generation?

Predicting Traits in Generation 2 of Plants

In the previous activity, students discovered that the PTC and tongue data did not always match with the plant data.

Suggested Prompts

- How did the human data compare to the plant data?
- When the purple plant was crossed with a purple plant, there were only purple offspring. Did this happen with human PTC tasting and tongue rolling? (*only in some cases but not in all*)
- When non-purple plants were crossed with non-purple plants, there were only non-purple offspring. Did this happen with human cases when non–tongue rollers (nontasters) were crossed with non–tongue rollers (nontasters)? (*yes*)
- When non-purple plants crossed with purple plants, the offspring were always purple. Did this happen in human cases? (*No, both were observed.*)
- At the end of the second activity, you wondered if the differences in human and plant data could be related to what you know or do not know about the parent generations. How could you test this idea?
- The purple plants you observed came from a long line of purple plants. Now you have purple plants whose parents were one purple and one non-purple. If you take these plants and grow them, do you think they will behave as their parent generation did?
- How could this be tested? (*The F_1 generation plants could be crossed to see if the results look more like the plant data they have or more like the human data.*)

To test out their idea, students will germinate seeds that have been taken from a cross of plants in their F_1 generations.

In Lesson 2, what combinations of parent crosses were tested to produce the F_1 generation?

- purple × purple
- non-purple × non-purple
- purple × non-purple

In this lesson, you observed that a cross of a purple and non-purple produced purple offspring, just like the cross of two purple plants.

- What do you think will happen if you take an F_1 generation purple plant that came from each of those crosses and crossed them?
- Is it possible that these two different plants could both be purple on the outside but have different instructions inside?

Add the general form of this last question to the Driving Question Board: Do all organisms that show the same variation of a trait pass the same instructions to their offspring? Students will return to this question at the beginning of Lesson 4.

Direct students to the "F_2 Generation Predictions" section on the last page of Activity Sheet 3.2. Have students complete the prediction for the F_2 offspring.

Setting Up Seeds for F_2 Generation

Assure students that the seeds they are germinating are the same as those that would be produced by crossing two plants from their F_1 generation.

- Group A's seeds will come from crossing two plants from the F_1 generation resulting from the purple/purple cross.
- Group B's seeds will come from crossing two plants from the F_1 generation resulting from the non-purple/non-purple cross.
- Group C's seeds will come from crossing two plants from the F_1 generation resulting from the purple/non-purple cross.

Remind them to label this Petri dish F_2 so that they will be able to tell it apart from the F_1 generation. Refer them to the instructions for the seed setup on Activity Sheet 2.2. Students should return their Petri dishes to the same location and make sure that there is enough water to keep them moist. They will return to these in Lesson 4 to collect their data.

Wrapping Up the Lesson

Ask students if there are any questions that they have based on their observations so far. Add those questions to the Driving Question Board and Driving Question Notes. In the next lesson, they will look at human traits for multiple generations and then return to their seeds.

- There are similarities and differences in the human and plant pedigrees.
- The differences may be present, but they do not know anything about the previous generation of tongue rollers or PTC tasters.
- Will the next generation show the same pattern?
- Do plants and humans pass down traits in the same way?
- How does this happen?

Introducing Reading 3.3 – Heredity Patterns—A Key to Diagnosis

Ask students to think about in what practical ways understanding inherited trait patterns could be helpful. For example, “How could doctors use inheritance patterns?” and “What information would be important to them?”

Lesson 4

Do Traits Show Patterns over Multiple Generations?

PREPARATION

Teacher Background Knowledge

Using the Data Summary Sheet

You will return to the Data Summary Sheets created during this activity in Lesson 6. It is important that the summary for each of the groups be posted so that it is available. The Data Summary Sheets created in this activity will be returned to in Lesson 6. It is important that the summary for each of the groups be posted so that it is available. When reporting the data for the C and F groups in the F_2 generation, you will need to add another circle or square. Students will have gotten both non-purple and purple offspring. Make sure students add this to their Data Summary Sheets as well.

- The Data Summary Sheets created in this activity will be returned to in Lesson 6. It is important that the summary for each of the groups be posted so that it is available.
- When reporting the data for the C and F groups in the F_2 generation, you will need to add another circle or square. Students will have gotten both non-purple and purple offspring. Make sure students add this to their Data Summary Sheets as well.

Setup

Specific instructions for activity setup are embedded within the lesson.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

At any point, students may wish to track traits and variations across their own family histories. Some students, of course, will be unable to trace family histories; therefore, it is important to be very careful even if making family history info-gathering an optional activity. Students might also raise other ideas about "family traits" they want to explore like the length of their second toe, or the size of their nose, or shape of their lips. For additional practice in applying the concepts and using the language of this unit, tie additional exploration of traits and variations to determining whether patterns found in class data hold up in their own data, as well.

Lesson 4

Do Traits Show Patterns over Multiple Generations?

TEACHING THE LESSON

Performance Expectations

Students will

- use data as evidence to develop claims for patterns in heredity data.
- analyze inheritance data to compare patterns between plant and human data.

Building Coherence

The purpose of this lesson is to continue the investigation into how traits get passed on by looking for patterns in multiple generations of humans and plants. It builds on students' understanding from Lesson 3 about traits in animals and about plant inheritance. The patterns that students develop here lead to the need to explain how this happens and raise the question of how instructions get passed from parents to offspring in Lesson 5.

Timeframe

2–3 Class Periods

Overview

Activity 4.1

Analyze human pedigrees of traits from Lesson 2.

Activity 4.2

Check and record the results of seed plantings set up in Lesson 3.

Activity 4.3

Synthesize information about heredity patterns from plants and humans.

Reading Follow Up

At the end of the reading, students generated a list of questions that they still have about how instructions for traits are passed from one generation to the next. Have students share the questions they still have and add them to the Driving Question Board.

Materials – Activity 4.1	
For the Class	***For Each Student***
• PI: Predictions of Variation in Human Traits	• Activity Sheet 4.1

Activity 4.1 – How Do Traits Get Passed On?

Introducing the Lesson

Students left Lesson 3 with questions about why some of the plant data and human data about traits were different. The following question was added to the Driving Question Board: Do all organisms that have the same variation of a trait pass the same information to their offspring? Because students only saw parents and offspring in both the human and plant data, they decided that they needed information about the trait in additional generations. In Lesson 2 students looked at pedigrees for tongue rolling and PTC tasting in order to see if they could detect any patterns. In Activity 3.3, they set up another generation of plants. In the first activity in this lesson, students will look at the ability to taste PTC across multiple generations of humans.

Ask how many generations they saw. Since students decided that looking at another generation of plants might help them figure out what is going on, ask if they think that looking at additional generations of humans may answer their questions as well. By looking at multiple generations, they will be able to see if PTC tasters who have PTC-tasting parents are the same as PTC tasters who have one tasting parent and one nontasting parent. Show PI: Predictions of Variation in Human Traits. In a class discussion, ask students to make predictions for the next generation in each of the three crosses. Record their ideas on the image. If the class does not agree on a single prediction for each cross, multiple predictions should be recorded. Where students do not agree, have them explain their reasoning.

Analyzing Family Pedigree Data

Students will need Activity Sheet 4.1 with the pedigrees of the three families. Ask how many generations are represented here. Students should work in groups to identify the patterns in each of the pedigrees. As they analyze the pedigree for each family, they should fill in the data table after the last pedigree. The questions in the data table correspond to the patterns on the Pattern and Evidence Chart from Lesson 3. Students should then answer the Making Sense questions. Once the groups have finished, bring the class together to share what they found. Return to PI: Predictions of Variation in Human Traits.

Suggested Prompts

- Were any of our predictions correct? If so, which ones?
- Were you surprised by the variation shown by any of the offspring?
- Which ones? (*Possible responses might include the following: In Family 1, a taster and a taster produced a taster offspring, but in Family 3, a taster and a taster sometimes produced a nontaster. In Family 3, a taster and a nontaster produced a taster, but in Family 2, it could be either one*.)
- Why?
- Do you think PTC tasters that come from a long family history of PTC tasting are the same as those who have one PTC tasting parent and one parent who does not taste PTC? Why? (*It is important for students to identify that they observed it was possible for PTC-tasting people who have one parent who tastes PTC and one parent who does not taste PTC to have children who do not taste PTC even if their husband/wife tastes PTC.*

This is evidence for students that PTC tasters that have nontasters as ancestors may not have the same instructions as PTC tasters who have only tasters as ancestors.)

- Do you think you will see the same patterns for purple-stemmed plants as you did PTC-tasting people? Why?
- Do you think that these patterns can only be seen for the traits of PTC tasting and possibly purple-stemmed plants? For example, if you looked at pedigrees for tongue rolling, do you think you would see the same patterns? Why?

In the next activity, students will examine their data for the stem color trait.

Materials – Activity 4.2

For the Class

- PI: Class Seed Data

For Each Student

- Activity Sheet 4.2
- Activity Sheet 3.1

For Each Group

- Petri dishes with seeds from Activity 3.2
- Data Summary Sheet

Activity 4.2 – What about the Next Generation of Seeds?

In the last activity, students saw that the human data were different from the plant data they got in Lesson 3. There seem to be two different kinds of tasters. People sometimes have variations of traits that their grandparents have but not their parents. Looking at plant data will give students more evidence about whether this pattern holds true for other traits in other organisms. They are trying to answer the following questions about stem color:

- Can the purple plants in the F_1 generation that came from a purple/non-purple cross be different from the original parent generation of purple plants? Even though they are both purple on the outside, could they be different on the inside?
- Will the offspring of the F_1 generation still be all purple, or will the plants be like the human data, where some PTC tasters were able to have nontaster offspring?

This activity allows students to observe a third generation of plants. Have students take out Activity Sheet 3.2. They will record the data from the F_2 generation on that data table so that all of the data about the seeds is in one place. Let students know that they have identified two possible new ideas about how traits are inherited:

- Not all tasters seem to have the same information to pass on.
- Sometimes traits seem to skip a generation. A child appears to have a trait that the child's grandparents had, but not a trait the child's parents had.

Have them look at the prediction they made about the F_2 generation of seeds. Based on today's data, would anyone like to change their predictions? Have them place an X through the predictions they want to change in Question 5 on Activity Sheet 3.2, and ask them to write the reason for doing so. Give students time to make their changes before proceeding.

Sharing Results

Each group needs the F_2 generations of their plants and Activity Sheet 3.2 with the seedling data. Have each group observe the final generation and record their findings on the seedling data table. Then instruct each group to share their results and record it on PI: Class Seed Data. If there is more than one group for each seed packet, be sure to combine their data on the seed data sheet. After students have completed the data table, they should complete the Data Summary Sheet for their group. The class should agree on the key for purple and non-purple so that all sheets appear the same. Explain that they will use this sheet to change the numbers on their data table into a pedigree for the plants. After they finish, allow students time to complete the Making Sense questions on the last page of Activity Sheet 3.2. When all groups are finished, have each group share their Data Summary Sheet with the class. Each student should fill out the Data Summary Sheets for the other groups in their student books. At the end of the activity, each student should have recorded the data from all of the groups. Using a document camera to project each groups chart will facilitate the discussion.

After each group shares their data, ask students the following questions:

- What does this tell you about the main question that you were trying to test—could two plants both be purple on the outside and have different instructions on the inside? (*All purple plants do not carry the same set of instructions. The purple plants that came from a long line of purple plants only had purple plants as offspring when they crossed with each other, but the purple plants that had both purple and non-purple parents, when crossed with each other, had purple and non-purple offspring.*)
- Did you see anything similar in the human data? (*Students should identify the same pattern in Case 3 of the human data. It showed that two tasters who have nontasters among their parents could have nontaster offspring.*)

These should then be posted on the Driving Question Board with the Pattern and Evidence Chart.

Making Sense of the Class Data

Discuss the Making Sense questions with the class in order to summarize as well as to lead into the next activity.

Suggested Prompts

- What patterns did you see in the plant data? (Use Pattern and Evidence Chart to summarize.)
- How are the F_1 and F_2 generations different?
- Why do you think the group that started with purple and white stems in the P generation ended up with all purple offspring? Why does their F_2 generation have both white and purple stems when none of their parent plants had white stems?

Materials – Activity 4.3

For Each Student
- Reading 4.3

Activity 4.3 – Synthesizing the Data

Refer to the class Pattern and Evidence Chart. Ask students if there are any additional questions that they want to add based on what they have seen. Students should recognize these as all of the patterns that they have identified. Students will be reflecting on the patterns they observed in Lessons 2 and 3 and their new observations from Lesson 4. Go through each of the five questions on the list and add any new evidence from either the human pedigrees or the plant data that students have found in this lesson. The results of these F_2 generation plants have important consequences for rows 3 and 4 in the Pattern and Evidence Chart. (See the annotated Pattern and Evidence Chart at the end of the lesson.) After the chart is filled in, engage students in a synthesizing discussion about what they have uncovered about the patterns of inheritance.

Discussion – Synthesizing

Purpose

Synthesize the questions about patterns of inheritance in both plants and humans and identify them as patterns based on the evidence collected.

Suggested Prompts
- Are there any questions that have evidence from both plants and animals that support them? (*Students should have evidence from both plants and animals for all of the questions they have identified.*)
- Do you think if the question could be supported by data from both humans and plants that it should be included on the final list of patterns?
- What patterns had evidence from either plants or animals but not both?
- Why do you think you did not see this pattern in both organisms?
- What pattern did you find evidence for in this lesson? (*the pattern that offspring could inherit a trait that neither parent showed: purple × purple producing non-purple or two tongue rollers producing a non–tongue roller*)
- Do you think that these patterns appear in all organisms? Why?
- Do you think this is the same pattern you will see for all traits? Why?
- Are there questions you still have about things you observed in these investigations? Use the following prompt to compare the data for specific human and plant traits: Go back and look at the human data again. Are there similarities between purple-stemmed plants and PTC-tasting people? Allow students to reference their old activity sheets to respond to this question.

Similarities should include the following:

- There seem to be two different kinds of purple-stemmed plants and two different kinds of PTC tasters:
  1. Those that mate with others of the same kind and produce offspring who all have the same variation of the trait
  2. Those that mate with others of the same kind and produce different variations of the trait in their offspring
- When two purple-stemmed plants that each had parents with non-purple stems are crossed, they can have seedlings that are non-purple. This is similar to two tongue-rolling people who have non–tongue rolling parents and also have non–tongue rolling offspring.
- Purple-stemmed plants that both have purple-stemmed parents and are crossed seem only to be able to have purple-stemmed offspring. This is similar to PTC-tasting parents that both have PTC-tasting parents and are only able to have PTC tasting offspring. (Case 1)

  Remind students that in Lesson 1 they learned that they inherit instructions for traits from their parents.
- What have you learned about these instructions based on what you just reported about certain traits in plants and humans? (*Students should suggest that organisms can somehow carry instructions about a trait from their parents that can be passed to their offspring, even if they are not using the instructions to show the trait.*)
- How was the pattern in the non-purple plants different? (*The pattern in the non-purple plants was different because two non-purple plants always had non-purple offspring.*)
- Did you see a similar pattern in humans? (The same pattern was seen in humans where two nontasters always produced nontaster offspring.)

Document this conclusion on the Driving Question Board under the Inherited Traits section. Students will explore how these instructions are carried in Lesson 5. This raises the question "Is there a difference between the instructions about a trait that are passed on and the variation of the trait that an organism actually shows?" Returning to the plants and humans, the question is linked to the idea that all purple-looking plants do not seem to pass on the same instructions to their offspring. The same is true of humans. This discussion can be used to assess the class's ability to compare inheritance patterns in plants and animals.

Wrapping Up the Lesson

At the end of this lesson, a final list of inheritance patterns should be posted on the Driving Question Board and students should record them in their Driving Question Notes. On the Driving Question Board, be sure to record any outstanding questions about inheritance that students still have. (How can organisms appear the same on the outside but not carry the same instructions on the inside?)

- There are patterns in how traits appear to be passed from parents to offspring.
- Somehow information about traits can be passed on even if it cannot be seen in parents.
- This happens in both plants and animals in the pedigree data.

In Lesson 1, students learned that the instructions are in the DNA molecule. From the data, it seems that everyone with the same trait does not have the same DNA. Since DNA is where the instructions are located, in the next lesson, students will take a closer look at DNA and try to answer the outstanding question.

Introducing Reading 4.3 – Why Are Patterns Important?

The reading focuses on the work of Gregor Mendel. Ask: "Before starting this unit, did you think about patterns in human traits?" Patterns are very important in science as noticing patterns leads to determining how and why things work the way they do. Explain that there once was a time when people didn't actually know that variations in organisms' traits got passed from parents to offspring. Someone had to figure that out. Tell students that is what they will be reading about next.

Pattern and Evidence Chart
(completed chart as of L4)

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
1. Can offspring get instructions for the variation of a trait from either parent?	*Offspring can get instructions for a trait from either parent.*	*Mom has blue eyes and Dad brown. My brother has blue eyes and mine are brown.*	**Activity 3.1:** • Pedigrees A1: Cases 3 & 4 • Pedigrees A2: Cases 10, 11, 13, & 14 • Pedigrees B1: Cases 2, 4, & 5	No evidence
2. Do all offspring from the same parents inherit identical variations of traits?	*Sometimes offspring inherit identical traits and sometimes they do not.*	*There are three kids in our family and we all have different colored hair. Two of us have brown eyes and one has green.*	**Activity 3.1:** • Pedigrees A1: Cases 3, 4, & 5 • Pedigrees A2: Cases 9, 10,11, 13, & 14 • Pedigrees B1: Cases 2, 3, & 5 • Pedigrees B2: Cases 9, 10, 11, 13, & 14	**Activity 4.2:** The cross of two F_1 purple plants (which each had both purple and non-purple parents) produced a mixture of purple and non-purple F_2 offspring.

QUESTION	CLAIM	EVIDENCE FROM OUR EXPERIENCE	EVIDENCE FROM HUMAN PEDIGREES	EVIDENCE FROM PLANTS
3. Can offspring show a variation of a trait that neither parent shows?	*Offspring can show a variation of a trait that neither parent shows.*	*My parents both have brown hair, but mine is red.*	**Activity 3.1:** • Pedigrees A1: Case 5 • Pedigrees A2: Case 9 • Pedigrees B1: Case 5 • Pedigrees B2: Case 9	**Activity 4.2:** The cross of two F_1 purple plants (which each had both purple and non-purple parents) produced non-purple F_2 offspring.
	Certain combinations of parents always have offspring that look like them.	*In our family, my grandparents on both sides have brown eyes, my parents have brown eyes, and my brother and I have brown eyes.*	**Activity 3.1:** • Two nontasters always have nontaster children (zero cell) • Two non–tongue rollers always have non–tongue rolling children.	In Activity 3.2, purple × purple, from a long line of purple plants, always gave us purple, but in Activity 4.2, purple that had purple and non-purple parents were able to produce non-purple offspring. In Activity 3.2, non-purple × non-purple always gave us non-purple.
4. If parents have different variations of a trait, does it seem that one is more likely to be passed on?	*When parents have different variations of a trait, one is more likely to be passed on.*	*Mom has blue eyes and Dad has brown. All siblings have brown eyes.*	**Activity 4.1:** • In the pedigrees, tasting seems to be passed on all the time when parents do not have the same variation of the trait.	**Activity 3.2:** • Non-purple and purple always gave us purple.

LESSON 5

How Do Instructions from Our Parents Get inside Us?

PREPARATION

Teacher Background Knowledge

See the Unit Overview for general background knowledge for this unit.

Setup

Specific instructions for activity setup are embedded within the lesson.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

LESSON 5

How Do Instructions from Our Parents Get inside Us?

TEACHING THE LESSON

Learning Goals

Students will

- describe how heredity instructions are organized in chromosome pairs, one from each parent.
- explain, using allele pairs, how an organism could carry instructions for a trait that the organism does not exhibit.

Overview

Activity 5.1
Compare cell division in somatic cells and sex cells to understand how each serves its function.

Activity 5.2
Demonstrate how alleles can separate to produce multiple combinations in gametes.

Reading Follow Up

Link the reading to what students observed.

- Did Gregor Mendel observe the same kind of patterns that you observed in your experiments?
- What conclusions did he draw from his observations? (*The inheritance of traits is determined by units or factors that are passed on to offspring unchanged. Offspring inherit one factor for a trait from each parent. A trait may not show up in an individual but can still be passed on to the next generation. Some traits were stronger than others.*)
- How did you respond to the last question in the reading? Do you think that you have enough information to explain how traits get passed on?

Building Coherence

This lesson begins Learning Set 2. Students learn how the instructions are passed from parent to offspring and develop the understanding that half of the instructions come from one parent and half from the other. Observations and data collected in the previous Learning Set prompted students to question how two organisms can appear the same on the outside but carry different instructions on the inside. This lesson explores that question. The ideas in this lesson prepare them to build a model of inheritance in Lesson 6.

Timeframe

2 Class Periods

Some students may feel they have enough information to explain how traits get passed on. Others may feel that they do not. Ask students who think they have enough information to provide an explanation. Students should use what they learned about Mendel's observations and the ideas from the Pattern and Evidence Chart that traits come from each parent. Next, have the students who feel they do not have enough information state some of their questions (e.g., they do not know how traits skip generations, or they have not seen that some traits are stronger). Encourage the first group to respond with evidence that could answer the questions.

Introducing the Lesson

Refer students to the Driving Question Board and the Driving Question Notes. Review what they know about the inheritance instructions so far.

- Instructions determine traits, but we do not know how.
- Some traits can be inherited.
- We think some instructions are made of DNA.
- DNA is in the nucleus of a cell.

Ask students to think about how they can investigate where these instructions come from.

Suggested Prompts

- Are there any of Mendel's ideas that you could investigate that might help with the question of how two organisms can appear the same on the outside but have different instructions on the inside?
- He said there are factors. Can you look for factors?
- Where would you look to see if there are factors?
- Where could you look to see if one factor comes from each parent? (*Students should recall that DNA is found in the cells, so cells would be the place to look.*)

Materials – Activity 5.1

For the Class

- PI: From Cell to DNA
- PI: Karyotypes
- PI: Cell Division
- PI: Sperm and Egg Cells (optional)
- PI: Gene
- PI: Gene for Stem Color

For Each Student

- Activity Sheet 5.1

Activity 5.1 – How Do I Get New Cells?

Comparing the Division of Somatic Cells to Sex Cells

If students worked with the IQWST LS2 unit, they looked at different levels of organization within the human body: system, organs, tissues, and cells. Show PI: From Cell to DNA from Lesson 1. Students should notice different levels of organization here as well: cell, nucleus, chromosome, and DNA.

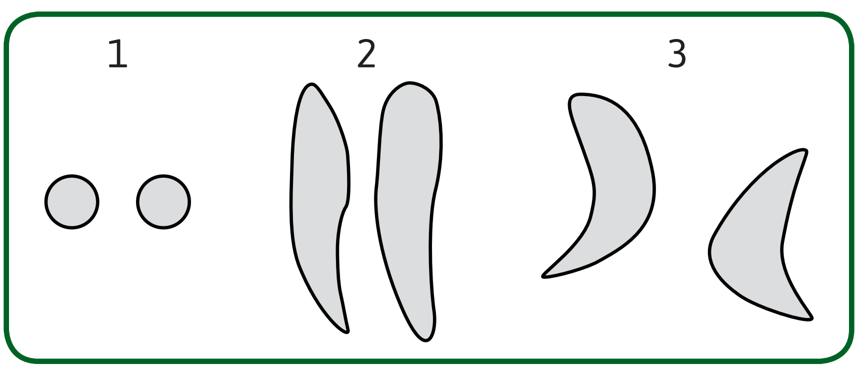
Draw students' attention to the single strands of DNA in the nucleus of the cell (not just the one that is drawn-out DNA). Remind them that these are compressed forms of DNA called chromosomes.

Examining Human Karyotypes

Explain that scientists studying chromosomes find it difficult to study them the way they appear in the cell. Therefore, they make charts that organize all of the chromosomes found in the cell. These charts are called karyotypes. Karyotypes allow scientists to compare individuals and analyze chromosomal behaviors. A karyotype of the chromosomes in a human cell would look like this (display PI: Karyotypes). Have students examine the karyotype.

Ask students how they think scientists could group the chromosomes. (*They put ones that are alike together. They seem to be in pairs.*) Point out that if they look carefully, they can see that there are two of each chromosome. Identify some of the more obvious pairs for students.

Engage students in a brief brainstorm about what they think they know about chromosomes related to the plant observations they have made. Put the following diagram on the board and have students copy it on a sheet of paper.



Looking at Plant Chromosomes

Explain that not only human chromosomes are organized in pairs. Plants have pairs of chromosomes as well. This diagram represents the chromosomes in a plant cell from the F_1 generation of Wisconsin Fast Plants® organized in pairs. Plant cells have more than three pairs of chromosomes, but this diagram has been simplified for this brainstorm. (Mendel's pea plants have 14 chromosomes.)

Remind students of the question they are trying to answer: How can some plants look the same on the outside but carry different instructions on the inside? They saw this in the cross they made with the F_1 generation of the Group C plants. They crossed two plants that appeared purple that resulted in both purple and non-purple plants.

Look at the images of the three pairs of chromosomes inside F_1 plants. These are chromosomes for three different traits. The trait for color is on pair two. Have students copy the diagram on a piece of paper. Begin with the first cross that they saw (purple × purple that produced purple) and color in the pair of two chromosomes with the instructions they think those plants would have for color. They should then take no more than three minutes with a partner to brainstorm what instructions are on the chromosomes for color. If you want part of the chromosome not to have purple instructions, then leave it blank. Briefly discuss what students did.

Ask: "What color did you make the chromosomes? Did you make them both the same? Why?" (*Students will likely color both purple since the offspring are purple, but any answer is acceptable since this is a brainstorm activity.*) Move on to the second group of plants that students crossed (non-purple × non-purple that produced non-purple). Again, have students color in the instructions that they think each chromosome carries.

Ask students again what color they made the chromosomes. Are they both the same? Why? (*In this example, students will likely color both chromosomes non-purple since the offspring are non-purple.*) Repeat these steps again for the third group of plants (purple × purple that produced both non-purple and purple offspring). This pair will likely generate more discussion and differences of opinion about what should be in the pair of chromosomes. Leave this as an open question for now.

Something is different about the third cross. There was purple on the outside, but something must be different on the inside, because they produced offspring that were purple and non-purple.

This leaves students with the question of how those different instructions ended up inside the plant's cells. Ask: "From where did the F_1 plant get its chromosomes?" (*from its parents*) "How do you think that works?" Review with students the key ideas about plant reproduction from Lesson 2.

- Plants have both male and female parts.
- Plants have eggs in the ovaries.
- Plants have pollen, which is like sperm and is needed to fertilize the egg. The seed is a fertilized egg.
- Fertilization happens when the pollen from one plant reaches the ovary of another.
- Plants produce offspring that have traits similar to their parents.

Prompt students to think about why there are two chromosomes in plant cells for color.

Suggested Prompts

- Where are the instructions for stem color located? (*They are located on a chromosome.*)
- Where did the chromosomes come from in the new plant (F_1)? Explain how. (*Based on Lesson 2, students should be able to state that an egg [cell] in the ovary of a plant was fertilized by pollen [cell]. Since we know that every cell has chromosomes, there must be chromosomes in the egg and pollen, too.*)
- How do you think this happens?
- If each plant cell has two chromosomes for each trait, when an egg and sperm cell combine, why doesn't the offspring have four copies of the chromosome? What do you think happens?

Tell students that they are going to look at the process of fertilization and the egg and sperm to see if they can figure out what happens.

Mitosis and Meiosis

Use PI: Mitosis and Meiosis and cover the meiosis side. (This is a simplified diagram using only two pairs, four chromosomes. It also does not include all of the steps in the mitosis process. If students studied the IQWST LS2 unit, they learned that body cells divide for growth and repair.) Review the steps in mitosis with them. Compare the cells at the end of mitosis with the sex cells they just discussed.

- How are these similar?
- How are they different?
- Why would combining cells that result from mitosis not work for fertilization? (*Students should see that the result would be offspring with twice the number of chromosomes.*)

Uncover the second half of the image with meiosis on it. Point to the third step in the process.

Suggested Prompts

- How do these cells compare to the body cells at the end of mitosis? (*They look the same. They have pairs of chromosomes.*)
- If meiosis stopped here, what would you have? (*You would end up with cells that have the same number of chromosomes as body cells. Students should recognize that this would be a problem because then the F_3 generation would double that number again. This would repeat over and over. There would be too many chromosomes.)*
- What has to happen to the sex cells before they become egg and sperm? (*If students do not suggest that they have to divide again, uncover the last part of the meiosis diagram and walk them through the process.)*
- Why are chromosomes in pairs in body cells? (*At this point, they should be able to say that they are in pairs because one came from the sperm and one came from the egg.*)
- Why would you have two copies of one chromosome?
- Where do chromosomes come from? (*They come from parents.*)
- How do you know that they come from both parents? (*Some offspring had traits like Mom, and some had traits like Dad. Since pairs split to make sex cells, it makes sense*

that they combine during fertilization. Each pair is half the mother's chromosomes and half the father's.)

Return to PI: Karyotypes and point out the bands on chromosomes 1, 9, and 16.

- What do you notice about their position on the chromosome? (*They are next to each other; they are on the same place on each of the chromosomes.*)
- What do you think these bands are?

Use PI: Gene and tell students that they will zoom in on chromosomes. One chromosome of a pair has been extended. Notice the pink section. What does this represent? (*a gene*) Point out that the bands are on each half of the pair and the gene is on each half of the pair. Ask students if it looks like Mom and Dad each give half of each pair, rather than some pairs coming from Mom and some from Dad. Follow up with the question "How do the different genes produce different traits?"

Ask students to think about the plants they observed.

- What was the plant trait you observed? (*stem color*)
- What were the variations of that trait? (*purple/non-purple*)
- Were the offspring always the same color as the parent plants?
- If there are two copies of a gene, how can there be a variation?

Let students share ideas. Remind them that if they worked on the IQWST IC3 unit, they may have learned that proteins are long chains of amino acids. Explain that the way that the amino acids are arranged determines how the protein functions in the body. DNA carries the instructions for how the amino acids are arranged to form proteins. The segment of DNA that is identified as a gene on the image is one arrangement of amino acids, and the next gene section would be a different arrangement that produces a different protein. As an example, you can talk about purple pigment in their plants.

Pigments are chemicals that are produced in the body that causes a chemical reaction to produce a color. Color in the plants you observed is produced by a chemical called ANL (anthocyanin). The gene in the plant carried the instructions for producing ANL.

- A DNA molecule consists of distinct segments called genes.
- A gene instructs for the production of a single type of enzyme.

Display PI: Gene for Stem Color. Explain that students are looking at a representation of a chromosome. A gene for a specific trait appears at the same place on both copies of the chromosome. This location is called a locus (loci in the plural form). This is a diagram of chromosomes that carry the trait for the stem color trait in their plants. The band represents the gene. The color represents the allele, the variation of the trait.

Refer to the plant color example. The instructions for the chemical reaction that produces ANL are carried by the alleles that are present on a chromosome. If the DNA in the cells does not have the right instructions, then ANL will not be produced. The stem color of the plants was determined by the instructions for producing ANL.

- Each allele is a version of the gene that carries the instructions for a chemical resulting in a variation of a particular trait.
- One allele comes from one parent and one comes from the other parent.
- If the two chromosomes were placed side by side (as in the diagram), the alleles would be next to each other. This is the banding that students observed in the chromosomes in the karyotype.

Updating the Driving Question Board

Enter the new information on the Driving Question Board and have students complete their Driving Question Notes. Refer back again to the Driving Question Board and the Lesson 4 question: How can two organisms appear the same on the outside but carry different instructions on the inside?

Suggested Prompts

- Which of Mendel's ideas do you now agree with that help you answer the question?
- What do we know about Mendel's factors or units? (*Genes are Mendel's factors that pass trait information from parent to offspring. Offspring inherit one variation of a trait from each parent.*)
- Ask students if they can answer the Driving Question Board question from Lesson 4. (*Since there are two copies of each chromosome, maybe they can carry information for a trait and pass it on, even though the person does not express it.*)
- Think about the human pedigrees and plant data you observed. Did all of the offspring in a generation look the same? If what you have just learned is true, why do all of the offspring in a generation not look the same?

Explain that this question will be explored next.

Materials – Activity 5.2

For Each Student

- Activity Sheet 5.2
- Reading 5.2

Activity 5.2 – How Can Parents Produce Offspring with Different Traits?

Remind students of the question they had leaving Lesson 4: Are all purples the same?

Suggested Prompts

- When you observed the seedlings in the F_2 generation in Lesson 4, what did the offspring look like? (*They were purple and non-purple.*)
- If all the offspring came from the same parent plants, why did they not all look the same?
- How could two purple plants produce some purple offspring and some non-purple offspring?
- What could cause the difference? (*The difference has to be that the instructions were different for the different offspring.*)
- How could the instructions look different for offspring that all inherited one copy of genes from their mother and one copy of genes from their father?

Remind students of meiosis, which they observed in the last activity.

- How many chromosomes are in a human cell? (*There are 46—the same number as the parent cell.*)
- After cell division in a somatic cell (mitosis), how many chromosomes are there in the new cells? (*There are 46 chromosomes or 23 pairs.*)
- After cell division in a sex cell (meiosis), how many chromosomes are there in the new cells? (*There are 23 chromosomes—half of the number of the parent cell.*)
- Why? (*The egg cells combine with sperm cells during fertilization to produce offspring, and then the resulting cell has 23 pairs or 46 total.*)

Direct students to Activity Sheet 5.2. This activity will help students see that each gamete produced during cell division of a sex cell will produce different combinations of chromosomes. To look at what happens when each gamete is produced by cell division, students will look at a fictional organism with just a few chromosomes and figure out all of the different things that could happen when it makes its gametes.

- An yllis has only six chromosomes—three pairs and only one trait per chromosome.
- Each trait has two alleles (variations).
- These genes carry instructions for the shape of mouth, nose, and eyes.

Go through the instructions with students. Point out the chart on the first page. This shows the yllis trait and the two possible variations. For this activity, students are to look at the DNA (three chromosome pairs) of an yllis and determine how many ways the alleles can be arranged in its gametes. Have students turn to the second page. The chromosome pair indicates the genetic makeup of one individual yllis. In the case of this yllis, each of its parents passed down a different allele for each trait. Another yllis may have had chromosome pairs that had the same alleles for a trait. Students are going to figure out how many gamete combinations that individual yllis will produce during its sex cell divisions (meiosis). Go through the two examples with students.

Comparing the Villis to Human Gametes

When students have finished, check that they were able to find eight possible gamete combinations. Ask them how they responded to the second Making Sense question. Most students will recognize that the number of possible gamete combinations in humans will be very large compared to the yllis. To give students a sense of how many actual combinations human chromosomes can produce, tell them that the number of combinations can be calculated mathematically. Use 2 for the two alleles as the base number. The number of chromosome pairs becomes the power number. Because the chromosome pair number is a variable depending on the organism, the formula would be 2*n*. Therefore, in the case of the yllis with three chromosome pairs, the calculation would be 2^3, which equals eight gamete combinations.

- Using this formula, ask students to calculate the possible gamete combination for organisms with the following:
- 5 chromosome pairs (2^5) (*32*)
- 6 chromosome pairs (2^6) (*64*)
- 8 chromosome pairs (2^8) (*256*)
- 10 chromosome pairs (2^{10}) (*1024*)

Now you can see that each adult yllis can produce eight different possible trait combinations in its gametes. Ask students to explain how this happens. Make sure students realize that there are eight different possible trait combinations in the sex cells (egg or sperm) that a particular individual produces. Different offspring can receive any one of these from Mom yllis and any one of these from Dad yllis.

Looking at these numbers, ask students again how big they think the number of possible gamete combinations for humans might be. 2^{23} is equal to 8,388,608.

Wrapping Up the Lesson

- Each parent contributes a copy of DNA instructions (genes) to an offspring.
- The offspring, therefore, has two copies (alleles) of the gene, half from each parent.
- During meiosis, a number of different combinations of the gametes will be produced.
- Each time a different egg from the same mother is fertilized by a sperm from the same father, different combinations of traits are likely to be in the egg and sperm.

Go back to the lesson question: How can two organisms appear the same on the outside but carry different instructions on the inside?

Suggested Prompts

- Can you answer this question? (*Responses may vary. Some may feel that understanding that there are two copies of each gene within an organism answers the question. Others may raise another question: If the instructions for each allele are different, what would the offspring look like? If the question does not arise, prompt for it.*)
- What happens during fertilization if the alleles for the trait are different?
- Which trait shows up in the offspring? (*One example is purple and non-purple alleles. Display PI: Gene for Stem Color again. Students may respond that the two genes would blend together; some may state that one color dominates over another.*)

- Did color blend in the plants you observed? (*No, offspring were either purple or non-purple.*)
- How could one allele dominate over the other?

Be sure the question "What happens if the alleles of a trait do not agree?" is placed on the Driving Question Board and in students' Driving Question Notes. In Lesson 6, students will construct models to try to figure out the answer.

Introducing Reading 5.2 – Discovering the Source

Sometimes when patterns do not turn out the way they are expected to, it gives scientists a whole new set of questions to ask that leads them, and the scientists who follow them, to new discoveries. In this reading, a unique occurrence in the genetics of one family is giving scientists something new to think about. In this reading, you will also see how scientists' work always builds on the work of the scientists who have come before them.

Lesson 6

Constructing a Model of Inheritance

PREPARATION

Teacher Background Knowledge

Teaching Strategies

Genotype/Phenotype

The distinction between genotype and phenotype is important as students develop their model of inheritance. Since both genotype and phenotype will be represented in their model, it is important that they understand the difference. Continuing to use the words, along with their descriptors, until students make them a part of their vocabulary, can be a helpful strategy. In addition, having students give extra examples of the distinction between genotype and phenotype will further reinforce the meaning of these two words.

Developing the Model

The creation of this model involves trial and error on the part of students. They need to take the evidence and information that they have and develop a model where all pieces of the data they have will work. This process is messy and may lead to the development of a model that is incorrect until students revise it to try to explain all of the data. It is essential that students be given the opportunity to develop this model through trial and error until they are able to account for all of the data.

It is possible that all groups will have the same version of Model 2. You may want to take the time to show students the other version if no groups introduce it. It may help students who are having difficulty working through the model.

Setup

Activity 6.2 – This activity uses a template to record possible genetic combinations. It requires students to make several trials in order to produce a final solution. Students will need either additional copies of the template, or paper on which to draw their own templates, in order to figure out the rules for their model. There is a copy of the template at the end of the lesson. In their student books, there is a copy where they should record their final version of the rules.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 6

Constructing a Model of Inheritance

TEACHING THE LESSON

Performance Expectations

Students will

- construct a model to explain how genetic information gets passed from parents to offspring.
- use their model to explain how genetic information gets passed from parents to offspring in plants.

Overview

Activity 6.1

- Develop a model of inheritance that explains all of their observations and data about plants.
- Test the model against the available evidence.

Activity 6.2

- Compare both models from 6.1 to try to explain the plant data they have collected.
- Determine which model better fits the data.

Building Coherence

In this lesson, students construct a model of inheritance in order to explain the patterns they have observed with traits in both humans and plants, as well as to predict what variations of traits are possible in the offspring of a set of parents with particular traits. This lesson builds on the modeling practice that students have developed in previous IQWST units, such as the PS1, IC1 and, ES2 units.

Timeframe

2–3 Class Periods

Reading Follow Up

Suggested Prompts

- In the reading, what were scientists trying to figure out? (*Instructions for variations are on a molecule called DNA found in cells.*)
- How does what they learned help you with what you are trying to figure out?

Materials – Activity 6.1

For the Class

- PI: Gene for Stem Color
- PI: Genotype/Phenotype

For Each Student

- Activity Sheet 6.1
- pencils*
- blank paper*

* This item is not included in the kit.

Activity 6.1 – Constructing a Model of Inheritance

Introducing the Lesson

Remind students that they are trying to understand how two plants that appear purple on the outside can have an offspring that is non-purple. They observed that is was possible for offspring to get a trait that neither parent seemed to have. They crossed two purple plants from the F_1 generation that was the offspring of purple and non-purple plants, and the result was some purple plants and some non-purple in the F_2 generation. They saw this same kind of pattern in the human pedigree data in Lesson 4 in Case 2. There were two PTC-tasting parents that had a nontasting offspring.

Developing the Need for a Model

In Lesson 5, students learned that each organism has two copies of instructions, called an allele, for each trait. Organisms go from these two copies of the instructions for a trait inside the cell, to the trait that can be seen. In this lesson, students will try to figure out how the two copies of the allele might work to determine a trait.

Using the Driving Question Board, review the following ideas about the instructions for traits from Lesson 5.

- There is something physical in cells that determine traits called DNA.
- Chromosomes carry the instructions for traits. Every human has 23 pairs.
- Sex cells (egg/sperm) are different from all other cells in the body.
- Sex cells have half the number of chromosomes as all other cells, and therefore, half the instructions.
- Offspring get half of their information from mom via the egg, and half from dad via the sperm.
- Each trait is determined by a pair of instructions, one from the mother and one from the father.

In this lesson, students will try to use this new idea of having a pair of instructions to see if we can explain our main question, how can two organisms with the same observable variations of a trait pass on different instructions?

Students have identified an important distinction between what can be observed and what are the instructions inside of an organism. In order to have a way to distinguish what can be seen from the instructions inside, scientists refer to them by different names. In class, students will use those same names in order to be able to discuss clearly what they are talking about. In Lesson 5, students learned that genes are the part of the chromosome that contains the instructions for specific traits. Scientists use the word *genotype* to refer to the instructions about a specific trait contained in the cell. The variation of the trait that can be seen is called the phenotype. Point out to students that this word sounds like the word *phenomena* which refers to something that you can see.

Example

Genotype – The instructions for hair color that are in the DNA in the nucleus of all cells of the person.

Phenotype – The variation of the hair color that can be seen, such as a person who has naturally blond hair.

In this lesson, students are going to develop a model of inheritance about how the genetic instructions for traits are passed from parent to offspring. The model must account for the genotype and phenotype of both the parents and offspring. The genotype must explain the phenotype of each organism—parent and offspring.

Suggested Prompts

- Can someone restate the question you are trying to solve using the words *genotype* and *phenotype*?
- How can you figure out how to go from genotype to phenotype? (*conduct experiments, collect data*)
- Since you already have data on plants and animals and have organized it, is there something else you can do to make sense of the data you have? Something that will help you understand the patterns? Something that, once you already have the data, and have figured out what you think is important about it, will help you to try out different ideas. (*If students do not suggest constructing a model, introduce the idea.*)

Beginning the Model

Ask students if they have any ideas about what form the model should take. Remind students of what they already know:

- There are two copies of the information for each trait.
- One copy comes from each parent.

Ask what they are trying to figure out: What is going on inside the organism with the two copies of the instructions that lead to the patterns students have seen? Ask students to identify some of the models they have developed in previous IQWST units: IC1 (the particle model of matter), PS1 (model of light and seeing), and ES2 (model of a storm). In those models, students were able to construct diagrams for smell traveling across the room and light interacting with objects to explain their data. In this model, they need to try different ideas and see if they can match the data that they have collected. Explain to them that it is like figuring out the rules. That is the kind of model they will make. They will develop a set of rules that instruct what to do when they have different combinations of alleles.

What do the rules for the model need to do?

- The rules need to fit all of the data collected so far. (*Models need to fit the evidence.*)
- The rules need to answer these questions:
  1. How can two purple plants behave differently when producing offspring?
  2. How can an organism pass on a trait that it does not show?
  3. How do organisms go from genotype to phenotype?

Ask students if they have ever done a Sudoku puzzle or a crossword puzzle. (Any similar type puzzle that students are familiar with will work as an example. It should be something that has rules to follow and where everything must fit together and follow those rules.)

> Walking through a simple example of a crossword or Sudoku puzzle is a helpful strategy for those students not familiar with the process for solving that type of puzzle. The important idea here is that these puzzles are solved by inserting letters or numbers that students think might work and then erasing and replacing them when they do not. This is the same method students will use in trying to create a model in this activity.

Explain that, like these puzzles where they try different things out to see if they will fit in the puzzle (while still following the rules), in building their model, they will try things out to see if they can make the data they have collected fit the rules. If not, they will need to change the rules of how their model works. Write *Model of Inheritance* on the Driving Question Board. This is where the class will identify and record their rules for the model as they reach a consensus on them. The model students develop must fit all of the data they collected and apply to both parents and their offspring.

Completing the Model

Remind students of the question from the end of Lesson 4: How can two organisms appear the same on the outside, but not carry the same instructions on the inside? This question can be restated: How can two organisms with the same phenotype have different genotypes? In Lesson 5, students learned that there are instructions that are passed on that result in the variation of a trait that can be seen. They also learned that there is a pair of instructions for each trait, one from each parent. Using those ideas, students will figure out how to go from genotype to phenotype.

The two questions the model is trying to answer are the following:

- How can two purple plants behave differently when producing offspring?
- How can an organism pass on a trait that it does not show?

Have students identify the two variations of plant color (phenotype) that they observed in the seedlings they grew (*purple and non-purple*). Explain that there are only two alleles that can be passed from parent to offspring for these variations (*purple and non-purple*). Combinations of these alleles produce the phenotypes they observed in their seedlings. Since students are going to be referring to both phenotype and genotype in their model, they need some way to distinguish between the two. Establish the following convention for labels in the model.

- Phenotypes will be the descriptive word written out: purple, non-purple.
- Genotypes will be represented by one- or two-letter abbreviations: p = purple, np = non-purple.

In the model, anytime students see a word, they know it refers to the phenotype. If they see letters, they know it is the genotype.

Representing Genotypes—For the purposes of the model, at this point, students have no reason to think that there is any difference between the two alleles (i.e., dominant/recessive). Therefore, each allele is represented by a lowercase letter. At the end of Activity 6.2, students will be introduced to the concepts of dominant and recessive and the convention for distinguishing between them.

Lead In

- In Lessons 3 and 4, students observed only two variations for color: purple and non-purple.
- Scientists say that there are two alleles for color in these plants. In Lesson 5, students learned that color is produced by a chemical called a pigment. One allele (p) has instructions for making the chemical that makes the stem purple and the other allele (np) does not.

Use PI: Gene for Stem Color from Lesson 5, which shows the two alleles for color in plants. Write *p* and *np* on the board. In this activity, students are trying to figure out what phenotype will be produced by various combinations of alleles. Since students are going to use letters to represent genotype, these letters represent the only possible alleles for color. Use the following prompts in order to have students identify all the possible combinations of alleles for the trait of color. As students identify the allelic combinations, write them in the genotype column on PI: Genotype/Phenotype. Use the following questions.

- How many possible combinations of these two alleles are there?
- What are they? (*p/p, np/np, and np/p*)

At this point, the chart should look like the one that follows.

GENOTYPE (INSTRUCTIONS)	PHENOTYPE (WHAT YOU SEE)
p/p	
np/p	
np/np	

The main question students are trying to answer with their model is how to determine the phenotype of an organism if you know its genotype. Engage students in a discussion to figure out the phenotypes for each of the genotypes in the chart. The discussion should begin with the p/p and move to the np/np. Save the np/p for last, because it will lead into Activity 6.2.

Note: As students agree on phenotypes, fill in the chart on PI: Genotype/Phenotype.

Suggested Prompts

- How would you write the genotype of a plant if it had two copies of instructions (alleles) that were for purple? (*p/p*)
- What do you think the phenotype would be? (*Most students will guess that because the only instructions the plant had were for purple, the plant would be purple.*)

- If you all agree that the plant with the p/p genotype would be purple, then what color would a plant with an np/np genotype be? (*Students should be able to reason that if the only instructions it has are for non-purple, the plant would appear non-purple.*)
- What about the last genotype, np/p? (This is a tricky case. The instructions are not the same.) What phenotype do you think this genotype will produce? (*This genotype can produce two possible responses from students: purple and non-purple.*)

Discuss the alternatives with students. If students suggest a color midway between purple and non-purple, remind them that we are talking about a trait that has only two possible variations in the phenotype, and we did not see any plants with a color halfway between. If students suggest both purple and non-purple, include both on the chart. Point out that this is the question students will try to figure out with their model.

GENOTYPE (INSTRUCTION)	PHENOTYPE (WHAT YOU SEE)
p/p	purple
np/p	purple? or non-purple?
np/np	non-purple

Have students fill in the chart on Activity Sheet 6.1 and answer the questions in the Making Sense section.

Reviewing the Rules for the Model

Have students identify the rules that they are sure about for the model they have constructed. What rule is still a question? Have them share their ideas from Question 2 in Making Sense.

Let students know that they have identified two rules for the model that work, and that they have a third rule to figure out.

- Rule 1: p/p always results in a purple phenotype.
- Rule 2: np/np always results in a non-purple phenotype.
- Rule 3: np/p is the rule that needs to be figured out. Does this genotype result in a purple or non-purple phenotype?

Ask students how they think they could figure this out. (*Students should suggest that they can test the model against the data they have collected.*) In the next activity, students will attempt to determine this by testing various examples.

Materials – Activity 6.2	
For the Class	***For Each Student***
• PI: Gene for Stem Color	• Activity Sheet 6.1
• PI: Genotype/Phenotype	• pencils*
	• blank paper*

* This item is not included in the kit.

Activity 6.2 – Testing the Model

Use PI: Possible Models and remind students of the rules of the model they decided and what they still have to figure out. In order to not confuse the models, construct two separate models like the ones that follow. Label these *Model 1 (Non-purple is stronger.)* and *Model 2 (Purple is stronger.)* so that students can keep track of which model they are testing. Point out to students where the models agree and disagree.

Lead In

- The models disagree when the alleles are not the same.
- Model 1 depicts that when you have p/np alleles, the offspring will be non-purple.
- Model 2 depicts that when the alleles do not agree, the offspring will be purple.

Model 1
(Non-purple is stronger.)

GENOTYPE (INSTRUCTION)	PHENOTYPE (WHAT YOU SEE)
p/p	purple
np/p	purple
np/np	non-purple

Model 2
(Purple is stronger.)

GENOTYPE (INSTRUCTION)	PHENOTYPE (WHAT YOU SEE)
p/p	purple
np/p	non-purple
np/np	non-purple

If the rules of the model are accurate, the models should explain the data students got when they did their germination experiments. Students will try to figure out the rule for np/p by testing each model against the plant data they collected. Explain that one way to figure this out is to try different possibilities using the rules to see which one will work. That is what they are going to do in this activity.

Testing Model 1

In this activity, students will work through Model 1 together and then try Model 2 in groups. Students should have Activity Sheet 6.2, pencils, and their Data Summary Sheets to do this activity. They also might want extra paper in order to draw extra pedigrees for more trials. Remind them to be sure to use pencil to record their ideas because they may need to erase ideas that do not work.

Activity Sheet 6.2 contains eight pedigrees that students will use to test their ideas. Each of the pedigrees corresponds to the seed groups on which students collected data. They are going to test the two models against all of the data on the Data Summary Sheet. (There are four sheets for each model. This is because we had two types of outcomes for Group C's and Group F's data. This allows students to test for both purple and non-purple offspring from the C/F Group data.) For each individual in the pedigree, students will fill in the genotype for both the body cell and the sex cell. PI: Activity Sheet 6.2 should be used during the discussion of the first model. Work with the class to figure out each step of applying the model to the data. Remind students that they are trying to explain the data they collected for the F_2 generation of seedlings, where they saw two purple F_1 generation parents produce non-purple offspring.

- There are two types of plants that appear in the F_2 generation: purple and non-purple depending on the parents. In order to test Model 1, students need to explain each type of plant. You will need to use the projector twice so that you can do one pedigree with the purple phenotype at the bottom in the F_2 generation and another for non-purple in that cell.
- Make sure that students understand that they must be able to explain both cases in order for the model to work. A model needs to fit all the data, and account for all the evidence.

Remind students that to test Model 1, they need to see if the rules fit the data. They must follow the rules of the model exactly. There were both purple and non-purple offspring in the F_2 generation that came from two purple F_1. (These are the data from the C/F Group.) The model needs to be able to explain both kinds of offspring. (It is important that students begin with the F_2 generation at the bottom of the pedigree and work up to the top. Starting at the top can cause confusion.)

1. Have students fill in their pedigrees with the phenotype of the offspring in the F_2 generation, purple. Remind students that this information is based on the crosses they made in the plant experiment and the results they got for the F_2 generation. To differentiate between phenotypes, students could either write the words *purple/ non-purple* or color-code the difference. (Color-coding makes it easier to read and compare the patterns.)

2. Next, use the rules from Model 1. What does Model 1 say the genotype is for a plant that has the purple trait? (*There is only one option. It has to be p/p.*)
3. What was the phenotype of the parent plants of the F_2 generation? (*The phenotype was purple*.) Have students fill in the chart for the phenotype of both plants in the F_1 generation as purple.
4. According to Model 1, what is the genotype of these F_1 plants? (*Students should see that the only genotype in Model 1 that produces a purple phenotype is p/p*.) Students should fill in the chart with a p/p genotype for both purple plants in the F_1 generation.
5. In testing Model 1 with a purple in the F_2 generation, students need to look at the parent plants of the F_1 generation.
   a. What was the phenotype of the parents of the F_1 generation? (*Students used one purple and one non-purple parent.*)
   b. What is the genotype for these two plants? (*Purple is pp and non-purple can be either np/p or np/np.*)
   c. Have students use genotype np/p so that they can get the purple gene they need for the F_1 generation.
6. To check the reasoning, students should use the following questions: (a) did they follow the rules, and (b) could the offspring get the combination of alleles they said it should have?
   a. Do all of the steps from genotype to phenotype fit Model 1? (*Yes, they are all genotype p/p and have purple phenotypes.*)
   b. Can the offspring get the alleles the students said they could get? (*Yes, each offspring has two p alleles, and each of the parents has only p alleles to pass on.*)

At the bottom of the activity sheet, students should record that Model 1 works for the purple offspring. Model 1 also needs to work for the non-purple offspring of the F_2 generation. Have students use the second copy of the table on Activity Sheet 6.2 for Model 1. Ask students if it is good enough to test the model against one offspring. (*Students should understand that the model has to work for all of the data.*)

Test Model 1 on the non-purple offspring the same way as for the purple offspring.

1. Fill in the pedigree with the phenotype of the F_2 generation. (*It is non-purple.*)
2. What do the rules for Model 1 say the genotype is for the F_2 generation plant that has a non-purple phenotype? (*There are two options: np/p and np/np.*)

Ask students which one to try.

Using the Model—According to Model 1, there are two options for producing non-purple offspring: np/np or np/p. You may begin with either one first. However, this activity is written as if students chose the np/np option first.

3. Next, move to the F_1 generation and fill in the phenotype first, because that is what students have observed in the plants. (*Both parents have a purple phenotype.*)
4. What is the genotype of these plants? (*It is the same as before.*) In Model 1, there is only one option for a purple phenotype: p/p. Have students fill in p/p for the F_1 generation for both parents.

5. Can the F_2 offspring get the alleles it needs from the two F_1 parents? (*No, both parents have only p alleles to pass on. The offspring needs two np alleles. It is not possible for the offspring to get the alleles it needs to follow the model.*)

Have students record what they found that does not work for this offspring and explain why in the table on the last page of the activity sheet. (*The problem with this model is that they cannot get the genotype np/np in the F_2 generation from these parents.*) Model 1 cannot be eliminated yet, because there is another option for this model. In Step 2, they said that another possibility for getting a non-purple phenotype was the genotype np/p. Have students erase the *np/np* in the genotype cell and replace it with *np/p*. Keep the same genotype and phenotypes for the F_1 generation, since this is the only option for the purple phenotype.

Use the following prompts:

- Can you get the alleles for this offspring from these parents? Use Model 1 to find out.
- Can you get a p allele for F_2 from these parents? (*Either parent could give a p allele.*)
- Can you get an np allele? (*No, because neither parent has an np allele.*)

Since the pedigree follows the rules of Model 1 and the alleles needed for the offspring cannot come from these parents, this model does not work. Students have tried both options and could not fit the data for the non-purple offspring. Have students record that the model does not work and why in the table on their activity sheets.

Completing the Pedigrees—At this point, some students may believe that since Model 1 did not work, Model 2 has to be the correct model. It is important that they understand they cannot assume the model works without testing it.

An analogy that can be used would be that if scientists discovered two vaccines for an illness and tested one and found it did not work, would they assume that the second one would work, or would they test it to be sure? Students may want to try to fit the data from Groups A/D and B/E using Model 1 before giving up on Model 1. You can point out that once we find a problem with the model, we do not have to test it on other cases, or you can choose to test the model on these other cases.

Testing Model 2

Have students work in groups to use the same steps for testing Model 2 for the data from Groups C and F. They can begin with either phenotype for F_2 but must make sure that all parts of the model work for both phenotypes. Ask students what the difference is between Model 1 and Model 2. (*Students should note that the models are different when there are two different alleles. Both models have np/np resulting in non-purple and p/p resulting in purple, but Model 2 depicts that when the alleles are different, the offspring are always purple.*)

Let students know that when using their model, they must apply the model to both purple and non-purple offspring in the F_2 generation for the data from Groups C and F. For example, there are two possible combinations of alleles that produce a purple phenotype according to Model 2: p/p and np/p. Students can try both of those combinations to fit the data to see if Model 2 works.

Students should begin by filling in the phenotype of the offspring for the F_2 generation. Next, work through the phenotypes for the F_1 generation and the parent generation. Once students have filled in the phenotypes, have them use the rules of Model 2 to fill in the genotypes for all three generations.

Below is the series of steps to help students fill in the table if necessary:

1. What is the F_2 phenotype? (*It is non-purple.*)
2. What is the genotype for this generation? (*There is only one possible answer: np/np.*)
3. What are the phenotypes for the F_1 generation? (*Students saw this in the experiment. They crossed two purple plants.*)
4. What are the genotypes for these parents? (*There are two possibilities that can give a purple: np/p or p/p.*)

If students suggest p/p for both parents, let them try to see if that pair of alleles will work. Then ask if they were able to get the np allele for the F_2 generation that they need. To get the alleles needed for the F_2 generation, np/p alleles are needed for both parents here.

5. Move up to the parent generation. Remind students that they crossed a purple and a non-purple plant here. They were told that they came from a long line of purples that never produced any non-purple plants, so students can assume the purple are p/p. The same was true for the non-purple, so they should have an np/np genotype.
6. Check the work:
    a. Did students follow the rules of Model 2?
    b. Does this produce the correct alleles for the offspring?

Next, have students follow the same steps, this time using a purple phenotype for the F_2 generation. When groups finish working through Model 2, have one group share what they did. Then ask if any groups filled in their pedigree differently. Repeat these same steps with Groups A/D and B/E. Remind students that the model must work with all of their data.

Suggested Prompts

- Why did Model 2 work? (*Model 2 explains both the purple and non-purple offspring in the F_2 generation. It can explain all of the plant data from the experiments, and Model 1 could not.*)
- What does this tell us? (*Since Model 2 is the best fit for the data, it is the model of how traits are inherited that they should use from now on.*)
- What does this tell us about when the two alleles do not agree? How does that fit with Mendel's ideas?

Students should now be able to say that when the alleles do not agree, one of them appears to be stronger and will be the one that affects the phenotype. This matches Mendel's idea of dominance; however, students still do not have an explanation for why this happens.

Making Sense of the Models

Return to the question that motivated this activity: How can two organisms appear the same on the outside but not carry the same instructions on the inside? In Lesson 5, they learned that every trait has two sets of instructions (alleles). Use the Making Sense question on the activity sheet to facilitate a brief discussion.

- Ask students how they think two plants can be the same on the outside and yet produce different offspring. (*Students should say that the genotype would be different even though the phenotype is the same.*)
- Ask students to give an example from the model. (*Both the p/np and p/p produced purple phenotypes. But only p/np carries the non-purple allele so that there can be non-purple offspring. The purebred purple will only have purple offspring.*)
- Can Model 2 explain why a purebred purple crossed with a non-purple produced all purple? (*Yes, because the model says p/np is purple.*)
- Can the model explain why two non-purples give us only non-purple? (*Yes, because there needs to be at least one purple allele in order to produce purple offspring.*)

Wrapping Up the Lesson

Patterns in how traits are passed on in plants can be explained with our model. In this activity, students have been using plant data to verify their model of inheritance. They have a model that works with their plant data. Ask students if they are convinced that Model 2 is the correct model for how genetic instructions are passed from parent to offspring. Post Model 2 on the Driving Question Board under the title *Model of Inheritance*. Students should also have a copy of the model in their Driving Question Notes.

In the next lesson, students will apply their model to the pedigree data they used earlier in the unit.

Lesson 7

Extending and Applying the Model of Inheritance

PREPARATION

Teacher Background Knowledge

See the Unit Overview for general background knowledge for this unit.

Setup

Specific instructions for activity setup are embedded within the lesson.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 7

Extending and Applying the Model of Inheritance

TEACHING THE LESSON

Performance Expectations

Students will

- explain how some genes are dominant over others.
- explain a model of inheritance for human data.

Overview

Activity 7.1

- Determine the genotypes in human pedigrees.
- Apply their model to those pedigrees.

Activity 7.2

- Explain dominant and recessive.
- Apply the ideas of dominant and recessive to another human example, albinism.

Reading Follow Up

Have students share something that they learned about how scientists use models that they did not know before. This could also be used as work for students to complete at the start of class.

Building Coherence

Students apply the model of inheritance that was developed in Lesson 6 to human data in order to see if the model fits the data for humans as well as plants. They apply the model to a human case that explains the idea of dominant and recessive traits. This lesson connects to the IQWST IC1 unit as well as the IC3 unit by using the molecular concepts learned there to further explain the idea of instructions.

Timeframe

2 Class Periods

Introducing the Lesson

Students left Lesson 6 with the question of whether they could make their model work for humans as well as plants. Using the model posted on the Driving Question Board, review the rules of the model with students.

Suggested Prompts

- How were you able to explain how two plants that were both purple on the outside (phenotype) could produce offspring that were not purple? (*This was observed in the plant pedigrees. The plant can carry the np allele that it inherited, but if it has both a p and an np allele, it will appear purple on the outside, the same as a plant that has two p alleles. It can pass the np allele to its offspring, and if the offspring gets two np alleles, it will appear non-purple.*)
- Do you think this model will work for traits in humans too?

Suggest that students could apply the model to human data to see if it would work. Remind them of the pedigrees that they used in Lesson 4. These could be the data on which they test the model.

In Lesson 4, students used pedigree data about two traits: PTC tasting and tongue rolling. In this activity, students will use their model from the previous activity to see if it can explain how those traits were passed from parent to offspring.

Materials – Activity 7.1

For the Class

- PI: Predictions of Variations in Human Traits
- PI: Model Chart (from Lesson 6)
- PI: Sample Pedigree from Activity Sheet 7.1

For Each Student

- pedigree data

Activity 7.1 – Extending and Applying the Model of Inheritance

Connecting the Model to Human Data

Use the following prompts to connect the model to the human data. Begin with the PTC data, but let students know that they will work on both sets of data as they complete the activity.

Suggested Prompts

- What phenotypes of PTC tasting did you observe? (*We observed taste and nontaste.*)
- What can the model help to figure out? (*The model can help figure out the genotype for the phenotype.*)
- Since there are only two variations of the trait, how many alleles do you think there are in the genotype? (*two—one for tasting and one for nontasting*)

In the previous model, students used letters to represent the genotype and words to represent the phenotype. Write the following on the board and review the symbols with students.

Phenotype (variation of trait): taste and nontaste
Genotype (alleles): t (taste) and nt (nontaste)

Use PI: Model Chart (from Lesson 6) and fill out the model using the PTC information. Students will work through PTC first and then go on to tongue rolling.

Suggested Prompts

- What do you think will happen if a person has a genotype of t/t? (*He or she will taste PTC.*)
- What if he or she has a genotype of nt/nt? (*He or she will be a nontaster.*)
- What will happen if a person gets one of each allele (t/nt), and what if this trait behaves like the purple/non-purple trait in plants?

In the plants, every time there was a p/np genotype, the offspring had a purple phenotype. Students may think that the same thing will happen here. This is what students need to figure out using the model.

When finished, the chart should look like the one that follows. Students will try to use this model, but if it does not work, they can then try the alternative rule for the second row and see if that can fit all the data for both traits. Students should copy this onto Activity Sheet 7.1.

GENOTYPE (INSTRUCTION)	PHENOTYPE (WHAT YOU SEE)
t/t	taste PTC
t/nt	taste PTC
nt/nt	nontaste

Use PI: Predictions of Variations in Human Traits from Lesson 4. In the circles and squares, it depicts instructions for tasting or not tasting. In Lesson 4, students did not know anything about what these instructions were.

Suggested Prompts

- What have you learned about where these instructions are? (*They are on the chromosomes in every cell in the body.*)
- What is represented in the squares and circles on this pedigree—genotypes or phenotypes? (*Phenotypes are represented.*)
- Do you know exactly what the instructions were? (*no, because we cannot see inside the cell to see the genotype*)

Be sure to emphasize the first two rows of the model and that both combinations of alleles produce tasters even though the genotype is not the same. In this activity, students will use the model to figure out the genotype of each member in a pedigree to see if the model can work for human data. The pedigrees that students are using come from the same data they looked at before with PTC tasting and tongue rolling.

Applying the Model to Human Data

Students should work in groups to complete this activity. On Activity Sheet 7.1, there are two pedigrees. Divide the class so that half the groups work on the Pedigree of Family 1 and half on the Pedigree of Family 2. They will compare their findings at the end of the activity.

Students should try to find a combination of two alleles for each person in the pedigree using the rules of the model. Remind them that each person in the pedigree must get the alleles from his or her parents. If they try one genotype for a taster and then go back to the parents and cannot get the alleles they need, they should try another genotype.

Remind students that the top two rows of the model have two possible genotypes for tasters. When they work through the pedigree, they may have to try more than one combination of genotype in order for the offspring to get the alleles they need to produce their genotype.

Work through the following examples on the board.

Example 1

Parent 1: nt/t
Parent 2: nt/t

What are all the possible combinations that they could pass on to a child? (*nt/nt, t/t, or nt/t*)

Example 2

Parent 1: nt/nt
Parent 2: nt/nt

What are the possible combinations that these parents could pass on? (*They could only pass on nt/nt.*)

Students should work in groups to complete Activity Sheet 7.1 by filling in the genotype for each phenotype on the pedigree. Next, answer the Making Sense questions.

Identifying Dominant Trait—In Activity 7.1, students made the assumption that the dominant trait was the trait with the observable phenotype, so tasting was dominant and nontasting was recessive. In this case, being nonalbino is dominant and being albino is recessive. It is important to point this out to students so that they do not assume that the observable phenotype is always the dominant one.

When the groups have finished, have students share their work. Begin with Family 1. Use PI: Sample Pedigree from Activity 7.1 and have one group fill in the genotypes on which they decided. Use the model to facilitate a discussion of the pedigree.

Discussion – Pressing for Understanding

Purpose

Evaluate whether the model from plants could be adapted to fit the human trait data.

Suggested Prompts

- Does each genotype follow the rules of the model?
- If there are any with which you disagree, tell why.
- What rule of the model does it not follow?
- Are there any examples of where a variation of a trait seemed to skip a generation?
- How did the model help account for what happened?
- Does the model work the same way for human data as it did for the plant data? (*Students should conclude here that the model works for both human and plant data.*)
- Is there anything that the model cannot explain? Is something missing from the model? (*Students should still have a question about what happens when the alleles are not the same. They have seen that purple seems to get passed on over non-purple and tasting over nontasting, but they do not know why it happens.*)

Use the same prompts to facilitate a discussion of the Family 2 pedigree. After looking at both pedigrees, students should have the same question about what happens when the alleles are not the same.

Scientists have names for the two types of alleles that students have observed. The allele that produces the purple phenotype is called the dominant allele. The allele that produces the non-purple phenotype is called the recessive allele.

Remind students of the Mendel reading from Lesson 4. One of Mendel's ideas was that some traits were dominant over others. If two alleles disagree, then the dominant one will determine the trait. Ask students if they have any information that Mendel did not have? (*Students should say that they know about alleles and how they are passed from one generation to the next based on their model. Mendel did not know about alleles.*)

Scientists use a kind of shorthand to indicate which allele is dominant and which is recessive when they are writing about them. In class, you have been using the letters p and np to indicate purple and non-purple alleles. Because purple is the dominant allele, scientists would use a capital letter P to show that it was the dominant allele. They would use a small p to indicate the allele that is recessive.

Ask students what would be used to indicate taster and nontaster if the ability to taste is the dominant form of the trait. (*T = taster; t = nontaster*) In the examples students have seen, when the alleles do not agree, purple is the one that produces the phenotype. Scientists would call the purple allele the dominant allele.

Use PI: Predictions of Variations in Human Traits and have students look at the taster/nontaster data. Ask students if they think the rule applies to this data the same as it did to the plant phenotypes. (*Students should identify that taster [T] seems to be dominant and nontaster [t] is recessive. The pattern is similar to the plants.*)

Note: At this point, students have evidence to support the idea that some alleles appear to be dominant over others. In the next activity, they will examine how this happens.

Materials – Activity 7.2	
For the Class	***For Each Student***
• PI: Picture of Brother and Sister	• Activity Sheet 7.2

Activity 7.2 – Introducing Albinism

The question students left Activity 7.1 with was: What actually happens when the alleles are not the same and one is dominant over the other? The model did not provide an answer to this question. The model shows that there are two alleles and that they combine. If there is one dominant and one recessive allele, they give the same phenotype as if there were two dominant ones, but the model does not demonstrate why this happens.

In this activity, students will look at the genetic disorder of albinism and the chemical story behind it in order to understand what is going on inside the organism to produce certain phenotypes and not others. Since students are not likely to be familiar with the genetic disorder of albinism, it will be necessary to discuss the condition and its causes. This is a good opportunity to link to the IQWST IC3 unit and how enzymes help to change the structure of molecules in a chemical reaction.

- In this activity, students will be studying a genetic disorder called albinism. It is called a disorder because it is an unusual genetic combination, but that does not mean it is a disease. People who have this disorder have very pale or nearly white skin and hair. Their eyes appear pink or red because they do not have any color. The blood vessels in the eye are very close to the surface and cause the eyes to appear red.
- A pigment called melanin produces color in the skin, hair, and eyes. Pigments are chemicals that are produced in the body when an enzyme (protein) causes a chemical reaction to produce melanin.

  Note: This is similar to the purple color in plant stems that students saw earlier in the unit. It is also similar to what students learned about in the IQWST IC3 unit, when they learned that enzymes help in the chemical reaction to break down food.

- The instructions for this reaction are carried by the alleles that are present on a chromosome. If the DNA in the cells does not have the correct instructions to make this enzyme, then the melanin will not be produced. The dominant allele has the instructions to make the enzyme. The recessive allele cannot make the enzyme.
- Having one allele that instructs the cell to make the melanin is enough to produce it. The allele to produce the melanin is the dominant allele. If a person has two chromosomes that carry instructions not to produce the enzyme, then the person will have albinism.

Using PI: Model Chart (from Lesson 6), fill in the table with the possible combinations of alleles for this trait. Remind students that a capital letter indicates the dominant trait and a small letter indicates the recessive. For this example, use A and a.

Suggested Prompts

- What are the possible combinations of alleles for a person with albinism?

Remind students that they are using the new representation for genotype. AA is the same as saying na/na in their previous way of referring to the genotype.

- What about someone without albinism?

GENOTYPE (INSTRUCTION)	PHENOTYPE (WHAT YOU SEE)
AA	nonalbino
Aa	nonalbino
aa	albino

Comparing Work—Since groups of students are working on different pedigrees, you may want to have students combine to compare data. Pairing up one Family 1 with a Family 2 and comparing data would allow students to work through their ideas before doing the whole-class discussion.

Show PI: Picture of Brother and Sister. Ask students to compare the two children. They should see that the brother has albinism. Explain that he is wearing sunglasses because of the lack of pigment in his eyes. This lack of pigment makes an albino's eyes very sensitive to all kinds of light.

Suggested Prompts

- What do you think are the alleles of the boy in the picture? (*The boy has to have "aa" alleles because he has the trait of albinism.*)
- Tell the students that neither of the two parents shows the albinism trait. Ask students what they think the combinations are for the parents. (*They have to have Aa.*)
- If students suggest that the parents could be AA, ask them where the son would have gotten his "a" allele. (*Students should understand that since offspring get one allele from each parent, if the parents only had "A" alleles, then there would be no way for the offspring to end up with "aa."*)

- Even though the parents have one of each kind of allele, the A allele is dominant, and that allele has instructions for producing the enzyme that makes melanin. That is enough for the parents not to have the trait of albinism.
- Individuals who have one dominant and one recessive allele are called carriers of the trait. Even though the parents do not show any sign of albinism, they still have the gene in their DNA and can pass it on to their children.
- Point out that this is like the np/p purple plants that look purple rather than non-purple but can pass on the np allele.

Explaining the Phenotypes

Have students fill out the chart at the top of Activity Sheet 7.2 with the possible genotypes and phenotypes for albinism. In this activity, students will answer the question "Could the boy in the picture have offspring that do not have albinism?" They will need to explain their answer and support it with evidence from their model and what they have learned about dominant and recessive traits.

This explanation is a good opportunity to assess students' understanding of how genetic information is passed from parent to offspring. See the sample explanation on the activity sheet.

After students have completed their explanations, have a few students share their ideas and the support they used.

- It is possible that not all students will agree on the answer to the question. Some students may say that it is not possible for these children to have nonalbino offspring because they only have "a" alleles to pass on. This is a good opportunity to have students who disagree try to convince students with the opposite view.
- This could be done either as a whole class or in groups. The key thing to emphasize to students is that they must use evidence from their model and what they have learned about dominant and recessive to support their claim.

Wrapping Up the Lesson

We now know the following information.

- Some alleles are dominant and some can be recessive.
- If the alleles are not the same, the instructions of the dominant allele show up in the phenotype.
- Individuals with one dominant and one recessive allele for a trait are called carriers. They can pass either allele on to their children.

Students should return to their Driving Question Notes and add any new information they have, for example, dominant/recessive. This explains the part of the model about what happens when two alleles are not the same.

In the unit so far, students have been examining traits with only two variations. In the next lesson, students will be introduced to the idea that there are traits with many variations.

Introducing Reading 7.2 – Which Instructions Get Followed?

Ask students if they have heard the term *cholesterol*. Spend a few minutes having them share what they have heard from either their parents, family members, or television ads. In this reading, students will learn about the genetic connection to cholesterol and build on their understanding of dominant and recessive. In addition, students see a way in which what they are learning has significance outside of science class.

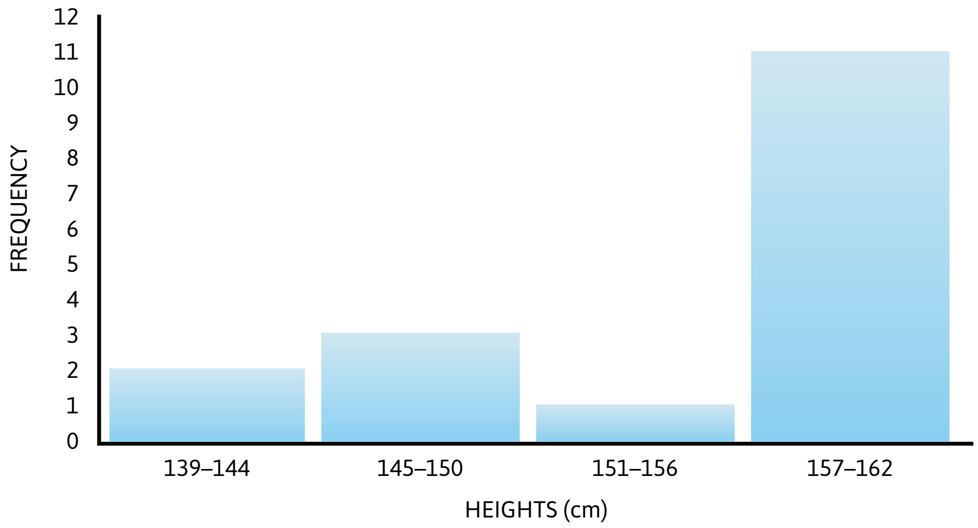
Lesson 8

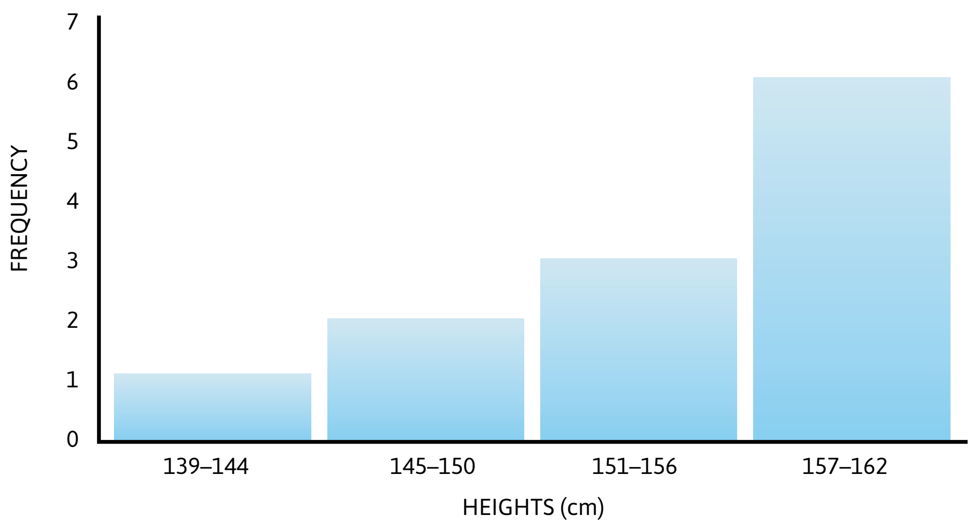
Variations, Variations, and More Variations

PREPARATION

Teacher Background Knowledge

Frequency Histogram with Multiple Values





- Data are organized into frequency intervals.
- The *x*-axis shows the data range intervals.
- These intervals are called bins. You are to determine how you will split the multiple values into groups with an equal amount of heights in each group (for example, 120–130 and 131–141).
- There is no exact formula for determining the number of bins. There are two points to consider:
  - There should be enough bins to show variations.
  - Too many bins will have too few data in each bin to see a pattern.
- The bar represents the interval. There is no space between the bars because the data in the bins are continuous.
- The *y*-axis shows the frequency or how often the item occurs. For this activity, the frequency is how many subjects' heights fit into a particular bin.

Height Genetics

- Height genetic research has been going on for a long time, but there are still many open questions about the genes that influence height.
- Scientists are certain that height is a polygenic trait—one involving many genes. Because of this, tracing the trait is difficult.
- Environment also has a huge influence on height.
- Recent research has produced some information that identifies sections of DNA that are linked to height.

Using a Simplified Model (Activity 8.4)

- Students may question how some people could be the heights in between those used on the chart (for example 5'9"). Remind them of the following:
  - This is a model that is simplified from the real situation just to explore the idea. Scientists are not sure how many genes contribute to height or how genes trigger growth. A model is a tool to use to help build understanding of how a process works.
  - Scientists know that the environment has a strong influence on height. That is not considered in this model.
- In this model, we are taking some liberties with what actually takes place. Height is a trait affected by multiple genes that are codominant and additive. Each dominant allele would affect height (for example, TT = 4"). Since we do not deal with codominance in this unit, we have simplified this so either one or two dominant alleles in one gene pair will have the same influence on height.
- The goal is to have students understand how multiple genes affect the range of variations for a trait.

Setup

Activity 8.1

- Prepare review graph cards for each group (optional). These can be found following the Preparation section. If your students need support in creating graphs, reviewing these graph cards is suggested.
- You may choose to have measuring tapes or metersticks attached to the wall in order to cut down on the measuring time. If so, before the class enters, prepare the following:
  - o Attach the metersticks (measuring tapes) on the wall with masking tape in several areas around the room.
  - o If your supply is limited, attach the tape high enough to accommodate the tallest students. If you do this, measure the distance from the floor to the beginning of the tape. Attach an index card next to the measuring tool with the distance between the floor to the bottom of the tool listed. Have a reminder that this amount must be added to their height.

Safety Guidelines

Activity 8.1

- Students will need to remove their shoes. Prior to the measuring activity, tell students they must wear socks on the measuring day.
- If you are not able to have shoes removed, have students devise ways to account for the additional height that their shoes may add.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 8

Variations, Variations, and More Variations

TEACHING THE LESSON

Performance Expectations

Students will

- explain how multiple genes can lead to variations of a trait.
- analyze data to describe the trait variations in the population.
- analyze distributions of trait data to compare the subgroups in a population.

Building Coherence

In this lesson, students will identify traits that have multiple variations and determine how to represent those variations for a large group. Students have identified traits, both inherited and acquired, in individuals and observed trait patterns in both plants and humans. They have identified how traits are transmitted by creating a model of inheritance. Using that knowledge, students will expand their focus of traits to those with multiple variations within a population.

Timeframe

3–4 Class Periods

Overview

Activity 8.1

- Identify a trait within the class population that has multiple variations (height).
- Collect data and figure out how to represent them.

Activity 8.2

Given data, create representations to compare two groups in a population.

Activity 8.3

- Observe organisms; identify traits and multiple variations.
- Analyze data from three different populations.

Activity 8.4

Engage in a teacher-led thought exercise to establish an understanding of how multiple variations can occur.

Reading Follow Up

Ask students, What does cholesterol have to do with genetics? Why do Sam's sisters not have sickle-cell anemia but Sam does?

Students should have a clear idea of how the dominant/recessive allele explains why certain combinations of genes from the same parent may produce offspring with different traits.

Materials – Introduction
For the Teacher   • PI: Line of People

Introducing the Lesson

Review how information on two-variation traits has been represented.

- For individuals—A pedigree was used to see patterns of traits passed from generation to generation, where the trait was written for each individual.
- For a single trait in a group—A table was used to identify and record the yes/no variation of a trait.
- For two traits in a group—A table was used to identify and record how many of each combination (for example, how many people who could taste PTC and also like Brussels sprouts).

Using PI: Line of People, facilitate a discussion about how traits allow us to identify the organisms in the picture.

Suggested Prompts

- What is this? (*It is a line of people.*)
- How do you know these are people?
- What traits let you know they were people?
- What are some differences? (*Some differences are male/female and some are taller, smaller, and heavier/thinner.*)
- Do all of these traits have only two variations? (*Some of these traits have more variations.*)
- Which of these traits have more than two variations? (*Traits like height, weight, and hair length have more than two variations.*)

Challenge students to think about how multiple variations of a trait could be represented. Height is a trait with multiple variations on which it would be easy to gather data. In this lesson, students collect class data on traits and figure out how to handle data about traits with multiple variations.

Materials – Activity 8.1

For Each Group
- (1) meterstick or metric measuring tape*
- tape for measuring stations* (optional)
- graph review cards (examples shown in this lesson activity)
- (1) compass and protractor* (only for groups doing the pie chart)

For Each Student
- Activity Sheet 8.1

* This item is not included in the kit.

Activity 8.1 – What Do I Do with All This Data?

The population will be a class of students in this activity. The data that will be collected are height data. There is variation in height. How much does the height trait in this population vary? The goal of this activity is to represent the data students have collected on a trait with multiple variations—height. The representation will show others what height variations there are in this population. The representation should help answer questions based on the data. Have a brief brainstorming session of the types of representations students know about and/or have used.

After a list has been compiled, briefly discuss the various representations. Use a table as an example.

- What would be the column headings? (*Subject's name and height would be column headings.*)
- How is this representation helpful in answering questions about the data? (*It shows information on the individual; it organizes the data collected; and so on.*)
- Is there a disadvantage to this representation? (*Making comparisons of the data is not easily determined. For example, questions like "What is the average height?" or "How does the height of girls compare to the height of boys?" are difficult to answer by looking at a table.*)

Follow the same type of questioning format to go through other graphic representations suggested. Some types of graphs that may have surfaced in the discussion are the following:

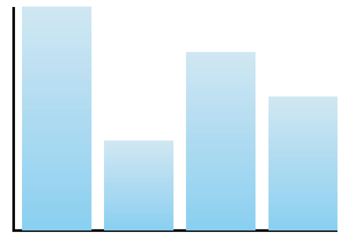
1. Bar graph with one bar per person
2. A frequency histogram with only two values—short and tall; *y*-axis is frequency
3. A frequency histogram with multiple values; *y*-axis is frequency

   Note: This is the representation that we want students to discover as the best tool. If students do not suggest it, do not put it out as a suggestion.

4. A pie chart with two values
5. A line graph with two values

BAR GRAPH

- Data is organized into amount intervals of data shown by bars.
- The bars are of equal widths and equal distances apart
- Usually the Y-axis shows the number of what is being measured. All of the data must fit on the axis
- The X-axis is the **discrete** data such as names, objects, or colors.
- There is one bar per discrete data.

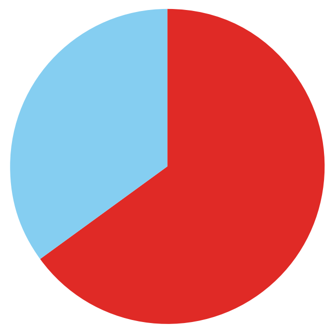


Example—My class's favorite sport
Y-axis = Number of students
X-axis = Sport (baseball, swimming, and so on)

Do not forget to label the X *and* Y *axes.*

PIE CHART WITH 2 VALUES

- Data is organized as percentages of the whole.
- Add the total number of what's being represented. Calculate the percent in each category. Find the angle by converting one of the percents to a decimal (move the decimal point two places to the left).
- Multiply the decimal by 360°
- Draw a circle with a compass. Draw the radius from the center of the circle to the edge.
- Use a protractor and draw the angle.

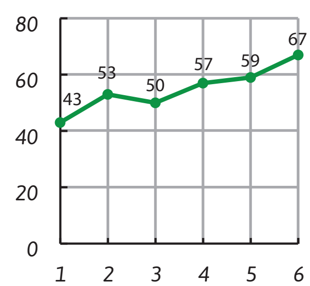


Example—The percent of people in my class who play baseball
Count the number of people in the class.
Count how many of them play baseball.
Baseball players/class
12/30 = .40 = 40%   18/30 = .60 = 6-%
.40 × 360 = 144°

Do not forget to label sections.

LINE GRAPH

- Line graphs can show how something changes over time.
- Two values can be plotted on the axes.
- The Y-axis usually has the numbers or what is being measured.
- The X-axis usually has continuous data of time.



Example—Temperature for a 12-hour period
Y-axis = *Temperature (continuous)*
X-axis = *Day of the week (continuous hours)*

Do not forget to label the X *and* Y *axes.*

Collecting the Data

Divide students into small groups of three to four. Using the equipment provided, students will measure their height (shoes off or compensate for sole height). If you are using measuring stations for the height, instruct students on which station their group should use and how to move to and from the station. Tell students that since a table is a good tool for gathering the individual data, they will use a table to collect data in the activity. Have students take out Activity Sheet 8.1. Students will record their data in the first half of the data table. Measurements should be done in metric units (cm).

After all measurements have been collected, each group should exchange data with another group. Challenge each group to choose a type of graphic representation that best shows the combined data they have collected. If needed, make the graph review cards available to students for guidance in constructing the graphs. It is possible that a group may ask to use a different type of graph than those suggested. Allow them to do so and include their graph in the evaluation.

Upon completion, have the groups share their representations. Have the class evaluate them as to which are the most useful in representing multiple variations of a trait in a large group. Possible prompts as each representation is presented are the following:

- Can you tell how many people are in the population?
- Are you able to see where most people in the population fall?
- Can you determine average height?
- Are you able to see the range of heights?
- Does this representation show all the variations in the group?
- Is this a good way to represent a very large number of subjects?
- Does it show the multiple variations of the trait?

Possible evaluations are on the following chart. Use the evaluation column as a guide for evaluating various types of representations students construct.

REPRESENTATION TYPE	EVALUATION
Bar chart with one bar per person	**Strength:** It keeps track of all the individuals **Weakness:** What happens if there is a really large number of subjects to keep track of—for example, the class?
A frequency histogram with two values, tall and short	**Strength:** Grouping makes sense. Having 30 bars would be too much. **Weakness:** It does not address a wide range of variation. It shows only two values. How can we tell what it means to be tall or short? The exact values cannot be read.
A frequency histogram with multiple values *Y*-axis = frequency; *x*-axis = series of ranges	**Strength:** Grouping is good, particularly if students thought about how the bins should be constructed. **Weakness:** The exact values cannot be read.
A pie chart with two values	**Strength:** It shows percent of total. **Weakness:** There are no exact values. It is hard to compare two sets of data. What happens if there is a really large set of data?

Representing the Data

After evaluating the graphs, ask students what type of graph might be the best to organize the large amount of height data if it were combined with the rest of the class (or multiple classes if available). Students should recognize the histogram as the best option for representing large sets of data with a wide range of variations. It is possible that frequency histograms are not familiar to the students and did not emerge among the graphs that students constructed. If it did not emerge, introduce this type of representation at this time.

Suggested Prompts

- Showing individual heights made it more difficult to see patterns. How could the data be more clearly displayed? (*The heights could be grouped [bins].*)
- If you do that, how should the bins be determined? (*Divide the total range into equal groups [bins].*)
- Why should you use equal bins?
- How do you know how many times that group occurs? (*You know by the number of times those group numbers occur. In this activity, it is the number of people in that height range [frequency].*)
- How should data be plotted on the graph?
- How are the axes labeled? (*They are labeled Frequency on the* y*-axis and Ranges of Heights on the* x*-axis.*)

If students are not familiar with this type of graph, construct a sample one with students. Some possible subjects with multiple data are the following: test grades, age distribution in a school, and so on. In the next activity, students' data will be used to create a class histogram to analyze class height data.

Materials – Activity 8.2	
For the Class • PI: Line of People • PI: Living Histogram * This item is not included in the kit.	***For Each Student*** • Activity Sheet 8.2 • Homework Sheet 8.2 • sticky notes* (one color for boys and another color for girls)

Activity 8.2 – How Can We Show Ranges of Variation?

Constructing a Histogram of Height Data

Remind students that they are investigating the best ways to display trait data when there are more than two variations. In the last activity, the class discussed a histogram as a good tool to represent the multiple values in this type of data. In this activity, students will use the combined height data from the first activity to construct a class histogram.

Distribute a sticky note to each student so that girls have one color and boys have another. Have them record their height that was measured in the last activity on the note. On the board or wall, set up the axes for the histogram.

Prompt students to construct the graph.

- What data should you plot on the *y*-axis? (*Plot number of students on the* y*-axis*)
- What data should you plot on the *x*-axis? (*Plot ranges on the* x*-axis*)
- How should you determine the range of height data? (*Ask each group for their smallest and largest values [height]. Next, figure out the complete class range from shortest to tallest.*)
- How should you determine the number of bins?
- What happens if you have too many bins?
- What happens if you have too few bins?
- How could you figure out the height range within a bin? (*Divide the range into equal bins [ranges of data]. Students will have varying suggestions for how to do this. Accept any workable suggestion. Bin data must be continuous. Make sure there are no gaps in the data between the ranges. For example, if the range is 100–105, 106–110, make sure you decide where 105.5 will go. Students can write 100–105, 106–110, and so on only if they decide that they are rounding up or down to the nearest centimeter.*)

Call up the boys in each group and have each person place his sticky note over the correct bin for his height. Then call the girls up and have them do the same. Make sure that the students keep a single column of heights within each range. The boys' heights are on the bottom and the girls' heights are on the top. Have students copy the class histogram onto Activity Sheet 8.2.

Discuss each component of the histogram with students. Bring out the following concepts.

- The individual is a single organism. Data about the individual were recorded in the data table.
- The population is a collection of individuals—all the same type of organism. The histogram displays data about a population—the class of students.
- The distribution shows how much of a population falls into each part of the variation.

Suggested Prompts

- Where did most of the students cluster on the graph? (*in the middle*)
- What parts of the range are smaller? (*the upper and lower ends*)

Ask students what information can and cannot be obtained from the histogram. Lead students to see the following:

- Individual information is lost when data are put into bins represented by bars.
- Only population is represented.
- Height clusters are easily detected.
- Common heights (highest frequency) are apparent.

Looking at a population like the one represented on the histogram, ask students what comparisons between multiple subgroups in a population would be interesting to make. (*Examples may be the following:*

- *the height of girls compared to boys*
- *the height of students in period 2 compared to period 4*
- *the height of these students compared to students in a different grade [A response like the height of 8th-grade boys to 6th-grade girls would not*

be a fair comparison because the height difference may not be gender based but rather age based.])

Consider the comparison of the height of boys and girls. Display PI: Living Histogram. Explain that this is a population of people a little older than 8th graders (college age).

What does the formation remind you of? (*histogram*) Explain that this is a living histogram. Height was measured in the English system (feet and inches) and people were lined up according to height. Girls had white shirts; boys had dark shirts.

- What information can you derive about the comparison of girls and boys from this histogram? (*Students should be able to see that the concentration of boys is to the right of the concentration of girls. They should also notice that there are areas of overlay with both boys and girls represented.*)
- Look at your class histogram. Do you see a similar trend? (*The same general trend may be observed, but most likely it is not as dramatic, since the young adults in the living histogram have probably completed their height growth.*)
- Do you think the trend would be similar in another population of the same grade-level class?
- How could we find out? (*Students should suggest getting data for another class and creating a histogram to compare the boys and girls. At this time, bring out the point that the class and living histograms have both groups represented on one histogram. Separating class data into two separate histograms (boys/girls) will make comparing the two easier.*)

Analyzing Height Data

Direct students to the data tables for 8th graders from Lincoln Middle School. Assign students the task of comparing multiple groups in a population by having them use the data on Activity Sheet 8.2 to compare the boys' and girls' heights in a typical 8th-grade classroom. This will provide additional data for the question "Is there a difference in the height of 8th-grade boys compared to 8th-grade girls?"

Have some students share the histograms they made on Activity Sheet 8.2. Use the following prompts to check for understanding:

- How did you determine the size of your bins?
- What did you do to organize your data so that you could compare the boys' heights to the girls' heights? (*For both histograms,* x- *and* y-*axes have to be the same.*)

Review the Making Sense section. In Question 3, be sure students can differentiate between population average and population size.

- What if you had only a few students on which data were collected? (*It would be difficult to determine average heights of 8th graders because there would be too few subjects.*)
- What could you do to have our data analysis be more reliable? (*Collect data from more people—for example, other 8th-grade classes.*)

Summarize what students understand about tracking data in a population. Have students record their ideas on their Driving Question Notes and on the Driving Question Board.

Summarize the activity using the following prompts:

- When do you use a histogram?
- How do you compare two histograms?
- What do you need to do to make a fair comparison? (*have the same range, bin size*)

Introducing Homework 8.2 – Who Uses Social Networks More?

Lead In

- How many of you use Facebook©?
- Do you think more boys or girls use Facebook©?
- Do you think there are more 8th graders or more 20-year-olds using Facebook©?

Students will complete Homework Sheet 8.2. They will create and analyze histograms about usage of the popular social networking environment.

Materials – Activity 8.3

For the Class

- PI: Monarch Butterfly Larvae
- PI: Snails
- PI: Guppies
- PI: Orchids
- PI: Blood Type Graph

For Each Student

- Activity Sheet 8.3

Activity 8.3 – Variation Everywhere, So What?

Homework Follow Up

Ask students to share their conclusions about Facebook© usage that the histograms helped them reach.

- Which age group had the most users?
- Were there more males or more females?
- Did that differ by age group?
- What trait had only two variations? (*gender*)
- What trait had many variations? (*age*)

Note: This was another case to use histograms to compare two subgroup's multiple variations.

Ask if students think that people are the only organisms that have traits with more than two variations.

Display PI: Monarch Butterfly Larvae. Explain that these are all monarch butterfly larvae (a stage of growth for a young, living insect). Ask students to study it.

- What trait and what variations of that trait do you see? (*Students may identify size, coloring, marking, and so on.*)
- Are there other organism populations where you might observe multiple variations of traits? (*Students may identify flowers, dogs, cats, and so on.*)
- What kind of variation would you see in those organisms?

- Can you think of any population of organism that would not exhibit one or more traits with multiple variations? (*Students should recognize that many populations have multiple variations.*)

Students will be observing variations of different traits in three different organisms and then will look at data that represent the distribution of variations of traits in a population.

- The observations in this activity could be enhanced by observing actual specimens.
- Some natural history museums, public aquariums, zoos, and so on have specimens to loan out to schools.
- Have students bring in specimens: collected beetles, flowers, tree slices, and so on.
- Use a field trip to a zoo or botanic garden to observe specimens.

Refer students to Activity Sheet 8.3. In Part 1, students will be looking at different organisms, just as they looked at the monarch butterfly larvae. Look at the first example of snail shells as a class. Display PI: Snails. Have students suggest a trait they see in the shells. Then ask them to share two or three variations of that trait. Have students complete the remainder of Part 1 on their own or in groups. For each organism, students should have three or four traits with two or three variations of each trait they identified. Seeing the three images in color will be important for differentiating the traits. To help students see the traits, display PI: Guppies and PI: Orchids while students are working through the activity.

After students complete Part 1, discuss some of their responses as a class:

- What were some traits you observed in each of the organisms? (*Compare students' responses when differences arise when they characterize these traits. Reinforce the idea that they should be measurable: number of spots or color gradient as opposed to dark, pretty, or big.*)
- What were variations of those traits?
- Do they think these traits were inherited or the result of environmental factors? (*Accept all answers. Some sample answers are the following:*
  - o *Students may respond with answers that identify that differences are due to something else that is neither inherited nor environmental, such as size that changes with age.*
  - o *Some differences, like flower color, might be due to different locations.*)

Reinforce the idea that many organisms have multiple traits and multiple variations of those traits.

- To understand the frequency of a certain variation of a trait in individuals or the percentage of the population with that variation, scientists observe large populations of organisms.
- Scientists seek answers to questions by observing these large populations in nature.
- By comparing different variations in populations, scientists can begin to find their answers. Ask students for suggestions as to how the number of organisms with different variations of traits could be measured in a population.

- How did you measure and represent the class height data?
- Why was it useful to represent data this way?
- Would this way of representing data work for all the traits you have named? (*Students should observe that height and other traits, such as length of petals, would require bins when making a histogram; however, other traits are discrete—meaning the bars on a graph can be labeled with categories or single numbers rather than a range. They can measure the frequency or percentage of organisms that show that variation of the trait.*)

In Part 2, students will analyze graphs of data that represent variations of traits in populations. Point out that they will be reading information about data that have been gathered by scientists. Have students complete Part 2 by reading the cases that describe the data, examining the graphs, and then completing the questions.

Comparing the Representations of Data

Have students share their responses to the questions from Part 2 of Activity Sheet 8.3. Ask students to compare these representations of data to each other and to the height graph that they created at the beginning of the lesson.

Suggested Prompts

- All of the graphs you have seen have been histograms and bar graphs, but they have not all been the same. What are some differences you have noticed between the graphs? (*Some measured frequency in numbers, others in percentages, and some required the creation of bins which represented a range of organisms within a category, while others just had categories.*)
- Why do you think scientists represented each of the data sets differently? (*If the data are continuous [like height] or discrete [like cow color], the data representation needs to account for that difference.*)
- Why do you think scientists gather this information about populations? (*Accept all answers, but try to get at the idea that it will help them understand how traits vary within groups and why.*)

As students leave this activity, they should know that scientists

- gather information and organize it in ways that can help them draw conclusions.
- use data to see whether something has changed in a population.
- do not always represent data in the exact same way.

Point out that the last question on the worksheet asked students to speculate about advantages of having certain variations of traits. Have some of the students share their responses. Advantages of variations will be explored in the next lesson.

Materials – Activity 8.4

For Each Student

- Reading 8.4

Activity 8.4 – How Do Genes Work for Continuous Traits?

Remind students of the model from Lesson 6. It was constructed around traits with two values—that is, purple/non-purple and tasting PTC/not tasting PTC. The model used two alleles to represent the instructions for the two variations of the trait. In the activities in this lesson, students have been looking at traits with multiple variations. These traits seemed to have a lot of values for the variation. All of these variations and similarities define a population.

Suggested Prompts

- How do these cases show a limitation of our current model?
- How could instructions in genes be different for these type of traits?

Developing a Model to Show Traits with Multiple Variations and Genes

As students begin the thought exercise with a height scenario, they should know the following:

- Height is a trait that is influenced by many genes.
- Science has not yet been able to determine exactly how many or which genes contribute to height. (Student reading tonight will be about the genetics of height.) However, they are fairly certain that it is at least three genes.

Tell students they are going to explore what happens to a trait when there are multiple variations. They are going to try out a simple model to try to capture some of what they know about the height trait.

- For the model in this discussion, three genes will be assumed to be dominant height and growth genes during the teen years.
- The genes are T, H, and M.
- All three genes are at three different loci on a chromosome pair.
- There are two alleles for each: Tt, Hh, and Mm.
- Uppercase letters indicate dominant alleles that produce proteins that build height. Lowercase letters indicate recessive alleles that do *not* produce the proteins that build height.
- Each dominant allele—T, H, and M—adds an equal amount of height: two inches. Ask students:
    - o What does TT do? (*adds four inches*)
    - o What does Tt do? (*adds two inches*)
    - o What does tt do? (*adds zero inches*)

Fill in the offspring genotype column and add the heading *Offspring Phenotype* to the second column. In this model, all offspring are five feet tall as they enter their teen years. Remind students that each dominant allele will add two inches of height. Since the first genotype contains only recessive alleles, no height will be added. Students should understand that the combinations in the following table are not the only possible combinations. These were chosen as sample possibilities, but there are many more. Prompt students to supply the following phenotypes.

OFFSPRING GENOTYPE	OFFSPRING PHENOTYPE (HEIGHT IN FEET AND INCHES)
tthhmm	5′
Tthhmm	5′2″
TtHhmm	5′4″
TtHhMm	5′6″

Suggested Prompts

- Can you find other combinations that would produce a height taller than 5′6″?
- What about a combination that would be shorter?

Remind students that this model is an example of how multiple genes can produce a great variation in offspring. Scientists have not, as yet, determined which genes are responsible for height.

Lead In

- What did you see in this activity?
- If there are multiple genes affecting a trait, does that affect the ranges of possible variation for the trait? (*The more genes that affect a trait, the more possibilities there are for large ranges of data.*)
- When you have a huge range of data, what is an effective representation to use? (*Frequency histograms are effective representations.*)
- What do you lose when you use frequency histograms? (*You lose data on the individual.*)

Wrapping Up the Lesson

Summarize the lesson with students. Use the following prompts to spark discussion.

- How are traits like height, weight, and skin color different?
- What influences these traits? (*multiple genes*)
- What kind of representations would be most effective in showing how much of the population falls into different parts of the trait variation range? (*frequency/histograms*)

For the remainder of the unit, students will be looking at traits in a particular population to help them better understand why organisms look the way they do.

Introducing Reading 8.4 – Height – Unraveling a Genetic Puzzle

In this lesson, you have looked at the height trait. You collected data and explored a scenario that shows how multiple genes can lead to variations in height. But why do we not know more about which genes determine height? Tonight's reading may help us figure this out.

Lesson 9

Do Variations between Individuals Matter?

PREPARATION

Teacher Background Knowledge

Peppered Moth

This information is meant for the teacher and is not necessarily meant to be shared with students.

- The peppered moth (*Biston betularia*) is a temperate species of night-flying moth. It is an example of polymorphism, which occurs when there are two or more phenotypes that exist within the same population of a species. Each of these forms is identified as a morph. The two morphs that students will investigate are morpha *typica* and morpha *carbonaria*. They will be referred to as typica and carbonaria throughout the lesson.
- To be classified as morphs, the organisms must occupy the same habitat at the same time and belong to a population with random mating. Morphs are responsible for some of the variety between individuals in a population. The numbers of each kind of morph may be influenced by natural selection.

Setup

Introductory Activity

- A bag of small, wrapped candy will need to be purchased prior to the introductory activity. Small, hard candy works well. Before class, place several pieces of candy on top of the door molding or some other spot in the room where some students will be able to reach it and others will not.

Safety Guidelines

Even though the candy in the introductory activity is wrapped, follow the rule of never eating anything in the lab. Students may take the candy with them to eat at a later time.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 9

Do Variations between Individuals Matter?

TEACHING THE LESSON

Performance Expectations

Students will

- analyze data about the consequences of variation in a trait for survival.
- construct an evidence-based explanation to account for the change of variation in a population.

Overview

Introducing the Activity

Students participate in an introductory activity that demonstrates how height can be an advantage in obtaining food.

Activity 9.1

Examine data about a real case where a variation in a trait proved to be advantageous: the peppered moth.

Building Coherence

In this lesson, students determine whether variation of a trait within a population affects the survival of individuals in that population. Students have been examining traits and their variations in previous lessons. They now make the link between variation in a trait and advantage in survival. This will lead to Lesson 10, where they investigate how trait variation affected a population of the Galapagos finches.

Timeframe

2 Class Periods

Activity 9.2

Construct an evidence-based explanation to account for the change in frequencies of the two types of moths.

Reading Follow Up

Ask students to think back to Lesson 1, where they grouped traits based on whether they thought the trait was inherited, influenced by the environment, or both.

Suggested Prompts

- Did you learn anything in the reading that made you change your mind about where you put the trait of height?
- Was there any evidence in the reading to support your idea about in which group height belonged?

Materials – Introducing the Lesson

For the Class

- wrapped, hard candy*

* This item is not included in the kit.

Introducing the Lesson

Throughout the unit, students have been looking at variations in different traits as well as different ways to keep track of the data they collected. Quickly review some of the traits and variations that they have seen. (*plant color [purple/non-purple]; PTC tasting [yes/ no]; tongue rolling [yes/no]; height*) Students may also include some of the traits and variations they saw in Homework 8.2.

In the IQWST LS1 unit, students may have learned that organisms have specific structures that perform specific functions. For example, all organisms have structures that help them obtain food and reproduce. In the IQWST LS2 unit, they may have learned that there are internal structures that perform specific functions, such as the cells in the blood that carry oxygen. These structures are traits of the particular organism, and some of them may exhibit variation. Students will engage in a short, introductory activity in order to begin to think about why variation of a trait might matter.

Tell students where you have placed the candy and call them up in small groups to try to reach it. Explain that they may not jump or stand on a chair. After all students have tried to get the candy, ask why some could not get the candy. (*Students should recognize that those students who were the tallest and had the greatest reach were the only ones who could get the candy.*)

Have a brief discussion about the advantage of height in this situation. Refer to the class histogram of height from the previous lesson.

Suggested Prompts

- If food became scarce and food was only found in high places, who would be able to get to the food?
- Which students on the histogram would have an advantage for reaching the candy? (*students on the right side of the histogram who were taller*)
- Do you think that being taller is always an advantage? Give an example for your response.
- What would you need to know in order to figure out if height were an advantage in a particular situation? (*Students should be able to state that understanding the environment would be necessary in order to determine if height would be an advantage. If food is in a very high place, like in class, then height would be an advantage. If the organism's food was found on the ground in a place with lots of low branches, then being tall would not be an advantage.*)

Let students know that if they studied the IQWST LS1 unit, they should have learned the following facts.

- Abiotic factors in the environment could change. Pollution in the Great Lakes caused the trout population to decrease.
- Biotic factors also caused a decrease in the overall trout population. The invasion of the sea lamprey had an effect on the trout. The data students had did not allow them to see whether some members of the trout population were affected more than others.
- Do you think that variations of a trait in other organisms could matter if there were a change in the environment? Explain your ideas.

Materials – Activity 9.1

For the Class

- PI: Peppered Moth, Carbonaria Variation
- PI: Peppered Moth, Typica Form (Hidden)
- PI: Peppered Moth, Typica Form (Visible)
- PI: Peppered Moth, Comparison Picture

For Each Student

- Activity Sheet 9.1

Activity 9.1 – The Case of the Peppered Moth

Introducing the Peppered Moth

Students will investigate the specific case of the peppered moth in order to begin to answer the question "Does variation in a trait matter?" Remind students that in Lesson 8, they looked at variations in different organisms like stripes on shells, spots on fish, and flower color. In this activity, students will be looking at moths. Show students the PIs of the carbonaria and typica variations of the peppered moth. Explain that these are variations of exactly the same species of moth. These moths were taken from the same location.

Lead In

- The branch of the tree is covered with lichens.
- Lichens consist of two organisms living together on the tree: a fungus and algae. It grows on the trunks and branches of trees.
- Compare the two moths (*The first moth is darker and a solid color. The second one is spotted and lighter in color. It is also harder to see on the branch.*)

Show PI: Typica Form (Visible) so that students can observe the same coloration of a moth on a different branch in order to better see what it looks like.

- These moths are found in England and are called peppered moths because of the speckled color on the lighter form of the moth.
- These variations occur on the adult moths.
- The coloration does not distinguish between male and female. Males and females may have either variation.

Students need Activity Sheet 9.1, which contains both a data packet with general background information on the peppered moth as well as two Making Sense questions.

Developing a Hypothesis about the Peppered Moth

Students should work in groups to read the information and answer the Making Sense questions. When students have finished, conduct a brief brainstorm discussion using students' ideas in the Making Sense questions in order to get out hypotheses for why the dark form of the moth is becoming more frequent and why the light form is less frequent.

Suggested Prompts

- What is the change in the moth population that they found? (*The dark form of the moth is becoming more frequent, and the light form is less frequent.*)
- What might be causing the dark form of the moth to become more frequent? (*Students may give the following responses: more of the light-colored ones are being eaten, people counted incorrectly because they could not see the lighter ones, or they are better hidden than the lighter ones when they are on dark branches.*)
- Why are the light ones becoming less frequent? (*Students may respond that people cannot see them to count them, and something is eating more of them.*)

Record students' ideas on the board. Ask students what they would have to investigate to figure out what happened to the moths. What kinds of things can affect populations? If students studied the IQWST LS1 unit, they should be able to identify the following factors.

- Other organisms can affect populations. This could be some change in the food web, such as a new predator that either directly or indirectly affected the organism being studied. Lamprey affected the trout, and they also affected the trout's food source.
- Abiotic factors such as pollution can affect populations. The pollution of the Great Lakes affected the trout.
- It could be both of the above, like what the students observed with the trout. There was both a change in the food web with the invasive species and also pollution in the lakes.

Since students cannot collect this information for themselves, in the next activity they are going to look at several studies about the moths that address each of these factors.

Materials – Activity 9.2

For Each Student

- Activity Sheet 9.2
- Reading 9.2

Activity 9.2 – How Does Variation Matter?

Analyzing the Data about the Peppered Moth

Begin by asking students why the carbonaria and typica moths change in relative frequencies.

In this activity, students will look at several sets of data in order to gather information to figure out what caused the change in the peppered moth population. Students will collect the evidence they need to write an evidence-based explanation for the change in frequencies of the two types of moths in Activity 9.3.

Scientists began to study these moths in the 1950s. They had some hypotheses about what was going on. Activity Sheet 9.2 is divided into four sections, each addressing a different study. Each group should be assigned one of the studies to analyze. On their activity sheet, they should record the evidence they find in their study and their analysis of that evidence. After the groups finish, they should jigsaw and form new groups made up of one person from each of the four studies. In their jigsaw groups, they will fill in the information about the remaining studies on their activity sheet. This will allow them to construct their explanation in Activity 9.3.

- Each student book contains the data for each of the students. Have each group circle the title at the top of the page with the data they are to use. This will help them to look only at their data. They will, however, need access to all of the data when they jigsaw to understand the other groups' interpretation of the data.

- There are four questions that the studies address. The studies are grouped as follows:
    1. Pollution Studies
    2. Predation Studies
    3. Pollution Reduction
    4. Inheritance

- This activity sheet has a series of studies that provide clues to what happened to the population of peppered moths.
- There are four sets of studies:
    - The first explores the type of environmental pollution and its effects on the moths' ecosystem.
    - The second explores how the predators of the moths interact with the two variations of the moth.
    - The third explores changes in the last 50 years as the pollution situation has changed.
    - The fourth looks at whether the variation is inherited.

Students should work in their groups to answer the question at the end of the section they have been assigned and fill in the evidence chart at the end of the activity sheet.

When all groups have finished with their assigned section, jigsaw the groups so that each new group is made up of one member from each of the section groups. Students should share what their group found, and all members of the new group should fill in their evidence sheet with information provided by the other groups. When this portion of the activity is complete, all students should have evidence and interpretations for all of the studies.

Sharing Cause-and-Effect Chains

Remind students of the question they are trying to answer with the data: Why did the carbonaria and typica peppered moths change in relative frequencies? In the Making Sense section at the end of the activity sheet, students were asked to construct a cause-and-effect chain using the evidence from the studies they investigated. This is similar to the chain of reasoning that students may have constructed if they studied the IQWST ES2 unit. That unit explained what happens to air and water in the air and how they are affected by temperature differences to cause a storm. Have students share some of their ideas.

In the next activity, students will write an evidence-based explanation using the evidence from the chart in this activity. Students write this first in groups and then construct a class consensus explanation using these data to answer the question about the moths.

Activity 9.3 – Explaining the Change in the Peppered Moth Population

In this activity, students will assemble a class consensus explanation about what happened to the moth population. Students should first work in their groups to produce a possible explanation based on the data they have. Then the class will put together a consensus explanation.

Using the Making Sense section from Activity 9.2, have students work in groups to write their evidence-based explanation. Each student should record his or her explanation on the activity sheet. After students are finished, bring them together and construct a class consensus explanation.

Discussion – Synthesizing

Purpose

Construct a consensus evidence-based explanation for the change in the frequency distribution of the moths.

Suggested Prompts

- What is the trait that varies in the population?
- What are the variations? (*There are two variations in color: typica and carbonaria.*)
- Can the variation be inherited? (*yes*)
- Which variation is dominant? (*Carbonaria is dominant.*)
- What evidence do you have for your answer? (*In the breeding experiment, two typica moths only produced typica. According to our model, that means that carbonaria is dominant, because it behaves just like our human data, where there was never a taster when both parents were nontasters.*)

- Did something in the environment change? If so, what? (*The amount of pollution changed. From 1850 to 1900, it increased; from 1959 to 2002, it decreased.*)
- What structure/function reason explains why one variation was better able to survive than the other? (*The predation experiments showed that birds find the typica moths more easily when the lichen is gone. This meant more carbonaria were surviving.*)
- If more carbonaria were surviving, what would that mean about the proportion of individuals with that trait in the population? (*Carbonaria would increase because the survivors would pass on their traits to their offspring. Across generations, the proportion of individuals with this trait would increase.*)

Walking students through these questions should allow them to generate a chain of reasoning to explain the change in the frequency distribution of the moths. It will be very helpful to represent the chain of reasoning step by step as a chain of cause and effect. The class version of the explanation should be posted on the Driving Question Board. Students should also record the consensus explanation in their Driving Question Notes.

Wrapping Up the Lesson

Ask if students think that this change in the frequency distribution of a variation in a population only happens with moths or if is it possible that it could happen in other populations as well. What would they want to look for in order to explain a change in another population? They should use the step-by-step sequence of the moth population to construct more general questions about each step. Make a list of questions to ask about a change in any population. Post these questions on the Driving Question Board. Be sure that the following questions are on the board, but also include other students' ideas that make sense.

- Variation in traits can have consequences for survival of organisms and populations.
- Can the variation be inherited?
- Is there a structure/function reason why individuals with one variation are more likely to survive the change than individuals with another variation?
- Do successive generations show the advantaged trait in greater numbers?

Introducing Reading 9.2 – How Does Variation Matter?

Ask students if they think that variation could affect the survival of plants like it did the moths. Using the Getting Ready on the reading, have students make a list of the variations in plants that students think might affect their survival. Explain that this reading is about a variation in a plant that affected the survival of populations of the plant in different parts of the country.

LESSON 10

The Finch Investigation

PREPARATION

Teacher Background Knowledge

Using Evidence as Data

Students often think that data only refers to numbers and charts or graphs. In the software, there is a great deal of data in the field notes. There are several possible strategies to get them to use the field notes:

- Make it explicit to students that you expect to see data from field notes in their data logs. On one of the days that they are using the software, check to see that every group has data from the field notes in their data logs.
- Let students know that field notes are very useful in exploring how the traits of the finches might help them, because the notes include scientists' observations of finches foraging for food, mating, evading predators, and other important behaviors.
- Let students know that in their final explanations, they need to have data from a variety of sources, and that includes the field notes.

Setup

- Students will need computer access for five or six days in this lesson. The computers will need Internet access because the software is web based.
- An LCD projector and computer are needed for the teacher to demonstrate the software.
- Teachers should review the investigation on the website in advance of the lesson to familiarize themselves with the interface, the data available, and the patterns in the data.
- To facilitate use of the software and initial start-up time, create a bookmark for the URL for the software on all computers.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Exploring the Software

Depending on how comfortable students seem with navigating the software, you can choose to do another comparison together as a group or allow the groups to look for information on their own. If you are moving to group research at this point, inform them of the following:

- Whether a variation is helpful or not depends on the environment.
- The idea of structure/function and the environment is important.

LESSON 10

The Finch Investigation

TEACHING THE LESSON

Performance Expectations

Students will

- analyze data to identify changes in the environment that influence the survival of a population.
- analyze data to identify traits that have changed in a population.
- construct an evidence-based explanation to account for the change in variation of a population.

Overview

- Explore the ecosystem of the Galapagos and learn about the ground finch, which will be the focus of their investigation.

Activity 10.2

- Learn how to use software to compare traits.
- Learn about the different types of data they will encounter.

Activity 10.3

Collect data to support their claim about what happened to the finches.

Activity 10.4

Compare explanations and identify gaps in their evidence.

Activity 10.5

Construct an evidence-based explanation for the two questions about the finch mystery.

Building Coherence

Students use both the conceptual and mathematical knowledge they have learned to analyze data collected by scientists in the Galapagos. The goal for students is to explore two questions about population change:

1. Why have so many finches died on Daphne Major?
2. How were some finches able to survive?

Using the data to support their claims, students write an evidence-based explanation to answer the questions.

The finch population change presents another example analogous to the change in the peppered moth population. It pulls together what students have learned about heredity, variation, and environmental influences on traits. Students revisit relationships and food webs (IQWST LS1) and structure/function (IQWST LS2).

Timeframe

7–8 Class Periods

Reading Follow Up

What was the variation in the clover you read about, and how did that variation affect the survival of the clover?

Responses to this question provide evidence of how well students understand the relationship among variation, environment, and population change.

Introducing the Lesson

In the last lesson, students investigated how a population of moths changed over time. Prompt students to recall what happened to the moth population and why.

- How did the moth population change over time?
- Why were some moths better able to survive in the changed environment?

Students should recall that it was the variation in coloration that mattered and allowed some moths to survive the change in the environment better than others and pass their traits to their offspring. This change in the moth population led to the question of whether this kind of change could occur in other populations as well.

At the end of Lesson 9, students developed a list of questions to ask about change in any population. Return to the Driving Question Board and review these questions with students:

- What is the variation in the population?
- Can the variation be inherited?
- What is the change in the environment?
- Is there a structure/function reason why individuals with one variation are more likely to survive the change than individuals with another variation?
- Does the advantaged trait appear in greater numbers in successive generations?

Students will return to these questions during this lesson to guide their investigation into the finch problem. Students will look at another population change over time by studying variation and environmental influences. It is presented to students as a mystery to solve.

Materials – Activity 10.1

For the Class

- computer connected to a projector in order for teacher to demonstrate software. Software can be found at http://bguile.northwestern.edu. (All that is needed for these activities is an Internet browser such as Safari or Firefox. Nothing needs to be installed on the computers students will use.)*

For Each Group

- (1) computer for groups of 2–3 students*

*This item is not included in the kit.

Activity 10.1 – Background to the Mystery

Background to the Mystery and Software Introduction

This activity serves as a guide to the software students will use throughout this lesson. The class will cover the major parts of the software together, and then groups will have time to investigate the background information and complete the activity sheet.

This activity is written assuming that students have access to computers and are working in groups of two or three. If that is not possible, the introduction can be done as a demonstration, but teachers are strongly encouraged to give students access to the software as soon as possible.

Project the Introduction section of the software. (Software can be found at http://bguile.northwestern.edu.) Ask if any students have heard of the Galapagos Islands and have them briefly share what they know. Use the map on the first page of the introduction to orient students to the location of the Galapagos and their location at the equator.

Lead In

- The Galapagos Islands are where the mystery they are going to try to solve takes place.
- Scientists have been studying a particular population of birds on the island of Daphne Major.
- The number of birds on that island dropped significantly during one time period. They are restored to their regular numbers now.
- Their task for this lesson is to figure out what happened.

Have student groups go to *Explore Ecosystem*. This is where they can find the information they need for their activity sheet. Have students click on the *Finch* button. They should see pictures of the ground finch (male and female).

Have students identify any traits they see in the picture and record their ideas on the board. Students should also record these ideas on their activity sheets.

- Traits could include the following: weight, height, color, length (or size) of wings, or length of beaks.
- Remind students that they should focus on traits that have important functions and might affect survival. In Activity 10.2, students will be able to see what traits are included in the data sets for this lesson.

Ask: "What factors might have affected the finch population?" Have students fill in the first column on their activity sheet that identifies the factors that affect survival: food, environment, and other organisms.

Exploring the Software

Students should use the buttons at the top of the *Explore the Ecosystem* page to find the answers to the questions on the activity sheets. There are many pages in this section, and students should go through the entire section. Once groups have had time to fill in the information on their activity sheets, bring the class together to share information. Let students know that if another group mentions information that they do not have, they should add it to their activity sheet.

Suggested Prompts

- What does the ground finch eat?
- Does it compete with other organisms for food?
- If so, what organisms?
- What organisms prey on the finch?
- Are there many organisms in this food web?
- How might that affect an organism's survival? Two important ideas should come out here:
  1. The limited number of organisms and interactions means that it would not be difficult to disrupt the ecosystem and make it difficult for certain organisms to survive.
  2. Because of the limited number of types of organisms on the island and the small population size, scientists found it a good place to study because there were not many organisms to keep track of.

Note on the map that the Galapagos Islands are located on the equator.

Suggested Prompts

- What do you know about the weather near the equator? *(Students learned that many places near the equator only have two seasons: wet and dry. The same is true of the climate on Daphne Major, which only has two seasons: wet and dry.)*
- What kind of data about weather can be measured? *(precipitation and temperature)*

Note: These are the two factors that best connect to this unit and what students will see. Some students may remember that they also looked at cloud and wind data.

- Do you think that the climate pattern on the Galapagos could have an effect on what happened to the finches? Why? (*Since environment was one of the factors they considered in the IQWST LS1 unit, students should suggest that it is possible for the environment to play a role in the finch mystery.*)

Discussing the Investigation Questions

In the software, students are introduced to the questions they will be investigating in this lesson. Ask students what problem they will investigate.

- Why did the birds die?
- Why did some of them survive? Did variation matter?

Suggested Prompts

- Given what you have learned about the finches and the environment, can you think of any possible causes for why so many of the finches died? (*Students may suggest ideas such as that there was an invader in the ecosystem that preyed on the finches or that something happened to the food they eat.*)
- Can you think of possible reasons why some finches may have survived? (*Possible responses might include that some could get away from the predators better or that some were better able to find food.*)
- Return to the list of traits that students identified at the beginning of the lesson. Would any of those traits matter for the survival of some finches over others? (*Responses may include the following: if their wings were bigger and stronger, they could fly farther to get food, and they might also be able to fly away from their predators better; if their beaks were smaller, maybe they could not eat as much; and if birds were heavier, they would need more food and eat more.*)

In the next activity, students will use the software to look at data about what finches survived, what finches did not, and whether variation in the finches and other factors might affect their survival.

Materials – Activity 10.2

For the Class

- (1) computer connected to projector for teacher demonstration*

For Each Group

- (1) computer for groups of 2–3 students*

For Each Student

- Activity Sheet 10.2

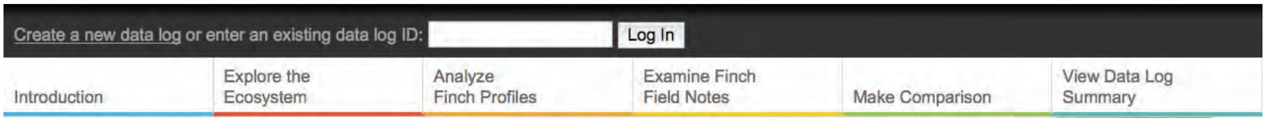
* This item is not included in the kit.

Activity 10.2 – Introducing Data Comparisons and Individual Finch Data

Creating a Data Log

Before beginning, organize students into groups. The ideal number of students in a group is two, providing there are enough computers. This will better enable the sharing activity in Activity 10.4, in which groups combine to total four students. Student groups will need access to a computer, but it would be helpful if the teacher could project the software during the discussion at the beginning of the activity.

Before students begin this activity, make sure they know how to save their data to their data logs so that they can return to it later when they are looking for data to help them answer the questions. Have students open the software and, on the first screen, find the section at the top that says *Create a new data log* or enter an existing data log ID.



They should begin by clicking on *Create a new data log* and following the steps on the screen. They should enter a name for their group and the teacher's name. There is a place at the top of Activity Sheet 10.3 for them to record their group's identifier. The next time they access the software, they will type their group's identifier in the box to access the data they saved.

Since the Galapagos Finch software is web based, students can access it from their home computers, the library, or the classroom. To see their group's data log, they will need to enter their group's identifier. They will be able to view all of the data the group has saved and also add new data.

In the previous activity, students saw that there were many different kinds of data in the software. In this activity, they will learn how to make comparisons in the software, examine individual finch data and field notes, and save their data to their group's log. Student groups should follow the various steps as they are demonstrated.

Comparing Traits Using the Software

Guide students through the steps to make a comparison of traits.

Lead In

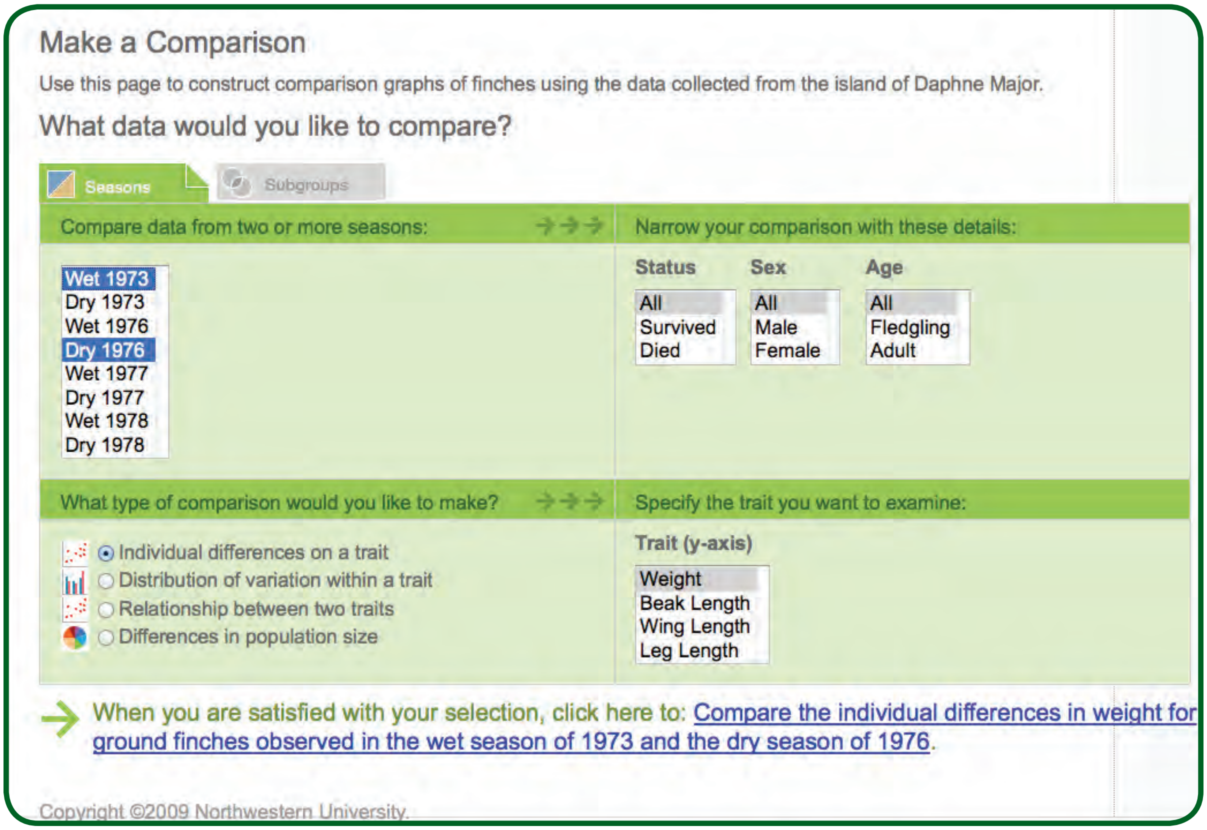
- There are two types of comparisons that can be made: over time (seasons) or between subgroups (such as male vs. female or survived vs. died).
- There are different kinds of data representations: bar graphs, pie charts, and scatterplots.
- Students may need to be reminded that they have seen all of these types of representations in this unit. If students still struggle with some of these representations, time may need to be spent explaining what each shows.

Demonstrating one comparison will give students some structure for using the software. Relate what they are about to do to the moth problem in Lesson 9.

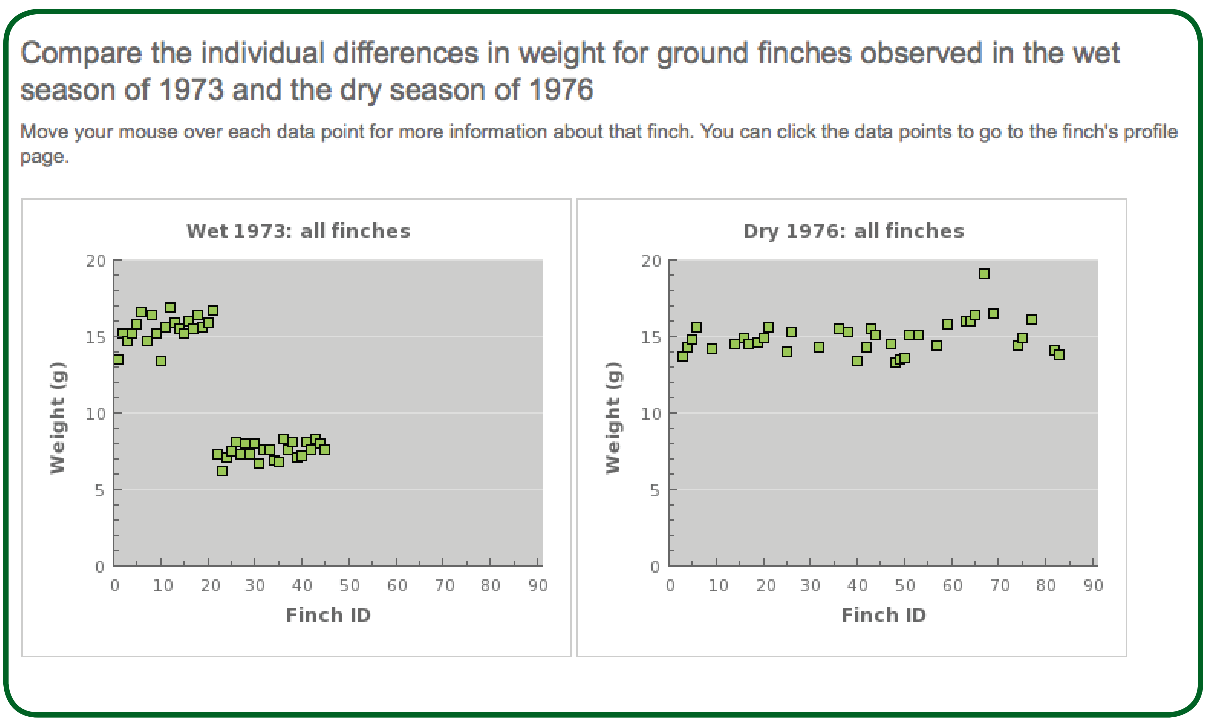
Students can make these same kinds of comparisons using the software. Walk students through one example of a comparison using the following steps:

- Click on the *Make Comparison* tab. One comparison that will help examine change over time is the *Seasons* comparison. Here students can compare changes in the population across seasons.
- Select two or more seasons that you want to compare. (On a Mac, you need to hold down the Apple key.)
- Click on *Wet 1973*; hold the Apple key and click on *Dry 1976*; then go to the *narrow comparison* field; and select *All* in each category.
- Next, choose the trait you want to compare. Choose *Weight*. Then select the type of comparison. Select the first of the four types, *Individual differences on a trait*. Point out to the students that they could select any of the traits or graph types.

- At the bottom of the comparison page, students should find a statement in blue that says, *Compare the individual differences in weight for ground finches observed in the wet season of 1973 and the dry season of 1976.* At this point, the screen should look like the following.



- Have students click on the blue statement, and they should see the following screen.



To check for students' understanding of the graph, use the following prompts:

- o What is the difference between the two graphs? (*The same finches are shown in two different seasons.*)
- o What is shown on each of the axes? (y-*axis = trait that was chosen;* x-*axis = finches*)
- o What does each of the green boxes represent? (*Each one represents a finch*.)

- Ask students to drag the mouse over the green boxes to show that it reveals an individual finch's weight. Students can get more information about that individual finch by clicking on the box.
- Have students find a profile that has a *Field Note*. Click on it and have students read through it so that they can see what is there.
- Show students how to save their data in the software. This allows them to have access to the data they thought were important and have notes about why they saved the data and how they help them answer the questions.
- Have students look at the graphs again and direct their attention to the right-hand side of the page. Students should find a side panel that displays *My notes*. If they click on *Add to my data log*, the graphs will be saved. They can then type notes that help them remember why they thought these graphs were important. The next time they log on to the software, they can open their data logs and see what they saved and their notes about why it was important.
- Stress to students the importance of not just saving the graphs or information from the field notes but also writing notes about why they thought the data were important.
- The questions they are trying to answer about the finches are as follows:
  - o Why did some birds die? (What changed and how did it change?)
  - o Why did some birds survive? Did variation matter?

Both questions must be answered with an evidence-based explanation with a claim, evidence to support the claim, and reasoning. Students should use the remaining class time to begin exploring the software for information that will help them answer their question.

Before students leave, remind them of the following:

- In their data logs, they should record anything they discovered and think is important to solving the mystery.
- They should also add notes about what they think the data show and why that idea is important to solving the mystery.

In the next activity, students will have two to three days to develop their claim and find supporting evidence using the software.

Some students may do research to find the answer to these questions, since it is a real-life scenario. If they confirm it is a variation in beak length that determined the birds' survival and think it is the right claim, explain that they should be able to find data in the software to support why this variation affected survival.

Materials – Activity 10.3

For Each Group
- (1) computer with Internet access*

For Each Student
- Activity Sheet 10.3

* This item is not included in the kit.

Activity 10.3 – Investigating the Finches

In this activity, students will continue their investigation into the finch problem and continue to collect data. Activity Sheet 10.3 contains sections that reflect the questions generated from the moth lesson and are posted on the Driving Question Board. Students should save all data they think might be useful in their data logs in the software. On the activity sheet, they should record only the data they think will be used in their evidence-based explanation. Their data logs in the software will contain all of the information they have viewed and saved. The activity sheet is a refined version of the data. The Finch Investigation Teacher Support pages, found at the end of Lesson 10, contains a summary for the teacher of the different questions and the areas in the software containing data relevant to each question.

- Students often forget to save the things they find to their data logs. Stopping their work a few minutes before the end of class and reminding them to save their most important findings from today to their data logs will help organize their ideas. This will also save time the next day so that they do not have to go back and try to find data that they forgot to save.
- Encourage them to write notes about their findings and why they think they are important.

In the next activity, students will engage in a midpoint sharing in order to refine their claim and evidence. Students should have at least two periods to work with the software to begin their search before the next activity. Depending on how much progress students make, another day (or two) may be needed to gather information from the software.

At the end of class, regroup briefly to assess whether students are making progress in collecting data.

Suggested Prompts

- What did you find today that is useful?
- What questions do you want to research next?
- Are there data you are looking for that you cannot figure out how to find?

If students are not sure what question to ask in order to get the specific data they want, take time to help them with the question now so that during the next class, they will be able to get started on their search right away. Encourage students to spend time at the end of every day putting pieces together. They should not wait until Activity 10.4 to begin to put the pieces together.

Introducing Reading 10.3 – Where Did the Data Come From?

Students have been introduced to software that contains a great deal of data. This reading gives background information on how those data were collected. Use the Getting Ready section to have students begin to think of the different ways that scientists can collect data.

Reading Follow Up

Ask students to share some of the unusual things the Grants had to do to collect the data about the finches. This could also be used as a bell ringer to check if students did the reading.

Materials – Activity 10.4

For Each Student

- Activity Sheet 10.4

Activity 10.4 – Midpoint Sharing

- The data are complex. The various traits are correlated.
- It is not necessary for all groups to come to the same conclusion about what trait mattered for survival and what the advantages of the trait were. What is important is that groups find a plausible explanation and support it with evidence and reasoning.

Engage students in a brief discussion about why sharing information with other groups and getting their feedback are important.

- This is similar to what they did when they built a consensus model in previous units.
- Comparing models can help to develop a better model using strengths from different groups.
- In the finch software, there are a lot of data to examine. Different groups may have chosen different pieces of data to use. Your group may learn something from another group that you can use, and your ideas may help another group to make a stronger explanation.

- If students have been working in pairs, this activity can be done by having pairs combine and form a group of four. That group of four can then complete the activity together to finalize their explanation. In this way, peer sharing becomes a consensus-building activity.
- If the original groups are larger, then use this activity to have pairs of groups exchange ideas and comment on each other's explanations. They can then complete the activity in their original groups. This activity has two parts: (1) Groups construct their explanations that they have so far, and (2) groups compare explanations.

Part 1: Pairs Construct Their Explanations (Day 1)

Placing students in the situation where they have to figure out where their explanations agree and disagree, as well as resolve the disagreement to converge on one explanation, pushes students to develop more thorough explanations.

The first step is for each group to synthesize the ideas they have so far into an explanation. Using Part 1 of Activity Sheet 10.4, each group should complete explanations for the two questions: Why are the finches dying, and why are some able to survive? For each question, groups should write out their claim and support it with the most important evidence they have found. They should provide a clear chain of reasoning that shows why their claim about the causes of death and survival of the finches makes sense. They should be sure to support each part of the reasoning with evidence wherever possible. Remind students of the questions that are posted on the Driving Question Board from the moth activity. Groups should be addressing these questions as they think about what might have happened to the finches.

Part 2: Two Pairs Work Together to Compare Their Explanations (Day 2)

Have two pairs share explanations. They should begin by reading the other group's explanation and asking questions to clarify it if necessary. They should then fill out Part 2 of Activity Sheet 10.4: Comparing Explanations. After they have filled out the activity sheet, they should discuss their evaluations of each other's explanations. The new group of four students will continue to work together for the rest of Lesson 10. Groups should identify the following:

- Where did they agree?
- Where did they disagree?
- Where can they combine ideas into a single explanation?
- What evidence could they investigate to resolve their disagreement?
- Can the two groups write a single consensus explanation?

Discussion – Summarizing

Purpose

Summarize the findings of the groups.

Suggested Prompts

- What were the areas of agreement?
- What were the areas of disagreement?
- What kinds of questions did the other group ask that made you realize where you had gaps in your explanation?
- What problems have to be solved before you can put your explanations together?

After this discussion, have each group fill in the Follow Up question. This question asks them to list what they are going to investigate next in order to take advantage of the feedback they received. This question is intended to focus their final day using the software.

Materials – Activity 10.5

For Each Group

- (1) computer use optional for this activity*

For Each Student

- Activity Sheet 10.5

* This item is not included in the kit.

Activity 10.5 – Explaining the Mystery

Students should now be working in their groups of four. In this activity, they can use the software to fill in any gaps in their data, resolve any disagreements uncovered in the midpoint sharing, and finalize their explanation for the finch mystery.

Students should use the suggestions from the midpoint sharing to find additional data to use as evidence to support their explanation. They should then write their final explanation using Activity Sheet 10.5.

- Their explanation must answer both questions: (1) Why did some birds die? and (2) Why were some birds able to survive?
- They need to identify the variation and why it made a difference in the survival of some birds. There should be a structure/function reason why some finches were able to survive.
- They should use a variety of evidence to support their claims (e.g., field notes, different types of graphs). Field notes are particularly useful for identifying why traits would matter, and students should be encouraged to include some field notes as evidence.

When all groups have completed their final explanations and have their reasoning and supporting evidence, bring the class together for groups to share their explanations.

- The flow of this wrap-up discussion will vary with each class. In some classes, a single claim may emerge early and the focus of the discussion may be more on evidence and reasoning.
- In other classes, the claim will be refined through the discussion until a consensus is reached. Be sure to press students for the answers to all the questions and the evidence and reasoning to support their ideas.
- It is also fine if a consensus builds around two different possible examples instead of getting everyone in the class to agree on the same explanation. However, each explanation must address the population change questions and be supported by evidence and reasoning.

Begin by determining how much agreement there is among the groups. Have each group share their central claim and record these on the board. Not every group needs to present. After the first group states its claim, determine if there are other groups that agree. It is possible that all groups are converging on the same story.

- Did any group have the same claim but use different evidence and reasoning to support it? The idea here is to get all of the evidence used and reach a consensus about what supports that claim. It is possible to have multiple evidence that supports an individual claim.
- Did the group answer all of the questions? If not, what is missing?

When all of the groups with the first claim are satisfied that they have all of the evidence and reasoning to support the claim, move on to any other claims that groups have and repeat this process.

Return to the questions on the Driving Question Board that came from Lesson 9. The answers to these questions explained what happened to the moth population. Students came into this lesson wondering if those questions could be used to explain other population changes. Use these questions to prompt a discussion about whether they can explain what happened to the finches.

Suggested Prompts

- What is the variation in the population? (*The variation is beak length.*)
- Is that variation inherited? (*Yes, it is inherited.*)
- What is the change in the environment? (*The change was three dry seasons in a row with very little rain during what should have been the wet season.*)
- Is there a structure/function reason why some finches were able to survive? (*Larger beaks were better able to crack open the Tribulus seeds that were most frequently available during the drought. Those remaining birds with smaller beaks could not get enough food.*)
- Do successive generations show the advantaged trait in greater numbers? (*This question cannot be answered for the finches as it was for the moths. Finches live multiple years and need time to grow up and mature in order to have fledglings of their own. There is only one generation past the drought in the data, so students cannot see changes in successive generations as they did with the moths. In the moth data, students were able to see many generations because each year produces a new generation. There were 50 years of moth data to show the change from 99% dark to 5% dark.*)
- What do you think will happen if there continues to be low rainfall—not necessarily drought, but less rainfall than normal—for many years in a row?
- What happens when drought survivors grow up and have fledglings of their own?
- What will the next generation look like? Why do you think that?

Students may need to be reminded that they said that beak length is an inherited trait. This means that if there were more survivors with larger beaks, those survivors would be more likely to produce offspring with larger beaks. If that went on for many years, the population would eventually contain a majority of birds with larger beaks.

Wrapping Up the Lesson

In Lessons 9 and 10, students saw two examples of population change and developed some ideas about how they may occur.

- Variation matters.
- Variation can cause certain individuals to survive and have offspring. This can cause the population to change.

Does what we have learned about moths and finches help explain how population changes can occur?

Suggested Prompts

- Were there any similarities between the finches and the moths? (*There was variation in both populations; the variation mattered; certain individuals survived and had offspring; and the populations changed.*)
- Were there any differences? (*There were data for many more generations of the moths; the finch variation made a difference in the finches' ability to get food; and the moth variation caused some of the moths to be preyed on more.*)
- Does what you have learned about moths and finches give you some ideas about how population changes can occur?

In the next lesson, students will explore that idea further and develop a general model about population change.

Introducing Homework 10.5 – What Happens Next?

In this homework, students are asked to extend their ideas about the population change in the finches. They are given additional information about the Grants and their work and asked to explain if they think the finch population changed after the drought in 2003. This is a good opportunity to assess students' understanding of what they have been learning in Lessons 9 and 10.

Finch Investigation Teacher Support
(This table contains the major questions students should be investigating and ideas about relevant data that can be found in the system. This is intended as a summary for the teacher.)

QUESTION	WHERE TO FIND THE DATA	CONNECTIONS
What is the change in the environment?	"Environment" button in the "Explore the Ecosystem" tab: Compare seasons during the crisis to prior years.	Students saw seasonal variation patterns year to year in *What Makes the Weather Change?* (ES2) They saw wet and dry seasons as well. In *Where Have All the Creatures Gone?* (LS1), they saw a change in abiotic factors.
What is the variation in the population?	• Find out what traits vary in finches and how they vary in this population. • Use "Subgroups" tab in "Make Comparisons" to compare male vs. female or fledgling vs. adult for available traits. • Look at the whole population across time using "Seasons" tab in "Make Comparisons." • For these comparisons, use buttons "Individual differences on a trait" or "Distribution of variation within a trait."	The graphs are histograms like those students built in Lesson 8. The scatterplots may look similar to some students' ideas about how to represent the individual data in Lesson 8.

QUESTION	WHERE TO FIND THE DATA	CONNECTIONS
How can the variation be inherited?		Here students need to rely on the general principles for understanding variation from Lessons 1–9. Students can assume body features like beak length and larger size and longer wings are all inherited variations in an organism. They do not have inheritance data to test this directly. However, they do have some support in seeing that the longer-beaked birds breed a next generation also with longer beaks.
Do successive generations show the advantaged trait in greater numbers?	• Use "Subgroups" tab in "Make Comparisons" to explore traits that might matter for survival by comparing surviving finches to finches that die. • Use the "Seasons" tab in "Make Comparisons" to check if any differences that students found show up in the next generation by comparing the next generation to the previous generation on the trait.	In Lesson 9, students compared histograms for moths. Here, the data are harder to interpret since the traits are not binary but rather continuous like the traits students looked at in Lesson 8. Students compared histograms of continuous traits in Lesson 8 to see if two subpopulations were different (e.g., boys vs. girls).

Lesson 11

Constructing a General Model of Population Change

PREPARATION

Teacher Background Knowledge

Resistance Traits

- Throughout most of this unit, students have investigated physical traits that are observable (color, size of beak, height, etc.). With the two cases presented here, they are introduced to resistance traits that are not observable (such as resistance to drought, disease, antibiotics, and so on). In both cases, these traits follow the Mendelian principles of inheritance.
- Biologists have discovered the specific gene that is responsible for insects being able to resist DDT. The biochemical mechanism that allows them to survive without harm has been identified.
- Gene coding for a particular protein produces antibiotic-resistance traits in bacteria.
- Students will have to infer the inheritability of the resistance traits.

Guiding the Discussion to Avoid Misconceptions

- During the discussion, challenge students to focus on how the population changes happened. Was the change within the individual bacterium/insect? Students are likely to persist in the idea that mosquitoes adapted to resist the DDT. Make sure students understand the following:
  - o The variation had to exist prior to the environmental change.
  - o The change was not a response of organisms to try to survive.
  - o Individual insects/bacteria did not change.
  - o Some individuals with certain traits survived.
  - o Surviving individuals were able to pass the trait to their offspring.

Setup

Activity 11.2

Prepare fact sheets for groups of students in Activity 11.2. You may chose to use one sheet per group or one sheet for each student in a group.

Safety Guidelines

Refer to IQWST Overview.

Differentiation Opportunities

Refer to IQWST Overview.

Lesson 11

Constructing a General Model of Population Change

TEACHING THE LESSON

Performance Expectations

Students will

- construct a model from two evidence-based explanations to explain population change.
- apply and evaluate a model of natural selection with cases of population change.
- analyze traits to determine which traits are influenced by heredity, environment, or population change.

Building Coherence

Students use the cases of the Galapagos finches and the peppered moths to identify common factors in the change in those populations. This provides the basis for constructing a general model of population change.

Timeframe

1–2 Class Periods

Overview

Activity 11.1

- Create a cause-and-effect chain of events for the population change in both the peppered moth and the Galapagos finches.
- Identify the commonalities between the two population changes.
- Build a consensus model of population change that reflects the central aspects of natural selection.

Activity 11.2

- Test the consensus model of population change against two new cases.
- Answer the Driving Question: Why Do Organisms Look the Way They Do?

Homework Follow Up

This homework is a good assessment of how well students understand the idea of how the population of finches changed and what caused that change. You may choose to review their ideas here or collect the homework and use it as an assessment.

Introducing the Lesson

Have students compare the two cases of population change that they have seen. Solicit one or two comparisons. Students will work out the commonalities of the complete cause-and-effect chain of population change in Activity 10.1.

- What is similar in the cases of the finches and the moths? (*Similarities are common factors like inherited traits [beak length for finches/color for moths]; an advantage for survival for some variations of the trait; and so on.*)
- What is different in the cases? (*Differences are environmental changes [weather changes for the finches/pollution for the moths]; the problems created for the population by the change [lack of food for finches/predation for moths]; and so on.*)

Materials – Activity 11.1

For the Class

- PI: Consensus Model of Population Change

For Each Student

- Activity Sheet 11.1
- Final explanation from Lesson 9 (moths) and Lesson 10 (finches)*

* This item is not included in the kit.

Activity 11.1 – Constructing a General Model of How Populations Can Change

Comparing the Moths and the Finches

Suggested Prompts

- If these two cases, finches and moths, have facets in common, do you think this type of population change can happen in other populations?
- If there are common factors, could we identify what is general in these cases?
- Could we make a model that fits both explanations we constructed for these cases?
- What would be the first step we would need to take to build a model?

Guide students to the idea that they would need to examine the common factors in both cases and then generalize those factors. This is similar to what students have done in prior IQWST units when they tried to make their model more general so that it could fit a new situation. Have students take out the explanations for the Galapagos finches and the peppered moths. They will use these to construct a table that compares the commonalities between the two cases. Go over the directions on Activity Sheet 11.1 for Part 1. Examine the table and make sure students understand that all steps in the table will be filled in. The first step for the finches is complete, other steps are starters (a phrase followed by . . .), and others are blanks that students will have to fill in. Assign students to groups and have them work on Part 1 of the activity sheet.

Developing a Class Consensus Model

When students have completed their charts, regroup the class. Ask several groups to share the steps on their charts. Look for agreements and disagreements. Through the discussion, create a class chart of the comparisons. Display PI: Consensus Model of Population Change. Fill in the two columns for each of the two cases that reflect the steps on which the class agreed. Develop a consensus model as a class. Remind students that the model will have to fit both explanations.

Possible Criteria

- Generality—Make sure the models fit both the finch and moth stories. For example, if one suggestion is that organisms vary in color, ask if that would fit the finch story.
- Enough detail to explain cause and effect—If students state something vague, like some organisms survive, press them to say why they survive. For example, individuals with one variation on a trait can survive the environmental change more easily.

As you develop the consensus model, keep mapping back each step to the moth and finch stories to make sure students all agree it fits both stories. Have students record the model on Activity Sheet 11.1 as it is being developed. Put the model on the Driving Question Board. Point out that scientists call this model natural selection. It is called natural selection because the change in the environment leads to some individuals who survive and reproduce. It is like selecting those individuals to continue and produce the next generation. This is not a deliberate selection—it comes about from certain traits that provide an advantage for survival to individuals in a population.

Have students brainstorm other kinds of environmental changes that might fit this model. Possible examples are food becoming scarce in a drought, food becoming scarce due to dying off of a prey species, pollution affecting plants where insects get food, and so on. Ask students if they can think of other types of variation that might have an advantage if the environment changes. In the next activity, students will investigate two more cases and will test the model with those cases.

Introducing Reading 11.1 – Does Selection Always Occur Naturally?

Ask students if they think that all population changes occur naturally. Have them suggest other things that might cause a change in the frequency of a trait in a population. Students may suggest ideas like people breeding dogs for certain traits or the genetic engineering of foods. In this reading, students will read about selective breeding and how it has changed the corn that we eat today.

Materials – Activity 11.2

For Each Group

- one of two fact sheets: Bacteria or Mosquitoes

For Each Student

- Activity Sheet 11.2
- one of two fact sheets depending on group assignment: Bacteria or Mosquitoes

Activity 11.2 – Does the Consensus Model Work?

Reading Follow Up

Ask students to contrast natural selection with selective breeding.

Testing the Consensus Model on Two Other Cases

Ask students how they would know that the consensus model is an effective model. Students will most likely suggest that it would have to be tested with other cases. That is what they are going to do in this activity. The two cases that groups will investigate will be (1) antibiotic-resistant bacteria and (2) DDT-resistant insects. Group students and then give half the groups the bacteria case and the other half the insect case.

- Each case has a fact sheet that presents the basic facts of the case.
- The fact sheets explain enough background so that students can see how the model could apply. For example, the fact sheets describe briefly what antibiotics are and what DDT is.
- The fact sheets give the general history of the introduction of antibiotics or DDT and the resistance that arose in the organisms.
- Some of these facts will fit the model. For example, students should be able to see that the change in the environment for DDT-resistant insects is the introduction of the chemical DDT into the insects' environment.
- For other parts of the model, students will not find direct evidence in the fact sheet. They will have to hypothesize the step in order to apply the model. For example, there is nothing on the fact sheet that says that mosquitoes can pass on their resistance to DDT to their offspring. They will have to infer this as a possibility in order to fit the model.

Direct students to Activity Sheet 11.2. Have students write out the consensus model in the first column. Students will take whatever facts from the group's fact sheet that can apply to the model and place them next to the corresponding step; for example, *introduction of DDT* would be placed next to the environmental change. Tell students to fill in what they suspect must be true but not to conjecture a detail that is not necessary (e.g., mosquitoes survive DDT because they are good at holding their breath). Assign the groups to work on the models. The Making Sense questions will be completed after the classroom discussion.

After students have completed the models on the activity sheets, have groups summarize the information about their organism and the problem. Next, have groups share their models as applied to the two cases.

Suggested Prompts

- Does the model fit the case? Why?
- How does the model lead to the observed result?
- How does the model lead to an increase in antibiotic-resistant bacteria?
- How does the model lead to an increase in DDT-resistant mosquitoes?

- What data would we need to gather to test the application of the model to the case? (*Accept logical responses. For example, we could try to gather insects that survived DDT and see if they breed other insects that can also survive in order to test whether this is an inherited trait.*)

After the class discussion, have students complete the Making Sense questions.

Reviewing the Model

Ask students whether the model, as written, works for the two cases or if we need to modify it. Reinforce the idea that this is a very general model that can explain how population change occurs. Discuss responses to the Making Sense questions. Have students summarize how the model applies across the four cases of finches, moths, mosquitoes, and bacteria. Point out that not all population change occurs through this process. Students should be able to identify the following critical factors to determine if natural selection is happening:

- naturally occurring variation
- change in environment
- advantage for individuals with the variation
- change in the population

Activity 11.3 – Putting It All Together – Why Do Organisms Look the Way They Do?

Return to the Driving Question Board and have students identify the main types of influences on organisms that they have investigated during the unit, and get examples of those influences from organisms studied in the unit.

1. Species differences—Big leaves on rainforest plant, small ones on desert plant; fish have gills, birds do not, and so on.
2. Inheritance of individual differences—Blond hair or brown hair; tall or short people; tongue rolling; PTC tasting.
3. Environmental influences on individuals (acquired traits)—Working out to get stronger muscles; changing hair color (with dye).
4. Both inherited and environmental influences on the individual—Hair color is inherited, but people change the color by dyeing it; eye color is inherited, but color can be changed with colored contacts.
5. Environmental influences on populations (population change, natural selection)—Beak of the finch; moth color; DDT resistance in bacteria.

PI: Trout and Lamprey and Plants could be used to address the five influences above.

Suggested Prompts

- What traits in these pictures are species differences? (*The traits are wings vs. legs and gills vs. lungs.*)
- What variations could there be in those traits?

- Are variations inherited? What evidence do you have?
- Could any be examples of individual differences? (*Possible responses might include the length of a shark's teeth, the size of a pelican's beak, and so on.*)
- Are there any traits that could be affected by environmental influences? (*How large the plants grow could be affected by the amount of rain or the nutrients in the soil. The pelican's size could be affected by the amount of food in the environment.*)
- What about both environmental and inherited influences? (*This idea may be a more difficult connection for students. It is more easily identified in humans, and students may use those examples here.*)
- Can you think of any ways that there could be an environmental influence on a population of one of the organisms in the transparencies that could cause a change in the population over time (natural selection)?
- On which of the five influences listed on the Driving Question Board does natural selection depend? (*It depends on traits that are inherited and environmental influences.*)
- You know that hair color is an inherited trait. If everyone were to dye their hair blue, over time would their offspring have blue hair? Why?
- How is the hair color example different from the finches? Why does natural selection explain what happened with the finches but not the blue-hair example?
- Following the rules of our model, is it possible to change the number of wings on a bird or the number of eyes on a human? Why? (*Students should be able to identify these as species traits, and the trait cannot be changed. What can be changed by the environment is the variation of the trait.*)

Ask students if there are any questions they still have about why organisms look the way they do.

If questions are posed that can be answered in the context of the unit, allow other students to answer those questions. For example, "Why do I look more like my cousin than my sister?" is a question that students should be able to answer. If questions are posed that require information not covered in the unit, explain that in high school, students will return to the study of biology.

Some examples of those types of questions are the following:

- I know DNA carries instructions for making proteins that influence traits. How does that happen? What is it that makes the proteins?
- I have heard that pollution can cause mutations in organisms and change them.How is that like what we have been studying?
- What happens if natural selection takes place over really long periods of time, like centuries and centuries?

Explain to students that these questions will be addressed in high school. They require science ideas that they have not studied yet and that are too complicated to be addressed in middle school.

Teacher's Edition

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