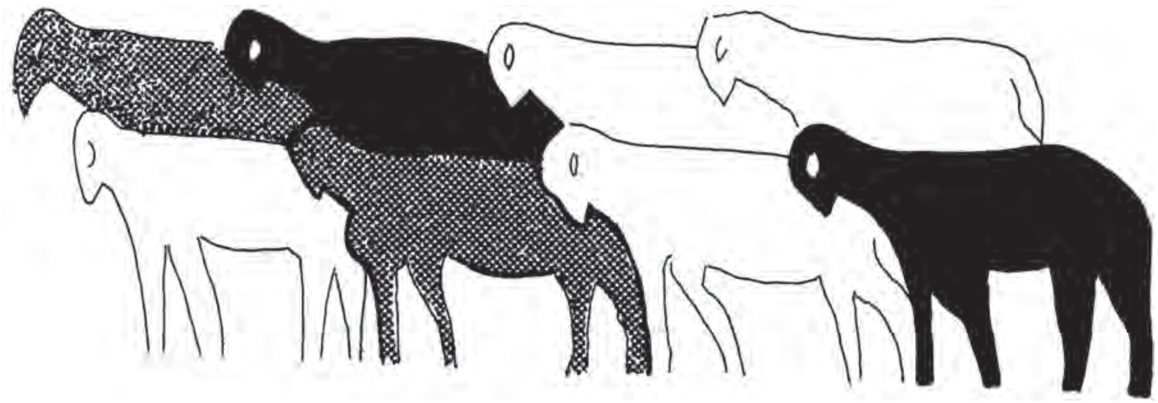
Exploring Populations



High School Biology
Immersion Unit

Award No. 0227016

SYSTEM-WIDE CHANGE FOR ALL LEARNERS AND EDUCATORS
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Step 4 Lesson 2, *A Scientific Explanation for Change in a Population*, is based on a lesson from Chapter 2 of *BSCS Biology: A Human Approach*, Copyright © 1997, 2003 by BSCS, and used with permission.

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Ask-a-Biologist. Arizona State University, School of Life Sciences. http://askabiologist.asu.edu/podcasts/transcripts/vol13_transcript_aab_podcast.html

"Ask Milk!" Campaign Video. Japan Dairy Council. * http://www.youtube.com/watch?v=gDJ48QUrYb0

A Mutation Story. http://www.teachersdomain.org/resources/tdc02/sci/life/gen/mutationstory/index.html

Adaptive Radiation: Darwin's Finches. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/adraddarfinch/index.html

All in the Family. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/allinthefamily/index.html

Allopatric Speciation. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/allopatric/index.html

An Origin of Species. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/anorigin/index.html

Animal and Plant Cell. http://www.teachersdomain.org/resources/tdc02/sci/life/cell/animplant/index.html

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Common Genetic Code. http://www.teachersdomain.org/resources/tdc02/sci/life/gen/comgencode/index.html

Coral Reef Connections. http://www.teachersdomain.org/resources/tdc02/sci/life/eco/coralreefconnections/index.html

Darwin's Letters: Collecting Evidence. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/darletters/index.html

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Evolution of the Eye. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/nilssoneye/index.html

Evolution on Double Time. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/doubletime/index.html

Evolving Ideas: How Does Evolution Really Work? http://www.teachersdomain.org/resources/tdc02/sci/life/evo/howreally/index.html

Evolving Ideas: Why Does Evolution matter Now? http://www.teachersdomain.org/resources/tdc02/sci/life/evo/whymatters/index.html

Evolving Ideas: Who Was Charles Darwin? http://www.teachersdomain.org/resources/tdc02/sci/life/evo/dar/index.html

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How Cells Divide: Mitosis vs. Meiosis. http://www.teachersdomain.org/resources/tdc02/sci/life/gen/mitosis/index.html

How Genetic Disorders Are Inherited. http://www.teachersdomain.org/resources/tdc02/sci/life/gen/inherited/index.html

Is Love in Our DNA? http://www.teachersdomain.org/resources/tdc02/sci/life/evo/islovedna/index.html

Inside a Seed. http://www.teachersdomain.org/resources/tdc02/sci/life/stru/insideseed/index.html

Journey into DNA. http://www.teachersdomain.org/resources/tdc02/sci/life/gen/journeydna/index.html

Masters of Disguise. http://www.teachersdomain.org/resources/tdc02/sci/life/colt/disguise/index.html

Mendel's Law of Genetic Inheritance. http://www.teachersdomain.org/resources/hew06/sci/life/gen/mendelinherit/index.html

Microbe Clock. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/microbeclock/index.html

Mimicry: The Orchid and the Bee. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/mimicry/index.html

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Monohybrid Cross in Fast Plants. http://www.fastplants.org/activities.variation.monohybrid.php#menu

Organelles in the Cytoplasm. http://www.teachersdomain.org/resources/tdc02/sci/life/cell/organelles/index.html

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Shape of Trees: The Frustration Principle. http://www.teachersdomain.org/resources/tdc02/sci/life/evo/shapetrees/index.html

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Teachers' Domain of Multimedia Resources for the Classroom and Professional Development. WGBH Educational Foundation. http://www.teachersdomain.org/app/asset_download/license/tdc02_vid_comgencode

Understanding Genetic Disorders. University of Utah, Genetic Science Learning Center. http://gslc.genetics.utah.edu/units/disorders/ *

* Denotes resources where permission has been requested, but not yet received.

Table of Contents

Unit Overarching Concepts

- Populations of living organisms change or stay the same over time as a result of the interactions between the genetic variations that are expressed by the individuals in the populations and the environment in which the population lives.
- Science knowledge advances through inquiry.

Unit Supporting Concepts

- Individual organisms with certain variations of traits (adaptations) are more likely than others to survive and reproduce successfully.
- When environmental conditions change it can affect the survival of both individual organisms and entire species.
- Natural selection determines the differential survival of groups of organisms.
- A small advantage in escaping a predator, resisting a drug, etc. can lead to the spread of a trait in a modest number of generations.
- Mutations are a source of variation in an individual's genotype, and it can result in a change in phenotype—good or bad.
- Scientific progress is made by asking meaningful questions and conducting careful investigations, using appropriate tools and technology to perform tests, collect data, analyze relationships, and display data.
- No matter how well one scientific explanation fits observations, a new explanation might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of explanations, new and old, never ends.

Evidence of Student Understanding

By the end of this unit, the student will be able to:

- *Describe how the frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time.*
- *Explain how evolution is the result of genetic changes that occur in constantly changing environments.*
- *Identify and engage in all aspects of scientific inquiry.*
- *Explain how studying natural phenomena through scientific inquiry advances knowledge.*
- *Apply their knowledge of inheritance and the interaction of genetics and environment to explain how a population of living organisms can change over time.*
- *Recognize how science knowledge progresses over time.*
- *Effectively design, conduct, and analyze experimental results, and develop a strong scientific explanation.*

Unit Preview

Earth changes; we know that because we hear about it on the news when events like earthquakes occur, and we learn about discoveries that reveal how large climate changes happened in the past. How do these changes impact the populations of living organisms inhabiting Earth? What is the scientific explanation for how populations keep up with Earth's changes, and what happens when they do not? Those questions underpin this Immersion Unit.

Through multiple scientific inquiries, some conducted through experimentation and some conducted through research, this Immersion Unit engages students in an in–depth study of key genetics concepts and evolution.

Exploring Populations focuses on the overarching question: *What causes populations to physically change or stay the same over generations?* The evidence for the answer depends on understanding the relationships among genotype, phenotype, environment, inheritance, and selection. Throughout this Immersion Unit, students collect and synthesis the evidence that culminates in understanding the explanation for the answer to the overarching question.

Students develop understandings to explain that:

- Populations are made up of individuals that differ due to genetic variation.
- Populations change or stay the same over time in response to environmental factors.
- Some genetic variations cause individuals to express traits that give a small advantage in growth and/or reproduction in a particular environment.
- Natural selection for these advantageous traits can change a population living in that environment in a modest number of generations.

By engaging in guided inquiries in this unit, students uncover many lines of evidence that support their understanding of genetics and evolution. They inquire to develop an explanation for data showing changes in average human height, investigate genotypes, phenotypes and inheritance in Wisconsin Fast Plants and yeast, and develop explanations for the development of antibiotic–resistant bacteria. In addition, students apply their growing understanding to explain the connections among phenotype, genotype, and the regional distribution of sickle cell disease. Integrated throughout the unit, video clips and interactive animations illustrate abstract ideas and add interesting elements to lessons.

Students and teachers alike will find this unit to be a compelling and intriguing inquiry into how populations can change over time.

Unit Standards

Biology/Life Sciences - Grades Nine Through Twelve Science Content Standards

Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content of the other four strands, students should develop their own questions and perform investigations. Students will:
   a. Select and use appropriate tools and technologies (such as computer–linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
   b. Identify and communicate sources of unavoidable experimental error
   c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
   d. Formulate explanations by using logic and evidence.
   g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.
   i. Analyze the locations, sequences, or time intervals that are characteristic of natural phenomena (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).
   j. Recognize the issues of statistical variability and the need for controlled tests.
   k. Recognize the cumulative nature of scientific evidence.
   l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
   m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.

Genetics

2. Mutation and sexual reproduction lead to genetic variation in a population. As a basis for understanding this concept:
   a. Students know meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
   b Students know only certain cells in a multicellular organism undergo meiosis.
   c. Students know how random chromosome segregation explains the probability that a particular allele will be in a gamete.
   d. Students know new combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
   e. Students know why approximately half of an individual’s DNA sequence comes from each parent.
   g. Students know how to predict possible combinations of alleles in a zygote from the genetic makeup of the parents.
3. A multicellular organism develops from a single zygote, and its phenotype depends on its genotype, which is established at fertilization. As a basis for understanding this concept:
   a. Students know how to predict the probable outcome of phenotypes in a genetic cross from the genotypes of the parents and mode of inheritance (autosomal dominant or recessive).
   b. Students know the genetic basis for Mendel’s laws of segregation and independent assortment.
4. Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism. As a basis for understanding this concept:
   a. Students know the general pathway by which ribosomes synthesize proteins, using tRNAs to translate genetic information in mRNA.

b. Students know how to apply the genetic coding rules to predict the sequence of amino acids from a sequence of codons in RNA.
c. Students know how mutations in the DNA sequence of a gene may or may not affect the expression of the gene or the sequence of amino acids in an encoded protein.
e. Students know proteins can differ from one another in the number and sequence of amino acids.

Evolution

7. The frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time. As a basis for understanding this concept:
   a. Students know why natural selection acts on the phenotype rather than the genotype of an organism.
   b. Students know why alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.
   c. Students know new mutations are constantly being generated in a gene pool.
   d. Students know variation within a species increases the likelihood that at least some members of a species will survive under changed environmental conditions.
8. Evolution is the result of genetic changes that occur in constantly changing environments. As a basis for understanding this concept:
   a. Students know how natural selection determines the differential survival of groups of organisms.
   b. Students know a great diversity of species increases the chance that at least some organisms survive major changes in the environment.
   c. Students know the effects of genetic drift on the diversity of organisms in a population.
   d. Students know reproductive or geographic isolation affects speciation.

Unit Timeline

Step	Lesson	Time	Key Concepts
Step 1	Lesson 1.1 Generations	50 minutes	Introduction to the Unit and the overarching question: *What causes populations to physically change or stay the same over generations?*
	Lesson 1.2 Analyzing Data	50 minutes	Scientists look for patterns in data that might be evidence to explain natural phenomena. Scientists give priority to evidence when formulating explanations. Scientific explanations are constructed of claims that are supported by evidence and strong reasoning.
	Lesson 1.3 What Do Scientists Think?	100 minutes	Predictions (hypotheses) are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available). In science, explanations that are not supported by evidence are given little credibility. The way that traits are expressed is influenced by many factors, diet, medical care, environmental conditions, and personal health behaviors. Populations can change over generations as a result of changes in their environment.

Step	Lesson	Time	Key Concepts
Step 2	Lesson 2.1 Taller and Taller?	50 minutes	In science, one explanation typically leads to more questions. Genes are a set of instructions encoded in the DNA sequence of each organism that specify the possible versions of traits, like height, that an organism can have. The traits expressed in an organism are determined by a combination of genes and environment.
	Lesson 2.2 Can We Predict Future Variations?	Five 50–min. class periods (ideally started on a Monday)	Model organisms are used in science for a variety of reasons, including the ease with which they grow and develop in a laboratory and the time it takes to complete a lifecycle. Meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type. Only certain cells in a multicellular organism undergo meiosis. Random chromosome segregation explains the probability that a particular allele will be in a gamete. New combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization). Approximately half of an individual's DNA sequence comes from each parent. One can predict possible combinations of alleles in a zygote from the genetic makeup of the parents.
Step 2	Lesson 2.3 Investigating Variation in Wisconsin Fast Plants	50 minutes	The genotypes of the individuals in a population determine the variation that is possible in that population. While the environment can affect how the traits are expressed, the potential for the traits is determined by the genotypes in the population. The majority of inherited traits are challenging for scientists to fully understand because they are determined by a variety of interactions among multiple genes. If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables.

Step	Lesson	Time	Key Concepts
Step 3	Lesson 3.1 New Traits	50 minutes	In science, one explanation typically leads to more questions. Yeast can serve as a model organism for understanding how the genetic code affects a population's ability to survive changing environmental conditions. Changes in DNA (mutations) occur randomly. Some of these changes make no difference to the organism, whereas others can change cells and organisms.
	Lesson 3.2 Comparing Similar Populations	Two 50–min. class periods (consecutive days)	Mutations in the DNA sequence of a gene may or may not affect the function or expression of the gene. Mutation can lead to genetic variation in a population. The genotypes of individuals within a population combined with the type and intensity of environmental change influences both the survivability of that population and how or if the population will change over time. A small advantage in growth / reproduction can change a population in a modest number of generations. Scientific progress is made by asking meaningful questions and conducting careful investigations, using appropriate tools and technology to perform tests, collect data, analyze relationships, and display data.
Step 3	Lesson 3.3 Mutations that Improve Survival	50 minutes	When environmental conditions change it can affect the survival of both individual organisms and entire species. Natural selection determines the differential survival of groups of organisms. There is always competition for resources and usually variation in populations, and hence selection is usually operating in natural populations. A small advantage in escaping a predator, resisting a drug, etc. can lead to the spread of a trait in a modest number of generations. Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects.

Step	Lesson	Time	Key Concepts
Step 4	Lesson 4.1 A Scientific Explanation for a Personal Mystery	150 minutes	Physical symptoms for genetic conditions are the individual's phenotype. Protein production in cells is what determines how the cells in an individual's body function. DNA codes for RNA that codes for the sub-molecules that are bonded together through protein synthesis to form chains, which are proteins. These proteins are essential for life. A small advantage, such as surviving a disease common in a population's environment, can lead to the spread of a trait in a modest number of generations. Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way. New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators.
	Lesson 4.2 A Scientific Explanation for Change in a Population	50 minutes	Mutation and sexual reproduction lead to genetic variation in a population. Evolution is the result of genetic changes that occur in constantly changing environments. A small advantage in escaping a predator, resisting a drug, etc. can lead to the spread of a trait in a modest number of generations. Natural selection explains a mechanism for evolution. Natural selection leads to organisms that are well suited for survival in particular environments.

Support Materials

Immersion Unit Toolbox and CD

The Immersion Unit Toolbox is central to this curriculum. It is a separate guidebook that discusses the concepts inherent in teaching science through immersion units. These concepts include engaging in scientifically oriented questions, giving priority to evidence in responding to questions, and formulating explanations from evidence.

The Toolbox also describes several pedagogical approaches (Think-Aloud strategies, for example) that are key to how these units work. Most of the strategies in the Immersion Unit Toolbox support student engagement in scientific inquiry based on the Five Essential Features of Classroom Inquiry (NRC, 2000).

Before you use *Exploring Populations* in your classroom, you may find it helpful to spend some time becoming familiar with the concepts addressed in the Immersion Unit Toolbox. It is also specifically referenced throughout the unit where the strategies in the Toolbox would likely be helpful to consider.

This Immersion Unit comes with a data CD containing multimedia files for use at various points throughout the unit. The best use of the materials can vary; sometimes, showing the referenced video clip and/or animation to the whole class from one projected computer is the best way to facilitate student learning, and sometimes students could be directed through working individually or in pairs at computers in a lab, if that is an option for you.

Here is a brief overview of some of the strategies you can use in your classroom.

Science Inquiry Map

The Science Inquiry Map on the following page illustrates the Five Essential Features of Inquiry. You can use this map in your classroom when you introduce Immersion Units to your students.

The science inquiry process is dynamic and does not necessarily follow a linear order. For example, a student may develop an explanation that leads to a new scientific question, or that student may revisit evidence in light of alternative explanations. On some occasions multiple features of an explanation may overlap, or, depending on the type of lesson, some features may have more emphasis than others. These variations allow learners the freedom to inquire, experience, and understand scientific knowledge. The Five Essential Features of Inquiry describe how engaging in science inquiry unfolds in the classroom.

Student Groups

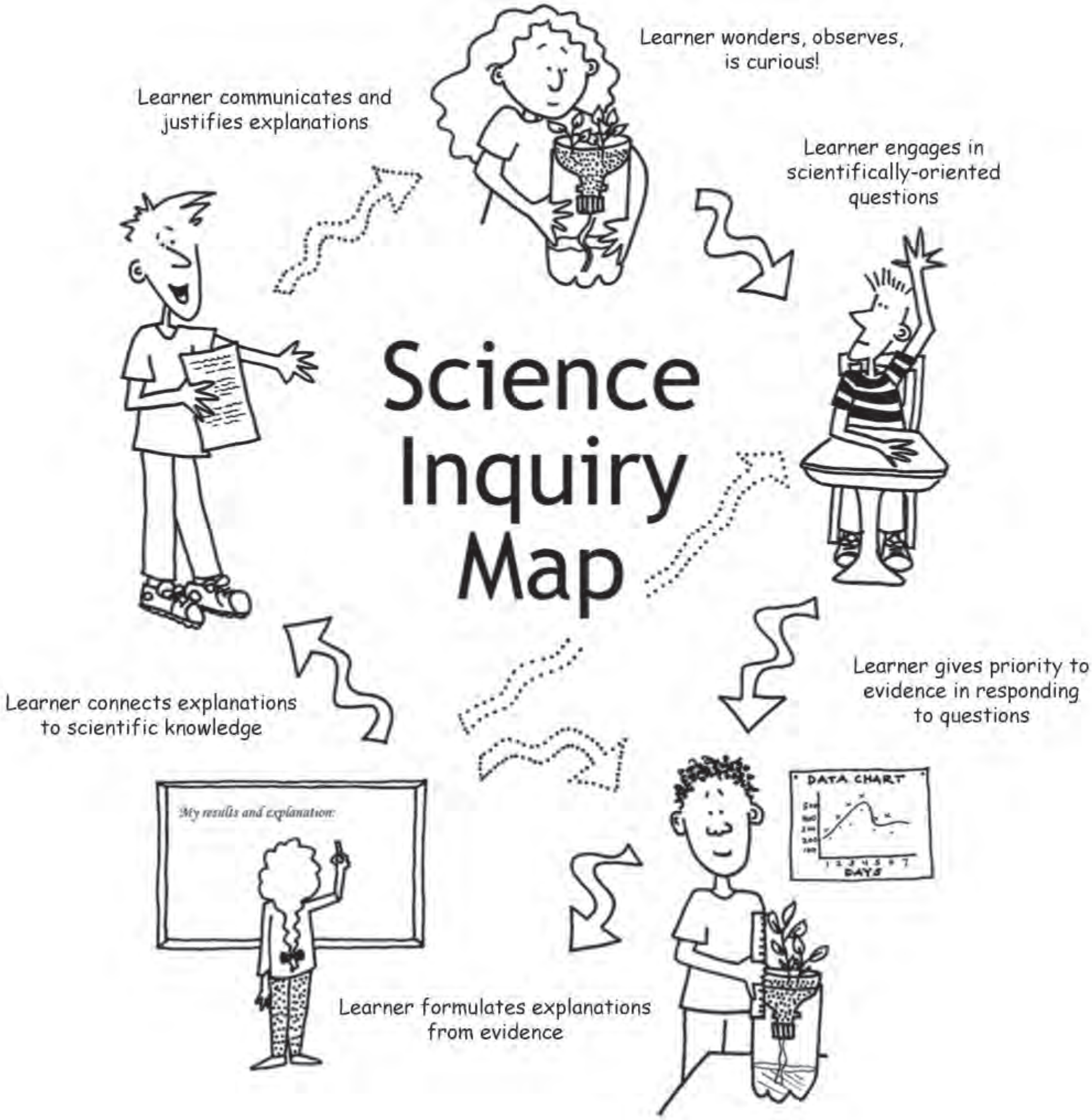
In this unit, students often work in groups. When working as a team in a group, the ideal is to have groups no larger than four students. Whatever the group size is, all students in the team need to have a job to do so they are individually accountable for focusing on the current science lesson.

Think-Pair-Share

Think-Pair-Share is a cooperative learning technique that allows students to think before they respond to a prompt, to test their response on their partner, and then to share their response (possibly revised) with a larger group. Specific instructions for implementing the Think-Pair-Share strategy are discussed in the Immersion Unit Toolbox. *Exploring Populations* uses this technique throughout the unit.

REAPS

REAPS is a method of formative assessment that combines the time-tested ideas of Blooms Taxonomy with new research on student assessment. The level of thinking increases from basic recall to complex analysis and predictions. On each Lesson Snapshot page is a series of REAPS prompts. This series of prompts is a simple tool that can be used throughout or at the end of each lesson. They can be used individually, in pairs or in groups to review what students know and are able to do. This provides an opportunity for the teacher to modify instruction as necessary based on student responses.


Science Inquiry Map
Learner wonders, observes, is curious!
Learner engages in scientifically-oriented questions
Learner gives priority to evidence in responding to questions
DATA CHART
DAYS
Learner formulates explanations from evidence
My results and explanation:
Learner connects explanations to scientific knowledge
Learner communicates and justifies explanations

Here are the types of prompts included in the REAPS.

R **Recall** new knowledge: Determines whether the student has learned the basic knowledge that is related to and supports the key concept including lists, drawings, diagrams, definitions.

E **Extend** new knowledge: Determines whether the student can organize the basic knowledge related to the key concept such as compare, contrast, classify.

A **Analyze** knowledge: Encourages the student to apply or interpret what they have learned including developing questions, designing investigations, interpreting data.

P **Predict** something related to new knowledge: Engages the student in thinking about probable outcomes based on observations and to engage them in a new topic that builds on prior knowledge.

S **Self/Peer Assess**: Encourages students to take responsibility for their own learning. Includes methods and/or activities for students to assess their own learning and/or that of their peers.

The prompts increase in cognitive difficulty with Recall as the easiest and Predict as usually the most advanced. Students most likely demonstrate confidence and ability when responding to the first few prompts, while demonstrating continuous improvement in responding to the Apply and Predict prompts. Students are not expected to master all of the skills, but are encouraged to extend their thinking.

Suggested responses are included in italics after the prompts. More detailed responses are included in the implementation guides for each lesson. While these are good responses, other responses may be valid with supportive evidence and reasoning.

Exploring Populations: Unit Level Graphic Organizer

NOTE: Throughout the unit, students are guided to construct the first two columns of the following sample Unit Level Graphic Organizer (ULGO) as a strategy for explicitly linking what is learned in each step back to the overarching unit key concepts and guiding question: ***What causes populations to physically change or stay the same over generations?*** The Lessons prompt you to have each class develop a Unit Level Graphic Organizer over time. The ULGO is built by guiding the class to add an entry after completing key lessons (those lessons that culminate in a scientific explanation that contributes to answering the unit's guiding question). Additions to the ULGO are specifically prompted to be made at the end of Lessons 1.3, 2.2, 2.3, 3.1, 3.2, and 4.1. The Snapshot pages for those lessons reads:

> You may choose to copy a blank ULGO on an overhead transparency, post a large version on chart paper that remains in the room, or use another method for constructing a whole class version of the chart. In addition, we recommend that students individually record the ULGO in their science notebooks for reference throughout the unit's lessons and as a resource for the final, Step 4 summative assessment lesson.

The following table depicts both the possible types of understanding that students may have as they progress through the unit as well as the benchmark understandings that they need to have when they complete each Engage→Explore→Explain cycle. The benchmark understandings are marked in shaded rows within the table; these represent the points in time when the instructions direct you to have the class make an entry in their Unit Level Graphic Organizer.

Example Unit Learning Progression (note: first two columns of shaded rows describe possible entries to the class's Unit Level Graphic Organizer)

Overarching Unit Question: ***What causes populations to physically change or stay the same over generations?***

lesson	what we think we know (claim at this point in time related to the unit question)	how we think we know what we know (evidence and their sources for the claim)	teacher notes about possible student logic and reasoning at this point in time
1.1	• Previous generations of human populations were made up of individuals who may have been smaller than we are now.	• prior knowledge, including experiences being in old homes, seeing pictures of ancestors, etc. • some information provided in class, including photographs from an old farmhouse, athlete size statistics over time, and the calculation of class averages for height and shoe size	Students may or may not have ever thought about their ancestors having been generally smaller in stature; however, both the idea and the evidence for it are engaging. This engaging exploration into humans directly relates to all students and effectively kicks off the unit's investigation into how populations change. Students are encouraged to formulate initial ideas without critique in this lesson.
1.2	• In the last 100 years or so, most human populations have increased in stature, and that is an example of a population changing over time. • The kinds of nutrition and health care available have changed over the generations, and this may be related to the changes in stature.	• Additional data provided on student pages about human height, cereal production, etc. • Discussion about an article that documents increases over time in human height for a variety of populations	Students need to be guided to select which evidence in the data they see as pertinent, identify why they think it is pertinent, and clearly state a claim based on that evidence they select. At this point, student ideas need to be challenged—they must be supported logically by the available evidence.
1.3	• When access to good nutrition and health care improves, humans grow taller are healthier and live longer. • The type of physical labor that individuals engage in during their lives also impacts their stature, health and longevity. • Nutrition is an environmental factor. • Environmental factors influence the variation in the traits that are expressed in a population. • Populations change or stay the same over time in response to environmental factors.	• Student page with an article by a noted scientist who studies historical changes in human stature and longevity.	By comparing their own explanations to an accepted explanation from the scientific community, students clarify their understanding. The article also serves as a strong example of how scientific inquiry in the field involves curiosity, questioning, observing and a tremendous amount of data collection.

Example Unit Learning Progression (note: first two columns of shaded rows describe possible entries to the class's Unit Level Graphic Organizer)

lesson	what we think we know (claim at this point in time related to the unit question)	how we think we know what we know (evidence and their sources for the claim)	teacher notes about possible student logic and reasoning at this point in time
2.1	• Environmental factors (nutrition is an example) are not the only thing that determines the traits we see. • Inheritance and the genetic code determines what traits are possible for an organism to have.	• Student page showing a correlation between parents' and offsprings' heights.	This is a lesson designed to serve as a transition in focus from environmental influences on variation to genetic influences on variation.
2.2	• Knowing the parents' genotype, one can predict the likely genotypes—and so, the likely phenotypes—in the offspring (the next generation). • Populations are made up of individuals that differ due to genetic variation.	• Teacher–guided Wisconsin Fast Plants experiment with three generations of seedlings (designed around the inheritance of the purple and non–purple stem trait) • Supporting lessons about meiosis and inheritance • Supporting lessons about modes of inheritance—Mendelian genetics	Refer to the teacher pages for more specific information about how students' explanations for the inheritance patterns they observed in the Fast Plants experiment occur in two stages, starting with initial, basic claims and building to thorough scientific explanations based on what is known about dominant/recessive modes of inheritance.
2.3	• An individual's genotype determines the possible phenotype it will have. • An individual's environment influences how its phenotype will be expressed.	• Student–centered Wisconsin Fast Plants experiment with purple–stem seedlings in different environments • Previous lessons	Students apply and combine what they learned in Step 1 and Step 2 in this lesson, providing an opportunity to check for understanding. At this point, students need to be clear that the observable traits an organism possesses are determined by a combination of genotype and environment.
3.1	• New genotypes can be introduced into a population if a mutation occurs in an individual's DNA. • Only some mutations that result in readable DNA might code for a trait. • Only some traits that result from mutation can be passed down to offspring.	• Interactive lesson on mutations • Application of standards included in Component 1	The concept of mutation is introduced in LAUSD Biology Instructional Guide Component 1. This lesson does not focus on the mechanisms of mutation or the terminology and types of mutations. Instead, this lesson emphasizes mutation as a source of variation.

Example Unit Learning Progression (note: first two columns of shaded rows describe possible entries to the class's Unit Level Graphic Organizer)

lesson	what we think we know (claim at this point in time related to the unit question)	how we think we know what we know (evidence and their sources for the claim)	teacher notes about possible student logic and reasoning at this point in time
3.2	• Some mutations cause those individuals who have it to have a different chance for survival. • The environment has a strong influence on whether a trait will affect survivability. • In an environment in which a mutation leads to a trait that makes individuals unable to survive, a whole population could become extinct. • Variation in a population makes it more likely to survive if the environment changes.	• Experimental data about the survivability of two yeast populations (one with a mutation causing UV sensitivity and one wild type) gathered through an investigation into the effects of different types of light exposure (environmental factors). • Student pages about Ultraviolet light and mutations. • Class discussions.	Understanding variation in heritable traits is foundational in this unit, and students need to be clear about what a trait is. The yeast experiment builds on the work with a heritable purple stem trait in Wisconsin Fast Plants, and provides an experience with a trait that occurs at the molecular level—the ability to repair damage caused by ultraviolet light. Students need to understand that a trait can be something that is expressed by the cells of the individual (in this case, the yeast is a single–celled organism, but in other instances a trait for a multicellular organism can also be cellular).
3.3	• Some mutations, or genetic variations, cause individuals to express traits that give a small advantage in growth and/or reproduction in a particular environment. • Natural selection for advantageous traits can change a population living in that environment in a modest number of generations.	• Tuberculosis case study video and analysis of the case. • Knowledge of natural selection from Grade 7 standards. • Possible extension exercises, using natural selection simulation software.	In both cases of mutation studied in Step 3 the organisms with the mutation were single cellular. It is important to check for students' understanding: in multicellular organisms who reproduce sexually, only those mutations that occur in the sex cells can be passed down to offspring. Therefore, populations of single–celled organisms, which also have a much faster generational cycle, can change as a result of environmental changes in a relatively short time period. This case study allows students to consider the very real impact that a new environmental factor, the presence of antibiotics, has on populations of tuberculosis bacteria.

Example Unit Learning Progression (note: first two columns of shaded rows describe possible entries to the class's Unit Level Graphic Organizer)

lesson	what we think we know (claim at this point in time related to the unit question)	how we think we know what we know (evidence and their sources for the claim)	teacher notes about possible student logic and reasoning at this point in time
4.1	• Natural selection for heritable, advantageous traits can change a population living in that environment in a modest number of generations.	• Information obtained through a story about a girl who learns she has the sickle cell trait. • Case study video about sickle cell and its regional distribution in Africa. • Lessons learned up to this point in the unit and DNA standards learned in LAUSD Biology Instructional Guide Component 1.	Students have an opportunity in this lesson to: • develop and apply a clear understanding of the link between genotype and phenotype • analyze the effects of variations in gene expression • learn about significant differences in phenotype that can result from homozygous and heterozygous genotypes (in the case of a polymorphism such as sickle cell) • Learn about an important piece of evidence that natural selection is a mechanism for change in a population—the variation in genotypes that occurs in human populations who live with malaria, where selection favored the heterozygote and disfavored the homozygote for sickle cell. This lesson represents an important formative assessment opportunity —check for students' understanding and readiness to analyze and interpret the scenarios in the summative assessment (Lesson 4.2).
4.2	• Populations are made up of individuals that differ due to genetic variation. • Populations change or stay the same over time in response to environmental factors. • Some genetic variations cause individuals to express traits that give a small advantage in growth and/or reproduction in a particular environment. • Natural selection for these advantageous traits can change a population living in that environment in a modest number of generations.	• Drawing from all lessons learned throughout the unit to interpret a scenario based on the real evolution of bacteria populations that are resistant to penicillin.	This short essay summative assessment could be complimented with additional assessment items to give students more opportunities to demonstrate their understanding of and ability to apply the unit's concepts.

Unit Overview

Populations of living organisms change or stay the same over time as a result of the interactions between the genetic variations that are expressed by the individuals in the populations and the environment in which the population lives.

STEP 1 | **STEP 2** | **STEP 3** | **STEP 4**

Lesson 1.1 Engage/Explore

This 50-minute lesson is intended to engage students in wondering about generational differences in human populations as an introduction to the unit. Students look at patterns while considering data about height, weight and shoe size to see if populations can change over time. Class averages of height, shoe size, etc. are calculated. Students create a class histogram to visualize variation in height.

Guiding Question

How would you explain similarities and differences between your generations and your Great, Great, Great, Great Grandparents' generation?

Lesson 1.2 Explore/Explain

Students give priority to different pieces of data as evidence for an explanation about how variation in human height within populations has changed over generations. This is a 50-minute lesson. Students consider additional human population data (changes in mean height in Europe, food availability, world nutrition and economic indicators). This lesson introduces the key parts of a scientific explanation and gives students their first opportunity to make claims based on observations and data. Logic and reasoning is expected to be limited based on data limitations.

Guiding Question

What additional evidence would we need to substantiate a claim that changes in environment have caused humans to increase in stature over the last several generations?

Lesson 1.3 Explain

This final lesson in the Unit's first Engage→Explore→Explain cycle, students compare their explanations for increases in average human stature to a scientist's explanation for how human populations have changed over time. They are given a reader-friendly article by noted scientist, Dr. Robert Fogel, who collected substantial evidence about human improvements in health, longevity and changes in height to show that populations can change over generations as a result of changes in the environment. Students have an opportunity to revise their explanations in light of this article.

Guiding Question

How have changing environmental factors, including nutrition, affected the human population?

Standards addressed in Step 1: 1a, 1d, 1k. Review of key concepts that must be understood from the Grade 7 Life Science standards and introduction to the Evolution standards.

Key Concept

- Introduction to the Unit and the overarching question: *What causes populations to physically change or stay the same over generations?*

Evidence of Student Understanding

The student will be able to:

- articulate the essence of the guiding question for the unit.

Time Needed

50 minutes

Materials

For each student

- 1 copy of Student Pages 1.1A-C ***What's Going On?***
- ½ of a 3"x5" note card or Post It note

For each group of 4 students

- metric tape measure or meter stick

For the class

- class data table(s) as needed
- wall space for a class histogram
- masking tape
- CD–ROM for *Exploring Populations*

Generations

Engage/Explore:

1. Introduce this new unit to the class by posing the questions, ***How would you explain similarities and differences between your generation and your Great, Great, Great, Great Grandparents' generation? What do you think the similarities and differences would be if you compared yourself to family members who lived several generations before you?*** Spend the first few minutes having students think about this question to just trigger students' thinking without yet asking for answers. Students will likely generate a mix of ideas that may or may not include some physical differences between themselves and previous generations. The purpose here is to simply engage students' thinking about generations without trying to steer the direction at this point.

   Follow up with a brief explanation that over the next several weeks, your class will engage in this unit, *Exploring Populations,* to develop a scientific understanding about populations through generations.

   By the end of the unit, the class will have gathered much information to explain the similarities and differences between their generation and their Great, Great, Great, Great Grandparents' generation.

2. Explain to the class your expectations for using Science Notebooks during this unit (see the Immersion Toolbox for Science Notebook strategies). Individually, have students prepare a place in their notebooks for recording questions that arise and ideas generated in this lesson.

   You may wish to also assign students into groups at this time. Groups of four students will work together later in the lesson to analyze data.

3. Ask the class what evidence they would need to have to answer the question about what causes similarities and differences between their own generation and a generation that lived 100 years ago. Use a line of prompts like the following to guide students to realize what type of evidence is needed:
   - What do we know about OUR generation? Record a list that the class generates by brainstorming.

Continued on following page

- What data could we collect right here in class about this generation?
- Then, what other data would we need to gather to help us use our class data to answer the question?

Explain that the class will begin with the data that can be collected in class, but students need to be thinking about where to look for the other kinds of data and information that will be needed—information about generations in the past as well as more information about their generation.

4. Help students acknowledge that having as much information as possible is important when working in science to answer a question. Restate the question for this lesson, *How would you explain similarities and differences between your generation and your Great, Great, Great, Great Grandparents' generation?* and review the observations and data that the class currently has. Emphasize that the focus is on human size at this point (though initial ideas about differences between this and previous generations may have included ideas like societal changes).

   Provide space for class data tables about shoe size, height, furniture size, etc., and allow 20–25 minutes for students to gather and record some data to calculate class averages.

   Additional time can be provided during the next lesson as needed.

   - Guide the class to generate a histogram representing students' heights using the following strategy. ***Save this histogram for later reference as an example of an inherited trait that is controlled by multiple genes.***
     a. Individually in their Science Notebooks, have students draw one graph (histogram A) that shows their prediction for what a graph of the variation in height of their classmates will look like.
     b. Use masking tape and paper to make and label x and y axes on a large wall in your classroom, in the hall, or another large open area. The x–axis will be ***number of students*** with a range of 0 to 10 being sufficient, and the y–axis will be will be ***height in centimeters*** (have students determine an appropriate range for their class using increments of 5 centimeters).

        NOTE: The scale of the graphing area needs to be large enough for each student to post half of a note card or Post It note to represent their height.
     c. Have students measure their height in centimeters (round to the nearest 5 centimeters) and record it on half of a note card or Post It note (all students need to use the same size card).
     d. Direct students to post their height cards to develop a histogram.

   Direct student groups to discuss the data generated by the class and to calculate the average.

5. Ask the class, Do you think you would have the same average height data if you only did the girls in class? Would it be the same for a senior class? For the whole school?

   Explain that using data from class as evidence for average height and shoe size for the current generation is limited by the number of individuals measured and the fact that everyone measured is in the same grade, lives in the same region of the United States, etc. Therefore, it is important to look at additional data about this generation.

   - Briefly, discuss where one might look for data about average height for people in the world or in specific regions of the world. Students may suggest the Internet, and the discussion can go deeper if you ask for suggestions about what sources on the Internet you would consider most reliable for this kind of information.
   - Share that you have some sources of information from the World Health Organization's website that gives average adult height around the world.
   - Review the World Health Organization data on Student Page 1.1A, and compare it

to the class data. Discuss similarities and differences.

6. Pose the following question to the class: What other evidence do we need to begin to answer the original question: How would you explain similarities and differences between your generation and your Great, Great, Great, Great Grandparents' generation?
   - Guide the discussion as needed so that students acknowledge the need for data about past generations that is similar to the data they have for the current generation so that comparisons can be made.
   - Distribute Student Pages 1.1B. Provide time for students to read and wonder about this new information.
7. Explain to the class that important evidence sometimes comes in the form of data in tables, from observations like those made in the photographs, and sometimes in scientific journals, or articles. Share that you have a story that was written in a college magazine that seems to have some interesting information about shoe sizes in both this generation and previous generations.

   Read the story on Student Page 1.1C aloud to the class or use a reading strategy that supports all students to understand the key points.
8. Explain that the next lesson will involve gathering more information about the changes that have happened over the last century's generations, so what is discussed at this time will likely still include quite a bit of speculation.

   Individually, have students record in their Science Notebooks what they predict (at this point in time) is similar and different about their generation and populations living 4 generations ago.

   Resist the temptation to look for answers or explanations for any inferences about how the population has increased in size over time and through generations.

   Conduct a whole–class discussion about particularly interesting observations that students made about the data, and encourage volunteers to share their views about possible causes for trends observed.
9. Post the Unit's overarching question, *What causes populations to physically change or stay the same over generations?* where it can remain, and explain that this first lesson is just the start of an extended inquiry into this question. As a class, you will explore and gather evidence throughout the unit to explain an answer to this question.
10. Use the REAPS questions to stimulate further class discussion and as closure, or assign them as homework and review at the start of the next lesson.

REAPS

R What was the time period for the data about average basketball player height? *1951–1999.*

E Approximately how many generations would you expect to have existed during that time? *If you assume approximately 25 years for a human generation, then the timespan given involves about two generations.*

A What in the data that you analyzed today did you find most interesting? *Responses to the Analysis and Predict REAPS questions will depend on the individual student. This lesson is intended to engage students in an initial common experience that is relevant to the Unit's overarching question, so students are not expected to draw conclusions at this time.*

P Before looking at the data today, what kind of differences might you have expected to see between people living six or seven generations before you?

S What did you think about when you tried to picture differences and similarities in the generations that came before you? For example, did you think about certain differences between yourself and your mother, grandmother, grandfather, or aunts and uncles? *Use student responses to this question to get a sense of students' current understandings about inheritance and, perhaps, their ideas about environmental influences on phenotype.*

Average adult height around the world

Below is a table of average heights measured around the world. These figures are assembled from very widely disparate sources (listed following the table) for purposes of illustration only, and may or may not be authoritative, depending on the reader's standards. *Source: World Health Organization Publication*

	Metric system		Imperial system		
Country/Region	Males	Females	Males	Females	Age range sampled
Australia	178.4 cm	163.9 cm	5 ft 10.2 in	5 ft 4.5 in	18-24 (measured)
Australia	179.8 cm	164.8 cm	5 ft 10.8 in	5 ft 4.9 in	18-24 (self reported)
Brazil	168.9 cm	160.3 cm	5 ft 6.5 in	5 ft 3 in	Adult population
Brazil	175.5 cm	165 cm	5 ft 9.2 in	5 ft 5 in	17-19(measured)
Canada	174.0 cm	161.0 cm	5 ft 8.5 in	5 ft 3.4 in	adult population (measured)
Canada	180 cm	165 cm	5 ft 11 in	5 ft 5 in	18-24 (self reported)
China (PRC)	164.8 cm	154.5 cm	5 ft 4.9 in	5 ft 0.8 in	30-65 (measured)
Czech Republic	180.3 cm	167.3 cm	5 ft 11 in	5 ft 6.0 in	18 (measured)
Denmark	180.3 cm	165.2 cm	5 ft 11 in	5 ft 5.0 in	18-24 (measured)
Dinaric Alps (Serbia/ Montenegro)	186 cm	171 cm	6 ft 1.1 in	5 ft 7.3 in	17
Estonia	179.5 cm		5 ft 10.5 in		17
France	173.2 cm	161.8 cm	5 ft 8.1 in	5 ft 3.7 in	
France	176.6 cm	164.0 cm	5 ft 9.5 in	5 ft 4.5 in	20-39 measured
France	175.7 cm	162.5 cm	5 ft 9 in	5 ft 4.0 in	
Finland	176.7 cm	163.5 cm	5 ft 9.5 in	5 ft 4.3 in	
Finland	178.2 cm	164.7 cm	5 ft 10 in	5 ft 4.7 in	15-64 (self reported)
Germany	178.1 cm	165 cm	5 ft 10 in	5 ft 4.9 in	over 18
Iceland	181.7 cm	167.6 cm	5 ft 11.5 in	5 ft 6 in	20
Israel	175.4 cm	163.3 cm	5 ft 9 in	5 ft 4.2 in	20+ (between 1980-2000)
Italy - Middle & North	176.9 cm	163.2 cm	5 ft 9.5 in	5 ft 4.2 in	20(between 1994-2000)
Italy - South	174.2 cm	160.8 cm	5 ft 8.6 in	5ft 3.3 in	20(between 1994-2000)
Japan	166.7 cm	153.0 cm	5 ft 5.2 in	5 ft 0.2 in	
Japan	170.8 cm	158.0 cm	5 ft 7.1 in	5 ft 2.4 in	17
Japan	169.2 cm	157.2 cm	5 ft 6.6 in	5 ft 2.1 in	20
Korea, South	173.6 cm	161.0 cm	5 ft 8.3 in	5 ft 3.3 in	17
Korea, South	174.3 cm	161.2 cm	5 ft 8.6 in	5 ft 3.4 in	20
Korea, South	173.6 cm		5 ft 8.3 in		19 examination for conscription
Lithuania	181.0 cm	167.6 cm	5 ft 11.5 in	5 ft 6.0 in	20
Malta	169 cm	159 cm	5 ft 6.5 in	5 ft 2.6 in	all adult population
Malta	175.2 cm	163.8 cm	5 ft 9 in	5 ft 4.5 in	25-34
Malta	165.3 cm	156.8 cm	5 ft 5 in	5 ft 1.7 in	65+

Continued on following page

Continued from previous page

	Metric system		Imperial system		
Country/Region	Males	Females	Males	Females	Age range sampled
Netherlands	178.8 cm	167.1 cm	5 ft 10.3 in	5 ft 5.7 in	
Netherlands	181.8 cm	170.1 cm	5 ft 11.5 in	5 ft 7 in	university/college age
Netherlands	183.0 cm	170.6 cm	6 ft 0 in	5 ft 7.2in	21
New Zealand	177.0 cm	165.0 cm	5 ft 9.7 in	5 ft 5 in	19-45
Norway	180 cm	167.2 cm	5 ft 10.8 in	5 ft 5.9 in	men measured at 18-19
Russia	176 cm	164 cm	5 ft 9.3 in	5 ft 4.6 in	
Singapore	171.0 cm	161.0 cm	5 ft 7 in	5 ft 3 in	
Spain	170.1 cm	160.3 cm	5 ft 6.9 in	5 ft 3.1 in	
Spain	173.1 cm	161 cm	5 ft 8.2 in	5 ft 3.3 in	entire population (self reported)
Spain	177.1 cm	164.3 cm	5 ft 9.7 in	5 ft 4.6 in	18-29 (self reported)
Catalonia, Spain	173.0 cm	164 cm	5 ft 8 in	5 ft 4.6 in	18 (measured)
Madrid, Spain	177.0 cm	164 cm	5 ft 9.7 in	5 ft 4.6 in	18 (measured)
Galicia, Spain	177.0 cm	164 cm	5 ft 9.7 in	5 ft 4.6 in	18 (measured)
Zaragoza, Spain	177.0 cm	162 cm	5 ft 9.7 in	5 ft 4.6 in	18 (measured)
Sweden	180.2 cm	167 cm	5 ft 10.9 in	5 ft 5.7 in	16-24
Switzerland	175.5 cm	164.0 cm	5 ft 9 in	5 ft 3.8 in	
Taiwan	171.38	159.08	5 ft 7 in	5 ft 3 in	18
Taiwan	172.75 cm	160.48 cm	5 ft 8 in	5 ft 3 in	adult population (measured)
United Kingdom	175.3 cm	161.4 cm	5 ft 9 in	5 ft 3.5 in	adult population (16 years +)
United Kingdom	177.0 cm	163.2 cm	5 ft 9.6 in	5 ft 4.2 in	16-24
USA	175.8 cm	162.0 cm	5 ft 9.2 in	5 ft 3.7 in	adult population (20 years +)
USA	176.4 cm	162.5 cm	5 ft 9.4 in	5 ft 4 in	20-39
USA	178.2 cm	164.0 cm	5 ft 10.1 in	5 ft 4.6 in	20-39 non-Hispanic whites
USA	177.8 cm	164.0 cm	5 ft 10 in	5 ft 4.6 in	20-39 non-Hispanic blacks
USA	169.7 cm	166.9 cm	5 ft 6.8 in	5 ft 2.2 in	20-39 Mexican Americans

Based on: Thomas D. *Health, nutrition, and economic prosperity: a microeconomic perspective.* (CMH Working Paper Series, Paper No. WG1: 7. Available at: URL: www.cmhealth.org/wg1_paper7.pdf).

Student Page 1.1B: What's Going On?

In a visit to Old World Wisconsin, a historical museum with houses and farm buildings that were used by settlers up to 200 years ago, Allison and her young friends noticed something unusual. Everything felt small. Allison is 5'7" tall, yet she and her shorter friends felt like giants compared to the doorways, ceilings, and furniture. Yet these were really the buildings used by pioneers. It made them wonder, why were things so small back then?

Baseball Statistics

ERA	Total HR Champs	Average Height	Average Weight (lbs)	Average HR Output
1991-2000	15	6'3"	218	48
1981-1990	20	6'3"	208	40
1971-1980	13	6'2"	201	40
1961-1970	11	6'1"	202	46
1951-1960	15	6'1"	194	42
1941-1950	13	6'0"	195	36
1931-1940	11	6'0"	194	40
1921-1930	10	6'0"	187	41

Source: DOES SIZE REALLY MATTER? Today's major leaguers are bigger and stronger than those of earlier eras – physical size of baseball players. Baseball Digest, July, 2001 by Peter Schmuck

National Basketball Association Player Height and Weight Averages

AVERAGE PLAYER HEIGHT AND WEIGHT

Season Height Weight	Season Height Weight	Season Height Weight
1949-50 - 6'4" 197 lbs.	1950-51 - 6'4" 198 lbs.	1951-52 - 6'4.5" 198 lbs.
1952-53 - 6'4.5" 200 lbs.	1953-54 - 6'5" 205 lbs.	1954-55 - 6'5" 203 lbs.
1955-56 - 6'5" 206 lbs.	1956-57 - 6'5" 207 lbs.	1957-58 - 6'5" 205 lbs.
1958-59 - 6'5" 208 lbs.	1959-60 - 6'5.5" 206 lbs.	1960-61 - 6'5.5" 207 lbs.
1961-62 - 6'5.5" 208 lbs.	1962-63 - 6'5.5" 208 lbs.	1963-64 - 6'6" 211 lbs.
1964-65 - 6'6" 213 lbs.	1965-66 - 6'6" 211 lbs.	1966-67 - 6'6" 210 lbs.
1967-68 - 6'6" 211 lbs.	1968-69 - 6'6" 214 lbs.	1969-70 - 6'6" 211 lbs.
1970-71 - 6'6" 210 lbs.	1971-72 - 6'6" 211 lbs.	1972-73 - 6'6" 211 lbs.
1973-74 - 6'6" 210 lbs.	1974-75 - 6'6" 208 lbs.	1975-76 - 6'6.5" 209 lbs.
1976-77 - 6'6.5" 208 lbs.	1977-78 - 6'6.5" 207 lbs.	1978-79 - 6'6.5" 206 lbs.
1979-80 - 6'6.5" 208 lbs.	1980-81 - 6'6.5" 209 lbs.	1981-82 - 6'6.5" 210 lbs.
1982-83 - 6'7" 211 lbs.	1983-84 - 6'7" 211 lbs.	1984-85 - 6'7" 212 lbs.
1985-86 - 6'7.5" 214 lbs.	1986-87 - 6'7.5" 215 lbs.	1987-88 - ??? ???
1988-89 - 6'7" 214 lbs.	1989-90 - 6'7" 214 lbs.	1990-91 - 6'7" 215 lbs.
1991-92 - 6'7" 216 lbs.	1992-93 - 6'7" 217 lbs.	1993-94 - ??? ???
1994-95 - ??? ???	1995-96 - 6'7" 223 lbs.	1996-97 - 6'7" 224 lbs.
1997-98 - 6'7" 223 lbs.	1998-99 - 6'7" 224 lbs.	1999-00 - 6'7.5" 225 lbs.
2000-01 - 6'7" 224 lbs.		

Source: *The Association for Professional Basketball Research, P.O. Box 35771 • Phoenix, AZ 85069-5771* *http://members.aol.com/bradleyrd/apbr-faq.html*

Finding shoes to fit big feet by Theresa Bradley

Adapted from: Columbia News Service » Mar 1, 2005, http://jscms.jrn.columbia.edu/cns/2005-03-01/bradley-bigfeet/

The ever-expanding American foot is nearly double the size it was 100 years ago, and, after a long lag, retailers are stepping up to the plate.

For decades, Barbara Thornton crammed her size 11 1/2 feet into a size 10 shoe. Her toes curled into claw-like nubs, deformed by the pinch. Pain twice sent her under the operating knife. Hammertoe surgery aside, it never occurred to her that she might need a bigger pair of shoes; that simply wasn't an option, because she'd never seen a single style that came in her proper size.

"A lot of women who are perfectly intelligent in the rest of their lives think that whatever the largest size they can find must be their size," Thornton says. "At some place around fifth or sixth grade, I was buying the biggest size that existed, and that's all I knew." Thousands of women like Thornton have hobbled through life in too-tiny shoes, unaware, embarrassed and underserved by a shoe industry that largely failed to make stylish footwear big enough for their feet.

After a long lag that banished big feet to a desert of ugly shoes, the mainstream footwear industry is waking up to a full-footed demand. Upper-end sizes have crept to 11 at stores from the discounter Payless to high-end fashion houses Prada and Christian Dior. At the same time, sales are booming at online niche outlets that only sell hip, larger shoes, challenging industry business models and prodding manufacturers to make more.

Behind the boom is the ever-expanding American foot, which is growing bigger than ever before. More than a third of American women today wear a size 9 or larger, triple the number who did 18 years ago. "The people who wear size 12 are 12 years old, and they're not getting any smaller," says Thornton, a one-time city planner who seven years ago founded her own oversize shoe company, DesignerShoes.com.

At any given time, her Boston-based outlet stocks 700 styles of size-11-plus shoes. It shuns the grandmotherly orthopedics traditionally unloaded on full-footed customers, opting instead for fuchsia suede buckle-boots and zebra-print ballet flats.

No one is entirely sure why feet are expanding, but they are. The average women's shoe sold last year, a size 8.5, was nearly double the typical 4.5 sold in 1900, and a full size bigger than the average sold a generation ago.

The size hike could also reflect that for the first time, people are simply reporting their sizes accurately--because they are finally finding shoes that fit. Teen feet, doctors agree, are especially big, but kids don't seem too anxious to downplay their size. Among the hottest girls' styles are oversized UGG boots, souped-up flip-flops and clunky Steve Maddens. "Some shoes look cool on big feet instead of small," wrote a contributor to SmartGirl.org, an interactive Web site for teens. "Shop around, the people with small feet will be jealous!"

The new generation could avoid a lot of the damage that too-tiny shoes can cause, preventing the corns, bunions and mallet toes that can deform feet in ways reminiscent of ancient Chinese foot-binding. Some 80 percent of all foot ailments are in fact shoe-related, according to the late podiatrist and footwear guru William Rossi. Doctors estimate that American women spend more than $3 billion a year on surgical foot repair.

In New York, Keran Grant, 36, shops almost weekly at Tall Size Shoes of Fifth Avenue, recently sampling pairs of size 12 paisley slip-ons and tasseled lavender sling-backs. "My mother used to take me to Red Cross to get shoes, and I used to cry," she says. "Those grandma shoes make you feel sorry you have feet."

Not long ago, Grant says, she bought a rotating shoe rack to organize the 132 pairs of snazzy shoes and high-heeled boots that now spill from her closet. "I only wish I had more money," she says, "so I could buy some more."

1945 Shoe Facts

"In 1945—Shoes for members of the Women's Army Corp were manufactured in 148 regular and supplemental sizes ranging from 2 1/2A to 12A. Most popular size for WACs was 6 1/2B . . . Size 7B was next in popularity . . .

[In 1945]—Most popular shoe size for Army men was 9D . . ."

Source: Quimby, Harold R. (1946). *Pacemakers of Progress: The Story of Shoes and the Shoe Industry*. Chicago, Illinios: Hide and Leather Publishing Co.

Key Concepts

- Scientists look for patterns in data that might be evidence to explain natural phenomena.
- Scientists give priority to evidence when formulating explanations.
- Scientific explanations are constructed of claims that are supported by evidence and strong reasoning.

Evidence of Student Understanding

The student will be able to:

- recognize and select evidence that is logically linked to their predicted explanation for the presented data about human height changes.
- explain why they select some data patterns as important for understanding the trend towards increasing size in the population being studied.
- develop an initial explanation for patterns in the data

Time Needed

50 minutes

Materials

For each student

- 1 copy of Student Page 1.1 ***What's Going On?*** (from the previous lesson)
- 1 copy of Student Page 1.2A ***The Evolution of Adult Height in Europe: A Brief Note***

8 1 copy of Student Page 1.2B ***Additional Data About Human Populations***

- 1 copy of Student Page 1.2C ***Developing a Scientific Explanation***

For each group of 4 students

- tape measure or meter stick

For the class

- class data table(s) as needed
- overhead transparency or large version of Student Page 1.2C ***Developing a Scientific Explanation***

Analyzing Data

Explore/Explain

1. Guide a whole class reflection on the previous lesson's work using the REAPS questions from Lesson 1.1.
2. Explain to students how scientists working to understand questions about human *stature* gather data about height from many sources and carefully consider the reliability of those sources. Share that Student Page 1.2A ***The Evolution of Adult Height in Europe: A Brief Note*** is an additional source of data that the class can use to work on answering the question, *What causes populations to physically change or stay the same over generations?*
   - Note: Students need to know the term *stature* as it is used in the article.

   Hand out one copy of Student Page 1.2A ***The Evolution of Adult Height in Europe: A Brief Note*** to each student, and explain the scientist's methods (described in the first pages of the article, which are included in the Teacher Background information—beginning on page 41). Allow time for students to individually examine the data from the article and record notes and ideas in their Science Notebooks.
3. Use a Think–Pair–Share strategy to help students understand how the article, ***The Evolution of Adult Height in Europe: A Brief Note*** provides strong data for the class about average human height over generations.
   - Pose questions to the class, including *How can we define "normal" for traits such as height? What, for example, is "normal" height, and where does "short" end and "tall"*

Continued on following page

begin? Would your answer be different for different populations of humans?

This is an important discussion, particularly for students with heights outside of the mean. The distribution for height clearly shows that most people aggregate around the mean, and society often has come to associate "average" with "normal." Ask students to consider as normal the entire range of human variation for height. Use this as an opportunity to begin using the term *variation*.

Point out that the range encompassed by normal extends far beyond average on both sides of the distribution. It is interesting to note that society often is more accepting of "outliers" to the right of the mean than to the left. For example, we hardly consider 210-cm basketball players "abnormal"; in fact, we reward them with large salaries and public commendation. However, we may consider an extremely short person abnormal and may even discriminate against him or her. Our designations are largely arbitrary.

4. Ask students, *What additional evidence would we need to make a claim about what may have caused humans to increase in stature over the last several generations?* After guiding a discussion that helps students recognize the links between evidence and claims they are beginning to make, distribute Student Page 1.2B ***Additional Data about Human Populations***, and provide time for students to analyze and record notes from that data.

5. Model for students how to recognize and begin to explain significant patterns in data by constructing an explanation table as a whole class, using an overhead transparency or large version of Student Page 1.2C ***Developing a Scientific Explanation***.

   Guide students to give examples and put into their own words the meanings for the terms ***claim, data, observation,*** and to recognize that a ***scientific explanation*** is made by explaining the logic behind how evidence supports a claim.

   - Compare and contrast *opinions* to *scientific explanations* to emphasize the importance of citing evidence in the case of a scientific explanation.
   - **For valuable information about scientific explanations and teaching strategies to support students to write them, see the *Immersion Toolbox*.**
   - Include the **R**ecall and **E**xtend ***REAPS*** questions in the class discussion.

6. Once you have modeled how to complete the table for one claim as a class, have students in their groups of four complete additional rows to explain their own claims about the data.

   At this time, also encourage students to collect additional data to support their claims as appropriate (e.g. average furniture size in the class, average student height or shoe size, etc.)

   Circulate around the room, talking with groups to check for understanding about what constitutes evidence and how to logically link evidence to claims.

7. In their Science Notebooks, have students individually complete the directions in #3 and #4 from Student Page 1.2C *Developing a Scientific Explanation*. Emphasize that responses to these two directions need to be in each students' own words to keep from having members of the same group copy one response rather than thinking for themselves.

8. Explain to the class that as a whole group you will discuss a selection of individual responses to #3 from Student Page 1.2. At this point, it is important to establish a clear expectation that all discussion, including critique, must be respectful.

   Use a random selection strategy to choose several students' explanations and read each paragraph aloud to the class (you may wish to do this anonymously).

   After each paragraph is read, guide a discussion about strengths in the explanation and ways it could be strengthened. Help students reflect on the following question for each claim made: *What additional evidence would we need to further substantiate this claim that changes (in environment) have* *caused humans to increase in stature over the last several generations?*

9. Conclude the class discussion about explanations by using a Think–Pair–Share strategy for students to reflect on how their claims, evidence selection, and explanations have changed as a result of hearing and discussing their classmates' explanations.

   Explain that working scientists experience a similar process of listening to and learning from their peers and then revising their explanations and asking new questions.

9. Provide time for students to revise the explanations recorded in their Science Notebooks.

10. Use the REAPS questions to stimulate further class discussion and as closure or assign them as homework and review at the start of the next lesson.

REAPS

R What are the key parts included in a **scientific explanation**? *A **scientific explanation** is made by explaining the logic behind how **evidence** and **observations** support a **claim**.*

E Describe how **data** is related to **evidence**? ***Evidence** is scientific data that supports the claim. It can come from an investigation or other source, such as observations, reading material, or archived data.*

A Explain what a *pattern in the data* is? Give an example of a pattern from the data included in ***The Evolution of Adult Height in Europe: A Brief Note***. *A pattern is an arrangement of trends or tendencies that occur consistently in the data and may indicate a relationship among two or more variables. Examples could include the increase in average height in Northern European males or females.*

P Where would you look for or how might you collect additional evidence to strengthen your explanation? *Responses will depend on students' claims and ideas for sources. Use responses to this question to help gauge students' understanding of potential information sources.*

S Explain how something you did in this lesson was like what a scientist does? *Responses may include reflections about analyzing data, deciding which data was useful evidence, constructing explanations, etc.*

Teacher Background Information

The Evolution of Adult Height in Europe: A Brief Note*

Jaume Garcia

Universitat Pompeu Fabra, Department of Economics and Business

Climent Quintana-Domeque

Princeton University, Department of Economics and Industrial Relations Section

First version: December 2006. Revised version: February 2007.

Abstract

This paper presents new evidence on the evolution of adult height in 10 European countries for cohorts born between 1950 and 1980 using the European Community Household Panel (ECHP), which collects height data from Austria, Belgium, Denmark, Finland, Greece, Ireland, Italy, Portugal, Spain and Sweden. Our findings show a gradual increase in adult height across all countries. However, countries from Southern Europe (Greece, Italy, Portugal, and Spain) experienced greater gains in stature than those located in Northern Europe (Austria, Belgium, Denmark, Finland, Ireland, and Sweden).

JEL Codes: I31, J11

Keywords: Europe, height, ECHP.

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Garcia, Jaume, and Climent Quintana-Domeque. "The Evolution of Adult Height in Europe: a Brief Note." Journal of Economic Literature Dec (2006): 1-18. 10 Sept. 2007 http://ideas.repec.org/p/upf/upfgen/1002.html

1. Introduction

Trying to measure wellbeing in a society using only one measure is a challenging task, if not an impossible one. Usually, economists consider Gross Domestic Product (GDP) per capita or Gross National Product (GNP) per capita as conventional measures of living standards. Consumption per capita is also used. However, the use of these indicators is not without its shortcomings. One basic concern is about how to measure these variables. For instance, what goods should be included in GDP (GNP) is controversial. Another relevant issue, in particular for welfare analysis, is about the comparability of such measures across countries or individuals: both GDP and consumption need to be adjusted using PPP and equivalence scales. Other kinds of adjustments are even more complicated. This is the case of food consumption, which must be adjusted to account for individual nutritional needs.

Stature is a measure that can help us to circumvent these caveats, but even more important, stature is interesting in its own right: it is a useful summary measure of biological wellbeing, as emphasized by Komlos and Baur (2004). First, stature is a measure that incorporates or adjusts for individual nutritional needs (Steckel, 1995). Second, it also meets satisfactorily the criteria set forth by Morris (1979) for an international standard of physical quality of life. Third, stature is a welfare measure that satisfies the approach to the standard of living suggested by Sen (1987): functionings and capabilities should be balanced. Fourth, it generally correlates positively with many health outcomes throughout the life course, and in particular, it correlates negatively with mortality (Waaler, 1984; Barker et al. 1990). Hence, physical stature can be used as a proxy for health, which as any inherently multidimensional concept is difficult to measure. Fifth, height also has been found to be positively associated with earnings, perhaps because height is a marker for cognitive development (Case and

Paxson, 2006). Finally, measuring stature is easier than measuring income, consumption, health status, etc., at least in principle and particular at the regional level by gender, or for social groups. Nevertheless, we should bear in mind that there are measurement error issues depending on whether height is self-reported or directly measured. In spite of its shortcomings, stature complements the standard wellbeing indicators used in economics.

In this note we aim to describe briefly the evolution of adult height in several European countries for the cohorts born between 1950 and 1980. The reported data in the appendix of this paper offers several possibilities for future research by making the mean heights available in a conventionally accessible form. This information is likely to be very useful for social researchers interested in studying socioeconomic and country specific determinants of human stature.

The paper is organized as follows. Section 2 offers a description of the source of the data used to construct average heights. Section 3 shows the evolution of human stature in different European countries for the cohorts of men and women born between 1950 and 1980. Finally, section 4 concludes.

2. Data

The data used in this paper come from the European Community Household Panel (ECHP), Eurostat, a survey based on a standardized questionnaire that involves annual interviewing of a representative panel of households and individuals in member states of the European Union during the period 1994-2001. The ECHP covers a wide range of topics on living conditions, and its standardized methodology and procedures yield comparable information across countries[1]. The ECHP contains data on self-reported height for 10 countries: Austria, Belgium, Denmark, Finland, Greece, Ireland, Italy, Portugal, Spain and

Sweden. Other available information is year of birth, sex, year of interview, and migration trajectory.

It is a well known fact that self-reported height is subject not only to random error, but more importantly, systematic reporting bias (Boström and Diderichsen, 1997). The bias depends on several factors: age, sex, education, and mode of interview. Without having another source on measured height, it is not obvious how we should proceed to deal with such an issue. Empirical evidence in Thomas and Frankenberg (2002) and in Ezzati et al. (2006) shows that for the US, men over-report their height more than women of the same age and the bias tends to increase with age for older people (above 60 years old), although the bias for both men and women is more or less constant for the age group between 20 and 50.

Since adult height can be achieved above 18 years old we consider that final height is achieved at 21 to be on the safe side. Also, because of both mortality-related selection and shrinking of the elderly, we are going to focus on individuals below age 51[2]. Moreover, computing heights for this demographic group helps us to deal with the age-bias in self-reported height, if the evidence for the US in Thomas and Frankenberg (2002) and Ezzati et al. (2006) also holds for the European countries under analysis.

For the reasons mentioned above, and given that the collection of the self-reported height data spans from 1997 to 2002, we restrict our sample to those individuals between age 21 and 51 who where born 1950 and 1980. Furthermore, we only include individuals born in the country of present residence during the interview, who did not live abroad before. This last information is not available for Sweden, so we were forced to include all individuals in that case. Also for Sweden, the last interview corresponds to 2000, what means that average

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height is not available for the cohort of 1980 because we only have information about height for those who are 20 years old.

We compute average height for each country by cohort and sex. Average cohort height was computed using the available weights in the ECHP. We use the cross-sectional weight in all countries but Sweden, where the baseline weight must be used when using individual information. Information on the reliability of such averages can be better understood when considering the number of observations by each country-cohort-sex cell. Tables 1A and 2A in the appendix present such information. Notice also that the effective sample sizes are substantially smaller because of the panel structure, with most individuals appearing three or four times.

3. The Evolution of Height in Europe

Annual average heights are computed at the country-cohort-sex level (Tables 3A and 4A in the appendix; standard deviations of heights are also reported in Tables 5A and 6A) and quinquennial averages are reported in Tables 1 and 2.[3] Three main features of these data stand out. First, we find that heights in all countries increased during this period. Second, the average stature in the Northern European countries is higher than in the Southern ones for all the cohorts and for both males and females. Third, the intensity of such a growth is heterogeneous: Northern versus Southern differences are visible. For instance, looking at Table 1, we see that Finnish men born in the first half of the 50's were 177.8 cm tall, while those born in the late 70's achieved 178.7 cm. The less than 1 cm increase by Finnish males contrasts sharply with the growth experienced by Spanish males: from 171.3 cm to 176.1 cm, almost 5 cm. In Table 2, we note that there are also huge differences between the growth experienced by Italian and Spanish women, more than 5 cm, in comparison to that of Danish women, only 1.4 cm.

[Insert Table 1 about here]

[Insert Table 2 about here]

This pattern of higher growth rates for both males and females in the Southern European countries becomes more evident when considering Table 3, where annual growth rates between the 1950-55 and the 1976-80 cohorts are reported (0.10% for Southern countries, 0.05% for Northern countries, and the total mean growth is 0.07%). Also we can point out that height growth rates are almost equal for males and females according to this geographical classification. There does not seem to be a clear pattern in terms of gender across countries. Some countries have experienced higher absolute gains for women (Belgium, Finland, Italy, Spain and Sweden) whereas some others have experienced greater gains for men (Austria, Denmark, Greece, Ireland and Portugal).

[Insert Table 3 about here]

Considering the evolution of heights separately for the Northern and Southern European countries (Figures 1 - 4) some generalizations are evident. First, for the Northern countries, the cohorts of Danish males are always the tallest: 180.3 cm at the beginning and 183.7 cm at the end of the period. Second, the reverse situation is shown by the Irish males, who are the shortest in the Northern Europe sample during the whole period, 174.9 cm for those born in 1950-1955 and 177.4 cm in 1976-1980. Similar qualitative results are found for females.

From the evidence in Figure 3 and Figure 4 we can conclude for the Southern European countries that Greeks are the tallest for both males and females and Portuguese are the shortest ones in both cases. Both countries show a similar evolution profile in the period under consideration. At contrast, Spanish males and females for the last cohorts are growing more significantly than those in the other Southern European countries.

[Insert Figure 1, Figure 2, Figure 3 and Figure 4 about here]

4. Discussion

This paper has offered a brief description of the evolution of human stature for the cohorts born between 1950 and 1980 in several European countries. Our descriptive analysis shows two main results: first, heights increased throughout the period in all countries; second, the pattern of growth in stature was heterogeneous, with Southern European countries growing more than their Northern counterparts. However, there does not seem to be any convergence in height among Northern or Southern European countries considered separately. The data reported in the appendix, permits more detailed analysis of socioeconomic and country specific determinants of average height.

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Student Page 1.2A: The Evolution of Adult Height in Europe: A Brief Note

TABLES AND FIGURES

Table 1. Average heights by year of birth, men, centimeters

	1950-55	1956-60	1961-65	1966-70	1971-75	1976-80
Denmark	180.3	179.7	181.0	181.7	181.3	183.7
Sweden	179.6	179.4	180.9	180.5	180.4	181.2
Austria	176.3	177.0	179.2	178.5	178.7	179.6
Belgium	176.2	177.3	177.2	179.4	179.2	179.5
Finland	177.8	179.0	179.6	177.9	178.0	178.7
Greece	174.7	175.4	176.6	177.0	178.4	178.6
Ireland	174.9	176.3	176.1	176.9	177.0	177.4
Italy	172.5	174.3	174.9	174.7	175.4	177.1
Spain	171.3	171.7	173.3	174.7	175.7	176.1
Portugal	168.8	170.0	170.0	169.8	172.1	172.9

Source: Authors' calculations from the European Community Household Panel.
Note: The average for Sweden corresponding to 1976-80 is calculated over the cohorts born between 1976 and 1979 because of data availability problems mentioned in the introduction.

Table 2. Average heights by year of birth, women, centimeters

	1950-55	1956-60	1961-65	1966-70	1971-75	1976-80
Denmark	167.2	166.6	167.5	168.5	168.1	168.6
Belgium	163.4	164.9	165.0	166.4	166.2	167.8
Sweden	165.4	166.4	166.7	166.9	166.7	167.2
Austria	165.6	166.2	166.7	166.3	167.7	167.1
Italy	161.4	162.3	163.0	163.9	164.4	166.5
Finland	164.3	164.9	165.5	165.5	165.2	165.9
Greece	163.3	164.1	164.8	165.5	166.4	165.9
Spain	160.4	161.0	161.3	162.8	164.4	165.5
Ireland	162.7	162.7	163.2	164.1	164.7	164.4
Portugal	158.9	159.3	160.5	160.8	162.5	162.5

Source and note: See Table 1.

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Garcia, Jaume, and Climent Quintana-Domeque. “The Evolution of Adult Height in Europe: a Brief Note.” Journal of Economic Literature Dec (2006): 1-18. 10 Sept. 2007 http://ideas.repec.org/p/upf/upfgen/1002.html.

Evolution of Height

Figure 1: Northern European countries, men

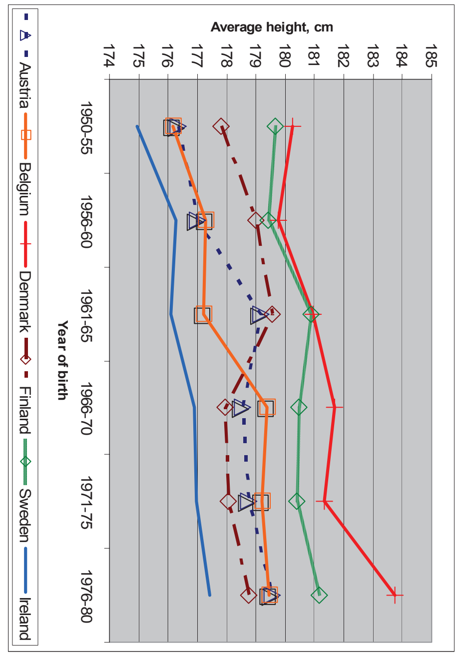


Figure 2: Northern European countries, women

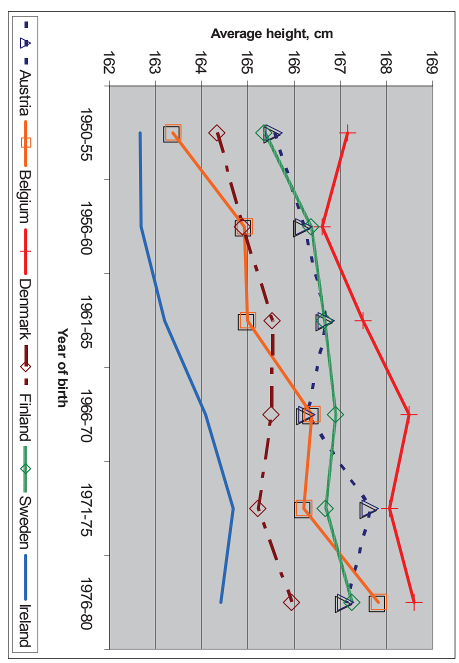


Figure 3: Southern European countries, men

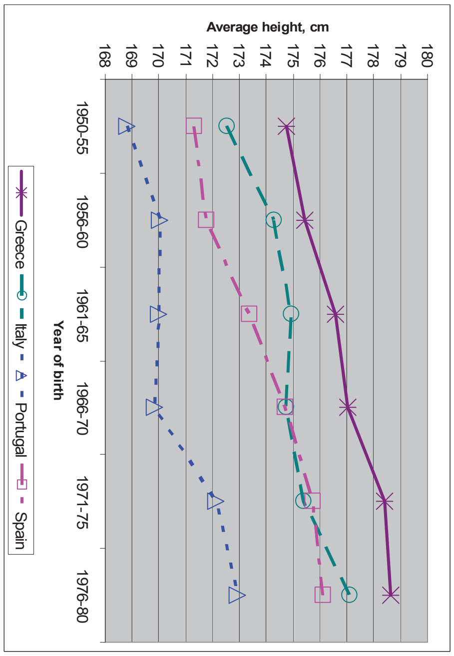
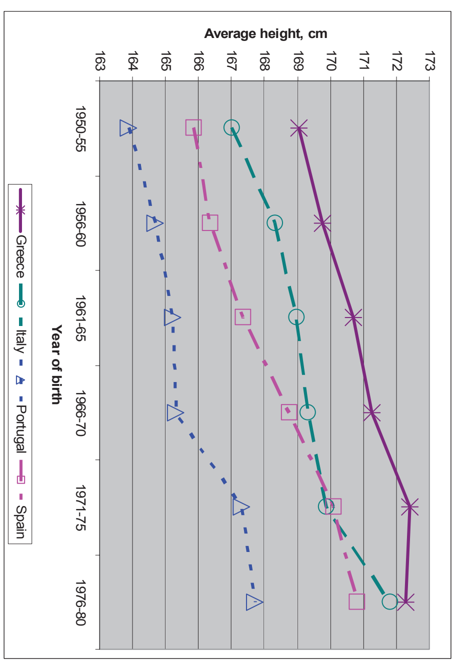


Figure 4: Southern European countries, women



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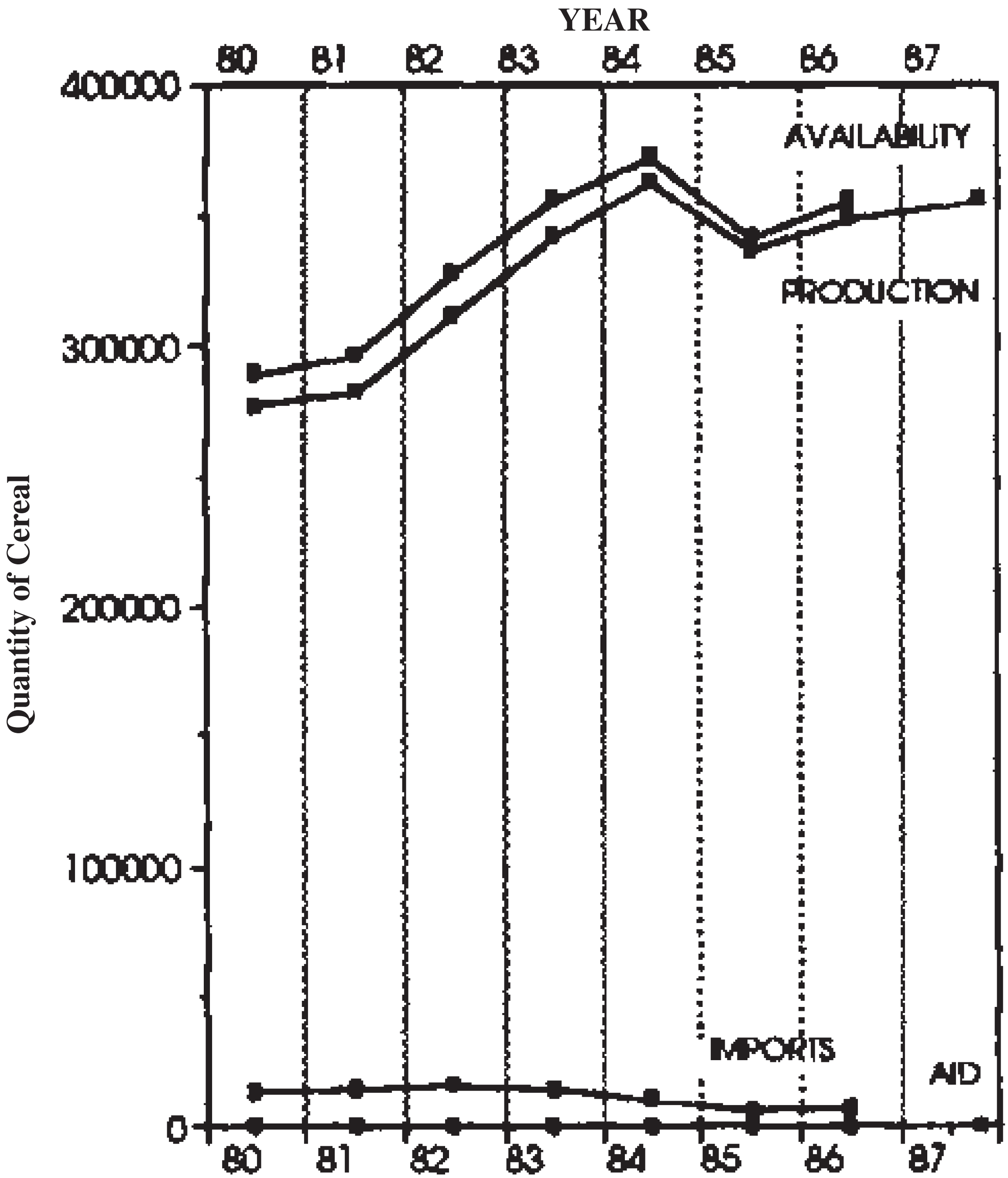
Garcia, Jaume, and Climent Quintana-Domeque. "The Evolution of Adult Height in Europe: a Brief Note." Journal of Economic Literature Dec (2006): 1-18. 10 Sept. 2007 http://ideas.repec.org/p/upf/upfgen/1002.html.

Source: The United Nations Administrative Committee on Coordination–Sub–Committee on Nutrition: Second Report on the World Nutrition Situation

China

Cereal Production and Availability — 1980–87

Source: ACC/SCN, 1987. "First Report on the World Nutrition Situation"; ACC/SCN, c/o WHO, Geneva.

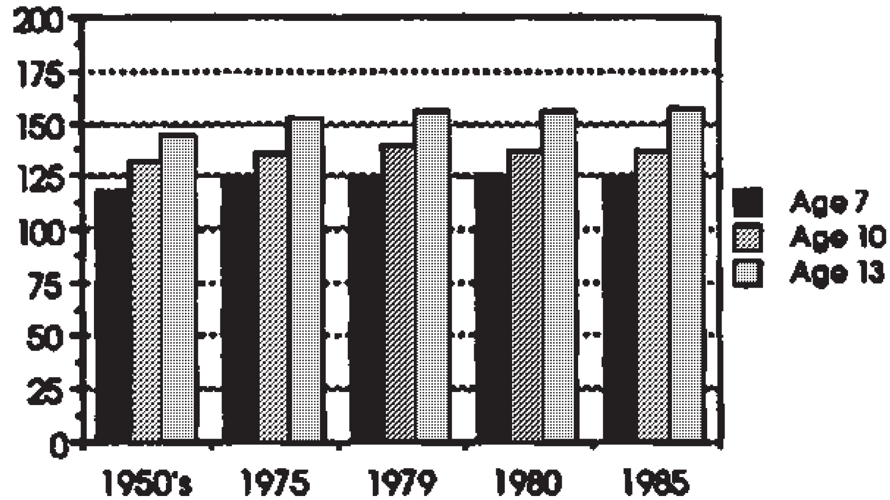


Student Page 1.2B: Additional Data About Human Populations

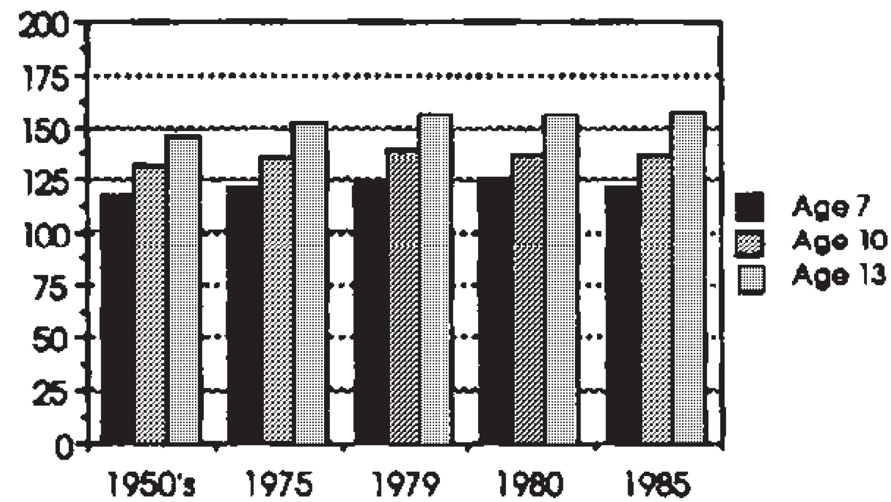
China (continued)

Source: ACC/SCN, 1987. "First Report on the World Nutrition Situation"; ACC/SCN, c/o WHO, Geneva.

Change in mean height (cm) in males 7–13 years in Beijing (Urban): 1950's to 1985

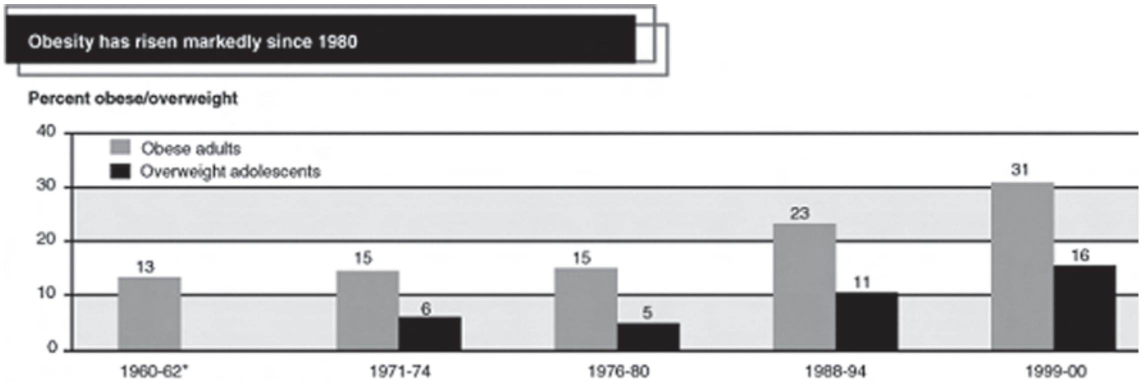


Change in mean height (cm) in females 7–13 years in Beijing (Urban): 1950's to 1985



Student Page 1.2B: Additional Data About Human Populations

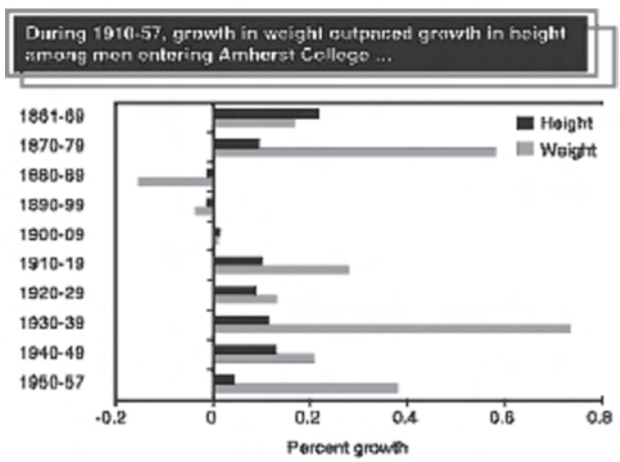
Source: Variyam, Jayachandran. "The Price is Right: Economics and the rise in Obesity." Amber Waves February 2005. 12 2005. 16 08 2007 http://www.ers.usda.gov/amberwaves/february05/features/thepriceisright.htm.

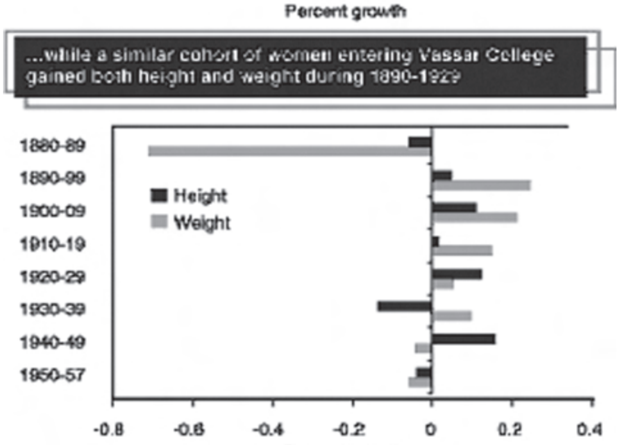


*Data not available for adolescents in 1960-62.

Note: Adults with a Body Mass Index (BMI) at or above 30 are classified as obese. Adolescents are identified as overweight if their BMI equals or exceeds the 95th percentile of BMI-for-age in CDC growth charts. BMI is calculated as weight in kilograms divided by height in meters squared.

Sources: K.M. Flegal, M.D. Carroll, C.L. Ogden, and C.L. Johnson, "Prevalence and Trends in Obesity Among U.S. Adults, 1999-2000," and C.L. Ogden, K.M. Flegal, M.D. Carroll, and C.L. Johnson, "Prevalence and Trends in Overweight Among U.S. Children and Adolescents, 1999-2000," both in the *Journal of the American Medical Association*, Vol. 288, No. 14, October 9, 2002.





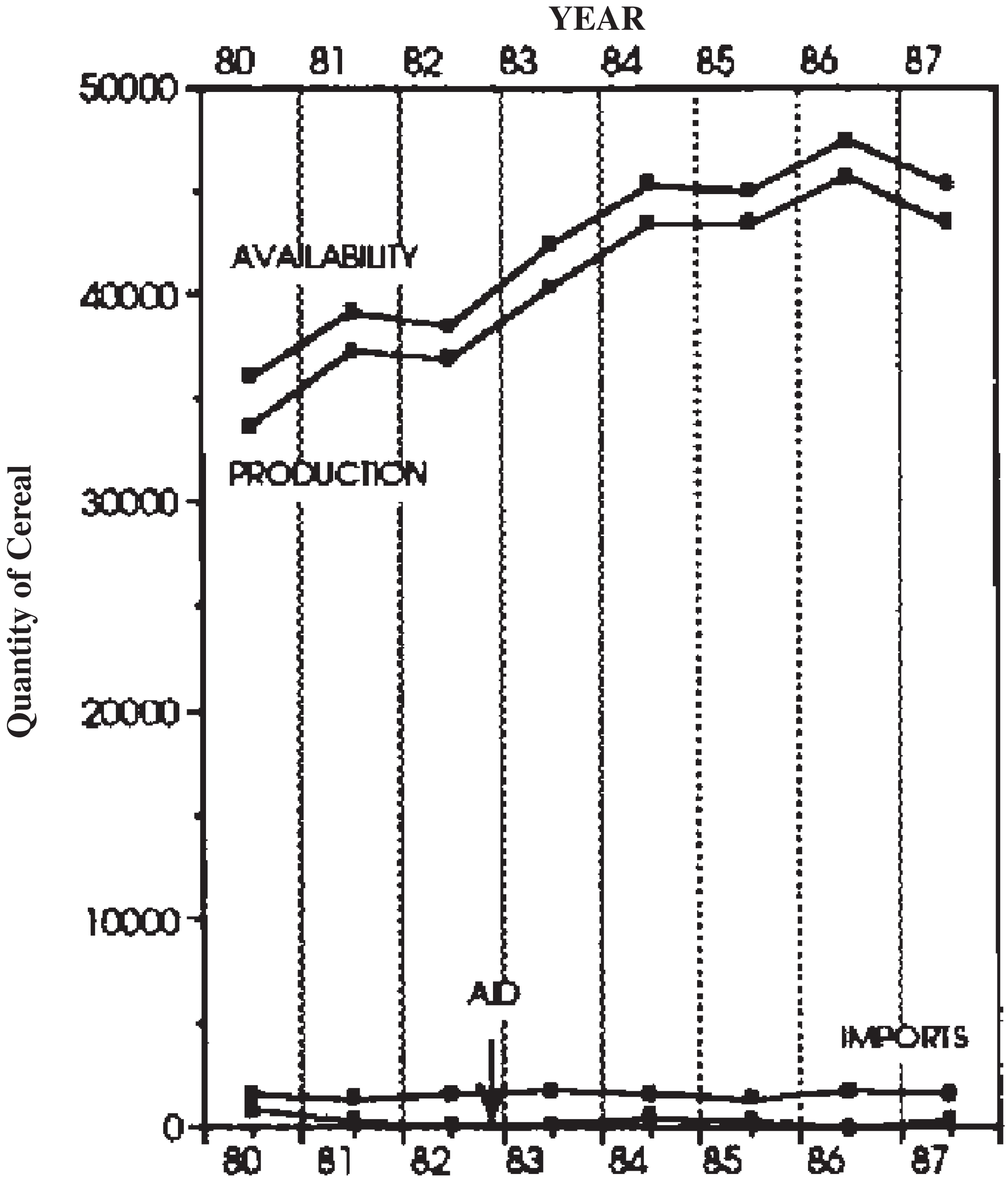
Source: *Heights and Weights of Adults in the United States*, by Milicent L. Hathaway and Elsie D. Foard, Home Economics Research Report No. 10, USDA/ARS, August 1960, Tables 18 and 21.

Student Page 1.2B: Additional Data About Human Populations

Source: The United Nations Administrative Committee on Coordination–Sub–Committee on Nutrition: Second Report on the World Nutrition Situation

Indonesia

Cereal Availability and Production

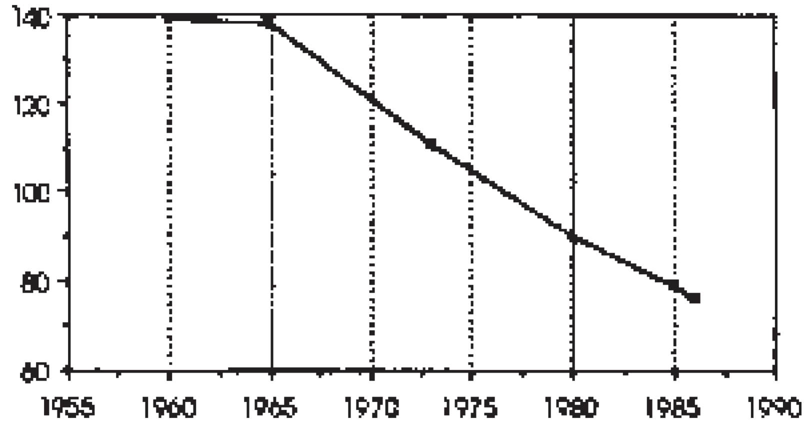


Student Page 1.2B: Additional Data About Human Populations

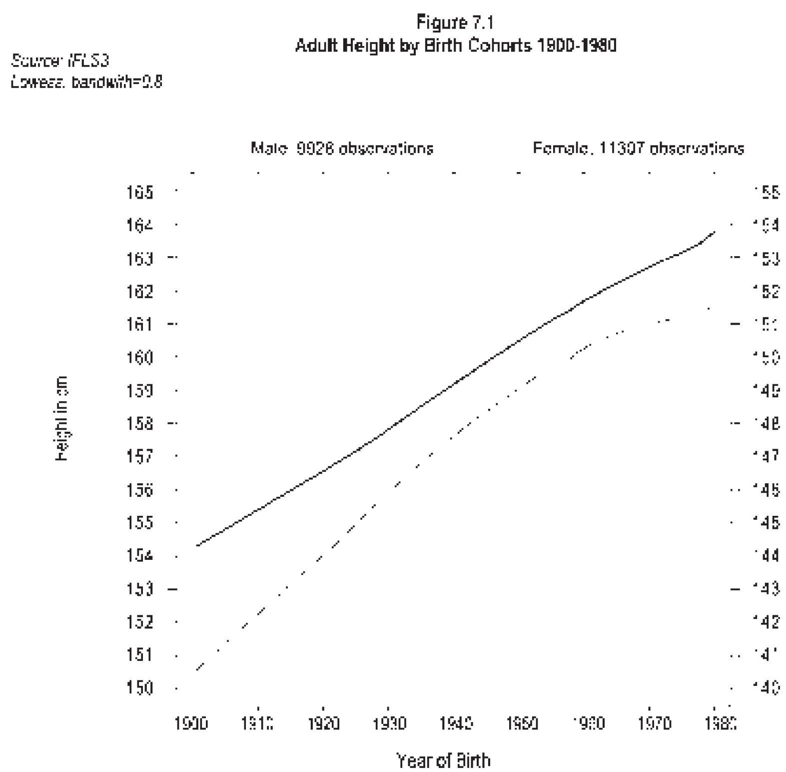
Source: The United Nations Administrative Committee on Coordination–Sub–Committee on Nutrition: Second Report on the World Nutrition Situation

INFANT MORTALITY RATE

Change in Infant Mortality Rate between 1960 and 1987

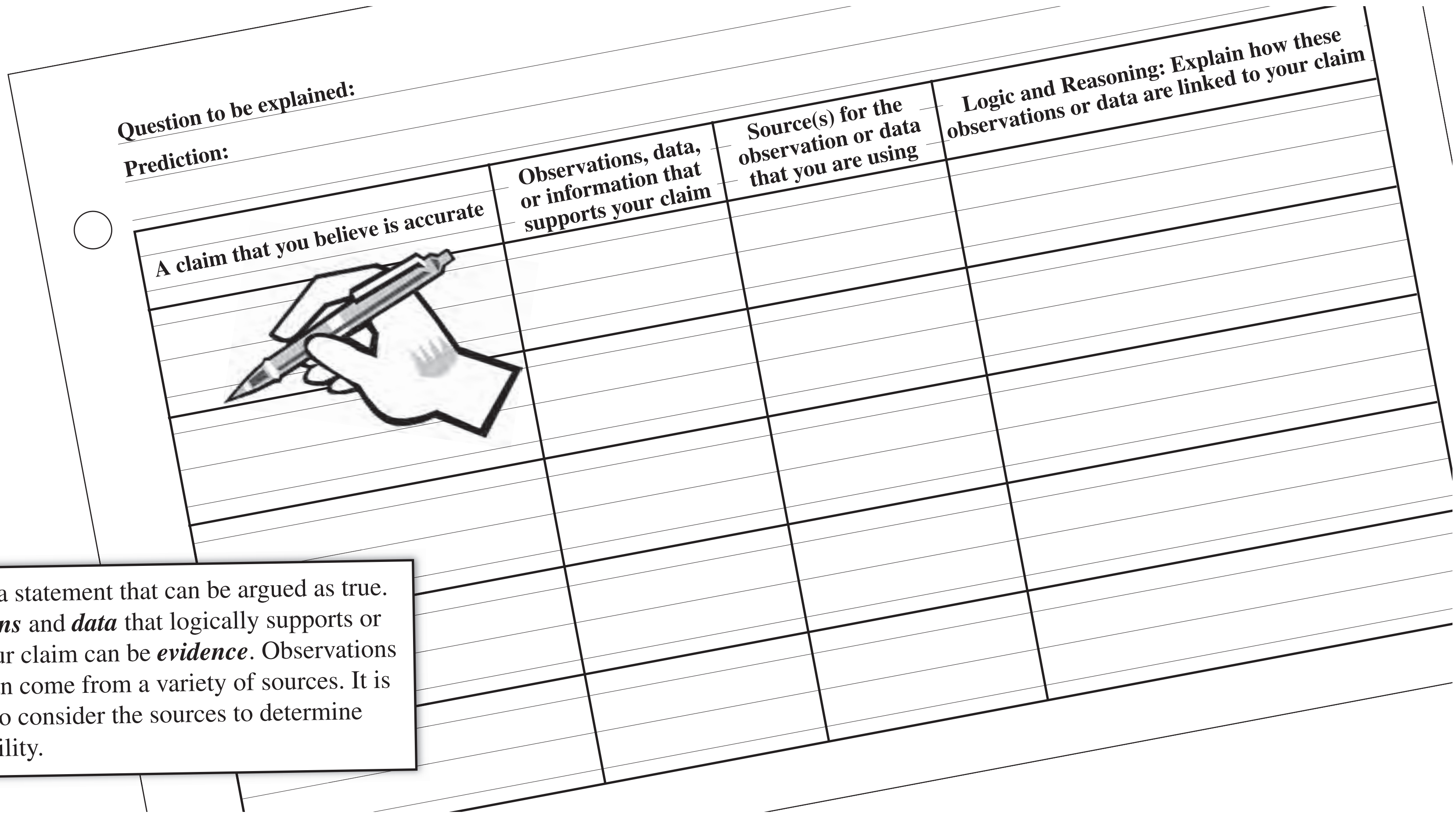


Source: Strauss, John. "Indonesian Living Standards Three Years After the Crisis: Evidence From the Indonesia Family Life Survey." RAND Report (2002): 151.



Student Page 1.2C: Developing a Scientific Explanation

1. Begin a new page in your science notebook. At the top of the page, record today's date, and record the question that you are going to be working on answering in your scientific explanation.
2. Below the question you wrote in #1, record your initial prediction for the answer to your question. Explain the prediction.
3. In your Science Notebook, complete a chart like the following to develop an explanation for patterns in the data you analyzed.
4. In your Science Notebook, write your explanation in paragraphs that include complete sentences, stating your claim and explaining the evidence and information that you are using to support it.
5. After writing your explanation, record any new or modified questions that you have about this natural phenomenon.
6. Write three or four sentences comparing your current explanation to your original prediction (#2 above).



A *claim* is a statement that can be argued as true. ***Observations*** and ***data*** that logically supports or negates your claim can be ***evidence***. Observations and data can come from a variety of sources. It is important to consider the sources to determine their reliability.

Key Concepts

- Predictions (hypotheses) are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).
- In science, explanations that are not supported by evidence are given little credibility.
- The way that traits are expressed is influenced by many factors, diet, medical care, environmental conditions, and personal health behaviors.
- Populations can change over generations as a result of changes in their environment.

Evidence of Student Understanding

The student will be able to:

- recognize and select evidence that is logically linked to their predicted explanation for the presented data about human height changes.
- explain why they select some data patterns as important for understanding the trend towards increasing size in the population being studied.

Time Needed

100 minutes

Materials

For each student

- Student Page 1.2B ***Developing a Scientific Explanation*** (from the previous lesson)
- 1 copy of Student Page 1.3 ***The Human Equation***

What Do Scientists Think?

1. Use a Think–Pair–Share strategy to have students review and clarify what their current explanations are for differences in average human sizes over generations.
2. Explain that an important part of science involves learning what other scientists' explanations are for similar questions and comparing your own claims to theirs to look for similarities and differences. So the class can make some of those comparisons, you have an article about studies done by scientists studying *What causes populations to physically change or stay the same over generations?* The article is in Student Page 1.3 ***The Human Equation***.

   Distribute to each student a copy of Student Page 1.3, and use an appropriate reading strategy for your class to read and analyze the article.
3. Guide an interactive class discussion to have students compare their own explanations for the change in average human height over generations to Robert Fogel's explanation. This discussion may include the following strategies:
   - Work in small groups to complete additional rows, including claims, evidence, and reasoning in Student Page 1.2C ***Developing a Scientific Explanation*** that come specifically from the ***The Human Equation*** article.
   - Think–Pair–Share focused on having students evaluate their explanation comparison with Fogel's.
   - Quickwrite in which students explain how their explanation is supported by other pieces of information from Fogel's work.
   - Line of Learning used for students to rewrite their explanation referencing Fogel's explanations, evidences and current scientific understandings.

Continued on following page

- Science Notebook entry in which students individually write a comparison between their revised thinking and their previous thinking.
- Discussion of how predictions (hypotheses) are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).

Note: Specifics about these strategies can be found in the ***Immersion Unit Toolbox***.

4. Point to the posted unit question, *What causes populations to physically change or stay the same over generations?* and conduct a brainstorm session about what students know at this time to answer this question. Guide the brainstorming session by having students reflect on the question underlying Step 1, *How have changing environmental factors, including nutrition, affected the human population?*

   Record the list generated by the class into a T–chart. Arrange the chart and title it like the following example to reinforce the use of claims supported by evidence to build scientific explanations.

   The class will return to and continue adding evidence to this graphic organizer (called a Unit Level Graphic Organizer, or ULGO) throughout the unit. For examples entries for the chart, see the Unit Overview section before Step 1.

   - Remind students that to scientifically answer the question, *What causes populations to physically change or stay the same over generations?* any claims need to be supported by evidence. Have students explain the source and/or evidence for the ideas given to help answer the question.
   - Check for students' understanding during this brainstorm session. At this point in the unit, students need to grasp that environment influences the variation in traits that are expressed in a population, and if the environment where a population lives changes, the population may change over generations as a result.

5. Use the REAPS questions to stimulate further class discussion and as closure or assign them as homework and review at the start of the next lesson.

What causes populations to physically change or stay the same over generations?

what we think we know (claim at this point in time related to the unit question)	**how we think we know what we know** (evidence and their sources for the claim)

REAPS

R Explain how the scientist in ***The Human Equation*** came to study patterns in human height over generations. *Robert Fogel noticed a big difference in how chicken pox was treated when he was a child compared to when his son was a child, and he wondered why it had changed. This is typical in science—that an common day experience triggers a wondering that can lead to a scientific inquiry.*

E Imagine a scientist who found a population of rabbits living in an environment where food was quickly becoming hard to find. Explain what they would likely expect to see happen to the average rabbit size in future generations. *If food continues to be difficult to obtain, future rabbit generations are likely to have a smaller average rabbit size.*

A Explain what makes some scientific explanations stronger than others? *Explanations that are not well supported by evidence or are supported by evidence from questionable sources are given little credibility.*

P Explain which of the following you think has the most influence on how an organism develops and looks: **environmental conditions** or the **genetic code** that an organism inherited? *Use students' responses to this question as an indication of their understanding about inheritance and the role that DNA plays in determining the traits that are possible to be expressed in an organism.*

S Explain how the resources (money, time, information, etc.) that a scientist who studies patterns in human height over time compares to what you had in Step 1, Lessons 1–3? How can the resources that are available affect the explanations that are developed? *Scientists working in this field have much more data and significantly more time to analyze it. In addition, scientists have more experience and background knowledge. The resources available often determine how much data (and so how much evidence) is available to analyze, and that has a big impact on the type and reliability of explanation that can be developed.*

Teacher Background Information

Robert Fogel is a Charles R. Walgreen Distinguished Service Professor of American Institutions at the University of Chicago and winner of the Nobel Prize in 1993 for Economic Science. Fogel conducted preliminary research for a decade, collecting data from a wide range of sources prior to his research project being accepted by peer review committees at the National Institutes of Health and National Science Foundation. Fogel won the approval of peer review committees after much skepticism regarding his ability to effectively link together data. However, Fogel convincingly linked together these large data sets in a sophisticated analysis that examined up to 15,000 variables. These sources included data such as the following: censuses, probate records, military and pension records, genealogies, public health records, death certificates, tax rolls, U.S. National Archives, Genealogical Library of the Church of Christ of Latter Day Saints. Robert Fogel's autobiography can be found at the following URL:http://nobelprize.org/nobel_prizes/economics/laureates/1993/fogel-autobio.html

Source: Excerpts taken from The Human Equation. *The University of Chicago Magazine*, (2007, May/June). Retrieved July 11, 2007 from http://magazine.uchicago.edu/0726/features/human.shtml.

Student Page 1.3: The Human Equation

How have changing environmental factors affected generations of human populations?

When he was six years old, Robert Fogel—Nobel laureate, Chicago professor, and pioneering economic historian—came down with chickenpox. It was 1932. He left school feeling sick, and his mother summoned a doctor. “Two hours later,” Fogel recalls, “the New York City Department of Health slapped a sticker on the door to our house: ‘No one may leave or enter this apartment until this sticker is taken down.’” Fogel’s older brother, not yet home from school, and his father, still at work, bunked in a neighborhood boarding house for two weeks. Each day his father would place a basket of groceries on the Fogel family stoop, then ring the doorbell and walk away. “And that’s how we were fed,” he says. “It was very traumatic.”

Two decades later, Fogel’s son Michael, then six or eight, came home with chickenpox. Still in New York and anticipating a similar tribulation, Fogel called the pediatrician. “He said, ‘Good! This is a very good year for chickenpox; it’s very mild.’” Within days Fogel’s son returned to school, covered in spots. “So an entirely different environment,” Fogel says. Once a frequently fatal disease and a public-health menace, chickenpox had become, by the mid-1950s, an inconvenience. “The same was true of mumps and measles,” Fogel says. “They were all transformed,” even before the widespread use of antibiotics and vaccines. “The question is: what happened?”

What Happened? Have the Pathogens that Cause Chicken Pox Become Weak or Have Some Human Populations Changed Over Generations?

The answer, he has concluded after decades of research, is that the pathogens didn’t get transformed; the people did. “Over the past 300 years”—and particularly during the 20th century—“human biology has changed,” Fogel says. People in the industrialized world are taller, heavier, stronger. They’re more resistant to disease and more likely to overcome it when they do get sick. They live longer, their lives less fraught with chronic ailments. “We’re just not falling apart like we used to,” says Fogel, who has taught at Chicago since 1964, minus a six-year hiatus at Harvard. “Even our internal organs are stronger and better formed.” Along with coauthor Dora Costa, PhD’93, Fogel has dubbed this process of improvement “technophysio evolution.” The phenomenon, he insists, is “not only unique to humankind, but unique among the 7,000 or so generations of human beings who have inhabited the earth.”

People in the industrialized world are taller, heavier, stronger.

Fifteen years ago the evidence led Fogel and Dora Costa to the theory of technophysio evolution. He argues that changes to the human form accumulate, generation upon generation.

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> Human populations who began living in cleaner, safer environments with easy access to proper nutrition show an increase in stature over generations.

People owe their rising physiological fortunes, Fogel and Costa say, to increasingly salubrious surroundings: labor-easing technologies, better medical care and public health, proper nutrition, greater wealth, cleaner cities, and sanitary water supplies. "Chicago exported a lot of typhoid down to St. Louis during the early 1900s," Fogel says, by dumping wastewater into the Illinois River. "And flies—when I was growing up, you always shared your breakfast with flies." Hanging from the kitchen ceiling, his mother's flypaper was constantly covered with bugs. "Now if we get a fly in this house, it's an emergency."

A Scientist Collects Extraordinary Amounts of Evidence

Fogel, along with Chicago-educated colleagues—many of whom, like Costa, are his former students—have unearthed mounting evidence for physiological change. They've traced the shifting trajectory of aging and disease in dozens of working papers and journal articles. In 2004 Fogel published The Escape from Hunger and Premature Death, 1700–2100: Europe, America and the Third World (Cambridge University Press), a study that draws on data from the U.S., Britain, France, Norway, the Netherlands, Ghana, and India to assemble a picture of humanity's changing biology. Since 1700, he wrote, Westerners, liberated from centuries of malnutrition, have more than doubled their average longevity and increased their average body size by more than 50 percent. In 1790 French men in their 30s weighed about 110 pounds; today they weigh closer to 170. Between the third quarter of the 18th century and the third quarter of the 20th, Norwegian men added five-and-a-half inches to their average height. American men added about two inches. As their economies grow, developing countries are starting to see similar gains. In India, life expectancy at birth rose from 29 to 60 between 1930 and 1990.

Some of the most dramatic evidence for technophysio evolution has arisen from a research project examining the health records of roughly 45,000 Union Army veterans, including 6,187 black soldiers. Directed by Fogel and involving dozens of researchers, the Union Army Study compares the Civil War generation, the first to turn 65 during the 20th century, with those who followed.

[Robert Fogel] and his colleagues slogged through files at the National Archives, using money from Chicago, BYU, and the National Bureau for Economic Research to collect and collate data from a sample of 2,400 veterans. The task took four years. "It was not like falling off a log—that was hard work," Fogel says. In 1991 the NIH approved Fogel's grant application, which launched a 15-year process of collecting and standardizing the records so they could be used.

Patterns About How Sick Americans Were Emerge Upon Fogel's Examination of the Data

Over the past two decades the study has yielded some unexpected results. Foremost, perhaps, was the discovery of how sick Americans were, and from how early on. Nearly everyone in the Civil War generation endured painful, debilitating ailments for the better part of their lives. Even so, 65 percent of men between 18 and 25 volunteered for the Union Army. A quarter of those volunteers were sent home because of physical disabilities: hernias, arthritis, tuberculosis, cardiovascular

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disease, blindness. Teenagers didn't escape illness either. One-sixth of Union recruits aged 16 to 19 were rejected because of infirmity. "These men were much sicker," Costa says, "than anything we'd imagined."

Their health only worsened with age. By 1910, 68 percent of veterans 65 or older suffered from musculoskeletal disorders such as arthritis, and 76 percent had heart disease. For World War II veterans of the same age, those figures were 48 and 39 percent. One in two Union Army veterans ages 60 to 74 endured back problems, compared to 30 percent of men the same age in 1994.

Fogel Focuses on Height and Weight Measures to Determine Standard of Health

Another puzzle has been figuring out what made 19th-century Americans so sick so young. Why are there such gaping disparities between those who fought the Civil War and those who fought the Great War or World War II? The answers, Fogel and Costa say, seem to lie in early life. Of the children born between 1835 and 1845, nearly a quarter died in infancy, and another 15 percent perished before they turned 15. Those who survived to adulthood, says Fogel, endured persistent malnutrition. Inferring body-mass index from height and weight measures, he argues that one in six young adults was dangerously underweight by modern standards of proper health. Owing in part, perhaps, to undernourishment, children and adolescents often suffered acute infection: typhoid or tuberculosis, measles or rheumatic fever.

Work compounded the hardship. "This was a world where manual labor was the norm, and it was unmechanized labor," Costa says. On average, Americans worked about 78 hours per week, from dawn to dusk Monday through Friday and half a day on Saturday. "The farmers were particularly striking," Costa says. As young men they enjoyed the best health, having escaped exposure to many of the worst diseases that plagued urban dwellers. "But once they reach older ages, they're falling apart." People

Inferring body-mass index from height and weight measures, he argues that one in six young adults was dangerously underweight by modern standards of proper health.

in cities, meanwhile, often didn't reach older ages at all. In large metropolises like Boston, New York, and Philadelphia, life expectancy at birth in 1830 was 24 years—"ten years less," Fogel says, "than that of Southern slaves."

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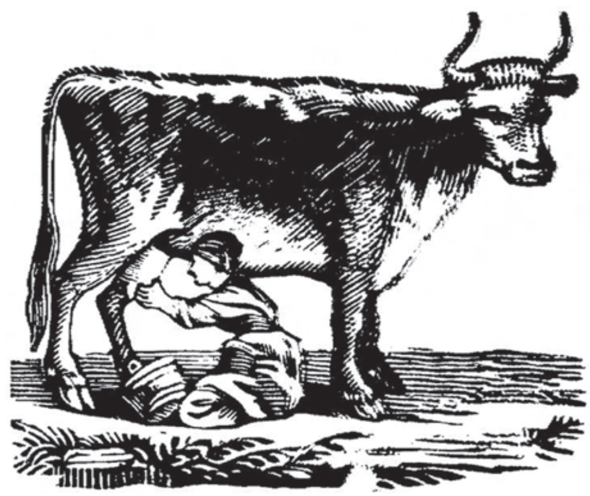
A Scientist Continues to Ask Questions

Last November Fogel turned 80. His life bears out the sweeping progress his research chronicles. When he was ten, Fogel's parents took out a life-insurance policy in his name. Two years later a cousin died of rheumatic fever. She was 11 years old. "Polio was still a tragedy then too," says Fogel, who as a grown man became an early beneficiary of antibiotics when he contracted pneumonia in 1950. His life expectancy at birth was less than 60; for newborns today it is almost 80. "My oldest granddaughter was born in 1981," he says. "According to my forecasts, she has a 50-50 chance of living to be 100 years old."

Fogel still can't pinpoint the reasons why. Despite all he's learned, he says, technophysio evolution doesn't yet offer a full answer. "We've seen these gains in health and longevity, but what percentage is due to improvements in public health?" Half a century after he enrolled in graduate school, Fogel is still [asking questions].

Source: Excerpts taken from The Human Equation. *The University of Chicago Magazine*, (2007, May/June). Retrieved July 11, 2007 from http://magazine.uchicago.edu/0726/features/human.shtml.



Unit Overview

Populations of living organisms change or stay the same over time as a result of the interactions between the genetic variations that are expressed by the individuals in the populations and the environment in which the population lives.

STEP 1 | **STEP 2** | **STEP 3** | **STEP 4**

Lesson 2.1 Engage

In a fast paced 50-minute lesson, students transition from focusing on the impact that environment has on variation in populations, to thinking about the role of inheritance and genetics on variation. Students critique the claims made in three funny milk commercials that imply great increases in size, beauty and strength are possible by drinking milk.

Guiding Questions

Can you control your height with what you choose to eat? Is environment the only factor that determines the variation in traits that occurs in a population?

Lesson 2.2 Explore/Explain

This lesson is broken into a 5-day sequence. Students engage in a scientifically-oriented question and conduct an investigation to figure out the mode of inheritance of the purple stem trait in Wisconsin Fast Plant seedlings. In addition, students learn through a wide variety of activities how the genetic code is passed from parent to offspring through meiosis. An understanding of meiosis makes it possible to predict the probability of inheritance of a particular trait. Students formulate an explanation from evidence for the link between genetics and variation.

Guiding Questions

What can we figure out about the origins of traits observed in individuals in a population by looking at inheritance patterns? How can we use an understanding of inheritance to predict the variation that is possible in population's future generations?

Lesson 2.3 Elaborate/Evaluate

Students are guided in this 50-minute lesson to synthesize what they learned about inheritance (Lessons 2.1 and 2.2) with what they learned about environmental influences on variation (Step 1). Student groups develop and design a student-directed experimental inquiry into environmental influences on the variation of the purple stem trait in Wisconsin Fast Plants.

Guiding Question

How do environmental factors and genetics interact to determine the observable variation present in a population?

Standards addressed in Step 2: 1a, 1b, 1c, 1d, 1g, 1i, 1j, 1k, 2a through 2g, 3a, 3b, 7a.

Key Concepts

- In science, one explanation typically leads to more questions.
- Genes are a set of instructions encoded in the DNA sequence of each organism that specify the possible versions of traits, like height, that an organism can have.
- The traits expressed in an organism are determined by a combination of genes and environment.

Evidence of Student Understanding

The student will be able to:

- develop a logical explanation why humans cannot "control" their height with what they choose to eat.

Time Needed

50 minutes

Materials

For each student

- 1 copy of Student Page 2.1A ***Anticipation Guide*** and have students complete it individually before reading Student Page 2.1B ***What Determines Human Height?***
- 1 copy of Student Page 2.1B ***What Determines Human Height?***

Taller and Taller?

Engage

1. Show students the video commercial, *Ask Milk!* and ask what the commercial is claiming. Next, ask the class to respond as a scientist to the claim that drinking milk could make a person grow taller.
   - Pose the question, *Can you control your height with what you choose to eat?*
   - Use a Think–Pair–Share strategy to facilitate a 5–7 minute discussion of the video and question asked.
   - Emphasize that milk, like all nutrition, is an environmental factor.
2. Review students' responses to the **P**redict ***REAPS*** question from Lesson 1.3, *Explain which of the following you think has the most influence on how an organism develops and looks:* ***environmental conditions*** *or the* ***genetic code*** *that an organism inherited?*
   - Explain that scientists around the world have wondered for years and continue to ask questions about when the environment (nurture) influences organisms' traits and when traits are controlled by an organism's genetic code (nature).
   - *Briefly* review what students learned before this unit about how offsprings' traits are inherited from their ancestors in previous generations.
3. Share that you have an article that summarizes some of the key research into what determines an individual human's height.

   Distribute Student Pages 2.1A and 2.1B. Guide the class to read and analyze the key ideas.

   Note: This reading is intended as a transition between a focus on how populations can change as a result of environment to a focus on the role that genetics plays in determining variation in a population.
4. Remind the class of the height histogram made in Lesson 1.1, and facilitate a discussion about how a similar graph might look different if it were made for a class in the past (shifted towards shorter average), in the future (probably

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not much change in the US), or in a different region of the world (depending on the population's genetics and nutrition).

- Conclude this discussion by referring to the question posted in Step 1, *What causes populations to physically change or stay the same over generations?* and Unit Level Graphic Organizer, re–emphasizing the concept that **Populations can change over generations as a result of changes in their environment**.

5. Explain that in Step 2 of this unit, the class will be looking into the role that inheritance plays in how populations of all kinds of organisms change or stay the same over generations.
6. Use the REAPS questions to stimulate further class discussion and as closure or assign them as homework and review at the start of the next lesson.

REAPS

R What is a histogram? *A histogram is a graphic representation of data.*

E What is typically considered "normal" for a particular trait in a population? *"Normal" usually refers to the version of the trait that occurs with the greatest frequency in the population.*

A Explain what the relationship is between human parents' and their offspring's heights. *According to the research done by Chao-Qiang Lai, 80% of what determines how tall a human will be is genetic. A complicated mixture of genes that are passed*

P Does inheritance occur in the same way for all types of organisms? *This question is posed to gather information about students' recognition that all organisms have a genetic code that is passed from parent to offspring, but not all organisms pass that code to offspring in the same way (sexual versus asexual reproduction, for example).*

S What learning activity helped your learning about the relationship between human height and environment (nutrition) the most? *Some responses to this question can be helpful in planning instruction for future lessons.*

Student Page 2.1A: Anticipation Guide

Name: ____

Date: ____

DIRECTIONS: Read each statement and place a check in the **ME** column if you agree with it and a minus if you do not agree with it. Then, read the text related to height and again use a check or a minus, except place it in the **AUTHOR** column. Compare your opinions with those of the author.

Me	Author	Statements from 2.1 Reading	Paragraph
		1. Environment mostly determines human height.	
		2. Parents' heights mostly determine human height.	
		3. Height is a trait that is inherited.	
		4. All human populations inherit the factors that determine height exactly the same way.	

TAKING IT FURTHER:

1. **Change all the minus statements in the author column so that they agree with the textbook, and write down the paragraph number where you found the information.**
2. **Did your level of agreement change due to the reading assignment? Why or why not?**

3. **What evidence do you now have to help explain what causes populations to physically change or stay the same?**

Student Page 2.1B: What Determines Human Height?

Are you taller than your cousin who is the same age? Are you shorter than some of your younger classmates? How much variation in height among individuals can be attributed to your parents, and how much can be attributed to the effects of the environment (for example, good or bad nutrition)? Molecular biologist Chao-Qiang Lai of Tufts University set out to answer this question. He analyzed the results of lots of studies of how height is inherited, and wrote an article for Scientific American that provided an answer. He claims that about 60 to 80 percent of the difference in height between individuals is determined by inherited factors, and 20 to 40 percent can be attributed to environmental factors like nutrition.

First, Professor Lai explains that height is a trait that is controlled by multiple genes and environmental factors. These factors work together to determine a person's height. For example, two humans with identical genetic codes (such as identical twins) might still have different heights, or they might not, depending some environmental factors. Here are some of the results of the different studies that Professor Lai noticed.

One group of researchers tried to establish a relationship between the degree of separation among relatives, and the degree of similarity among their heights. For example, they tried to discover if very closely related relatives (sisters and brothers, for example) had very similar heights, and they concluded that they do. Scientists can measure the number of markers in the genetic code that individuals share. If individuals who share a lot of genetic markers have very similar heights, then that leads researchers to believe that height is strongly linked to heredity. Some researchers in Australia, who took this approach, decided that heredity of height is 80%. They based this conclusion on a study of 3,375 pairs of Australian twins and siblings. Another study, done in the U.S. among men of European descent, also estimated the effects of heredity at 80%.

What does it mean to say that height heritability is 80%? It means that

- 80% of the difference in two people's height is due to their genetic code, and
- 20% is due to environmental factors such as nutrition.

For example, suppose a population of European men has a heritability of 80%, and an average height of 178 centimeters (five feet, 10 inches). Now imagine one man in that population:

- Sven is 183 cm (six feet tall), making him 5 cm (two inches) taller than average.

According to the research, 80% of his extra 5 cm is due to genetic variation, and 20% is due to his environment. In other words, of the 5 cm that Sven is taller than average men in his population, 4 cm is due to the genetic code he inherited, and 1 cm is due to his nutrition and other environmental factors.

Other researchers found that height heritability can vary from one ethnic group to another. In Asian populations, the heritability is far lower than 80%. A scientist in China studied this question and determined that height heritability is about 65% among Chinese men. Another study of African populations concluded the same thing: height heritability is about 65% among the people of western Africa. This lead to even more questions about why heritability is different among different human populations.

Although the percentage of heritability varies some among populations, the research shows that a person's genetic code is a much stronger influence on height than environmental factors. While it's always a good idea to eat right and get enough sleep, you can't really make yourself taller by doing so!

Can We Predict Future Variations?

Explore/Explain

Key Concepts

- Model organisms are used in science for a variety of reasons, including the ease with which they grow and develop in a laboratory and the time it takes to complete a lifecycle.
- Populations are made up of individuals that differ due to genetic variation.
- Meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
- Only certain cells in a multicellular organism undergo meiosis.
- Random chromosome segregation explains the probability that a particular allele will be in a gamete.
- New combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
- Approximately half of an individual's DNA sequence comes from each parent.
- One can predict possible combinations of alleles in a zygote from the genetic makeup of the parents.
- Scientific explanations are developed by using logic and reasoning to connect evidence and claims.

Evidence of Student Understanding

The student will be able to:

- explain why an inquiry into how the purple stem trait in Wisconsin Fast Plants is inherited provides evidence that can be used to understand inheritance in all living organisms.
- draw chromosomes marked with a gene that has two alleles in gametes undergoing meiosis, and explain how the drawing shows what happens in gamete formation and fertilization that results in both similarities and differences between parents and offspring.
- use evidence from an investigation into how the purple stem trait in Wisconsin Fast Plants is inherited to explain the pattern of inheritance for phenotype and genotype of parents, F1, and F2 generations.

Time Needed

5 50–minute class periods (ideally started on a Monday)

Materials

For each student

- 1 copy of Student Page 2.2A ***Traits*** (optional)
- 1 copy of Student Page 2.2B ***Fast Plant Germination Protocol***
- 1 copy of Student Page 2.2C ***Modeling Meiosis***

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For each student (continued)

- 1 copy of Student Page 2.2D ***Meiosis and Tracing the Inheritance of One Gene***
- 1 copy of Student Page 2.2E ***Developing a Scientific Explanation***
- 1 copy of Student Page 2.2F ***The Language of Genetics***
- colored pencils

For each group of four students (Days 1 and 2)

- 2 Petri dishes
- 15 Wisconsin Fast Plants seeds (F_1)
- 15 Wisconsin Fast Plants seeds (F_2)
- paper towels
- eye dropper
- 1 or 2 hand lenses
- shallow tray or bottom from a 2-liter soda bottle

For each group of two to three students (Day 4)

- 1 piece of poster–sized paper
- 2–3 markers (preferably a variety of colors)

For the class

- CD–ROM for *Exploring Populations*
- projector and computer as needed to show video clips from the CD–ROM
- an overhead of Teacher Page 2.2A ***Parent and Offspring Heights***
- an overhead of Teacher Page 2.2B ***Pea Color Inheritance Observations***
- an overhead of Teacher Page 2.2C ***Pea Color Inheritance Observations: Phenotypes and Genotypes***
- an overhead of Teacher Page 2.2D ***Practicing Citing Evidence and Making Claim***
- 2 Petri dishes
- 15 Wisconsin Fast Plants seeds (P_1)

Lesson 2.2 Overview

2.2 Day 1:

This lesson continues the transition started in 2.1 to shift the focus from environmental influences on traits to genetics and inheritance.

Introduction of the experimental question: *Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?*

Learn the protocol and plant F_1 seeds.

2.2 Day 2:

Students make their initial observations of the F_1 seedlings. Then, the class is introduced to looking for inheritance patterns, using a simple pea simulation on the Unit CD (no genotypes are given, only the trait, pea color, is traced through multiple generations). After seeing the value in observing multiple generations of offspring, students plant F_2 seeds (seeds just like those that would have been produced by breeding two F_1 plants).

2.2 Day 3:

A line of questioning leads the class to try explain how genetic information is passed from parents to offspring; then meiosis is introduced. The whole class engages in an interactive discussion of a flash animation depicting meiosis, then teams act out the basics of meiosis with students representing chomatids. At this time, there is no mention of alleles and little use of genetic terminology.

After the work understanding meiosis, students return to their Fast Plant experiment, observing stem color in the one parent given, the F_1 and the F_2 generations. Students begin to make claims linked to evidence to explain their observations.

2.2 Day 4:

The meiosis simulation is revisited, using the genetic terminology learned and with the addition of alleles. This provides additional evidence for explaining the patterns of inheritance observed in the Fast Plants experiment.

Also, additional chromosomes are added to model how independent assortment explains the variation possible among offspring. Then, X and Y chromosomes are introduced into the model to teach how gender is determined.

Finally, Fast Plant observations (P_1, F_1 and F_2) are made, clearly showing patterns of inheritance for the purple and non–purple stem trait. Students record additional claims and evidence in their explanation charts.

Special Note: In preparation for Step 3, begin to grow yeast cultures now. See the yeast protocol in Lesson 3.2 for directions.

2.2 Day 5:

After initial review of students' claims and evidence, the class practices linking claims and evidence, using given samples. After revising their explanations in light of this practice, students are challenged to test their explanations. They predict, using their explanation, what the P_2 phenotype (and possibly the genotype) must have been. Then, they evaluate their explanations based on how well they predict the breeding outcomes in a Fast Plant stem color inheritance simulation.

Next, Mendel's work is introduced through an interactive lecture. Afterwards, the pea simulation from Day 2 is revisited, now with genotypes added.

Students revise and add to their claims and evidence charts, applying their understanding of meiosis and dominant/recessive alleles to their explanations for inheritance of purple traits in fast plants.

Finally, after receiving teacher feedback on the scientific explanations written, the Fast Plant purple and non purple stem inheritance simulation is used again. This time, genotypes are added to the simulation to check students' understandings and abilities to explain the outcomes and to relate the changes in generations to the overarching question, What causes populations to physically change or stay the same over generations?

Advance Preparations

In this inquiry, students use evidence observed in three generations to explain inheritance patterns for a trait in Wisconsin Fast Plants that is regulated by one gene with a dominant and a recessive allele. They engage in a guided inquiry and conduct an experiment directed at answering the following question: Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?

When the investigation begins, students do not know what trait they will observe, but it soon becomes clear that purple or non–purple stems are an obvious trait to track. The one known parent and its first generation offspring clearly have different versions of the stem color trait. But the other parent is an unknown. Students develop initial explanations for the traits observed and make predictions about the unknown parent.

Next, a second generation of seeds are germinated, seeds that represent the offspring resulting from mating two F_1 offspring. Observations of the F_2 seedlings, combined with the previous observations, provide sufficient evidence for students to develop explanations that align with Mendel's explanations for simple inheritance patterns (and to determine what the unknown parent's phenotype was).

This lesson's more teacher–directed inquiry serves as a strong foundation for the more student–directed inquiry in Lesson 2.3 (which also uses Wisconsin Fast Plants). The procedures for both Lessons 2.2 and 2.3 strategically use observations made on one– and two–day old seedlings to significantly reduce the amount of experimentation time required. In Lesson 2.2, three generations are investigated in approximately five days.

Before beginning Lesson 2.2, prepare the correct number of Petri dishes and water trays to hold the Petri dishes for your class(es), as described in the Wisconsin Fast Plant Germination Protocol (see Student Page 2.2B). Also, plan for supplying light directly to the trays of Petri Dishes.

NOTE: Once seeds are placed in Petri dishes and exposed to moisture, provide 24–hour direct light exposure, using a fluorescent desk lamp or tube fixture positioned no more than six inches from the dishes. Low light levels will result in poor seedling development and reduced expression of the purple stem color.

The following chart is provided as an overview for the teacher, NOT for students. The goal is for students to gather evidence from their own Fast Plant seedlings to explain the inheritance patterns observed.

Key to Phenotypes and Genotypes

Parent$_1$
(one Petri dish, planted by the teacher on Day 1)

phenotype **observed** to be:
non–purple stem
genotype **known** to be:
homozygous anl/anl

X

Parent$_2$
(no actual seeds planted)

phenotype **determined** to be:
purple stem
genotype **determined** to be:
homozygous ANL/ANL

F$_1$ Generation

(one Petri dish per group of students, planted by students on Day 1)

phenotype **observed** to be:
all purple stem

genotype **determined** to be:
heterozygous ANL/anl

F$_2$ Generation

(one Petri dish per group of students, planted by students on Day 2)

phenotype **observed** to be:
3 : 1 ratio (within statistical reason)
3 purple stem to 1 non–purple stem

genotype **determined** to be:
approximately ¼ homozygous anl/anl
¼ homozygous ANL/ANL
½ heterozygous ANL/anl

When Planted	What is Planted	Who Plants	Purpose and Rationale
Day 1	1–2 Petri dishes per class with 15 P1 seeds	Teacher	After observing the F1 seedlings on day 2 and 3, one parent's phenotype is shown by sharing 1 or 2 Petri dishes as a class so that students can recognize the stem color as a significant trait and wonder about how it is passed from one generation to the next. The other parent's phenotype (and genotype) is left as an unknown, to be determined by examining the F_2 generation.
Day 1	1 Petri dish per group of 4 students with 15 F_1 seeds	Student Groups	Generation 1 will all show the dominant, purple stem trait because all offspring are heterozygous.
Day 2	1 Petri dish per group of 4 students with 15 F_2 seeds	Student Groups	Observing phenotypes in the offspring of the second generation (produced by breeding two plants from the first generation), and calculating the ratio of those with purple stems to non–purple stems provides evidence, that can be used to figure out the phenotype and genotypes of the original parents. Students can then develop an explanation for how the purple stem trait is inherited (not unlike how Mendel figured out monohybrid inheritance). • These seeds are planted one day later than the others to build in time to wonder and predict what the phenotypes will be for this generation. In addition, students can develop inheritance models, anticipating how various results could be interpreted before actually seeing the results of this cross. In this way, students will more likely be invested in observing and analyzing their results. ***Note:*** This lesson could be modified so that the seedlings are grown from seeds produced by the F_1 generation—it will take approximately 45 days to grow the F_1 plants through flowering, pollination, and seed production, then the seeds produced can be germinated in a Petri dish. This approach makes it more tangible to students where the seeds F_2 originated. See www.fastplants.org for detailed growing instructions.

Can We Predict Future Variations?

Explore/Explain

1. Remind students that the **P**redict question in Lesson 2.1 ***REAPS*** asked *Does inheritance occur in the same way for all types of organisms?* and conduct a brief discussion to review what the class has studied about reproduction and inheritance before this unit. This question is posed to gather information about students' recognition that all organisms have a genetic code that is passed from parent to offspring, but not all organisms pass that code to offspring in the same way (sexual versus asexual reproduction, for example).
   - Explain again that in Step 2 of this unit, the class will be looking into the role that inheritance plays in how populations of all kinds of organisms change or stay the same over generations.
2. Use the graph on Teacher Page 2.2 ***Parent and Offspring Heights*** and a brief discussion about its meaning to prompt responses to the questions that follow. Have students record their individual responses in their Science Notebooks. Either write the questions on the board, project them, or make copies of Student Page 2.2A ***Traits*** so that students can read the question chosen as they write their response.
   - **Question A** What can we predict about the traits we will see in offspring? For example, if two frogs with a trait for white spots mate, what can we know and what can we infer about the traits their offspring will have?
   - **Question B** What can we tell about where the traits we observe in an individual came from? For example, if a puppy has red hair, what can we know and what can we infer about her parents?
3. Ask several students who answered Question A and then Question B to voluntarily read their responses.

   Note: Before they read, explain to the class that these are beginning ideas and are not open to critique by the class. When the class has completed Step 2, everyone will revisit their responses to these questions and see if their thinking has grown or changed.
   - Resist any temptation to correct or challenge the ideas students share at this time; however, encourage students to recall prior experiences with learning about the "genetic code" or "DNA" if references to them occur.
   - Although most genetic terminology will be introduced and practiced later in this lesson, students do need to know what is meant by the term *trait*. Point out instances during the discussion when students reference "traits," and guide the class to recognize that traits refer to an organism's observable features (even if it takes a microscope to observe them).
4. Explain that in this lesson the class will be focusing on what it is about nature that makes it likely that the next generation will closely resemble its parents' generation? (even though we saw that over many generations there can be some changes that result from changes in the environment).

   Point out that while it is not possible to conduct experiments in class with humans to learn about how traits are passed to offspring, the same or similar processes are at work when other organisms reproduce. Some organisms can be raised in the classroom. Explain that this is one of the challenges that scientists often face, too.
   - Use the Interactive Flash Animation, ***Model Organisms*** on the Immersion Unit CD–ROM to illustrate a variety of model organisms used in science and explain why they are useful.
   - Call attention to the non–animals in the animation—like plants and bacteria—and how they can be useful as model organisms to learn about animals because of the many similarities. Use this transition to introduce students to Wisconsin Fast Plants.

- Explain for those who are not familiar with Wisconsin Fast Plants that they grow much more quickly than most plants. This will make it possible to investigate several generations in a week to look for inheritance patterns. Show the video, ***Time Lapse Pollination and Embryogenesis in Wisconsin Fast Plants***, and explain that this will be the model organism students will get to use for experimentation.
  - Use this video and a Think–Pair–Share strategy to review sexual reproduction in flowering plants and be certain that students understand that seeds contain the offspring embryo, which received half of its genes from each of its two parents. *Note: in some flowering plants, like the Arabidopsis pictured in the animation, seeds can be produced when flowers on the same plant pollinate each other (called selfing). Wisconsin Fast Plants cannot self–pollinate, and that is an advantage for this and other genetics experiments because we can be sure that offspring received half their genetic material from each of two different parents.*
  - To review the basics of pollination and seed formation, two resources are included on the Unit CD–ROM that may be useful. The first is a short pollination video, *Floral Arrangements*, about how pollen from one flower reaches another to accomplish fertilization. How sperm contained within pollen reaches an egg within the flower to form a seed is a key understanding that students need to grasp. A diagram of a seed, titled *Inside a Seed*, is also included on the CD–ROM as an optional supplement to help students who may not realize that a plant embryo exists inside each seed. Although this is a monocot seed, it represents what is in a dicot seed, such as a Fast Plant seed.

5. Post and read the following question that will be investigated over the next several lessons:
   - ***Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?***
6. Explain to students that they will be using a ***protocol*** for raising seedlings in a Petri dish in which they will very quickly be able to observe some traits because they appear in the first few days after germination. The timeframe for this first investigation with Fast Plants is 3 days.
   - Distribute to each student a copy of Student Page 2.2B ***Fast Plant Germination Protocol*** to read while you explain the procedures.
   - ***Note:*** For this investigation, the seeds will be planted both during this first lesson and one day later. Using this strategy, students will discover a purple stem trait that can be observed and tracked through generations for evidence of how the trait is inherited. The table that follows explains which seeds are planted when and why.
7. In their Science Notebooks, have students individually draw what they expect the early seedlings will look like as their Wisconsin Fast Plant seeds germinate. Making this prediction will heighten curiosity and interest in how germination will proceed.

Can We Predict Future Variations?

Explore/Explain

1. Ask students in a whole class discussion to review the steps taken in the previous lesson. Guide the discussion to be sure that the purpose of the Wisconsin Fast Plants experiment is made clear. Remind the class of the question driving the experiment, ***Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?***
2. Explain your expectations for students to make and record observations in the Science Notebooks. Emphasize the importance of recording quantitative as well as qualitative data, and conduct a brainstorm about the types of quantitative observations that can be made of the germinating F_1 seeds.
   - Guide the brainstorm to include recognition that the number of germinating seeds/seedlings with a particular variation of a trait can be counted and recorded. ***Resist the temptation to tell students about using trait ratios to figure out parental genotypes; this will be something students have an opportunity to discover after simulating meiosis.***

   For helpful Science Notebook strategies, see the ***Immersion Toolbox***.
3. Time 10 minutes for student groups to retrieve, observe, and record data about their Petri dishes with germinating F_1 seeds.
4. Conduct a whole class, small group, or individual interaction with the **Pea Plant breeding (meiosis) simulation** software guided by the following question: ***What patterns do you see in the breeding and inheritance of the pea color trait?***
   - In their science notebooks, have students record their observations in a table like the one shown in Teacher Page 2.2B ***Pea Color Inheritance Observations***.
   - A sample script, including prompts and questions, is provided with the Pea Plant breeding simulation on the Unit CD.
   - The terms phenotype and genotype are not yet introduced or defined at this time. These terms will be used on Day 4 of Lesson 2.2.
5. As a whole class, record students' ideas about observed patterns from the simulation. Keep in mind that there will be additional opportunities to consider similar patterns when they observe their Wisconsin Fast Plants seedlings.
   - Reinforce for the class that in the Wisconsin Fast Plants experiment that they are conducting, they are looking for evidence to answer the question, ***Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?*** In their Science Notebooks, have students record this question and their predicted answer with an explanation.
6. Explain that, like it was helpful to have multiple generations to look for inheritance patterns in the pea simulation, the class will be able to gain information about inheritance patterns in Wisconsin Fast Plants if they have seedlings to observe from a cross between two F_1 parents.
   - Depending on the types of patterns students identified from the computer simulation, students may be ready to suggest why this would be helpful. However, keep discussion short, and provide sufficient time to plant the F_2 seeds.
7. Explain that you have seeds that were collected from plants with parents just the same as those F_1 seedlings. Have student groups follow the same protocol as used in the previous lesson to germinate 10–15 F_2 seeds in a Petri dish.
   - Review the ***Time Lapse Pollination and Embryogenesis in Wisconsin Fast Plants*** video on the Unit CD–ROM to again illustrate how the F1 seeds were produced. Point out the bee–stick used to pollinate the flowers.

Can We Predict Future Variations?

Explore/Explain

1. Conduct an interactive whole-class discussion to introduce meiosis with a series of prompts like the following:
   - *What happens when our Fast Plant seedlings grow?* Collect students' ideas of all types while looking for indications of growth or development involving production of more cells. Use ideas related to growth and development to lead to ask about cells.
   - *When does an organism need to produce more cells?* Chart students' responses to this question to generate a list.
   - *Where do more cells come from?* Guide the class to acknowledge answers that may include ideas such as: from bigger cells that produce new cells (students may not realize that these bigger cells divide to become the new cells), from parent cells joining (students may or may not understand gamete formation or fertilization), from other cells that divide.
   - *We keep saying that traits (which involve cells) are coded for by the genetic code and DNA. Where IS and organisms' DNA?* After some discussion of this question, use the flash animation, Journey Into DNA, on the Unit CD–ROM to help students visualize that DNA is in nearly every cell that makes up an organism.
   - *What evidence do we have that DNA must be in sex cells?* This line of questioning is designed to guide students to recognize that offspring have the genetic code they need to grow, develop and sustain life, they resemble their parents, and they resemble their other ancestors is strong evidence that the genetic code is passed from parents to offspring through sex cells. Use this discussion as an opportunity to ask students "How do you know?" when appropriate to establish the expectation that science is characterized by evidence-based discussions.
   - *If parents pass their genetic code to their offspring, what keeps the offspring from having double the amount of DNA that their parents had?* Use this question to informally assess students' prior conceptions about inheritance and possible knowledge of meiosis. You may choose to have students individually record their response to this question in their science notebook to gain strong individual investment in understanding the meiosis process (to see if it explains their response).
   - *What are the sex cells in humans, and what do you know about how they are formed?* This question can be the transition to introducing meiosis as the process that leads to gamete formation.
2. Explain that the process for sex cell development is called meiosis, and conduct an interactive discussion using the flash animation on Teacher's Domain, How Cells Divide: Mitosis vs Meiosis, or a similar resource.
   - Explain in advance that student groups will be working in small groups to model the process of meiosis, following this interactive discussion.
   - Provide Student Page 2.2C ***Modeling Meiosis*** for students to use as a reference and to take notes to use when they model (act out) meiosis, next.
3. Select four students to demonstrate how to "act out meiosis" and gather the class in a large circle (representing the cell membrane) around the demonstration. Guide the four students to model what happens to one chromosome through the stages of meiosis.
   - Provide simple props for students to use to represent the location of a gene on the chromatids (not alleles, yet), centromeres, nuclear membrane, and cell membrane.
   - Keep in mind that students will re-visit meiosis and this model again on Day 4 after learning genetic terminology, including genotype, types of genotypes,

alleles, etc. This first run-through of the model is intended to focus on the general meiosis process.

4. Have students work in groups of four or five to design and model meiosis.
   - Circulate among teams to check for understanding about the structures involved and the end products (gametes with half the amount of DNA as the parent cells).
   - Have each team demonstrate their model to you individually or to the class for constructive critique.
   - After the modeling is completed, have students record their understanding on Student Page 2.2D ***Meiosis and Tracing the Inheritance of One Gene***.

   Be sure that students keep Student Page 2.2D ***Meiosis and Tracing the Inheritance of One Gene*** in their science notebooks if the work is not already there. The page can be taped to a page of the notebook. It will be an important reference later.

5. Explain that gamete formation occurs in Wisconsin Fast Plant flowers when pollen and eggs are formed prior to fertilization. Remind students that they will be observing their seedlings, which are the offspring in this investigation.
   - Explain that on the first day you also planted a Petri Dish containing seeds that were identical to the mother plant. Student groups will take turns observing these seedlings, while observing their own F_1 seedlings.
   - Provide approximately 10–15 minutes for students to make and record in their Science Notebooks observations of the F_1 generation seedlings.

6. As a whole class, discuss observed traits and variation among the F_1 and P_1 seedlings.
   - List for the class all reported patterns observed in the data collected.
   - Guide the discussion to focus on the trait purple stem or non–purple stem.
   - As students report ideas, be sure they also state *how* they know what they share to clearly differentiate between evidence and inference.
     - List inferences separately from evidence.
     - When more than one group reports the same evidence, highlight that in science having more evidence strengthens that evidence.

7. With a partner, have students fill in the question and their initial prediction (recorded in their Science Notebooks on Day 1), and at least one claim/evidence entry in an explanation graphic organizer in their Science Notebook. Use the format of the graphic organizer shown on Student Page 2.2E ***Developing a Scientific Explanation***. Students need to be prepared to share and explain their ideas to the class.
   - Re-emphasize to students that strong scientific explanations include a claim, cite evidence, and give clear reasoning that links the evidence to the claim.
   - *Note:* Genetic terminology will be formally introduced at the start of the next lesson to make it easier to communicate ideas.

8. Remind students that in the previous lesson, seeds like those that would be produced by breeding two of their F_1 seedlings were placed in a Petri dish to germinate and will be ready to observe tomorrow.
   - Individually, have students record in their science notebooks what they predict they will observe for stem colors in those seedlings and explain their prediction. Relate this prediction back to the overarching question that is driving the experiment, ***Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?***

Can We Predict Future Variations?

Explore/Explain

1. Point out any instances that you can cite from Lesson 2.1 or 2.2 in which communication was clumsy because students lacked experience with genetic terminology.
   - Explain that before observing the F2 seedlings and developing explanations in this lesson, the class will gain some common understanding of key genetics terms.
2. You may wish to again guide the whole class through a review of where DNA is located using the flash animation, ***Journey Into DNA***, on the Unit CD–ROM.
3. Divide the 6 terms (Term A through Term F) among the class, and have students individually read the paragraph(s) explaining their assigned term.
   - After students read their term, form groups of 2–3 students who read the same term to discuss and answer each other's questions about it. **Note**: Term C: **Genotype** includes explanations for the terms **heterozygous** and **homozygous**. Students need to be clear about the meaning of these terms.
   - Circulate among student groups to help with any questions about the meaning of their term.
4. Assign each student group (working on a term together) to use approximately 15 minutes to make a poster that includes:
   - their term in bold print, written large enough to be seen by students seated in desks,
   - a picture and no more than 5 words to explain what the term means.

   Decide in advance where in your classroom students can post their posters and reference them through the rest of this unit. If this is not possible (or in addition), consider having students use the class posters for ideas to generate their own illustrated glossary in their Science Notebooks.

   Circulate as posters are made, and challenge any misconceptions and errors to be sure that the posters accurately represent the meaning of these key genetics terms.

   Have students who complete their poster first post it on the wall and then read the other terms to see if other groups' posters make sense to them.
5. Transition back to now wonder about the genotypes and phenotypes of the P_1, F_1, and F_2 Wisconsin Fast Plants by randomly choosing students to describe, using terms from the posters, the investigation that has been taking place over the last three days.
   - Point out the question posted earlier that is guiding the Wisconsin Fast Plants investigation, ***Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?***
6. Organize students into the groups with whom they have been investigating Fast Plants, and use a Think-Pair-Share strategy for students to discuss what they predict stem colors will be in the F2 seedlings and why.

   Then, allow time for students to make and record F2 seedling observations.
7. Gather F_2 seedling observations from the entire class to increase the amount of data available for students to analyze and use as evidence for inheritance patterns.
   - Include in the data table the **number of purple stem seedlings** and the **number of non–purple stem seedlings**.
   - Have student groups fill their data into a class data table as soon as they are able. An overhead transparency works well for this.
8. Facilitate a whole class discussion from which you chart a list of claims that students are beginning to make about the inheritance of the purple stem trait in Wisconsin Fast Plants. Record in separate lists the evidence (observations made) and reasons students offer for their ability to explain the traits they observe in the different generations.

- Have students take out and refer to their work on Student Page 2.2C ***Meiosis and Tracing the Inheritance of One Gene*** as an additional source of evidence and support for reasoning.
- During the discussion, model how to (and encourage other students to) ask those offering ideas to specifically reference the evidence for the ideas they present.

9. Re–emphasize the way that genetic material is passed from parents to offspring through fertilization and the fusion of their male and female gametes by using a Think–Pair–Share strategy to review this early step in sexual reproduction. Transition to re–visiting meiosis with questions, such as:
   - *How much DNA will each parent give its offspring?*
   - *What keeps offspring from ending up with twice the amount of DNA that their parents had if both parents pass DNA to them?*
   - *How are the cells that participate in sexual reproduction different than other cells in the body?*
   - *Which type of cells will be involved in sexual reproduction, and how are they formed?*

10. Explain that you expect students can probably see a number of limitations in the accuracy of their simulated meiosis act from Day 3. Now, with additional terminology and experience, the class can add more detail to the simulation so that it better explains what they understand about inheritance and meiosis.
    - Again, have the class form a "cell membrane" circle around a group two students, and indicate their location inside the nuclear membrane.
    - Conduct an interactive discussion with the whole class, while having the demonstration group re–create the meiosis simulation as previously done. In addition to how it was first modeled, include the following:
      - o markers on the "genes" to indicate two different alleles for the trait governed by the gene (start with a heterozygous parent cell, and make note of the possible gamete genotypes produced)
      - o additional chromosomes (two important concepts need to be explained here: 1) in meiosis, genes on different chromosomes sort independently—demonstrate this by analyzing possible gamete genotypes produced, and 2) gender is determined by the chromosomes inherited—add an X and Y chromosome first, then two X's. Discuss the gender of the parent cell and which parent determines the sex of human offspring.

    After the modeling, provide time for students to add alleles, labels, notes, and lessons learned to Student Page 2.2D ***Meiosis and Tracing the Inheritance of One Gene***.

11. Conclude the lesson with a homework assignment for students to record in their Science Notebooks additional claims and evidence they now have for answering the experimental question, ***What can we tell about parents' traits by observing their children's and grandchildren's traits?*** Continue to use the graphic organizer for a scientific explanation that was started on Day 2 of this lesson (see Student Page 2.2E ***Developing a Scientific Explanation***).

Can We Predict Future Variations?

Explore/Explain

1. To review what the class is working to understand and bring students who were absent up to speed, call randomly on students to provide summaries for the following questions:
   - *What is the question we are trying to answer through the Wisconsin Fast Plants investigation?* Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?
   - *How does this question relate to questions about inheritance in other types of organisms?* Wisconsin Fast Plants are the model organism the class is using to understand inheritance patterns in general.
   - *What have we done so far to answer this question scientifically?* Review the steps taken and evidence gathered so far. End with a summary of the previous lesson's discussion about the combined class data for the F_2 generation and homework assignment.
2. Guide an interactive discussion with the whole class to practice making claims and linking evidence to claims. Use a Think-Pair-Share strategy to complete the sample claims without evidence and evidence without claims chart that is given on Teacher Page 2.2C ***Practice Making Claims and Citing Evidence***.

   Next, pair students who completed the homework, and provide 3–5 minutes for them to compare, discuss and review their claims, evidence, and explanations for the investigation question.
   - Direct students who have not completed directions 1 and 2 on Student Page 2.2E to work individually to record their thinking at this time.
3. Conduct a whole–class review of students' current explanation development for the inheritance patterns observed in their Wisconsin Fast Plants experiments. At this time, students are ready to predict, using their scientific explanations, what the P_2 phenotype (and possibly the genotype) must have been.

   Develop a chart in which to gather the various claims and evidence that students make.
   - If students have difficulty stating claims, begin by asking what evidence they think is significant. Then, ask what is significant about that evidence, and what you hear stated will likely be the student's claim. Paraphrase back to help clarify the claim, and record it on the chart.
   - Guide students to explicitly add the logic and reasoning for why some evidence supports the claims being made to build complete explanations. Many explanations are made up of multiple claims that are supported by evidence, with logic and reasoning that link everything together.
4. Explain that the class can use a model of the Wisconsin Fast Plants experiment to evaluate if their explanations can predict the traits that will be inherited over generations.
   - Have students exchange Science Notebooks so that they use another student's explanation to predict the inheritance of the purple or non–purple stem trait in the simulation.
     - o Provide time for students to check that they understand their peer's explanation before beginning.
   - Launch the Wisconsin Fast Plants Inheritance Simulation on the Unit CD , and facilitate an interactive discussion about students' explanations and their ability to predict stem color.

   Note: DO NOT reveal the genotypes for the seedlings at this time. Acknowledge any suggestion that knowing the genotype would help, but explain that this information will be shared later.
5. Continue working as a whole class, and explain how scientists often are able to turn to the work that other scientists have done to see how their evidence and explanations compare.

- Share a brief explanation of how Gregor Mendel worked to understand inheritance by making observations very similar to those made by the class in the Wisconsin Fast Plants investigation.
- Explain that Mendel was among the first to study inheritance patterns and did his work before scientists had discovered genes, so his work was very cutting edge.

Following this brief introduction, explain that you are going to show a summary of the work Mendel did with peas so that students can compare the explanations they have developed with Mendel's explanations.

- Stress that the purpose is for students to look for both similarities and differences in the experimentation, the results, the claims, and the reasoning and use this information to revise and strengthen their own explanations.

Show the two Mendel flash animations from the Unit CD–ROM. First show and discuss, ***Some Genes are Dominant***, then show and discuss, ***Mendel's Laws of Genetic Inheritance***.

- Use a Think–Pair–Share strategy after each animation sequence for students to discuss how Mendel's work and explanations compare to their ideas. When pairs share as a whole class, focus the discussion on any "aha's" students had from watching the animation and any questions it raised.

6. Run the Pea Inheritance Simulation with genotypes on the Unit CD. This Simulation is just the same as the one used on Day 2, except the genotypes are given.
   - Step through the simulation, pausing before each new generation to have students predict the phenotypes and genotypes that may be produced.

   Throughout running the simulation, stress that this model cannot predict the actual outcomes for phenotypes and genotypes produced by real pea plants. Rather, this model can only simulate the possible phenotypes and genotypes that can be produced and the probability that they will occur.

   For additional strategies to use when students evaluate scientific explanations, see the ***Immersion Toolbox***.

7. Individually, have students add to, revise, and complete Student Page 2.2E ***Developing a Scientific Explanation***. Tell students to be prepared to read and explain their explanation to the class.

8. Select a student to read his or her explanation and invite discussion about its strengths and possible challenges.
   - Explain how this process of communicating and evaluating strengths and weaknesses in explanations is an important part of how science works.
   - Select two or more additional students to also present, and use the discussion to highlight how—just like scientists—two individuals working with the same data can reach different conclusions and/or use different reasoning to reach the same conclusions.

   For additional strategies to use when students communicate scientific explanations, see the ***Immersion Toolbox***.

9. Use the REAPS questions to stimulate further class discussion and as closure for this extended lesson.

10. Read and provide feedback to students about the quality of their scientific explanations for the inheritance of the purple and non–purple stem traits and their justification for the traits predicted for P2.
    - Facilitate an interactive review of meiosis and stem color inheritance in Wisconsin Fast Plants, using students' Science Notebook notes and the Fast Plant Inheritance Simulation on the Unit CD. Re–emphasize the following key concepts:
      - o Seeds contain embryos that grew from

the fusion of the parent plants' male and female gametes (pollen and egg).

- o The male and female gametes in plants, like in other organisms, are produced through meiosis.
- o Pairs of chromosomes separate and segregate randomly during cell division in meiosis to produce gametes with one chromosome of each type.
- o New combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
- o Random chromosome segregation explains the probability that a particular allele will be in a gamete.
- o Half of an individual's DNA comes from each parent.
- o We can predict possible combinations of alleles in a zygote from the genetic makeup of the parents. Similarly, we can predict the possible combinations of alleles in a parent plant from the genetic makeup of offspring.

Scientific explanations are developed by using logic and reasoning to connect evidence and claims.

- As new generations are simulated, challenge students to relate the changes in frequencies of phenotypes and genotypes to the overarching question, What causes populations to physically change or stay the same over generations?

11. Have students turn to the unit graphic organizer and the posted overarching unit question, ***What causes populations to physically change or stay the same over generations?*** and guide the class to develop another T–chart, adding new information and evidence to use in forming an answer.
    - Check for students' understanding that populations are made up of individuals that differ due to genetic variation.

Summative REAPS (for use on Day 5)

R What is meant by a 3 to 1 ratio? *In Mendelian genetics, this ratio describes the inheritance probability for a single, dominant/recessive trait. It means that for every three offspring who present the phenotype coded for by the dominant allele, one will present the phenotype coded for by the recessive allele (and be homozygous for the recessive allele).*

E In fast plants, purple stem color (P) is dominant over green stem color (p). What would be the genotypic and phenotypic ratios of the offspring produced from two parent plants that are both heterozygous for stem color? Use a drawing that shows meiosis or a Punnett square to illustrate your answer. *The following represents the ratios using a Punnett square:*

Parent 2 → **Parent 1↓**	**P**	**p**
P	**PP** *(purple)*	**Pp** *(purple)*
p	**Pp** *(purple)*	**pp** *(non–purple)*

A A healthy man and woman marry and have three children. The first two children are healthy, but the third is born with the condition cystic fibrosis. The doctor who sees the first child tells the parents that her genotype is *cc* for the cystic fibrosis alleles. What can you know about which allele is dominant for the trait that determines if an individual has the condition, cystic fibrosis? What can you know about the genotypes of the other people in the family? *The parents must be heterozygous for the cystic fibrosis determining trait. Together they can produce children who are also heterozygous or are homozygous for either the dominant or the recessive allele. The first two children are healthy, so they must either be heterozygous or homozygous for the dominant allele.*

P How could a sex cell from an individual in a population ever contain an allele that is brand new to the population? *This question sets the stage and can provide insight into students' prior knowledge about mutation.*

S Write a list of the "top 5" things you learned during your work with Wisconsin Fast Plants. For each learning on your list, write one sentence that explains why you included it.

Teacher Background Information

Background Information

What happens after pollination between fertilization and seed harvest? **Fertilization** in sexually reproducing organisms represents the beginning of the next generation. Immediately following fertilization, the pistil and other maternal structures will grow and change functions. Within the ovules, the embryos also grow and differentiate through a series of developmental stages known collectively as **embryogenesis**.

Fertilization

Fertilization is the reproductive process in which a male and female gamete fuses to form a zygote. In Wisconsin Fast Plants™, fertilization also results in the development of endosperm to nourish the developing embryo. Double fertilization, as in Wisconsin Fast Plants™, follows pollination with a pollen tube growing from each of the many compatible pollen grains adhering to the stigma. Each tube contains two sperm cells and its own nucleus. Only a few of the hundreds of pollen tubes that enter the ovary cavity will successfully fuse with an ovule, and each ovule is joined to only one tube.

One sperm from the pollen tube then unites with the egg cell nucleus (1n) in the ovule to produce a zygote (2n), which will develop into the embryo. The second sperm unites with the ovule's two polar nuclei (each of which are 1n) to form the endosperm (3n). This process is sometimes referred to as double fertilization because it involves two sperm uniting with two separate nuclei.

Embryogenesis

Embryogenesis is the development of a healthy seed and its accompanying fruit, following fertilization. It is a highly coordinated sequence of developmental events within the ovule and supporting maternal ovary tissues. The following processes of embryogenesis are responsible for the production and packaging of the next generation (the seed):

- the endosperm is formed;
- the zygote develops into an embryo;
- ovule cells differentiate to produce a seed coat; and
- the ovary wall and related structures develop into a fruit.

After fertilization, and before embryo development, the endosperm and supporting maternal tissues rapidly grow and develop. The triploid (3n) endosperm nucleus that formed during fertilization divides very rapidly and repeatedly to form the nutrient-rich, starchy liquid endosperm. This liquid endosperm bathes the developing embryo, providing it with nutrients. In the latter stages of embryo development of brassicas and other plants, the embryo converts the starchy reserves in the endosperm into lipids that are stored in the embryonic cotyledons. As the embryo matures to a seed, it comes to occupy the space that was filled by the endosperm.

As endosperm formation begins, the first mitotic division of the zygote marks the beginning of embryogenesis. After successful pollination and fertilization, Wisconsin Fast Plants™ embryos mature into seeds in 20 days.

While the embryo develops, the integuments (the walls of each ovule) develop into a seed coat. This coat of maternal tissue protects the new generation until favorable conditions for seed germination are present.

Finally, as the ovule develops into a seed, the ovary wall and other maternal structures in the pistil grow to become the fruit. In some plants, this tissue (which surrounds the enlarging seeds) may thicken, differentiate and develop into a fleshy fruit. In other plants, such as with Wisconsin Fast Plants™, it may dry into a pod. In addition to protecting the developing ovules, the fruit often serves as a means of seed dispersal.

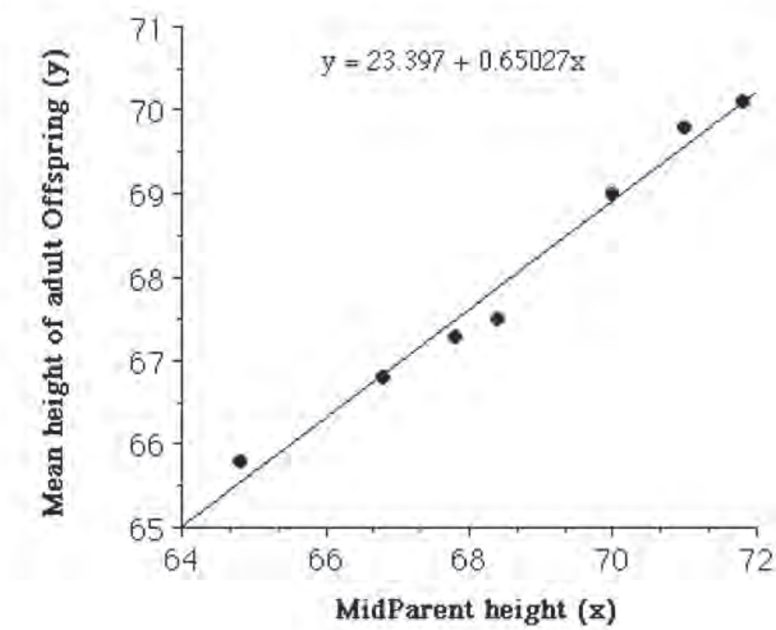
Senescence

As a plant ages and matures, certain tissues and organs no longer have any use. From a casual observation it may seem that they are simply discarded by the plant. However, plants actually initiate a complex sequence of events (called *senescence*) before disposing of these tissues and organs (called *abscission*). In Wisconsin Fast Plants™, the nectaries (located at the base of the pistil) dry up, the sepals, petals, and stamens wither and fall as they are no longer needed, following fertilization.

Senescence is an active developmental process. At the genetic level, sets of senescence-associated genes (SAGs) are expressed and a corresponding array of proteins are synthesized and become active. In turn, these proteins are responsible for the recovery of valuable resources (including amino acids, sugars, nucleosides, and minerals) from the tissues that are about to be discarded.

For Wisconsin Fast Plants™, the process of senescence allows the plants to transfer accumulated resources from the tissues to be discarded into the synthesis and maturation of seeds. In this instance, senescence is genetically preprogrammed. Other ***annuals*** (plants with a one-year life cycle) also have genetically regulated senescence. In other cases of senescence, such as the falling of leaves from trees in autumn, the trigger is mainly environmental.

Teacher Page 2.2A: Parent and Offspring Heights



$\dfrac{\text{sum of all children's heights}}{\text{total number of children}}$

$\dfrac{\text{(mother's height + father's height)}}{2}$

Source: Walsh, B.. (2007). Human Height Correlation Figure. Retrieved July 11, 2007 from http://nitro.biosci.arizona.edu.

Teacher Page 2.2B: Pea Color Inheritance Observations

Trait being observed: ***Pea Seed Color***

Note: Using colored dots (green or yellow) to represent the seed colors in this table can help when looking for patterns in the data.

Simulation Generation	Parent 1	Parent 2	Offspring generated
1			
2			
3			
4			
5			

Teacher Page 2.2C: Pea Color Inheritance Observations: Phenotypes and Genotypes

Phenotype (trait) being observed: ***Pea Seed Color***

Genotypes for the phenotypes:

Note: Using colored dots (green or yellow) to represent the seed colors in this table can help when looking for patterns in the data.

Simulation Generation	**Parent 1** ***phenotype / genotype***	**Parent 2** ***phenotype / genotype***	**Offspring generated** ***phenotypes / genotypes***
1			
2			
3			
4			
5			

Teacher Page 2.2D: Practicing Citing Evidence and Making Claims

1. What are you explaining?
Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?

A claim that you believe is accurate	Observations, information or data that supports your claim	Source(s) for the observation or data that you are using	Logic and Reasoning: Explain how these observations or data are linked to your claim
mother and father plants can have babies with the opposite color stem as themselves	**?**	*my observations and the class experimental results*	*If the parents could only have babies with the same color stem, than the F_2 seedlings would have all had purple stems because both parents were purple stemmed.*
?	*The mother and father from the F_1 generation were both purple but had quite a few non–purple stem babies.*	**?**	*Maybe something just happened to keep some of the seeds from germinating that would have grown to be non–purple F_1 seedlings.*

Teacher Page 2.2D: Practicing Citing Evidence and Making Claims (annotated)

1. What are you explaining? *Using Fast Plants as a model organism, what can we tell about parents' traits by observing their children's and grandchildren's traits?*

A claim that you believe is accurate	**Observations, information or data that supports your claim**	**Source(s) for the observation or data that you are using**	**Logic and Reasoning:** **Explain how these observations or data are linked to your claim**
mother and father plants can have babies with the opposite color stem as themselves **This is certainly a claim that students can and likely will make**	? **The P_1 stem color was non–purple, but all the F_1 had purple stems. Also, the F_1 had purple stems, but some of the F_2 did not**	*my observations and the class experimental results* **Experimental results are the only source for the Fast Plant observations**	*If the parents could only have babies with the same color stem, than the F_2 seedlings would have all had purple stems because both parents were purple stemmed.* **This is an example of sound logic and reasoning.**
? **Use this as an opportunity for students to practice forming a claim. Based on the evidence in the next column, the claim could be something like the one above,** *mother and father plants can have babies with the opposite color stem as themselves.* **However, the logic and reasoning given in this column suggest the claim was something like,** *Whatever stem color the parents have, they will have offspring with both purple and non–purple stems*	*The mother and father from the F_1 generation were both purple but had quite a few non–purple stem babies* **Use this example to demonstrate how this observation could be used as evidence for a number of claims, some based on sound reasoning and some not.**	? Experimental results are the only source for the Fast Plant observations	*Maybe something just happened to keep some of the seeds from germinating that would have grown to be non–purple F_1 seedlings* **Use discussions about this reasoning to challenge its validity. Ask the class what evidence would be needed to support this claim. If there were seeds that did not germinate in the F_1 Petri dishes, that could be used as evidence to support this claim, though it would not be particularly strong unless the experiment was repeated and it was found that when all seeds germinate, some F_1 seedlings *do* have non–purple stems.**

Student Page 2.2A: Traits

Select either Question A or B to complete in your Science Notebook.

1. **Question A** What can we predict about the traits we will see in offspring? For example, if two frogs with a trait for white spots mate, what can we know and what can we infer about the traits their offspring will have?

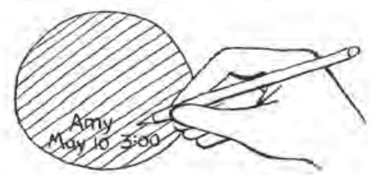
2. **Question B** What can we tell about where the traits we observe in an individual came from? For example, if a puppy has red hair, what can we know and what can we infer about her parents?

Student Page 2.2B: Wisconsin Fast Plant Germination Protocol

A ***protocol*** is a detailed plan for how to perform a task. The following steps describe the procedure for germinating Wisconsin Fast Plants seeds in a Petri dish. This protocol explains an effective way to set up a controlled environment in which to germinate Wisconsin Fast Plant seeds in a Petri dish. It is ***not*** an experimental design; there are no manipulated variables described in this protocol. This method for germinating the seeds can be used in a wide variety of experiments.

Protocol

1. From a paper towel or a piece of filter paper, cut a circle 8.5 cm in diameter to fit in the cover (larger half) of a Petri dish. With a pencil, label the bottom of the paper circle with your name, the date and the time.

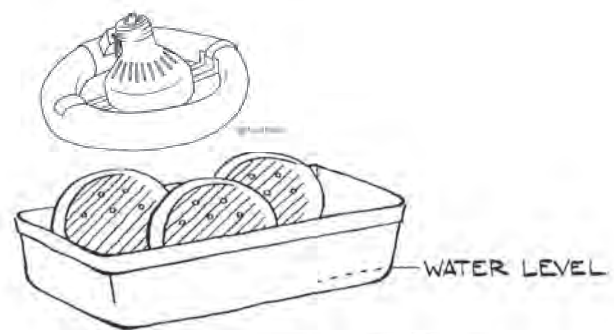


2. Moisten the paper circle in the Petri dish with an eyedropper.

3. Place 20–25 Wisconsin Fast Plants™ seeds on the paper circle along the arranged evenly and then cover with the bottom (smaller half) of the Petri dish.

4. Place the Petri dish at a steep angle (80˚– 90˚) in shallow water in a tray so that the bottom two centimeters of the paper is below the water's surface. Be sure the water is just soaking the paper towel which will wick water to the seeds. If seeds are under water, it can inhibit germination.

5. Set the experiment in a warm location approximately 10 centimeters under a flourescent light source (optimum temperature: 65–80˚F). Check the water level each day to be sure the paper circle stays wet.



6. On your individual data sheet record the day, time, and initial environmental conditions for the experiment.

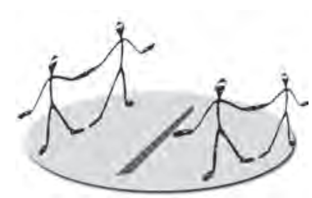
Over the next 3–4 days observe the germinating seed and seedlings using a magnifying lens.

Source: Wisconsin Fast Plants, www.fastplants.org

Meiosis Simulation Instructions

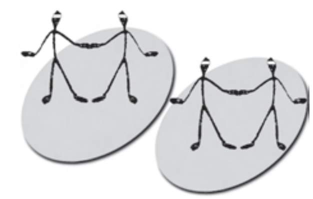
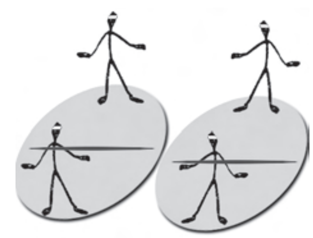
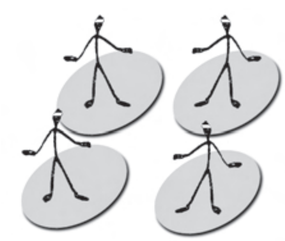
Directions Use the following steps and cartoons as a guide. Organize and plan with your team to use props and actions to simulate meiosis. Be sure that your simulation includes the following:

1. people who represent chromosomes, including sister chromatids
2. centromeres
3. one gene that is located on the chromosome represented in the simulation
4. movement that represents what happens during meiosis
5. something to indicate where there are cell membranes
6. at least one team member to narrate and explain what happens as the team moves through its simulation

Before meiosis, the nucleus of the cell contains pairs of chromosomes—one from the father and one from the mother. These are called homologous chromosomes In humans, there would be 23 pairs of chromosomes, but we will do this simulation with only one pair. Each person at this stage represents one of a pair of homologous chromosomes. The white headband represents the location of gene on this chromosome. Before meiosis begins, the chromosomes are loosely organized, and they are called chromatin.	
Prophase of first meiosis. Each chromosome replicates, forming 2 sister chromatids that are joined by a centromere. The nuclear membrane breaks down during this phase	
Metaphase of first meiosis. Pairs of homologous chromosomes (one came from each parent) now move to the center of the cell along the region where the cell will divide. In our example, the only two chromosomes in the nucleus are homologous.	
Anaphase of first meiosis. The chromsomes (both sister chromatids still joined) go to opposite poles. At this point note that entire chromosomes with two chromatids go to each pole.	

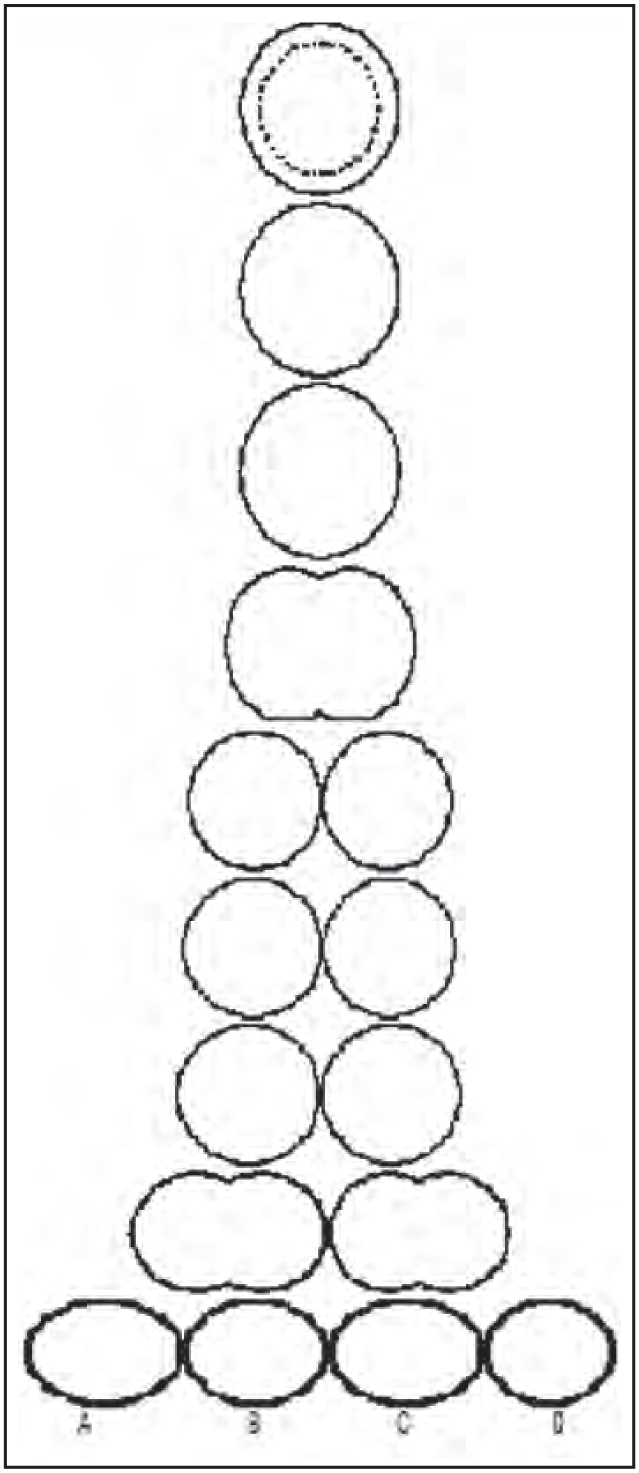
Continued on following page

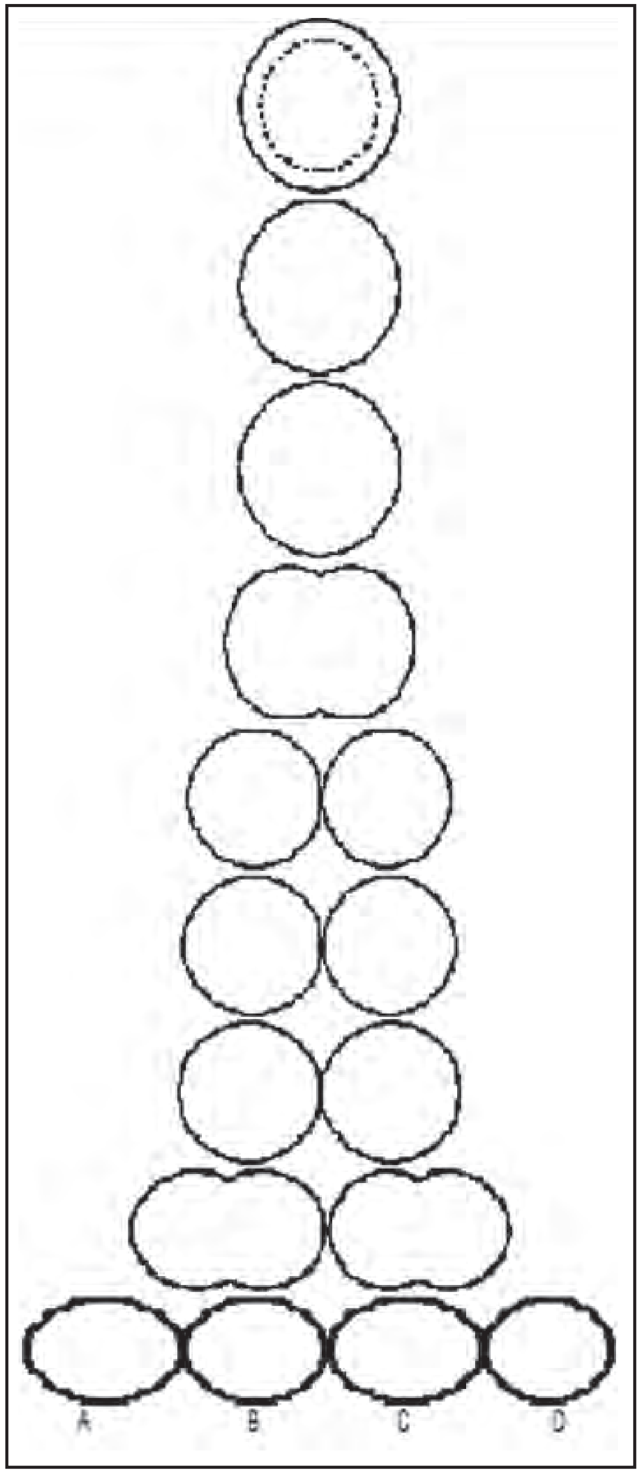
Student Page 2.2C: Modeling Meiosis (continued)

Telophase of first meiosis: The cell divides, forming two cells that each ohave one of the two homologous chromosomes that were both in the parent cell. Sister chromatids are still joined at the centromere.	
Metaphase of second meiosis Again the chromosomes line up on the center of the cell in the region where it will divide in half. However, this time they have no homologous chromosome with which to pair.	
Anaphase of second meiosis. This time the chromosomes separate into at the centromere, and the chromatids go to opposite poles. In second meiosis, the number of chromosomes going to each pole is the haploid number.	
Telophase of second meiosis. Parent cells divide and nuclear membranes begin to form again. We now have four cells, each with a complete haploid set of chromosomes. These cells become the sex cells, like sperm and eggs.	

Student Page 2.2D: Meiosis and Tracing the Inheritance of One Gene

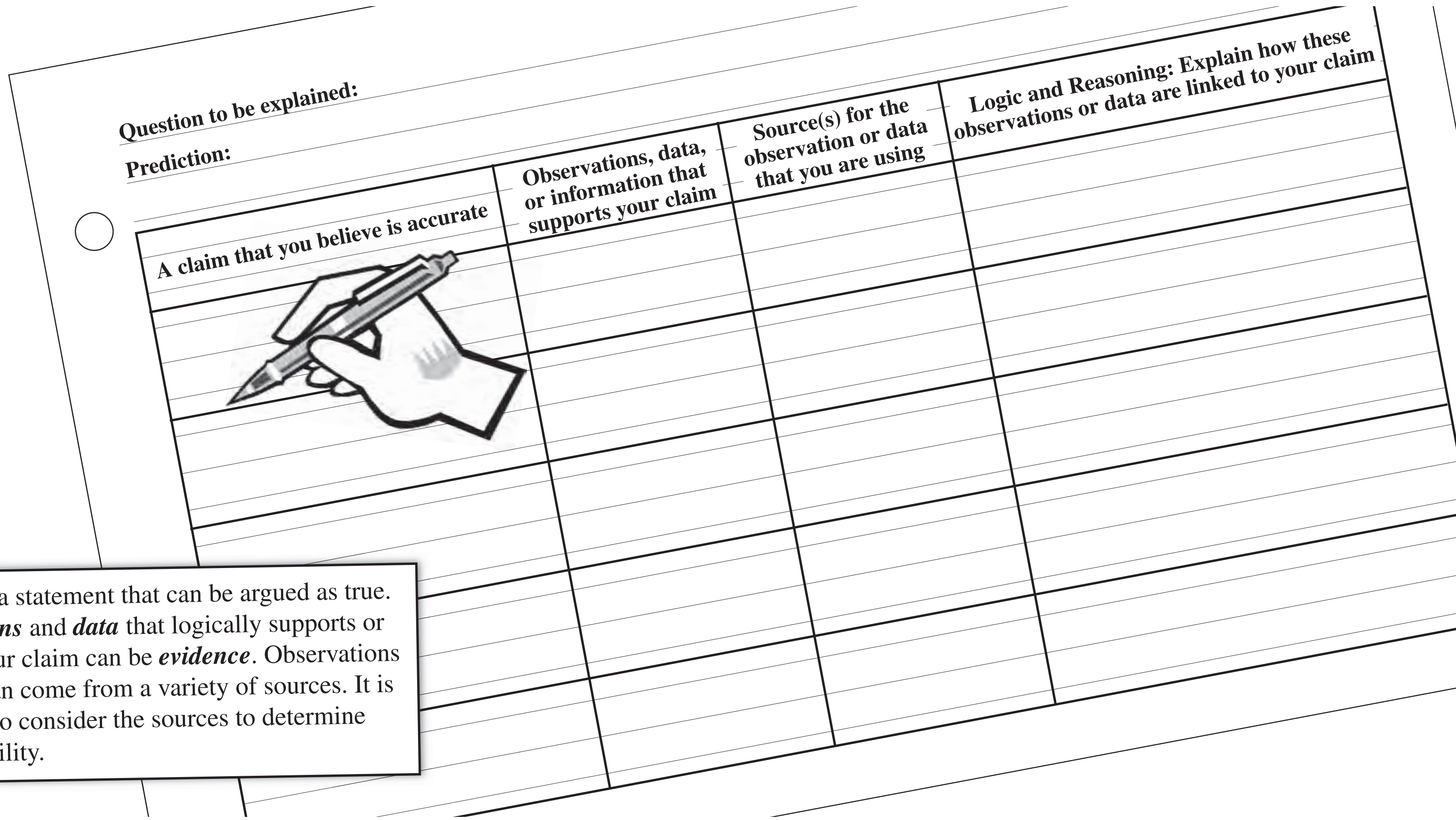
1. Label the cells that represent the pollen and egg. Draw in each of the two parent sex cells one paired chromosome with a portion colored to indicate the location of a single gene.





Student Page 2.2E: Developing a Scientific Explanation

1. Begin a new page in your science notebook. At the top of the page, record today's date, and record the question that you are going to be working on answering in your scientific explanation.
2. Below the question you wrote in #1, record your initial prediction for the answer to your question. Explain the prediction.
3. In your Science Notebook, complete a chart like the following to develop an explanation for patterns in the data you analyzed.
4. In your Science Notebook, write your explanation in paragraphs that include complete sentences, stating your claim and explaining the evidence and information that you are using to support it.
5. After writing your explanation, record any new or modified questions that you have about this natural phenomenon.
6. Write three or four sentences comparing your current explanation to your original prediction (#2 above).



A ***claim*** is a statement that can be argued as true. ***Observations*** and ***data*** that logically supports or negates your claim can be ***evidence***. Observations and data can come from a variety of sources. It is important to consider the sources to determine their reliability.

Student Page 2.2F: The Language of Genetics

TERM A: A **population** is all of the organisms of one species living together in one area at the same time. As members of the same species, these organisms share certain common characteristics. Nevertheless, within any population there also is some variability in characteristics (just look around your classroom for examples of this variation). Any type of organism can form a population. There are populations of oak trees, populations of mosquitoes, populations of bacteria, and populations of mushrooms.

TERM B: Phenotype. Blood type, ear shape, and petal color are all physical traits that we observe when the information in an organism's genetic plan is expressed. Observable traits are called an organism's **phenotype**. The term phenotype can refer to either a specific trait or to the collection of traits that characterize an entire organism. For instance, we can say that a collie has a long hair phenotype rather than a short hair phenotype. We also can say that a collie has a very different phenotype from a Great Dane. A collie has longer hair, a different pattern of colors, and shorter legs than a Great Dane. The genetic plan passed from parents to offspring provides the blueprint for the offspring's phenotype. Thus, offspring typically have a phenotype similar to their parents' phenotypes.

Phenotype is not determined only by the genetic code. Environmental factors play an important role as well. Height is a phenotype that we studied in Step 1, and it is determined by a combination of genetic and environmental factors. Most phenotypes are the result of the interaction between an organism's genetic code and the environment in which it lives.

TERM C: Genotype is the actual genetic make up of an individual organism. In humans, any particular gene on a chromosome typically occurs in two copies because 22 chromosomes are paired (the X chromosomes are paired in females, the X and Y chromosomes occur as a pair in males). When an organism has two different alleles for a gene its genotype is called **heterozygous** (*hetero* = different). When an organism has two copies of the same allele for a gene, its genotype is called **homozygous** (*homo* = the same).

Scientists use upper– and lower–case letters to represent alleles for a trait. Upper–case letters are used to represent the dominant allele. For example, if a human is homozygous for the gene that determines cystic fibrosis, the genotype is written cc (the allele that causes the condition is the recessive allele). How would you write the genotype for a human who is heterozygous for the gene that determines cystic fibrosis? If phenotype is the result of a genetic plan that is influenced by the environment, what is the genetic plan itself? The genetic plan, or **genotype**, consists of all of the genetic information in an organism. This genetic information is stored in **DNA** (deoxyribonucleic acid) molecules.

TERM D: Chromosomes are organized DNA molecules that are found inside of cells. Chromosomes are made up of a single long piece of DNA that contains genes and other genetic sequences. Nearly every human cell contains chromosomes (red blood cells do not). Each human chromosome contains the DNA for just a small part of the total genetic information. The largest human chromosome contains about 2,500 genes. The smallest human chromosome is the Y chromosome. It contains only about 250 genes.

The cells of humans and other eukaryotes contain structures called chromosomes. The number of chromosomes varies among different types of organisms. A cow has 60 chromosomes; a cabbage has 18, a dog has 78, and a pea has 14. Most human cells have 23 pairs of chromosomes for a total of 46 chromosomes. However, human sex cells (sperm and eggs) contain half that number. Can you explain why that is?

Continued on following page

Student Page 2.2F: The Language of Genetics (continued)

TERM E: Scientists working in genetics refer to a particular piece of a chromosome that does a job for the organism as a **gene**. A gene controls how, what, when, and where an organism will make the proteins necessary to live. For example, the very tip of one human chromosome contains the genetic information that causes the blood to clot. In this example, the gene produces a blood-clotting protein in healthy individuals. Each of the 46 human chromosomes contains many genes. Each gene occupies a specific location on the chromosome.

Populations have individuals with more than one version of most genes. For example, some individuals have a blood type gene that specifies type A blood. Others have a version of the same gene that specifies type B blood.

TERM F: The term **allele** refers to different versions (for example, type A and type B) of the same gene (for example, blood type). The particular combination of alleles determines the organism's phenotype.

Organisms that reproduce sexually generally receive two alleles for every gene. One set of alleles (on one set of chromosomes) comes from the mother's ovum. Another set of alleles (on a second set of chromosomes) comes from the father's sperm. A large variety of allele combinations are possible when gametes combine to form a new organism. This helps explain why there is usually much variation in sexually reproducing populations.

Key Concepts

- The genotypes of the individuals in a population determine the variation that is possible in that population.
- While the environment can affect how the traits are expressed, the potential for the traits is determined by the genotypes in the population.
- the majority of inherited traits are challenging for scientists to fully understand because they are determined by a variety of interactions among multiple genes.
- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables.

Evidence of Student Understanding

The student will be able to:

- design and conduct a scientific experiment to gather evidence about how an environmental factor influences expression of the purple stem allele.
- explain the sources of variation in the observable traits (primarily the purple stem trait) in Wisconsin Fast Plant seedlings that are raised in a variety of environmental conditions.

Time Needed

50–minute class period plus approximately 10 minutes at the start of the next two class periods, followed by time to develop and present scientific explanations for experimental results.

Materials

For each student

- Student Page 2.3A ***The Genetics of Height***
- 1 copy of Student Page 2.3B ***Developing a Scientific Explanation***

Continued on following page

Investigating Variation in Wisconsin Fast Plants

Elaborate

1. Begin this lesson by asking students to take 1 minute to individually draw in their Science Notebooks the x– and y–axes for a bar graph that could be used to represent the data for the purple stem color trait gathered for the F_2 generation.
   - The purpose of this introductory exercise is to help students recognize that the purple (or non–purple) stem trait is an example of simple inheritance (dominant/recessive) of a trait controlled by a single gene. Inheritance of height in humans, on the other hand, is much more complex, as is most inheritance.
2. Ask several volunteers who finish first to make a copy of their axes on the board, and at the end of a minute, have them briefly explain their reasoning.
   - Point out that typically, the x–axis (or in some cases the y–axis) will include two distinct categories: purple stem and non–purple stem. It is possible that one or two students will mark one axis with degrees of "purpleness," in which case it is important to note that the data used to determine the parental genotype was strictly purple or non–purple.

   As a class, generate a chart like the example that follows. Guide a discussion to review that the variation in height was found to be determined by genetic and environmental factors, while the presence or absence of purple stems was (so far) found to be determined by genotype.

Continued on following page

Trait	Variation Observed in Our Class Populations	Determining Factors
Height		
First Generation of Fast Plants		
Second Generation of Fast Plants		

Continued from previous page

For each group of four students

- 1 Petri dish
- 1 Transparency-plastic Ruler Disk, cut out (see Teacher Page 2.2B ***Ruler Disk***)
- 15 Wisconsin Fast Plants seeds (F_1)
- paper towels
- eye dropper
- hand lens
- shallow tray or bottom from a 2-liter soda bottle

For the class

- CD–ROM for *Exploring Populations*
- projector and computer as needed to show video clips from the CD–ROM
- light sources that can be controlled in a variety of ways (e.g. desk lamps that can be positioned at different distances from the Petri dish germination system)
- colored gels that can be placed over Petri dishes to control light color
- other materials as available to vary environmental conditions (e.g. aluminum foil to cover a Petri dish so it grows in total darkness, heat lamp or warm location to raise temperature–not higher than 100°F)

  Note: Varying light—full light exposure versus total darkness—will likely generate the greatest variation in "purpleness" but one key goal in this lesson is for the experiment to be student–centered, offering an opportunity for students to develop their own question and design an experiment to try answer it.

- Compare the distinct purple versus non–purple characteristic to the human height characteristic that students charted on a histogram in Step 1.
  - Pose the question, *What similarities and differences to you see between the effects of genetics and environment on height in humans and on purple stem in Wisconsin Fast Plants.*

3. Distribute copies of Student Page 2.3A ***The Genetics of Height***, and provide time for students to read it individually.
   - Allow 1–2 minutes for students to turn to a partner and discuss the reading before facilitating a whole class discussion about the significance of a trait being determined by multiple genes.
     - The key concept for students to take away from this reading and discussion is that **the majority of inherited traits are challenging for scientists to fully understand because they are determined by a variety of interactions among multiple genes.**
4. Wonder aloud what would happen if you repeated the protocol for growing Wisconsin Fast Plant seedlings in a Petri dish using the F_1 seeds (that all had purple stems) but changed their environmental conditions. If you made careful observations, would you see variation in the purple that the genetics code for?
5. Use a Think–Pair–Share strategy for students to generate questions about how the environment might effect purple expression in stems. Record a list of questions volunteered during the whole class discussion (Share).

- Guide the class to develop and understand criteria for testable questions, and model how to analyze and revise these initial questions to generate one that can drive an experiment (using the Petri dish protocol).
- For techniques and strategies for facilitating students to generate testable questions, see the ***Immersion Toolbox***.

6. Show and explain the materials available to students for their experiments. Divide students into groups of four, and give 15 minutes to
   - select a question,
   - revise the chosen question to become testable, and
   - outline an experiment designed to produce evidence that can be used to explain an answer to the question.

   Circulate among groups, prompting careful consideration about how questions fit the criteria for a testable question and experimental design is planned. The ***Immersion Toolbox*** contains ideas and strategies for supporting students to develop effective plans for collecting experimental data.
7. Provide materials and time for students to construct their Petri dishes and set up experiments. Student groups will need approximately 10 minutes during the next two days to gather data. Then follow a process parallel to the one used in Lesson 2.2 for students to review each other'
8. While the experiments unfold over the next two days and students develop explanations for their evidence about how environment influences "purpleness," continue with the unit's lessons. Returning to the overarching unit question that was posted in Lesson 1.1 and added to in Lesson 1.3 will is important at this time. Making another entry of claims and evidence now will summarize the key concepts in Step 2 and set the stage for Step 3.
   - Point to the posted unit question, *What causes populations to physically change or stay the same over generations?* and conduct a brainstorm session about what students know at this time to answer this question. Like was done at the end of the Step 1, record the list generated by the class in the Unit Level Graphic Organizer.
   - Remind students that to answer the question, *What causes populations to physically change or stay the same over generations?* scientifically; any claims about it need to be supported by evidence. Have students explain the source and/or evidence for the ideas given about answering the question.
   - Check for students' understanding during this brainstorm session. At this point in the unit, students need to understand that
     - **The genotypes of the individuals in a population determine the variation that is possible in that population.**
     - **While the environment can affect how the traits are expressed, the potential for the traits is determined by the genotypes in the population.**
9. Use the REAPS questions to stimulate further class discussion throughout and as closure for the next lesson.

REAPS

R Why was it important to have one Petri dish with seeds germinated in the same conditions as those in Lesson 2.1? *This was the experimental control.*

E Explain why it wouldn't work to change both the temperature and the amount of light for one Petri dish with F_1 seeds to see if variation in purple stems is caused by temperature or light. *If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables.*

A Explain how the genotypes of the individuals in a population determine the variation that is possible in that population. Use genetics to explain why a human baby born in your region will not be born with purple hair. *This concept is key for students to understand. A trait or version of a trait can only show up in a population if there are genes for that trait and an allele for that version of a trait.*

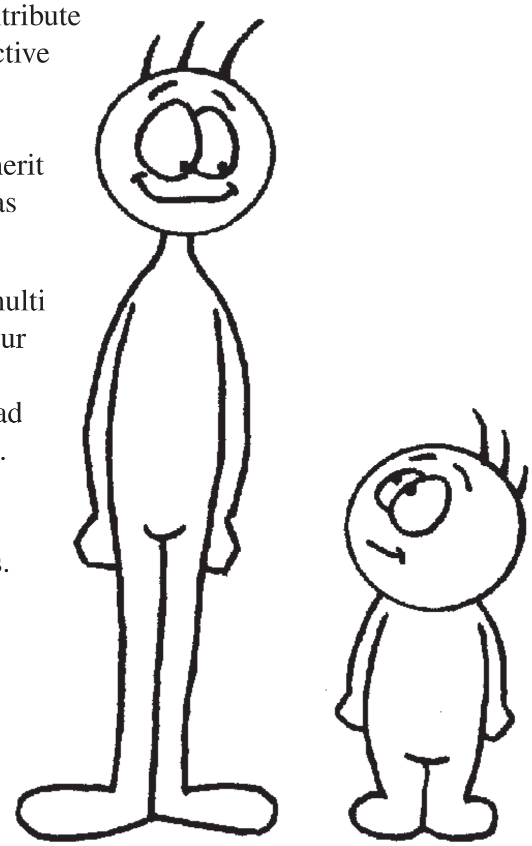
P What other factors do you think may need to be added to the class chart that is developing an explanation for the question, *What causes populations to physically change or stay the same over generations?*

S What have you done so far that makes the most sense in this unit as part of the answer to the question, *What causes populations to physically change or stay the same over generations?*

Student Page 2.3A: The Genetics of Height

If height were controlled by a single gene and tall were dominant, then only two heights would be possible, tall and short. Even if height were incompletely dominant, in other words, being heterozygous blended the two other phenotypes, only tall, medium and short would be possible. This obviously isn't right. Height is under the control of more than one gene, perhaps many. It depends on how many active alleles you inherit from your parents.

Let's say that height is controlled by 3 genes each with 2 alleles. So, there are 6 possible active alleles, or alleles that actually contribute to height. Lets say that your father is medium tall or has 4 active alleles and two inactive. Lets say mom is medium and has 3 active and 3 inactive. Their children can have as many as 6 active alleles (3 from each) and be very tall. Or they can inherit as few as 5 inactive alleles and be quite short (although not as short as possible).

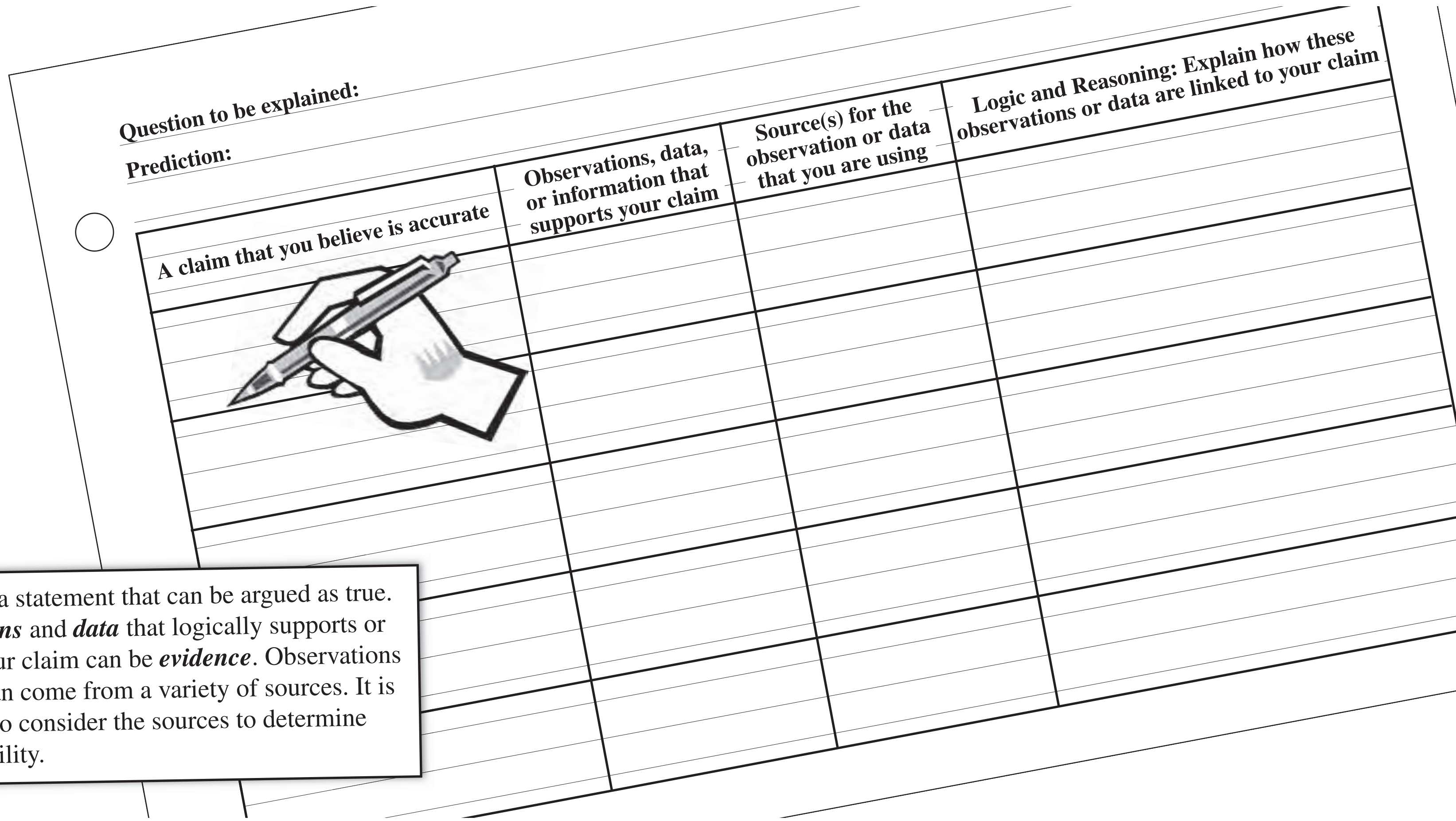


There is another factor to consider though, height is also a multi factorial trait—the environment has a role in determining your final height. Lets say that you were genetically programmed to be tall but you didn't have access to good medical care, had a poor diet and your mother smoked while she was pregnant. You may not reach your possible height. Also, boys have testosterone, which increases muscle mass and bone growth more than estrogen does, so boys usually are taller than girls. So, height is a complicated genetic factor.

Source: Vanhoeck, "Genetics and Height." Ask A Scientist. 1999. Newton BBS. 19 Jul 2007 <http://www.newton.dep.anl.gov/askasci/mole00/mole00125.htm>.

Student Page 2.3B: Developing a Scientific Explanation

1. Begin a new page in your science notebook. At the top of the page, record today's date, and record the question that you are going to be working on answering in your scientific explanation.
2. Below the question you wrote in #1, record your initial prediction for the answer to your question. Explain the prediction.
3. In your Science Notebook, complete a chart like the following to develop an explanation for patterns in the data you analyzed.
4. In your Science Notebook, write your explanation in paragraphs that include complete sentences, stating your claim and explaining the evidence and information that you are using to support it.
5. After writing your explanation, record any new or modified questions that you have about this natural phenomenon.
6. Write three or four sentences comparing your current explanation to your original prediction (#2 above).



A ***claim*** is a statement that can be argued as true. ***Observations*** and ***data*** that logically supports or negates your claim can be ***evidence***. Observations and data can come from a variety of sources. It is important to consider the sources to determine their reliability.

Unit Overview

Populations of living organisms change or stay the same over time as a result of the interactions between the genetic variations that are expressed by the individuals in the populations and the environment in which the population lives.

STEP 1 | **STEP 2** | **STEP 3** | **STEP 4**

Lesson 3.1 Engage/Explore

This is a 50-minute guided exploration. Given that genetics limits the possibilities for variation in traits, students are asked to think about how brand new traits can ever arise in a population. Without using genetic terminology or explicit references to protein synthesis processes, a word and sentence analogy is used to engage students' prior knowledge about and introduce genetic mutation as a source of variation in a population

Guiding Question

What can cause a brand new trait or never-before-seen version of a trait to appear in a population?

Lesson 3.2 Explore/Explain

Two consecutive 50-minute periods are used to engage students. This is a guided inquiry into the effects of an introduced mutation in a population of yeast. Two populations of yeast–one with and one without a mutation that eliminates the ability to repair cell damage caused by ultraviolet light–are used in a controlled experiment. From this experiment, students develop scientific explanations for how different environmental conditions, combined with the presence of a genetic mutation, can impact survivability in a population.

Guiding Question

If a mutation occurs that leads to a new trait, how does the environment influence the likelihood that future generations will have more or fewer individuals with that trait?

Lesson 3.3 Elaborate/Evaluate

This is a 50-minute lesson in which students apply their understanding of the concepts from Lessons 3.1 and 3.2. Students explain how, as a result of natural selection, a strain of antibiotic-resistant tuberculosis bacteria is an example of a population that has changed over generations. Because of mutation and environmental influences, new populations of bacteria that cause tuberculosis now show a greater number of individuals with the trait for antibiotic resistance.

Guiding Questions

Are all mutations harmful? If a mutation occurs that results in a beneficial trait, what can the effect be on future generations of a population? What is the mechanism that explains how a population can evolve to have a trait become more or less prevalent?

Standards addressed in Step 3: 1a, 1b, 1c, 1d, 1g, 1i, 1j, 1k, 4c, 7a through d, 8a, 8b.

Note: Yeast needs to be prepared in advance for lesson 3.2 (*see* Advance Preparations section in Lesson 3.2).

Key Concept

- In science, one explanation typically leads to more questions.
- Yeast can serve as a model organism for understanding how the genetic code affects a population's ability to survive changing environmental conditions.
- Changes in DNA (mutations) occur randomly. Some of these changes make no difference to the organism, whereas others can change cells and organisms.

Evidence of Student Understanding

The student will be able to:

- articulate the guiding question for Step 3
- explain how yeast is genetically similar to humans
- respond in writing to the question *What can cause a brand new trait or never–before–seen version of a trait to appear in a population?*

Time Needed

50 minutes

Materials

For each student

- 1 3x5 note card

For the class

- CD–ROM for *Exploring Populations*
- projector and computer as needed to show video clips from the CD–ROM
- 1 overhead copy of Teacher Page 3.1A ***Genes Are Like a Sentence***

New Traits

Transition / Explain

1. Transition to Step 3 by using a Think–Pair–Share strategy to review the ***A****nalysis* and ***S****elf Assess* ***REAPS*** questions (from Lesson 2.3):

   A Explain how the genotypes of the individuals in a population determine the variation that is possible in that population. Use genetics to explain why a human baby born in your region will not be born with purple hair. *This concept is key for students to understand. A trait or version of a trait can only show up in a population if there are genes for that trait and an allele for that version of a trait.*

   S What have you done so far that makes the most sense in this unit as part of the answer to the question, *What causes populations to physically change or stay the same over generations?*

   The concept that the collective individual genotypes determine the genotypes (and thus the phenotypes) possible in a population is key for students to understand at this point.

2. In their Science Notebooks, have students individually record a response to the following prompt. Either write the prompt on the board or project it so that students can refer back to it as needed while writing a response. Give the class approximately 2 minutes to complete this Notebook entry.
   - What is your current thinking about what can cause a brand new trait or never–before–seen version of a trait to appear in a population?

   When 2 minutes has passed, explain that the focus for Step 3 will be on how new traits and new versions of traits in populations can affect the population over time.

3. Remind the class that sometimes model organisms are used by scientists studying

Continued on following page

populations. Facilitate a fast–paced brainstorm from which you chart a list of student responses to the question, *What do you remember about model organisms from the previous Step 2?*

- To keep the charting from slowing down the brainstorm, you may wish to have two students do the charting. Position them at the board so that each writes on their own list, and have them alternate who records the brainstorm ideas. In this way, one will have time to finish writing while the other charts the next idea.

4. Explain that in Step 3 the class will use a different model organism, and show the video, ***The Common Genetic Code***, from the Unit CD–ROM.
5. Review how the video clip talked about mutant yeast cells that did not behave the same as the other yeast cells.
   - Give students a minute to individually write on a 3x5 note card a list of questions that they wonder about mutation.
   - Collect the note cards when they are completed and draw 4 or 5 randomly to read aloud.
   - Save the note cards to review to get a sense of what students know and wonder about mutation. You may choose to post some or all of these wonderings to refer to as students learn more about mutation in the rest of this Step and Step 4.
6. Facilitate a discussion about mutation basics using the following steps and Teacher Page 3.1A ***Genes Are Like a Sentence*** in a sequence like the following script.
   a) Begin with a page covering the overhead transparency of Teacher Page 3.1A ***Genes Are Like a Sentence*** and explain: *We know that DNA is an organism's genetic **code**, and we know that each gene in an organism's DNA **codes** for a trait. Let's think about "codes" and what it means to have a code mutation.*
   b) *One kind of code we are all familiar with is our alphabet and written words and sentences. Whatever languages we know, we understand because we learned the code—certain letters represent certain sounds, and put together in the right way, they represent words, which can be used together to represent ideas.*
   c) *Let's look at the following sentence code.* Reveal the first line of the overhead, showing the sentence:**THESUNWASHOTBUT THEOLDMANDIDNOTGETHISHAT.** *Decode this sentence, and write it down.*
   d) *This sentence,* **The sun was hot but the old man did not get his hat.** *represents a gene. What if you shifted the three-letter "reading frame?"*
      - Reveal the next line on the overhead. *You would end up with gibberish.*
      - *As you can see, only one of these three "reading frames" translates into an understandable sentence. In the same way, only one three-letter reading frame within a gene codes for the correct protein that is needed for the trait controlled by that gene.*
      - *In cells, sometimes the DNA can be changed in a way similar to how we just changed this sentence. This is what we call a **mutation**.*
      - *Now, go back to the original sentence. See how you can mutate the reading frame of this sentence by inserting or deleting letters within the sentence. That is like what randomly happens to DNA sometimes.*
   e) *What are some other codes that you are familiar with?* Wait for students to suggest codes such as computer codes, secret codes, Morse code, etc.
      - *Might it be just as troublesome to one of those codes, say to the code for a computer program, if the software developer randomly changed the code while typing?*
      - *Can you think of an example where an accidental mutation–like change in the code—say in computer software code––might not necessarily be harmful?* Collect student ideas. *In some cases, a change in software code might not*

have any effect, or it might make the program do something the developer didn't intend it to do. In most cases, the developer will catch the mistake and correct it or else the change will become an error that keeps the program from running at all.

- *Like software code is checked by developers before it is compiled, most mutations are corrected by factors in the nucleus that check for accuracy when new DNA is built in the cell. However, some mutations get by the correction factors, and not all are harmful.*

f) *It's easy to make mutations that create "nonsense" sentences. Can you make mutations that maintain or change the meaning of the sentence without creating such nonsense? Can you think of a three–letter word that you could substitute or a single letter that you could insert or take out that would just change the sentence's meaning without turning it into gibberish? Is there one that wouldn't change the meaning at all?*

- Show the question on the overhead transparency. Give students time to work individually to find examples. Substitute and try out various student responses, and highlight any that change the meaning but still make sense. *Mutations in DNA occur randomly, and sometimes they happen to have an effect like the words you just substituted, they cause a change in what the code means (and so the phenotype changes), but they are not harmful. In fact, in some cases the new phenotype may turn out to be useful in some situations.*

g) Use a Think–Pair–Share strategy to have students develop an answer to the question *What has to be true about a mutation for it to be inherited by the offspring of a parent with the mutation?* Be sure that during the whole class discussion students who have figured out the answer or those who are close are helped to share the key point that only mutations in cells that are involved in reproduction (e.g. sperm and egg in sexual reproduction, the whole organism in a single–celled organism) will be inherited.

7. Focus the attention back to Science Notebooks and the earlier entries made in response to the question, What is your current thinking about what can cause a brand new trait or never–before–seen version of a trait to appear in a population?
   - Have students draw a line beneath their response, and beneath the line record their new understanding about what causes new traits to appear in a population.
   - If students suggest that immigration could be a factor, acknowledge that a population might gain a new allele for a trait if an individual of the same species and from a different population moves into the area and mates with an individual in its new population. This example describes how an allele that already exists can be introduced, rather than how a *new* allele can arise (through mutation). Both are important sources of variation in populations.
8. Explain that the investigation the class will begin in the next lesson will use yeast as a model organism, and it will involve a mutation. Use the REAPS questions to stimulate further class discussion and as closure or assign them as homework and review at the start of the next lesson.

REAPS

R How can a trait that has not ever existed before get introduced into a population? *mutation*

E How is a gene like a sentence? *Both are codes, and both are made up of smaller parts that are also codes.*

A Explain why most mutations are harmful? *Most mutations cause genes to be read incorrectly so they cannot code for what is needed.*

P What real–world examples can you describe where you believe that mutation may have caused a change in a population? *Use responses to this question to check for students' prior knowledge about things like antibiotic resistance in bacteria.*

S What do you know about how Earth changes over very long periods of time? Give examples of at least three ways Earth has changed. *Use this question to gauge students' current knowledge of how important environmental factors such as climate and physical structures (mountain building, continent positions, etc.) on Earth have changed. These are the types of changes that living organisms must adjust to through variation and natural selection to survive.*

Student Page 3.1A: Genes Are Like a Sentence

THESUNWASHOTBUTTHEOLDMANDIDNOTGETHISHAT.

THE SUN WAS HOT BUT THE OLD MAN DID NOT GET HIS HAT.

T HES UNW ASH OTB UTT HEO LDM AND IDN OTG ETH ISH AT.

or

TH ESU NWA SHO TBU TTH EOL DMA NDI DNO TGE THI SHA T.

Can you make mutations that maintain or change the meaning of the sentence without creating nonsense?

- **a 3–letter word that you could substitute for one of the current 3–letter words** that would cause the sentence to either have the same or a different meaning, or
- **a single letter that you could take out** that would cause the sentence to either have the same or a different meaning, or
- **a single letter that you could insert** that would cause the sentence to either have the same or a different meaning

THE SUN WAS HOT BUT THE OLD MAN DID NOT GET HIS HAT.

Key Concept

- Mutations in the DNA sequence of a gene may or may not affect the function or expression of the gene.
- Mutation can lead to genetic variation in a population.
- The genotypes of individuals within a population combined with the type and intensity of environmental change influences both the survivability of that population and how or if the population will change over time.
- A small advantage in growth / reproduction can change a population in a modest number of generations.
- Scientific progress is made by asking meaningful questions and conducting careful investigations, using appropriate tools and technology to perform tests, collect data, analyze relationships, and display data.

Evidence of Student Understanding

The student will be able to:

- draw a picture and use five words to explain how ultraviolet light exposure can lead to DNA mutations in cells that may or may not affect the function or expression of the gene (or survival of the individual).
- refine and conduct the yeast experiment to answer a question about the impact of UV on yeast.
- explain from the results of the yeast experiment how the genotypes of individuals within a population combined with the type and intensity of environmental change influences both the survivability

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Comparing Similar Populations

Explore/Explain

1. Introduce this lesson by reminding students of the yeast video watched yesterday. Explain that using a single–celled organism (yeast) will make it possible to observe one or two generations of whole populations in the classroom.
   - To emphasize the role that genes play in controlling gene expression as well as the use of model organisms (like yeast and Fast Plants), show and facilitate a discussion about the video Gene Control on the Unit CD.
   - Check to be sure that students understand what is meant by the term ***population*** by pointing out the poster that was developed for the term in Lesson 2.2 and/or having students turn to their own Science Notebook glossaries, and give the prompt: ***Describe where we might find a population of yeast?***
   - You may wish to emphasize how yeast are microscopic individuals that make up populations, which may look like a single organism to some talking briefly about this point and showing additional yeast images. A very thorough video about yeast can be viewed at ***Microbiologybytes.com*** out of the University of Leicester.
2. Reconnect the class to the overarching unit question, *What causes populations to physically change or stay the same over generations?* Explain that the yeast investigation in Lesson 3.2 will involve using two yeast populations to gather evidence to help explain the following questions:
   - What is the difference in survivability for these two populations of yeast—one

Continued on following page

of that population and how or if the population will change over time.

- participate in generating a new entry on the class evidence chart for the overarching unit question—one that reflects an understanding that a small advantage in growth / reproduction can change a population in a modest number of generations.

Time Needed

two 50-minute class periods

Materials

For each student

- 1 copy of Student Page 3.2A ***Laboratory Protocol for Growing Yeast in a Petri Dish***
- 1 copy of Student Page 3.2B ***Ultra Violet Light and Living Organisms***
- 1 copy of Student Page 3.2C ***Developing a Scientific Explanation***

For each group of 4 students

- sets of materials outlined in Student Page 3.2A ***Laboratory Protocol for Growing Yeast in a Petri Dish***
- a variety of types and intensities of light sources and a variety of UV blockers (see *Modeling the Effects of Ultraviolet Radiation* online at http://www.phys.ksu.edu/gene/f_12.html for a list of possibilities and descriptions)

For the class

- CD–ROM for *Exploring Populations*
- projector and computer as needed to show video clips from the CD–ROM

with virtually no variation in the trait that controls DNA repair (all are missing the allele(s) that control repair) and one with variation in that same trait (though most all have fully functioning alleles coding for DNA repair)?
- What is the difference in survivability between the two populations in a variety of light–type or light–intensity environments?
- Can we see in experiments with these two populations evidence for how variation in the genotypes within a population might explain how populations change over time?

Explain **Population A** and **Population B** as follows:

The two yeast populations are different genetically. Population A has been bred and selected artificially to be made up of nearly all individuals with mutation that causes one or more of the genes that control DNA repair not to function correctly. Population B is called the “wild type” population because it was bred to produce healthy colonies in laboratory conditions without selection for any one particular kind of trait. The variation among the individuals in population B is greater than the variation in Population A.

3. Facilitate a class brainstorming session using a Think–Pair–Share strategy to develop questions about how different types of light conditions might effect these two yeast populations. The following prompts may help stimulate the discussion and generation of questions.
   a. Where does yeast grow in the wild? What kind of light conditions would it likely experience in its wild environment?
      - Consider how bakers or brewer’s yeast might have been discovered—what conditions does it thrive in during fermentation of wine or beer or bread making?
   b. Are light conditions in nature constantly the same? What are some ways that different types of organisms experience

different levels of light exposure even though they live in the same overall habitat?
    - How might that affect the types of environmental conditions experienced by yeast in the wild?
    - How might those types of light variables be simulated in our classroom?

4. Assign students to groups of four to select and refine a question about how a particular light variable will affect survivability in the two yeast populations. Use the testable question criteria agreed upon by the class in Lesson 2.3 as a guide (see the ***Immersion Toolbox*** for additional strategies to help students with scientific questioning and planning to collect relevant evidence).

5. Explain to the class the materials available and share the ***Yeast Protocol*** on Student Page 3.2A. Review the protocol procedure so that student groups can further refine their selected question in light of the types of data they can take given the materials available.
    - Suggest to all groups that the control for experiments can be made by covering half of a Petri dish with opaque material, such as aluminum foil so that portion of the population receives no treatment.
    - If you only have enough materials for each student group to have two total Petri dishes—one each of Populations A and B––but students come up with questions and experiments that require two Petri dishes each of Population A and B (as described in the example below), you can have two student groups of four combine to explore the same question, each conducting a different portion of the same experiment.
    - Assign roles within student groups so that the following are accomplished by different students during the initial planning stage:
        a. refined/revised question is recorded for the class to see along with the identified variable in the experiment
        b. outline of the experimental plan is written and submitted for teacher and/or peer review
        c. data table for recording observations, including the times when observations will be recorded is developed for the group
        d. all predicted outcomes are written along with explanations for those predictions.

Check each group's progress in completing these four tasks as you circulate among them. It is critical that all are completed prior to beginning the experiment so the group has a well–reasoned plan, buy–in to find out if their predictions are correct, and clarity of purpose.

- Focus experimental plans so that the evidence gathered will be helpful for students trying to understand how genetic variation can make it possible for living organisms to keep up with environmental changes (or not). The following is an example of a possible experimental question and procedure.

NOTE: The experiment example below is a SAMPLE OF WHAT STUDENTS MIGHT PRODUCE at this point in the process, it DOES NOT describe actual experimental results.

Question: What differences in survivability will the two yeast populations show if they are exposed to a single, short exposure to light (simulating being uncovered in the wild) versus continuous exposure to light (simulating a long term change in environmental conditions)?
Variable: light exposure time
Experimental Design: *Day 1:* Four Petri dishes are poured and allowed to settle over night— 2 with Population A, and 2 with Population B   *Day 2:* The tops of all four Petri dishes are half covered with aluminum foil. All four Petri dishes (two each of Population A and B) are placed perpendicular to and 36 inches away from a standard fluorescent light. Two Petri dishes (one each of Population A and B) are removed after 30 minutes, and two Petri dishes (one each of Population A and B) remain under the lights until the same time on Day 3.   *Day 3*: Observe yeast growth in all Petri dishes
Prediction: Both Population A and B will show similar growth patterns if exposed to fluorescent light for only 30 minutes because both will grow enough after the exposure that no damage will be apparent.   However, where light exposure is constant for a day, Population A will show little growth; because any offspring of survivors may be genetically sensitive to UV even if their parents were not.

6. Conduct the yeast experiments in small groups, and then post each group's experimental results for a whole class discussion.
   - Use an appropriate reading strategy to have the class read and discuss Student Page 3.2B ***Ultra Violet Light and Living Organisms*** once the experiments have been set up and students are waiting for the yeast to grow. Encourage students to highlight information in the reading that may be useful to cite in their scientific explanations when analyzing their experimental results.
   - One reading strategy, ***5 Words and a Poster***, is described in the Teacher Background information.
7. In their science notebooks, have students organize and record their thoughts, using the previous format, revisited in Student Page 3.2C ***Developing a Scientific Explanation***.
8. Refer students back to their responses to the ***S****elf Assess* question in the Lesson 3.1 ***REAPS*** questions, and facilitate a discussion to make the connection clear between environmental changes that occur on Earth and what can happen to populations if they cannot change, too, when their environment changes (extinction).

   S What do you know about how Earth changes over very long periods of time? Give examples of at least three ways Earth has changed. *Use this question to gauge students' current knowledge of how important environmental factors such as climate and physical structures (mountain building, continent positions, etc.) on Earth have changed. These are the types of changes that living organisms must adjust to through variation and natural selection to survive.*
9. Make another entry of claims and evidence to summarize the key concepts in Lesson 3.2 and begin to set the stage for Step 4.
   - Point to the posted unit question, *What causes populations to physically change or stay the same over generations?* and conduct a brainstorm session about what students now know that can also help

to answer this question. Like was done previously, record the list generated by the class into a T–chart that has space to record the source/evidence for each idea offered.

- Check for students' understanding during this brainstorm session. At this point in the unit, students need to understand that
  - the genotypes of individuals within a population combined with the type and intensity of environmental change influences both the survivability of that population and how or if the population will change over time, and
  - a small advantage in growth / reproduction can change a population in a modest number of generations.

10. Use the REAPS questions throughout the lesson where appropriate.

REAPS

R Why did you cover a portion of the plate with a piece of opaque material? *This kept half the population from being exposed to the experimental conditions—it served as the control.*

E How do the conditions you established in your yeast experiment compare to the conditions that a baker or brewery use for growing yeast? *This comparison will depend on students' experimental designs.*

A For a yeast population grown in a Petri dish, describe how the environment for one yeast **individual** compares to another. *The environment in the Petri dish is the same for all individuals in the population, except in the experimental conditions where half the Petri dish was covered with opaque material and half was exposed to light of some kind. Then, those individuals in the same half of the dish had the same environmental conditions.*

P If mutations arise that result in an increase in the variation in the genotypes of individuals in a population will those changes make the population more or less likely survive a random change in the environment? *Use this response to uncover misconceptions students may have about mutation being only harmful.*

S What was the most important contribution you made to your group's work with the yeast experiment? Explain how what you did helped others.

Advance Preparations

Materials (for growing one Petri dish)

- 1 sterile, disposable dropping pipette or sterile swab
- transparent tape
- glass-marking pencil or other method for marking the Petri dishes
- container of sterile flat toothpicks (optional)
- zip-type plastic bag labeled Waste
- 1 YED medium agar plate
- sterile test tube containing 8 mL of yeast suspension

Yeast strains usually come from the supplier growing on agar slants. To have the amount of yeast needed for student groups to prepare Petri dishes for their experiments, it is necessary to grow additional yeast before starting this lesson. In addition to needing sufficient quantity of yeast for student experiments, consider that contamination may be a problem when students use the original slants (if these are the teacher's only source for the yeast strains).

The procedure outlined on Student Page 3.2 can be used (with yeast in suspension) or the teacher can make master plates of the two yeast strains in advance for students to use for starting their experimental plates. If master plates are used, the following procedure has been found effective:

1. Student groups have one individual inoculate yeast on a YED agar plate using a sterile swab.
2. A small amount of yeast is picked up from the master plate with the sterile swab. The master plate lid is opened only momentarily and then closed again immediately to avoid contamination.
3. The student gently makes several streaks with the swab (containing yeast) across the surface of the agar in their group's plate. Again the cover is removed and replaced quickly.
4. The plate is turned so that the agar side is up so that any condensation will not drip on the yeast colonies. In this position, the culture is grown either overnight at 30 degrees C or for two days at room temperature.
5. Have students observe this initial growth for comparison and to become more familiar with yeast before beginning their experimental procedure.

For classroom management reasons, consider preparing one set of master plates for every class. This may be easier to manage when multiple groups send members to obtain yeast, though there will be enough yeast on one master plate to inoculate approximately 100 plates (if done carefully).

For additional information, we recommend the Gene Project Yeast Experiments website at http://www.phys.ksu.edu/gene/chapters.html.

Teacher Background Information

Five-Words and a Poster: An ELL (English Language Learner) Strategy for Reading Science Material

This can be used for readings that are broken into multiple sub ideas. (For example, Student Page 3.2B *Ultra Violet Light and Living Organisms*)

1. Divide the class into groups of three, with no more than four students each group. Assign each group one sub idea from the reading (two or more groups will have the same sub idea assignment).
2. Common instructions to student groups:
   - Take note of the images that come to mind as you read the passages to yourself.
   - As a group, decide what images would best convey to others the key idea(s) in your assigned passage. For example, if the passage were comparing and contrasting sharks and dolphins, then the images on the paper might include images of the shark and dolphin's dorsal fins and also the caudal fins.
   - Be prepared to cite where in the reading it referred to ideas directly related to whatever images you select.
   - Work together as a group to plan how to use a combination of images and no more than 5 words to create a poster that will communicate the key idea(s) from your assigned reading to the other students in your class. Remember, the goal of the poster is to illustrate the main points from the reading with as many pictures as you want, but no more than 5 words!
   - Symbols like number signs (#), and percent signs (%) are okay as well. Use as many as you like. BUT only 5 words.
   - The poster may have fewer than five words, just no more than five.
3. After the students have completed the posters, facilitate presentations and a whole–class discussion about the main ideas from the reading.
4. If there are illustrations on the poster that you feel were not represented in the reading, ask the students to provide evidence specifically for what inspired the drawing.

Student Page 3.2A: Laboratory Protocol for Growing Yeast in a Petri Dish

Note: An alternative to this protocol is depicted in the video, Yeast Protocol, on the Unit CD.

Materials (for growing one Petri dish)

1 sterile, disposable dropping pipette

transparent tape

glass-marking pencil

container of sterile flat toothpicks

zip-type plastic bag labeled *Waste*

1 YED medium agar plate

sterile test tube containing 8 mL of yeast suspension

SAFETY: Wear safety goggles when handling yeast.

a. Use a pipette to transfer 1 mL of the yeast suspension from the test tube directly onto the surface of each of 4 YED medium agar plates.

b. Replace the lid of the plate to maintain the sterile environment, and tilt and rotate the plate to spread the yeast cells over the surface of the agar. (If there are places that the liquid did not cover, use the flat end of a sterile toothpick to gently smear the suspension over those areas. Be careful not to puncture or tear the surface of the agar. Discard the toothpick in the plastic bag labeled Waste.)

c. Allow the agar to absorb the liquid until the liquid disappears (about 10 minutes.)

   Secure the lid to the bottom of the Petri dish by placing a small piece of tape on each side of the dish. Do not extend the tape over the top of the plate.

d. Place Petri dish in the selected growing conditions for the time planned (to look for responses to environmental stresses.)

e. Wash your hands thoroughly.

Student Page 3.2B: Ultraviolet Light and Living Organisms

We Need Sunlight

Most of us enjoy feeling the warmth of the sun against our skin. We sun provides energy necessary for all life on Earth; the sun's energy powers photosynthesis in plants and algae. And these producers provide most of the food consumed by Earth's other organisms. Even in humans, low doses of ultraviolet light in sunlight help make vitamin D. Vitamin D deficiency in growing children causes a bone disease known as rickets.

Not Too Much

Too much ultraviolet light, however, harms living things. In humans, high doses of ultraviolet light can damage our DNA and immune systems. Skin cancer, premature aging, and cataracts may result from this damage. How does ultraviolet light damage DNA? Ultraviolet light can cause the formation of abnormal chemical bonds between bases that make up the code on a strand of DNA. These new bonds distort the shape of the DNA molecule. This can cause one or more genes to quit functioning or change the way it is able to function. A delicate balance exists then between the need for—and protection from—sunlight.

Much Needed Repair

Unless repaired, a cell that has been damaged by ultraviolet light will die. Because yeast are single–celled organisms, death of a damaged cell means death to the whole organism. With accurate repair, a cell damaged by ultraviolet light will live and remain unchanged. However, if the repair process alters the DNA sequence, the cell may live but will be changed. A change in base sequence, called a mutation, may produce a cancerous cell. As you might guess, the genes that control the cell's ability to repair DNA damage accurately are very important genes.

Population A and Population B

The two yeast populations your class is using are genetically different. Population A was bred and selected artificially to be made up of nearly all individuals with mutation that causes one or more of the genes that control DNA repair not to function correctly. Population B is called the "wild type" population because it was bred to produce a healthy colony in laboratory conditions without selecting for any one particular kind of trait. The variation among the genotypes in population B is probably greater than the variation in Population A.

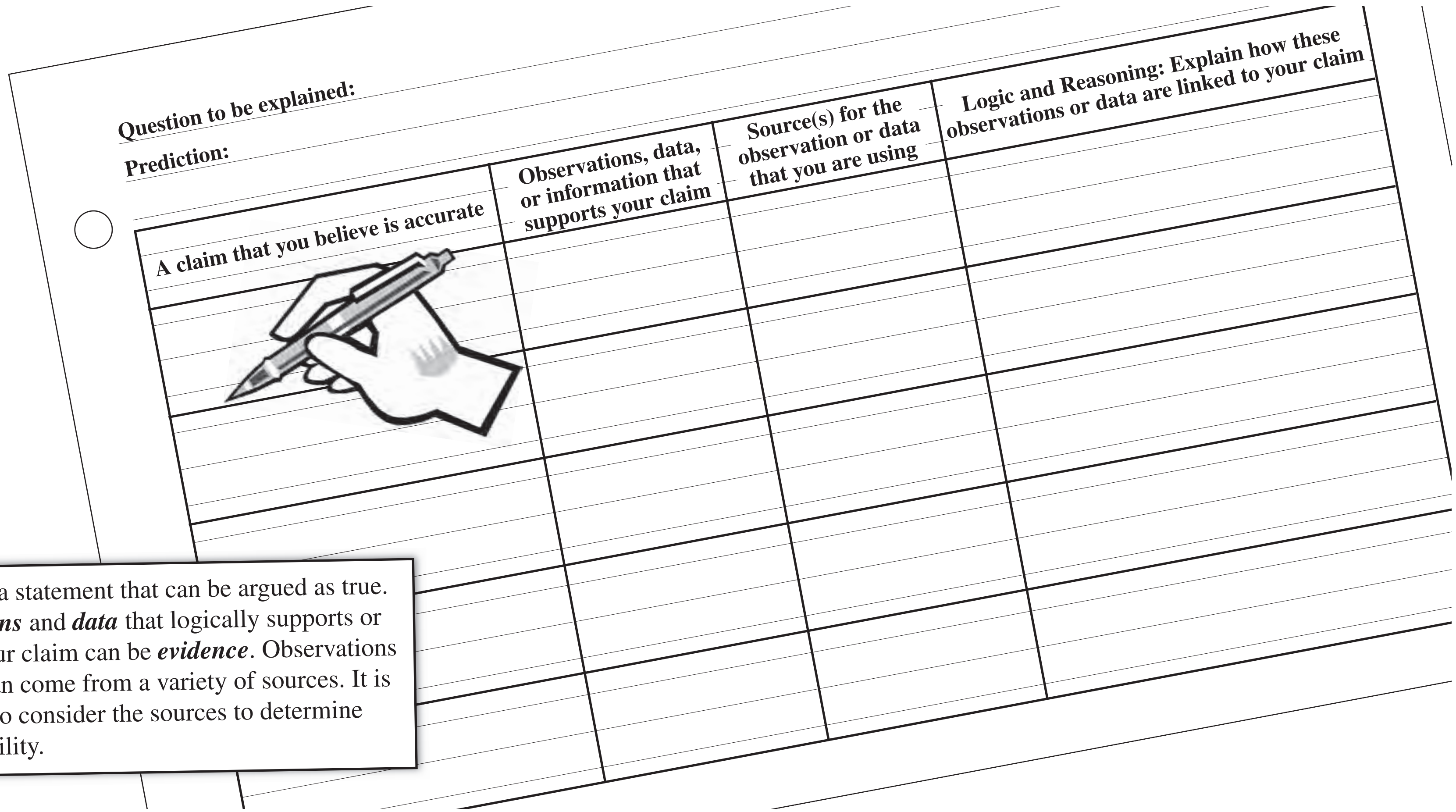
What is the difference in survivability for these two populations of yeast—one with virtually no variation in the trait that controls DNA repair (all are missing the allele(s) that control repair) and one with variation in that same trait (though most all have fully functioning alleles coding for DNA repair)?

What is the difference in survivability between the two populations in a variety of light–type or light–intensity environments?

Can we see evidence for how variation in the genotypes within a population influences how populations change over time by conducting experiments with these two populations?

Student Page 3.2C: Developing a Scientific Explanation

1. Begin a new page in your science notebook. At the top of the page, record today's date, and record the question that you are going to be working on answering in your scientific explanation.
2. Below the question you wrote in #1, record your initial prediction for the answer to your question. Explain the prediction.
3. In your Science Notebook, complete a chart like the following to develop an explanation for patterns in the data you analyzed.
4. In your Science Notebook, write your explanation in paragraphs that include complete sentences, stating your claim and explaining the evidence and information that you are using to support it.
5. After writing your explanation, record any new or modified questions that you have about this natural phenomenon.
6. Write three or four sentences comparing your current explanation to your original prediction (#2 above).



A ***claim*** is a statement that can be argued as true. ***Observations*** and ***data*** that logically supports or negates your claim can be ***evidence***. Observations and data can come from a variety of sources. It is important to consider the sources to determine their reliability.

Key Concepts

- When environmental conditions change it can affect the survival of both individual organisms and entire species.
- Natural selection determines the differential survival of groups of organisms.
- There is always competition for resources and usually variation in populations, and hence selection is usually operating in natural populations.
- A small advantage in escaping a predator, resisting a drug etc can lead to the spread of a trait in a modest number of generations.
- Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects.

Evidence of Student Understanding

The student will be able to:

- compare and contrast the explanation for how different survivability in yeast could effect future populations with the resistant tuberculosis scenario described in this lesson.
- participate in refining the last entry on the class evidence chart for the overarching unit question—one that reflects an understanding that a small advantage in growth / reproduction can change a population in a modest number of generations.

Continued on following page

Mutations that Improve Survival

Elaborate

1. Begin Lesson 3.3 by enthusiastically reporting to the class that you heard about changes like what you have been studying in this unit that are happening in microbes. Explain that there is an important reason why changes in microbes ought to be a concern for everyone, so it is going to be the subject of this lesson, and ask, *Just what are microbes?*
2. Use a Quickwrite or Think–Pair–Share strategy to have students take 2–3 minutes to record and/or discuss their ideas about the following:
   - What a microbe is.
   - Where microbes live.
   - If microbes are helpful or harmful for living organisms.
   - An example of a microbe.

   Once students have gathered their thoughts, play the first 4:28 seconds of the Ask a Biologist podcast from the Unit CD–ROM. ***STOP the broad cast after Dr. Stout explains that because microbiologists can now look at DNA, they are able to estimate that there are many more microbes than previously thought.***
3. Facilitate a whole–class discussion to now explore what students currently think about the earlier statement that everyone ought to be concerned about microbes changing over time. Resist the temptation to give examples or explain why this is a concern; rather, use this quick brainstorming session as a transition to the tuberculosis scenario that students will analyze next.
4. Explain that you have a short video documentary about a very serious situation that is currently taking place, involving microbes. When the class watches the video, explain that you want students to pay attention

Continued on following page

Continued from previous page

to how what they have learned so far in this unit is related to this current event story. Post or write on the board the following question:

- What is the relationship between the types of changes in populations that we've been talking about and evolution in microbes?

5. In their Science Notebooks, have students open to a new page and prepare to record important ideas and terms as they hear them in the video. Then, play the video on the Unit CD–ROM titled ***Why Does Evolution Matter Now?***
6. Assign students in pairs to work from their notes to complete the following chart from Teacher Page 3.3A ***Comparing Yeast and Bacteria that Cause TB***, comparing what the class has been learning about how populations change and how the bacteria that cause tuberculosis are evolving. Model how to begin making this comparison by filling in the first row in the sample table below (the amount of time required for each generation) before setting students to work on their own. The comparison might begin like the following:

Continued from previous page

Time Needed

50 minutes

Materials

For the class

- CD–ROM for *Exploring Populations*
- projector and computer as needed to show video clips from the CD–ROM
- audio speakers and equipment (e.g. computer) to play the *Ask a Biologist* segment on the Unit CD–ROM
- 1 overhead transparency of Teacher Page 3.3A ***Comparing Yeast and Bacteria that Cause TB***

Factors that We Have Been Studying about Change in Populations	What We Learned About Yeast in the Last Lesson	What We Know About the Evolution of Bacteria that Cause TB
Amount of time required for each generation.	As short as one hour	*Approximately 14 hours*
Environment where the population lives	Bread, brewing liquids, moist (typically dark) places with a food source	*Live inside humans*
Environmental factor in consideration that kills some individuals	UV light exposure	*Exposure to antibiotics*
Trait variation that some individuals have that causes them to be better able to survive and reproduce when the environmental factor above kills others ***(adaptation)***	Genetic variation that causes DNA damaged by UV light to be repaired	*Genetic variation that causes antibiotic resistance*
Cause of the variation (above)	mutation	*mutation*
Expected changes in the population over time	The UV light sensitivity variation is harmful for yeast, so it will not increase in frequency over time in a yeast population	*Resistance to antibiotics gives the individual bacteria with that trait an advantage; it is an adaptation. So, over time, the frequency of this trait in the population will increase.*

After students have had time to begin filling in responses, you may wish to replay the video segments so that students can better understand the tuberculosis scenario. The generational time period for the bacteria that cause tuberculosis is not given on the video. That row in the table is intended to make students stop and think.

7. Pose the following important question to the class: Why is it more challenging to see modern–day evidence for evolution in populations of mammals or plants than in bacteria? Use a Think–Pair strategy for students to form initial responses, then show the ***Microbe Clock*** simulation on the Unit CD–ROM to illustrate both the generational rates and mutation rates for bacteria.
   - You may decide to wrap up the simulation by telling students the generational times for yeast and TB bacteria (given in the table in #6) or have them calculate it to get a sense of how rapid it is compared to humans (details for this calculation can be found in an online bacteriology text book at http://textbookofbacteriology.net/growth.html).
   - Facilitate a reflection on the simulation that emphasizes the concepts that
     a. any advantage, like being resistant to a drug, can lead to the spread of a trait in future generations.
     b. in the case of microbes, for which multiple generations can develop in a single day, populations can evolve in a relatively short period of time. Because some microbes harm humans, this is a serious concern.
     c. Natural selection determines the differential survival of groups of organisms.
     d. While evolution is often though of as taking millions of years, that is not the case for populations of organisms that reproduce very rapidly so that the time between generations is a day or less.
8. Add to the posters defining key terms (from Lesson 2.2) and/or students Science Notebook glossaries the terms ***adaptation***, ***natural selection,*** and ***evolution***. The following explanations for the terms are adapted from the Grade 9–12 *Benchmarks for Science Understanding, Project 2061* and the *National Science Education Standards*. Have students develop definitions in their own words that align with these:
   - ***adaptation*** Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.
   - ***natural selection*** Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species, some of these characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase.
   - ***the theory of evolution*** The scientific theory first made public by Charles Darwin that biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.

If students need additional examples and support for understanding these central and key biological concepts, the interactive and inquiry–based simulations developed through the Virtual Courseware project at California State University, Los Angeles are included with this unit for use as a class or individually.

9. Take time to reflect on the last claims and evidence entry on the class chart to check for learning from this lesson that may lead to revisions and/or additions. Use this analysis time to transition from speaking only about changes in populations to thinking about how populations evolve as you transition to Step 4.

10. Use the REAPS questions throughout the lesson where appropriate.

REAPS

R How is it possible for a strain of antibiotic resistant bacteria that developed in a Russian jail to be a threat to people living in the United States? *An infected inmate who was infected with the bacteria was released from jail and flew to New York City for treatment, infecting 34 other people on the flight alone.*

E Could there be examples of microbe evolution that would be beneficial for humans? Give an example to explain your answer. *Yes, many microbes such as the bacteria discussed on the Podcast benefit humans. For example, if the bacteria living in the intestines that make it possible to digest and get nutrients from food evolve to be more resistant to attack from harmful bacteria, that would benefit humans.*

A Explain which of the following is NOT a part of Darwin's theory of evolution by natural selection? a) Individuals in a population vary in many ways. b) Some individuals possess features that enable them to survive better than individuals lacking those features. c) More offspring are produced than can generally survive. d) Changes in an individual's genetic material are usually harmful. *The fact that mutations are usually harmful (d) is not central to the theory of evolution or the mechanism of natural selection. Mutation is a mechanism for variation to be introduced into a population, and natural selection can explain why those individuals with the a trait caused by a mutation may or may not survive in its environment. Note: This question is taken from the Nation's Report Card released test items that are identified as commonly misunderstood by students (see http://nces.ed.gov/nationsreportcard/itmrls/itemdisplay.asp for more information).*

P Explain how using an antibacterial soap could be harmful for humans in the long run. *Use this question to assess students' prior knowledge about the societal concern that widespread use of antibacterial soap is leading to the evolution of bacteria that are resistant to antibacterial agents.*

S What have you learned about how science and society interact and are connected? *This lesson gave examples of how science can inform society in important ways that can help citizens make important decisions—both personal and policy level decisions. For example, when an individual understands that bacteria can evolve to become resistant to antibiotics, they can make an informed decision to avoid antibiotics for non–bacterial illnesses.*

Teacher Background Information

Transcript from Ask A Biologist, Podcast Volume 13

Bugs in Films –

Microbes are everywhere, but what are they? We get the inside story from microbiologist Valerie Stout about these tiny life forms including a slimy and gooey material many microbes make called biofilms. In fact, you have a daily encounter with biofilms and bacteria that can impact your health.

Content Info | Transcript | http://askabiologist.asu.edu/podcasts/mp3_files/ask_a_biologist_vol_013.mp3 (Length - 17:50) Vol 13

For a complete transcript of the podcast, go to http://askabiologist.asu.edu/podcasts/transcripts/vol13_transcript_aab_podcast.html

Topic	Time
Bacteria, not all are bad.	00:45
How much bacteria is in the body?	01:32
Where do we find bacteria?	01:48
What other things are microbes besides bacteria? Viruses etc..	02:52
Microbes comes from the Greek word "Mikros" meaning small. How much of the Earth's biomass is made up of microbes?	03:22
How many of the microbe species are there?	04:02
Biofilms	04:28
What do biofilms do?	05:42
Biofiilms and **antibiotics**.	06:34
Biofilms, your teeth and brushing your teeth.	07:45
E. coli - Esherisha coli	09:29
Viruses and what's is living and what's not living?	12:09
When did you first know that you wanted to be a biologist or scientist?	14:20
What would you be and do if you were not a biologist?	15:10
What advise do you have for young scientists?	16:09

Teacher Page 3.3A: Comparing Yeast and Bacteria that Cause TB

Factors that We Have Been Studying about Change in Populations	What We Learned About Yeast in the Last Lesson	What We Know About the Evolution of Bacteria that Cause TB
Environment where the population lives		
Environmental factor in consideration that kills some individuals		
Trait variation that some individuals have that causes them to be better able to survive and reproduce when the environmental factor above kills others ***(adaptation)***		
Cause of the variation (above)		
Amount of time required for each generation.		
Expected changes in the population over time		

Unit Overview

Populations of living organisms change or stay the same over time as a result of the interactions between the genetic variations that are expressed by the individuals in the populations and the environment in which the population lives.

STEP 1 **STEP 2** **STEP 3** **STEP 4**

Lesson 4.1 Engage/Explore/Explain

Over three 50-minute periods, this lesson provides an opportunity for students to synthesize their understandings of how environmental and genetic factors influence the traits in a population. The example used is the sickle cell trait. Scientific information is unveiled in sequential steps through a compelling story about a teenager with sickle cell trait. Students gather evidence from the story by recording illustrated notes from which they develop a scientific explanation for the inheritance of a trait.

A video is shown, explaining that populations where malaria is prevalent have a higher frequency of individuals with the sickle cell trait. The expectation is that students will develop a written scientific explanation, using appropriate scientific terminology to explain how it is possible that some human populations have a high frequency of the heterozygous genotype while other populations have a relatively low frequency.

Guiding Questions

What is the link between genotype and phenotype in the sickle cell trait? How can our understanding of genetics, environmental influences and natural selection lead to a scientific explanation for the frequency with which the sickle cell trait occurs in different human populations?

Lesson 4.2 Evaluate

This 50-minute culminating lesson shifts students' focus from the human population to a careful consideration of how mutation and natural selection have resulted in the evolution of populations of bacteria that now have antibiotic resistance. In this summative evaluation, students are given a final opportunity to demonstrate understanding of the key concepts in this unit. Students apply their understanding to interpret three scenarios about a teenage girl with a bacterial infection and three different outcomes.

Guiding Question

Using the bacteria in the scenario as an example, explain the following question: What causes populations to physically change or stay the same over generations?

Standards addressed in Step 4: 1d, 1g, 1i, 1k, 1l, 1m, 4a through e, 7a, 7b, 7d, 8a, 8b.

Key Concepts

- Physical symptoms for genetic conditions are the individual's phenotype.
- Protein production in cells is what determines how the cells in an individual's body function.
- DNA codes for RNA that codes for the sub-molecules that are bonded together through protein synthesis to form chains, which are proteins. These proteins are essential for life.
- A small advantage, such as surviving a disease common in a population's environment, can lead to the spread of a trait in a modest number of generations.
- Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.
- New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators.

Evidence of Student Understanding

The student will be able to:

- develop an explicit visual aid that explains the relationship between genotype and phenotype for sickle cell disease and the sickle cell trait based on a variety of information sources.

Continued on following page

A Scientific Explanation for a Personal Mystery

Engage/Explore/Explain

1. Decide in advance how you will have students engage in the reading on Student Pages 4.1A–D (see #2 below).
2. Introduce this lesson as an intriguing mystery in which students will have an opportunity to apply what they have learned about the connections among genotype, phenotype, and environment to interpret and explain a story about a fifteen-year-old girl.
   - Keep the introduction to this lesson short as the story itself is engaging. However, make your expectations for science learning clear—that students are to make connections to all that they have learned in this unit as they engage in the story.
   - Post the following list from Teacher Page 4.1A ***Lesson 4.1 Expectations*** that students need to accomplish by the end of the lesson. Explain that at this point, the information will not mean much to students—it will become clear after the class has engaged in the story. However, it is important for students to realize that they need to pay careful attention to the science in the story.
     a. Record a thorough set of illustrated notes in your Science Notebook with as much information as you can learn from the story about:
        - the girl's genotype, phenotype, and environment
        - the variations possible for the trait described in the story
        - the genotypes, phenotypes, and environmental conditions important for the variations possible for the trait described in the story.

Continued on following page

b. Develop a visual aid that the girl in the story could use to make a presentation to her school's teachers to explain scientifically the variations possible for people with the same or a similar genotype as she has.
   - Include specific illustrations of and explanations for the connections between genotype, DNA, protein formation, molecular structure, phenotypes, and medical implications.

c. Write a scientific explanation that explains how it is possible that some human populations have a high frequency of the heterozygous genotype for this trait while other populations have a relatively low frequency. Explain a plausible scenario for how this trait could have first appeared in a population and then become a common allele.

3. Explain that the story will unfold in pieces, and the class will have time to think about the additional information they learn from each new story segment. Explain how the story will be read. You may choose to read it aloud yourself, have students take turns reading it aloud, or have one student read the narrative while others read the words spoken by the characters. The main characters in the story are:
   - Frankie Jackson (the girl)
   - Ruth Jackson (the mother)
   - Dr. Westerson (general practitioner physician)
   - Dr. Shallcross (geneticist)

4. Guide the class through the sequence of readings and information on Student Pages 4.1A–F. Stop after each segment, and use a Think–Pair–Share strategy for students to process and record notes based on the expectations posted (from Teacher Page 4.1A).
   - You may want to structure the note taking using the Line of Learning strategy described in the Immersion Toolbox. Using the Line of Learning strategy, students record what they know at the end of each reading segment, and then draw a line beneath their notes. After the next reading segment, students record what they now think—revising, augmenting, clarifying, and refining their previous observations and statements.
   - When the story is completed, and students are given Student Pages 4.1E and 4.1F to investigate the DNA and protein synthesis involved with this hemoglobin gene, use the interactive animations on Teacher's Domain and other sources of information to introduce and/or review these processes with students.
   - Provide class time for students to develop a visual aid (poster, slide presentation, etc.) for Frankie and write their explanation for how a population could come to have the sickle cell trait (through mutation) and then increase in numbers of individuals with that genotype (in regions where the trait is an adaptation).

Continued from previous page

- develop a scientific explanation for how some human populations evolved to have a high frequency of individuals who are heterozygous for the sickle cell trait.

Time Needed

150 minutes

Materials

For each student

- 1 copy each of Student Pages 4.1A – 4.1D

For the class

- CD–ROM for *Exploring Populations*
- projector and computer as needed to show video clips from the CD–ROM
- 1 overhead transparency or poster of Teacher Page 4.1A ***Lesson 4.1 Expectations***

5. Plan for students to present their posters and/or explanations for population change effectively in class. You may want to precede the presentations with peer review to provide feedback and an opportunity for revision before the final products are presented.
   - You may wish to have a few students present and explain their visual aid before students begin writing their scientific explanations (2c above) to be certain all students grasp the key points before explaining how the trait could affect a population.
   - The video. ***A Mutation Story***, on the Teacher's Domain can be used either before students write their explanations for sickle cell in a population or after their first drafts, depending on their need for guidance to interpret the evidence given in the story.
6. Use the REAPS questions throughout the lesson where appropriate.

REAPS

R What caused the sickle cell allele to be different than the healthy allele? *A single mutation in the DNA.*

E How can a mutation be harmful in one environment and help in another. *The pressure or stress placed on individuals in an environment determines what traits are beneficial and which are not.*

A In the case of sickle cell disease, which population evolved—the one that gets the disease or the one that causes the disease? How does this compare to tuberculosis? *Sickle cell is not caused by an organism infecting humans, it is a genetic condition that is caused by a mutation in a hemoglobin gene. It is the human population that evolved to have this trait, and in some cases, to have populations where the trait is common in the heterozygous form because it is an adaptation. Tuberculosis is caused by a bacterial infection, and it is the bacteria that evolved to become resistant to the antibiotics humans put in its environment (the human body). Check to be sure that students understand the response to this question before proceeding with the final, summative evaluation.*

P How long do you think that it took for Anthony Allison to gather enough evidence to fully support his hypothesis that the heterozygous genotype for sickle cell is an adaptation in regions where malaria is common? *Students who are interested in knowing more about this remarkable discovery can learn more by researching the topic online. An article written by Anthony Allison about his discovery, titled* ***The Discovery of Resistance to Malaria of Sickle-cell Heterozygotes*** *(The International Union of Biochemistry and molecular Biology, 2002), may be an appropriate extension reading for some students.*

S How was the way that you received additional information with each new piece of the story similar to how a scientist receives information that is used to develop an explanation? How does the new information affect your explanation for what you knew previously? *Use student responses to this question to check for understanding that scientists must constantly review, revise, and augment their explanations in light of new evidence and information as it is acquired.*

Teacher Background Information

The physical structure of the sickle cell hemoglobin is directly related to the physical shape of the sickle red blood cells, and this is then directly related to the medical symptoms that individuals with the sickle cell trait experience. This makes the study of sickle cell a strong opportunity for students to link their growing understanding of genetics and genotypes directly to an individual's phenotype.

The following explains the key connections that students will discover as they explore the evidence in the story on the student pages and the information about the alleles' DNA.

- In low oxygen conditions (e.g. high altitude, poor air quality, etc.) , individuals with the sickle cell allele can experience medical symptoms that include shortness of breath and cramping.
    - Individuals who are homozygous for the sickle cell allele are diagnosed as having sickle cell disease, and this causes severe symptoms and can be fatal if untreated.
    - Individuals who are heterozygous for the sickle cell allele often go undiagnosed as symptoms are significantly less severe and are brought on typically by unusually low oxygen conditions or possibly during high oxygen demand (as during a hard work out). The condition can be effectively managed through ordinary actions, such as staying well hydrated when environmental conditions are stressful (low oxygen).
        - The alleles for hemoglobin gene demonstrate an example of an incomplete dominance. The heterozygous genotype experiences an intermediate expression of both alleles present.
- The genotypes possible for this hemoglobin gene are written as follows:
    - Homozygous for the healthy allele: $\boldsymbol{Hb^A Hb^A}$
    - Homozygous for the sickle cell allele (has sickle cell disease): $\boldsymbol{Hb^S Hb^S}$
    - Heterozygous (some sickle cells in low oxygen conditions): $\boldsymbol{Hb^A Hb^S}$
- The DNA sequence provided on Student Page 4.1E is the coding strand of the DNA for this hemoglobin gene. Be sure students recognize (and perhaps even determine the code for) the complimentary, non-coding strand also exists in the cell where DNA is double–stranded by nature.
    - The sickle cell allele differs from the healthy allele only in nucleotide #21, where there is a T to A substitution mutation.
- The mRNA sequences for the two hemoglobin alleles differs at the same position where the DNA sequences were different.
    - Glutamate (glutamic acid) in the healthy hemoglobin is replaced by valine in the sickle hemoglobin.
- The sequence of the amino acids determines what the shape of the hemoglobin molecule will be (healthy and fully functional or misshapen and likely to sickle in low oxygen conditions).

For additional information, see the background essay online in the Teacher's Domain resource for A Mutation Story at: http://www.teachersdomain.org/resources/tdc02/sci/life/gen/mutationstory/index.html

Teacher Page 4.1A: Expectations

a. Record a thorough set of illustrated notes in your Science Notebook with as much information as you can learn from the story about:

- the girl's genotype, phenotype, and environment
- the variations possible for the trait described in the story
- the genotypes, phenotypes, and environmental conditions important for the variations possible for the trait described in the story.

b. Develop a visual aid that the girl in the story could use to make a presentation to her school's teachers to explain scientifically the variations possible for people with the same or a similar genotype as she has.

- Include specific illustrations of and explanations for the connections between genotype, DNA, protein formation, molecular structure, phenotypes, and medical implications.

c. Write a scientific explanation that explains how it is possible that some human populations have a high frequency of the heterozygous genotype for this trait while other populations have a relatively low frequency. Explain a plausible scenario for how this trait could have first appeared in a population and then become a common allele.

Student Page 4.1A: A Medical Mystery with a Genetic Solution

Part 1

Frankie Jackson didn't care about the screen door's loud slam. She tried to stomp through the living room into her small bedroom, but even that seemed like too much work. Discouraged, angry, and very, very tired, she slumped down on the couch and stared at her Nikes, absent-mindedly thumping the toe of her shoe against the coffee table. At least, she consoled herself, she was home alone.

"Francine? Baby, is that you?

Her mother's voice, emerging cheerily from the back room, shattered even that comforting notion. Sullenly, fifteen year old girl ignored the question, picking up the remote to snap on the TV. *Leave me alone!* she thought—but didn't say.

"Francine!" Her mother stood in the living room doorway, her broad, dark face creased by a frown of concern. As usual, Frankie had the feeling that her mom saw right into her mind, and was gently rebuking her for an unfriendly thought. But when Ruth Jackson spoke, her tone was soft. "Honey, I thought you were going to be at basketball practice all afternoon."

The young woman shook her head, then sighed. "I tried, Mom," she said. "But we started out with running laps around the court, and after five minutes I couldn't even catch my breath. My legs started to cramp up, and the coach just started yelling. So I told him that I quit!" she concluded, glaring defiantly her mother.

Ruth Jackson didn't say anything for a moment. Instead, she came and sat beside her daughter. Something squawked away on the TV, but neither of them paid it any attention.

"Remember last summer?" Ruth said. "When I took you and Ronnie up to the Sierras? We were going to take that hike, but you said almost the same thing—you couldn't catch your breath, and you got a cramp in your leg."

"Yeah?" Frankie replied. "So what?"

"So, I'm worried about you," her mother said. "And, girl, I'm going to get you in to see the doctor!"

Student Page 4.1B: A Medical Mystery with a Genetic Solution

Part 2 (continued)

Doctor Emily Westerson had been working at the neighborhood clinic for nearly ten years, but Frankie had only seen her twice—once, when she broke her wrist in a fall down the stairs, and another time when a persistent fever had kept her out of school for a week, and had turned out to be pneumonia. After all, Ruth Jackson worked a job that didn't provide health insurance, so the members of the Jackson family didn't run to the doctor every time someone got a runny nose.

The fact that Ruth had been so determined to take her to the clinic made Francine wonder if something really *was* wrong with her. In fact, she was worried enough that she didn't even argue when her mother insisted on coming in to the examining room with her.

After a nurse collected data about Frankie's blood pressure, temperature, weight, and asked a few question about why she was here, the mother and daughter were left alone for a few minutes to wait for Dr. Westerson's arrival. Frankie sat on the edge of the paper-covered examining table, while Ruth wandered aimlessly around the small room.

"What do you think is wrong with me?" the girl asked, shaking her head glumly.

"Now, honey, probably nothing. But it's best to be sure," Ruth replied, looking at the doctor's diploma on the wall; at the desk with its neat supplies of tongue depressors, bandages, and strange tools; at the abstract painting on the wall.

Frankie suddenly realized that her mother was looking everywhere but at her.

"Mom!" she said insistently. "What is it?"

Ruth sighed, and sat down on the chair next to the examining table. "Did you ever hear of your Uncle Mikey?" she asked.

"Uncle Mikey? I don't have an Uncle Mikey!"

"No, you don't," Ruth replied. "He was your father's brother—he died before you were born. Even before I met your dad. But your father told me about him."

"How'd he die? How old was he?" Frankie was too surprised at the news to be upset.

Her mother shook her head. "About ten or eleven, near as your dad remembered. He was always a sickly boy. Lots of fevers. Suffered pain in his legs, his chest, all through his life. That poor little boy had a stroke when he was only nine years old! Then he got pneumonia, and it took him. I guess he went to the hospital, but it was just too late."

"Geez, Mom! I never heard about that." Francine suddenly had a chilling thought. "You don't think that I--?"

"No, no, of course not, honey. You're a healthy girl, a good athlete—you run fast, and you're so graceful. You hardly ever got sick. But, remember when you got that pneumonia, how scared your dad was? Well, it's because he remembered Mikey."

At that moment there was a knock on the door, and Doctor Westerson entered. She was a petite blond woman with a cheerful smile and blue eyes that seemed penetrating and, to Frankie, vaguely sad. She listened carefully while Francine, with a few interruptions from her mother, described the symptoms that led her to drop out of the basketball tryouts. At Ruth's prodding, she also mentioned the weariness and pain that had afflicted her on the summer trip high into the mountains.

"Did you have some water with you while you practiced?" the doctor asked.

Frankie shrugged. "No, but I had a pop before I went over to the court."

"Okay. Well, water is better—make sure you drink some before, and during, exercise. You say this happened last Saturday, right?"

The two Jackson women nodded.

Continued on following page

"I remember, that whole weekend the air quality was terrible. Lots of smog, no wind. And as to what happened last summer, you were up in the mountains. There's not as much air, as much oxygen for your blood, as there is at lower elevations." Dr. Westerson looked at Ruth. "Do you know of any family history of illness? Not necessarily these symptoms, but anything?

Her mother nodded, and then told the doctor the same facts about Uncle Mikey that she had just related to Francine.

"I see," the doctor said thoughtfully. She frowned for a moment, then stood up, her face brightening. "I'd like to do a couple of tests. All right?"

Frankie agreed. First, the doctor asked her to blow through a tube that measure the force of air coming out of her lungs. "Good," Doctor Westerson said. "It looks like you don't have asthma. Now, I'd like to draw some blood—just a small amount—for a lab test. All right?"

Frankie's eyes widened at the thought, but she quickly recovered and shrugged casually, as if people were trying to pull blood out of her all the time. "Sure, I guess," she agreed.

The girl couldn't help watching as the doctor, whose small hands proved to be very strong, swabbed her arm with disinfectant, the white cotton bright against her chocolate-colored skin.

"This might hurt just a bit," Dr. Westerson warned, holding a syringe with a long needle attached. She probed for a vein with her fingers, and when she found it she smoothly and quickly slid the needle through Frankie's skin and into the blood vessel. The girl was surprised it didn't hurt more, and it was fascinating to watch the doctor pull back on the syringe, seeing the clear plastic vial fill up with Frankie's bright, red blood.

"That's all," Dr. Westerson said cheerfully, removing the needle and smoothly placing an adhesive bandage over the puncture. "Just hold that in place for a few minutes, to let it clot."

"And then?" Ruth asked.

"We'll have to wait for some lab results. It should only be a couple of days—can the two of you come back then?"

"Of course," Ruth replied.

"What are you looking for in my blood?" Frankie asked.

"Well, it's only a hunch. But the story your mother told me of how your uncle had poor health all his life, and then died, as a child, from pneumonia, made me wonder if he might have suffered from sickle cell disease—they used to call it sickle cell anemia. But lots of times in the past it wasn't diagnosed."

"And you think *I* might have it?" Frankie gasped. Like most African Americans, she had heard of the disease, and knew its terrible reputation.

"No!" Dr. Westerson said, holding up both hands. "That is, if you had the disease, you would have noticed the symptoms long before now. But it's possible that you carry the trait—which many, many people do, and it's not a dangerous condition. As soon as we get the blood test back, we'll know for sure."

The doctor laid a comforting hand on Frankie's shoulder. "If we learn that you're a carrier of the trait, it's not going to change your life. *Everybody* should stay hydrated when they work out—you just have to make sure to remember that water bottle! Okay?"

Francine nodded, still not sure what to make of all this, but knowing it didn't seem fair.

"I'll call just as soon as I get the results," Dr Westerson said, as the two Jacksons made their way out the door.

* * * * *

Student Page 4.1C: A Medical Mystery with a Genetic Solution

Part 3 (continued)

"Why can't they get the lab results right away?" Frankie demanded, as soon as she and her mother got home. Ruth had stopped for a take-out pizza, and the two of them sat at the small kitchen table, picking at the food. Francine's older brother Ronnie was working the night shift at the drug store, so the two of them had the place to themselves. "Why does this have to happen to our family, anyway?" she groused.

"I wish I knew, sweetie," Ruth said. "I've heard of sickle cell, but I don't know much about it."

"Well, I'm going to look it up online," Frankie declared. Now that she had a plan, her appetite returned, and she beat her mother to the last pepperoni-covered slice. Ruth was still lost in thought as her daughter went to the computer in its niche in the living room corner. Francine booted it up, typed "sickle cell disease" into the Google search engine, and was rewarded with many millions of hits.

Shrugging, she started with the first link, and continued through many more.

She learned that sickle cell disease was first discovered in 1910, though it had obviously been around a lot longer. It apparently originated in Africa, and was passed along through the genes—that is, it was inherited from your parents, and couldn't be "caught" from another person the way you might catch a cold, or the flu. Most of the links told her about the disease itself, and not merely the sickle cell trait, and she reminded herself that Dr. Westerson had seemed very confident that Frankie didn't suffer from the disease.

She was surprised to read about one of her favorite performers, a woman named T-Boz , who was the lead singer for the group TLC. T-Boz not only had sickle cell disease, but she had become a spokesperson for an organization that tried to educate people about it, and also worked toward a cure. On one website, T-Boz herself talked about the effects of the disease, and the pain she had endured throughout her life. But she was upbeat and positive about her future, and as Frankie surfed on she was very much impressed by the woman's strength.

In the United States, she discovered, sickle cell disease was most prominent in the African American community, but it was not limited to people of her race; it could be encountered in Hispanics, Europeans, and Asians, as well. A common denominator seemed to be that it was found in people whose ancestors came from warm, tropical climates.

Frankie read about how the disease was named for an effect that was visible under a microscope: When a person had sickle cell disease, some of their red blood cells, which should be round and slippery, would become misshapen when they were deprived of oxygen. The cells distorted into shapes resembling boomerangs, bananas, or, in fact, sickles (a tool). This made it hard for those cells to flow through small blood vessels, because they tended to get tangled up with each other. When they did, they created a dam, or a blockage, in the blood flow; and this blockage could lead to pain, organ damage, and even strokes.

It was late by the time Frankie stopped surfing the web—and she still had countless other sites that she could have explored. She knew more about the condition, but, if anything, she was even more worried than she'd been before. The same emotion that had been her first reaction still echoed in her mind as she lay in bed and tried to get to sleep.

It just wasn't fair!

* * * * *

Student Page 4.1D: A Medical Mystery with a Genetic Solution

Part 4 (continued)

The lab results came in two days later, and Frankie and her mother took the first available appointment, arriving at the clinic right after the noon hour. When Dr. Westerson came in to the examining room, she was accompanied by a young doctor, a handsome black man whom she introduced as “Dr. Shallcross.”

“I’m actually a medical resident,” Shallcross said, almost apologetically. “I’m studying the specialty of genetic medicine. I did my early clinic work with Dr. Westerson, and she thought I might be able to provide some useful perspective on this consultation. Do you mind if I sit in?”

“No, I don’t mind,” Frankie replied, as her mother nodded in agreement. “I want to learn as much as I can about this.”

“Good,” said Dr. Westerson. She pulled out a folder, opened it, and laid it on the desk. She addressed Francine, talking to her like she was an adult. “The blood test came back positive—that is, it indicates that you are a carrier of the sickle cell trait. You do *not* have sickle cell disease.”

“Okay. I guess I’m not surprised,” Frankie said. “But what does that mean? And why did this have to happen to me?”

With a thin smile, Dr. Westerson looked at Dr. Shallcross, who answered.

“Believe it or not, the fact that you have this trait means that your ancestors were survivors. You see, sickle cell evolved in Africa, and other tropical locales, as an effective defense against malaria. This was discovered in the early 1950s by a Kenyan doctor, Anthony Allison, who trained in England but returned to his native country to study the evolution of many diseases.”

“How can something this bad have been good?” Frankie challenged.

“Excellent question!” replied Dr. Shallcross cheerfully. “You see, malaria is a parasite, a disease that is transferred to humans by mosquitoes. When Anthony Allison started his research, nobody knew of any relation between the sickle cell trait and malaria. By testing very young children in Kenya, he learned that people who lived in the moist, hot low country—where mosquitoes, and malaria, are very common—had a very high occurrence of the sickle cell trait. In some places as much as 30% or 40% of the population had the gene. But in the dry high country, where there is no malaria, less than 1% of the population had the gene.”

“So, maybe it had to do with ancestors,” Frankie said, unconvinced. “Maybe the people who lived in malaria country came from tribes that had the gene.”

“Good point!” Shallcross retorted. “But Allison thought of that. And, in Kenya, the people who lived in both environments have descended from the same ancestors. So he looked for a different cause.”

“I still don’t get it. How can something that makes people sick be good for you?”

“Well, you’ve obviously done some homework about sickle cell. Am I right?”

Francine nodded curtly.

“So you know about the changing shape of the red blood cells. Well, when a person gets malaria, the parasite that causes the disease tends to concentrate in the odd-shaped cells. In a healthy child, those cells are filtered out by the spleen—the sickle shape of the cells makes them get caught there, since the spleen is kind of a filter—and that effect makes the person much more likely to survive an attack of malaria. The carriers of the sickle cell trait would grow up and have children—who also had the trait—while

Student Page 4.1D: A Medical Mystery with a Genetic Solution

Part 4

(continued)

many children in the rest of the population would die from the disease. The sickle cell trait actually made them much more resistant to this terrible disease."

"But what about sickle cell disease? What about Uncle Mikey?" Frankie understood what the doctor was saying, but it was only making her more upset.

"Another good question," Dr. Shallcross said. He didn't seem so cheerful now. Instead, he sighed. "People with sickle cell disease didn't usually live long, back then. They certainly didn't become old enough to have children, so the disease itself was not passed on to the next generation, not from people who suffered from it, at least."

He stood up, and pointed to a poster on the wall—a poster that hadn't been there when Frankie first visited Dr. Westerson. The picture showed two people, a man and a woman, at the top of the part, and four people—obviously their children—on the bottom of the image.

"Picture the people at the top as your mother and father," Shallcross said. "Each of them has the sickle cell trait, just as you do. That means that one of their hemoglobin genes—that's part of the DNA code for your red blood cells, which carry oxygen through your whole body via your blood—carries the sickle cell tendency, while the other doesn't."

"Okay, I get it," Frankie said.

"Now, these four children are not real people—they just display the probabilities. So you see, this one on the left, he doesn't have the sickle cell trait. That happens in 25% of children, when both parents are carriers. That is, one child in four will not have the trait. These two in the middle, 50% of the children, carry the trait, just as their parents did. That's half of their children."

"Right. That's me," Frankie said sourly.

"Exactly!" If Dr. Shallcross noted her mood, he didn't let on. Instead, he pointed to the fourth child, the one off to the right of the diagram. "Now, when two carriers have a child, there is a 25% that the child will have both sickle cell genes, instead of one. This person will have sickle cell disease."

"Like Uncle Mikey," Francine said, feeling a pang of sadness for her father's brother, the boy who never had a chance to become a man.

"Right," Dr. Shallcross replied. "Like Uncle Mikey. Or me."

The last word seemed to hang in the air for a long time. Francine looked at her mother, then back to the African American doctor. "*You* have sickle cell disease?" she asked, her voice quiet.

He nodded, like it was no big deal.

"And you are—you're going to be—a doctor?" she asked.

"I *am* a doctor," he said, proud but not boasting. "And I want to specialize in diseases like this. You know, today someone with sickle cell disease can live a long, productive life. I have some pain, some issues I have to deal with—"

"Like T-Boz," Frankie interrupted.

"Yes, like T-Boz," Shallcross replied. He cleared his throat, like he wanted to get back to business. "But we're here to talk about you. You carry the trait, like a lot of African Americans, but you don't have the disease."

"Well, what does it mean for me?" she asked.

"The trait shouldn't change your life. Dr. Westerson gave you good advice—stay hydrated when you exercise. As long as you get enough oxygen, and your blood flows, you'll be fine. If you do get cramps, stop, take a rest. If the coach yells at you, tell him to chill!" Dr. Shallcross

laughed, a little sheepishly. “Well, maybe it would be better to show him the note your doctor will write for you. People with sickle cell trait can do anything anyone else can do—you know Marcus Dayne, the wide receiver for the Green Bay Packers? He has the trait, and it hasn’t held him back!”

Frankie wasn’t a football fan, but she was encouraged by the example. Still, another question percolated up in her mind. “What about…what about if I have children?” she asked.

Dr. Shallcross indicated the two people at the top of the chart. “If the father of your children doesn’t possess the trait, then there is no effect. If he *does*, well, you see the odds.”

She nodded. “There’s a 25% chance that our child will have the disease. If we have four children, the odds are that one would have the disease.”

“Yes, that’s right,” the resident confirmed frankly.

“Is there a cure?” she demanded.

Doctor Shallcross shook his head. “No, not yet. There’s been some success with bone marrow transplants, but that’s hard to arrange—and you have to be lucky enough to find a perfect donor. There are lots of medications that can help with the symptoms—I take several myself. But remember, Francine, that this is a genetic disease. It was only in the year 2003 that the whole of human DNA—our genetic blueprint—was even mapped out. I have no doubt that, in the very near future, more cures are going to be found.”

He allowed himself a modest smile. “Who knows,” he said. “I might even find one myself!”

* * * * *

DNA Strand A: The following is the sequence of DNA nucleotides for the allele that codes for healthy hemoglobin protein:

A G G T C T C C T C T A A T G G G T C T C C T T A G G T C T C C T

DNA Strand B: The following is the sequence of DNA nucleotides for the allele that codes for hemoglobin protein that sickles:

A G G T C T C C T C T A A T G G G T C A C C T T A G G T C T C C T

---

1. What is the difference in the DNA for the two alleles?
2. What are the consequences of the difference you found in the DNA for the two alleles? How does the difference effect:
   - the mRNA sequence that would be produced by transcription from the DNA strands
   - the amino acid sequence coded for by the mRNA sequence for the two different hemoglobin alleles
   - the relationship between the protein produced by the two different hemoglobin alleles and the hemoglobin molecule's shape.

The following resources (found on the Unit CD–ROM and on Teacher's Domain) may be helpful for cracking the DNA codes for the alleles and learning about hemoglobin's molecular shape:

- **From DNA to Protein**
- **Sickle vs. Normal Cell**
- **Student Page 4.1F, *Amino Acid Table***

Student Page 4.1F: Nucleotide Amino Acid Codes

Nucleotide Codes

A	Adenine	T	Thymine
G	Guanine	U	Uracil
C	Cytosine		

Amino Acid Table

	Second Position								
	U		C		A		G		
	code	Amio Acid	code	Amio Acid	code	Amio Acid	code	Amio Acid	
First Position									Third Position
U	UUU	phe	UCU	ser	UAU	tyr	UGU	cys	U
	UUC		UCC		UAC		UGC		C
	UUA	leu	UCA		UAA	STOP	UGA	STOP	A
	UUG		UCG		UAG	STOP	UGG	trp	G
C	CUU	leu	CCU	pro	CAU	his	CGU	arg	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	gln	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	ile	ACU	thr	AAU	asn	AGU	ser	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	lys	AGA	arg	A
	AUG	met	ACG		AAG		AGG		G
G	GUU	val	GCU	ala	GAU	asp	GGU	gly	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	glu	GGA		A
	GUG		GCG		GAG		GGG		G

Amino Acid Codes

Three–letter Symbol	Amino Acid
Ala	alanine
Asx	aspartic acid or asparagine
Cys	cysteine
Asp	aspartic acid
Glu	glutamic acid
Phe	phenylalanine
Gly	glycine
His	histidine
Ile	isoleucine
Lys	lysine
Leu	leucine
Met	methionine

Three–letter Symbol	Amino Acid
Asn	asparagine
Pro	proline
Gln	glutamine
Arg	arginine
Ser	serine
Thr	threonine
Sec	selenocysteine
Val	valine
Trp	tryptophan
Xaa	unknown or ‘other’ amino acid
Tyr	tyrosine
Glx	glutamic acid or glutamine

Key Concepts

- Mutation and sexual reproduction lead to genetic variation in a population.
- Evolution is the result of genetic changes that occur in constantly changing environments.
- A small advantage in escaping a predator, resisting a drug, etc. can lead to the spread of a trait in a modest number of generations.
- Natural selection explains a mechanism for evolution.
- Natural selection leads to organisms that are well suited for survival in particular environments.

Evidence of Student Understanding

The student will be able to:

- summarize the key concepts and evidence gathered throughout the unit on the chart, answering the question, *What causes populations to physically change or stay the same over generations?*
- develop a plausible and logical scientific explanation that includes claims, evidence, and explicit reasoning to explain the evolution in the population of bacteria that occurs in the three scenarios described in the Lesson 4.2 Student pages.

Time Needed

50 minutes

Materials

For each student

- 1 copy of Student Page 4.4 ***Change Over Time***

For the class

- teacher–developed rubric outlining the expectations for students' responses

A Scientific Explanation for Change in a Population

Evaluate

1. Remind students that the **A**nalysis question in Lesson 4.1 ***REAPS*** asked *In the case of sickle cell disease, which population evolved—the one that gets the disease or the one that causes the disease? How does this compare to tuberculosis?*
   - Use a Think–Pair–Share strategy for students to reflect back on and share their responses.
   - Check to be sure that students understand the response to this question before proceeding with this final, summative evaluation.

     Sickle cell is not caused by an organism infecting humans, it is a genetic condition that is caused by a mutation in a hemoglobin gene. It is the human population that evolved to have this trait, and in some cases, to have populations where the trait is common in the heterozygous form because it is an adaptation. Tuberculosis is caused by a bacterial infection, and it is the bacteria that evolved to become resistant to the antibiotics humans put in its environment (the human body).
2. Point to the posted unit question, *What causes populations to physically change or stay the same over generations?* and conduct a brainstorm session about all the students have done throughout this unit to answer this question.

Continued on following page

- Add a final entry or amend those that are already written in the Unit Level Graphic Organizer, based on what was learned from the sickle cell trait lesson.
- Check for students' understanding during this brainstorm session. At this point in the unit, students need to have a solid understanding of one of the unit's key concept:
    - There is always competition for resources and usually variation in populations, and so selection is usually operating in natural populations, and this can lead to changes in populations over time (evolution).

3. Explain that the final assessment for this unit is a short scenario about a situation that students will need to read, analyze, and explain using the concepts and terminology from throughout this Immersion Unit.
    - Review the instructions on Student Page 4.4 ***Change Over Time***, and be sure all students understand your expectations.
    - Use appropriate reading and writing strategies to support your particular students to accomplish this task and be able to effectively demonstrate their understanding, individually.
    - Provide a rubric that makes clear both the format and depth of explanation you expect to receive from students. Review the rubric as a class, and answer questions as needed.
4. Provide time in class for students to complete the instructions on Student Page 4.4 ***Change Over Time*** so that you can be available to answer clarifying questions as students work.
5. Once the assessment is completed, explain the correct analysis of the scenarios, and highlight how this is based on reality.
    - Provide some real–world context; for example, explain how the development of resistant bacteria has changed the way that doctors prescribe antibiotics. Discuss why it is a problem to prescribe antibiotics when a patient has a virus infection (it won't kill the virus, and it exposes bacteria to the antibiotic, providing another opportunity for selection of resistant individuals)
    - Additional information in the form of a Powerpoint slideshow is available at http://undmedlibrary.org/docs/MSP2004/MSP4_Flower.ppt

Encourage students to investigate on their own and learn more about the evolution of resistant bacteria and other interesting situations where genetics and environment interact to cause changes in populations.

Celebrate the completion of this Immersion Unit and all the learning that has taken place!

Student Page 4.2A: Change Over Time

You have been studying the evidence, inferences, and mechanism for change over time in populations . In this final lesson, you will apply your knowledge to explain three possible endings to a story about a teenage girl who had surgery. Use the scientific terms and concepts that you have learned to write well-reasoned explanations for the stories that follow the instructions below.

1. Read the background information on antibiotics and study the data that is provided. Decide why the outcomes for the 3 scenarios are different.
2. Write 3–5 paragraphs that explain why each outcome for the three different story endings is possible at that time in history.

A good explanation will include evidence and reasoning for your claim about how genotype, phenotype, and environment were involved in a population's evolution in these stories.

Base your explanations on your experiences in this Immersion Unit. Use evidence from the lessons in this unit, from the class chart that lists ideas and evidence for how populations can change, and the following data about penicillin.

Be sure to include the following key terms in your explanation:

- evolution
- variation
- natural selection
- mutation
- adaptation
- environment / environmental factors

3. Explain how the difference in generation time for humans (about 20 years) and bacteria (about 20 minutes) makes a difference in their rates of evolutionary change.

This is a fictional story about what could happen to a girl with a serious medical condition, living at three very different times with three very different endings to the same story.

The attendants wheel the teenage girl into the operating room as her mother waits anxiously in the sitting room at the end of the hall. The girl's appendix is so severely inflamed that her doctor worries that it might rupture before she can perform the operation. In spite of the danger, the operation goes smoothly, and the surgeon removes the girl's inflamed appendix without mishap. After surgery, nurses take the patient to the recovery room. In about 30 minutes, she regains consciousness and speaks to her mother.

All seems to be going well in the first 24 hours after surgery. However, on the following day, the girl begins to run a fever, which quickly rises. Her doctor realizes that she has contracted an internal infection during the surgery.

The girl in this story has a bacterial infection. A strain of *Staphylococcus* bacteria contaminated the open wound during surgery, and it continued to multiply inside her body. Will she survive this infection?

Use your knowledge of evolution and your scientific thinking skills to propose an explanation for what happens next.

continued on following page

Scenario 1

The year is 1925: The girl becomes delirious from fever; in a few days, she dies.

Scenario 2

The year is 1945: The girl receives an injection of the antibiotic penicillin, followed by repeated doses. Within 24 hours, her fever is reduced, and in a week, she is released from the hospital, well on her way to recovery.

Scenario 3

The year is 1980: The girl receives an injection of the antibiotic penicillin, followed by repeated doses. Despite this treatment, her fever continues, and she becomes delirious. In a few days, she dies.

Data Timeline: Development and Production of Penicillin

Date	Scientist(s)	Accomplishment
1896	Ernest Duchesne	noticed penicillin
1928	Alexander Fleming	observed that a mold produced a substance that killed the bacteria *Staphylococcus*
	Dorothy Crowfoot Hodgkin	uses x–rays to find the molecular shape of penicillin and other molecules
1939	Howard Florey	began intensive research on penicillin
1941	Howard Florey and Norman Heatley	brought a small package of penicillin to the U.S. for use
1943	Dr. Heatley and others	clinical trials of penicillin were conducted
1943 to 1946		full scale production of penicillin makes it affordable and widely available
early 1960s		early strains of penicillin resistant bacteria reported
late 1970s		multiple resistant strain of *Staphylococcus aureus* arose

Index of Links

Step 1

Association for Professional Basketball Research, The http://members.aol.com/bradleyrd/apbr-faq.html

Baseball Digest http://findarticles.com/p/articles/mi_m0FCI

Columbia News Service http://jscms.jrn.columbia.edu/cns/2007-02-27

Evolution of Adult Height in Europe: A Brief Note, The http://ideas.repec.org/p/upf/upfgen/1002.html

Fogel, Robert, autobiography http://nobelprize.org/nobel_prizes/economics/laureates/1993/fogel-autobio.html

Health, nutrition, and the economic prosperity: a microeconomic perspective www.cmhealth.org/wg1_paper7.pdf

Price is Right: Economics and the rise in Obesity, The http://www.ers.usda.gov/amberwaves/february05/features/thepriceisright.htm

Schmuck, Peter http://findarticles.com/p/search?tb=art&qt=%22Peter+Schmuck%22

Step 2

Fast Plant Inheritance Simulation http://www.fastplants.org/simulation_1/

Floral Arrangements http://www.teachersdomain.org/resources/tdc02/sci/life/stru/floral/index.html

Genetics and Height http://www.newton.dep.anl.gov/askasci/mole00/mole00125.htm

How Cells Divide: Mitosis vs Meiosis http://www.teachersdomain.org/resources/tdc02/sci/life/gen/mitosis/index.html

Human Equation, The http://magazine.uchicago.edu/0726/features/human.shtml

Human Height Correlation Figure http://nitro.biosci.arizona.edu

Inside a Seed http://www.teachersdomain.org/resources/tdc02/sci/life/stru/insideseed/index.html

Journey Into DNA http://www.teachersdomain.org/resources/tdc02/sci/life/gen/journeydna/index.html

Mendel's Laws of Genetic Inheritance http://www.teachersdomain.org/resources/hew06/sci/life/gen/mendelinherit/index.html

Model Organisms http://www.teachersdomain.org/resources/hew06/sci/life/gen/modelorg/index.html

Pea Inheritance Simulation http://www.fastplants.org/simulation_2B/

Pea Plant breeding (meiosis) simulation http://www.sonic.net/~nbs/projects/anthro201/exper/

Some Genes are Dominant http://www.teachersdomain.org/resources/hew06/sci/life/gen/dominantgene/index.html

Time Lapse Pollination and Embryogenesis in Wisconsin Fast Plants http://www.fastplants.org/mov/WFPreproduction.mov

Wisconsin Fast Plants Inheritance Simulation http://www.fastplants.org/simulation_1/

Wisconsin Fast Plants www.fastplants.org

Step 3

Ask A Biologist, Podcast, Complete http://askabiologist.asu.edu/podcasts/transcripts/vol13_transcript_aab_podcast.html

Ask A Biologist, Podcast, Volume 13 http://askabiologist.asu.edu/podcasts/mp3_files/ask_a_biologist_vol_013.mp3

Ask a Biologist podcast http://askabiologist.asu.edu/podcasts/mp3_files/ask_a_biologist_vol_013.mp3

bacteriology text book http://textbookofbacteriology.net/growth.html

Common Genetic Code, The http://www.teachersdomain.org/resources/tdc02/sci/life/gen/comgencode/index.html

Gene Control http://www.teachersdomain.org/resources/tdc02/sci/life/cell/genecontrl/index.html

Gene Project Yeast Experiments http://www.phys.ksu.edu/gene/chapters.html

Microbe Clock http://www.teachersdomain.org/resources/tdc02/sci/life/evo/microbeclock/index.html

Microbiologybytes.com

Modeling the Effects of Ultraviolet Radiation http://www.phys.ksu.edu/gene/f_12.html

Nation's Report Card http://nces.ed.gov/nationsreportcard/itmrls/itemdisplay.asp

Why Does Evolution Matter Now? http://www.teachersdomain.org/resources/tdc02/sci/life/evo/whymatters/index.html

Step 4

From DNA to Protein http://www.teachersdomain.org/resources/tdc02/sci/life/gen/proteinsynth/index.html

Mutation Story, A http://www.teachersdomain.org/resources/tdc02/sci/life/gen/mutationstory/index.html

Sickle vs. Normal Cell http://www.teachersdomain.org/resources/tdc02/sci/life/repro/sickle/index.html

Teacher's Domain www.teachersdomain.org