TEACHER EDITION

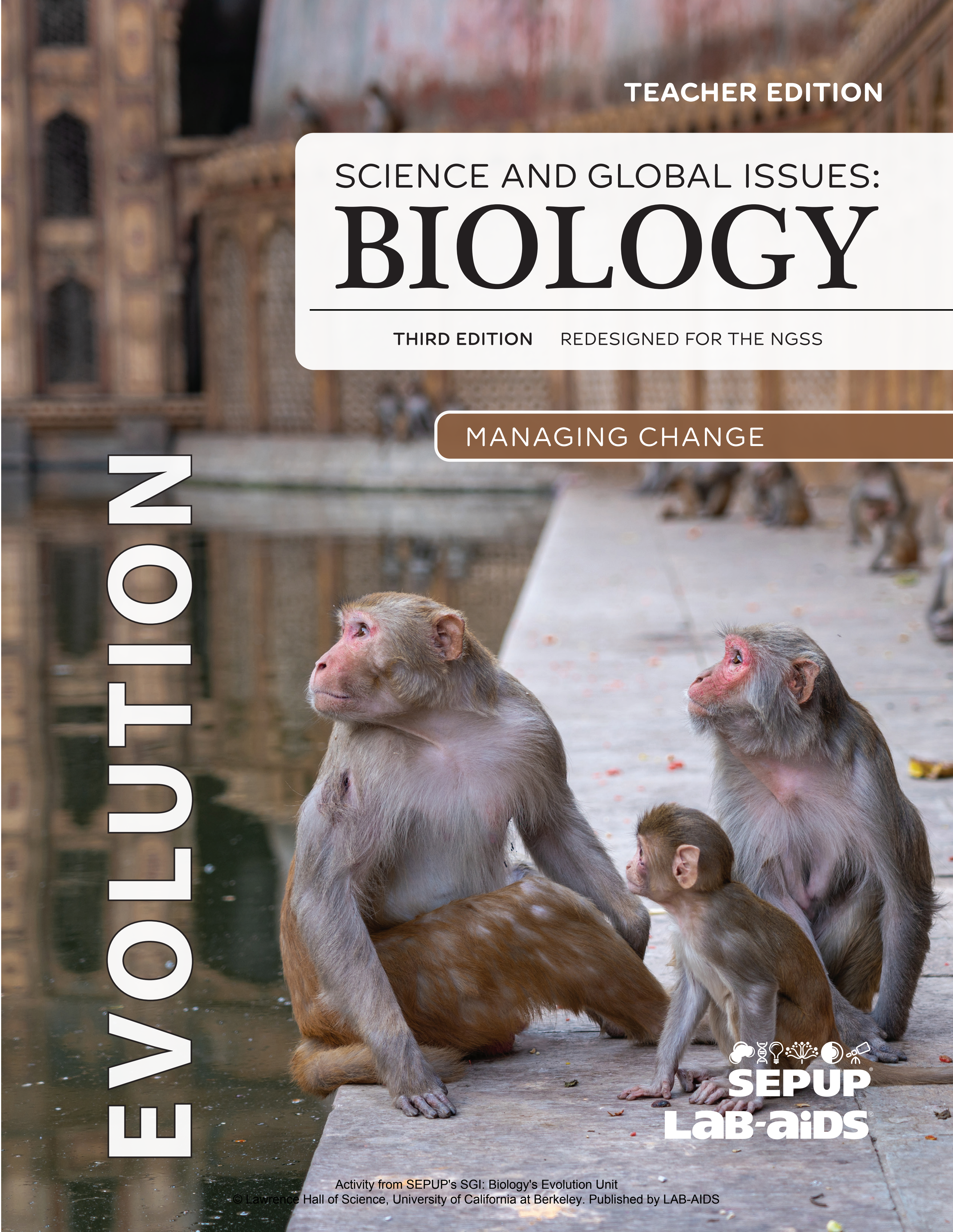
SCIENCE AND GLOBAL ISSUES:

# BIOLOGY

THIRD EDITION REDESIGNED FOR THE NGSS

## MANAGING CHANGE

# EVOLUTION



SEPUP

LAB-AIDS

# UNIT SUMMARY

## EVOLUTION: MANAGING CHANGE

**Unit issue:** Human activity can have evolutionary consequences for both biodiversity and ourselves.

**Overarching question:** How do human activities affect the evolution of other species, and what are the consequences for both biodiversity and ourselves?

**Unit storyline:** Students are introduced to the issue for this unit—*Human activity can have evolutionary consequences for both biodiversity and ourselves*—by considering infectious diseases. Students begin by considering tuberculosis, a disease that has a long shared evolutionary history with humans. They learn that the rate at which new diseases are evolving is increasing. Students' initial ideas and questions about the emergence of infectious diseases are elicited. Students also begin to consider how human activity may be affecting this evolutionary process and thereby affecting the three pillars of sustainability.

| Learning Sequence | Activities | Investigative Phenomenon | Performance Expectations Addressed |
|---|---|---|---|
| 1 | 1–6 | Salamanders along the Pacific Coast of North America show tremendous variability in color, despite all being members of the same species. | HS-LS4-1<br>HS-LS4-2<br>HS-LS4-3<br>HS-LS4-4<br>HS-LS4-5<br>HS-LS2-8 |
| 2 | 7–10 | Life on Earth is constantly changing—sometimes over short spans of time, and sometimes over long spans of time. | HS-LS4-1<br>HS-LS4-5<br>HS-LS2-7 |
| 3 | 11–15 | Chinook salmon body size has been declining over time. | HS-LS4-2<br>HS-LS4-4<br>HS-LS4-6<br>HS-LS2-7<br>HS-ETS1-3<br>HS-ETS1-4 |

# 4 Genetic Variation and Change

COMPUTER SIMULATION

2 CLASS SESSIONS

## ACTIVITY OVERVIEW

### STORYLINE

Students explore how changes in a population's appearance occur at the level of genes and are passed from one generation to the next. Using a computer simulation, students examine the factors that contribute to genetic variation in a population by focusing on the theorized relationship between cystic fibrosis and TB.

### SENSEMAKING PROGRESSION

- Students should understand that genetic variations, particularly genetic mutations, provide the basis for natural selection that can lead to heritable variation and evolution.
- Students may have little understanding of how a potentially lethal genetic mutation can provide resistance to an infectious disease.
- Key sensemaking: Students explore how a highly infectious disease (TB) helped to maintain a potentially lethal genetic mutation (cystic fibrosis) in a population over time. This key sensemaking step takes place in Build Understanding item 3.
- Students make connections between a population's level of wealth and the genetic variation within that population.
- Going forward: In the next activity, students draw on their growing understanding to explain what is required for evolution by natural selection to occur.

### NGSS INTEGRATION

Students use a computer simulation to analyze and interpret data that demonstrates the theorized connection between the protective effects of being a carrier of the cystic fibrosis mutation and reduced symptoms (and increased survival rate) when contracting TB. Students look for patterns across the data and apply statistical tests to analyze their results. Students are assessed on Performance Expectation HS-LS4-3.

## NGSS CORRELATIONS

### P Performance Expectations

*Assessing HS-LS4-3:* Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in relation to organisms lacking this trait.

*Working toward HS-LS4-2:* Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

*Working toward HS-LS4-4:* Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

### D Disciplinary Core Ideas

*LS4.B: Natural Selection:*

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

*LS4.C: Adaptation:*

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.

### S Science and Engineering Practices

*Analyzing and Interpreting Data:* Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

*Using Mathematics and Computational Thinking:* Use mathematical and/or computational representations of phenomena or design solutions to support explanations.

### Crosscutting Concepts

*Patterns:* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

### Common Core State Standards—Mathematics

*MP.2:* Reason abstractly and quantitatively.

*MP.4:* Model with mathematics.

### Common Core State Standards—ELA/Literacy

*RST-11.12.1:* Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

*WHST.9-12.2:* Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

## MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - Scoring Guide: ITEM-SPECIFIC – PE-HS-LS4-3
- *For each pair of students*
  - * computer with Internet access
- *For each student*
  - Student Sheet 4.1, "Cystic Fibrosis and Tuberculosis Simulation" (optional)
  - Scoring Guide: ANALYZING AND INTERPRETING DATA (AID) (optional)

* *not included in kit*

You may wish to prepare your students for discussions about cystic fibrosis. Many people (about 1 in 25 in the United States) are carriers for the mutation, and 1 in 2,500 have the disease. It is possible that your students are carriers, have the disease, or know someone who has cystic fibrosis. Students may appreciate knowing ahead of time that they will be discussing this topic.

Preview the Cystic Fibrosis and Tuberculosis simulation by visiting the student page of the *SEPUP Science and Global Issues, Third Edition: Evolution* website at **www.sepuplhs.org/high/sgi-third-edition**.

The ITEM-SPECIFIC Scoring Guide (PE-HS-LS4-3) for teacher use can be found at the end of this activity. The ANALYZING AND INTERPRETING DATA (AID) Scoring Guide for student use can be found in the Assessment tab in the back of this Teacher Edition and in Appendix C in the Student Book.

# TEACHING STEPS

## GET STARTED

Students read about the connection between being a cystic fibrosis carrier and experiencing less severe TB symptoms.

1. Let students know that in this activity they will investigate a particular genetic disease—cystic fibrosis, or CF—and ask students what they know about this disease.

   Be sensitive to the fact that students in your class may have CF, have a family member with CF, or know someone who has CF. Some students may be interested in sharing this information with the class, and others may not. Let students share as much or as little as they decide is comfortable for themselves.

2. Have students read the introduction and the guiding question for this activity.

   Elicit students' initial ideas about the role of genetic variation in evolution. Students are likely to have prior knowledge from middle school about this topic, so encourage them to use this knowledge in their responses.

   Tell students that they are going to explore the possible connection between CF, a genetic disease, and TB. Explain that this connection is a hypothesis, and it has not been tested in humans. However, the argument made by scientists for connecting the two diseases is strong and is well-supported by evidence. In this activity, students will explore this connection using a simulation based on real-world data from Europe, where the CF trait is thought to have originated. The simulation tracks the genotypes of adults in a population with varying exposure to TB and with varying degrees of wealth—and therefore access to health care.

## DO THE ACTIVITY

Students learn more about CF and TB and use a simulation to explore the hypothesized connection between them.

3. Support students as they complete Part A of the Procedure.

   Have students read the information about CF and TB and then answer the questions in Procedure Step 2 in their groups.

   Facilitate a class discussion by asking students to respond to the questions in Step 2. Accept any reasonable answers at this point. Let students know that they will see if their thinking was on track as they engage in a simulation in Part B.

4. Support students as they run the simulation in Part B of the Procedure.

   Direct students to the Cystic Fibrosis and Tuberculosis simulation on the student page of the *SEPUP Science and Global Issues, Third Edition: Evolution* website at **www.sepuplhs.org/high/sgi-third-edition**.

   You may want to have students set up a table in their notebooks to keep track of their chosen variables and the results of each run before beginning the simulation. As students run the simulation, remind them to change one variable at a time and to keep track of their chosen variables and results in their science notebooks. You may also want to remind students to examine the data about wealth distribution for each run.

   For students with learning disabilities and neurodiverse learners, consider providing them with Student Sheet 4.1, "Cystic Fibrosis and Tuberculosis Simulation," which offers more structure for recording their results from the simulation.

## BUILD UNDERSTANDING

Students summarize their findings from the simulation and make connections between genetic variation and evolution.

5. Facilitate a class discussion by asking students to summarize their findings from the simulation about the connection between TB and CF.

   From the simulation, students should come to the following main conclusions:

   - The number of CF carriers and patients increased after the 1950s, due to improved health-care options that allowed people with CF to live into adulthood and reproduce.
   - As the probability of contracting TB increases, so does the frequency of the CF mutation, causing the number of CF carriers and patients to increase. The CF mutation (even in carriers) is protective against the symptoms of TB, so more people with the CF mutation survive to adulthood and reproduce.
   - Adults in the top 20th percentile in wealth are more likely to survive than those in the bottom 20th percentile in wealth, due to better access to health care.

   Ask students to describe how the data from the simulation could be used as evidence for evolution. Students may suggest that since the data span 30 generations and since there is an upward trend for CF carriers and patients, the data imply that this gene mutation will continue to persist into future generations—especially since it provides protection against diseases like TB.

6. (AID ASSESSMENT, HS-LS4-3; KEY SENSEMAKING) Use Build Understanding item 3 to summatively assess Performance Expectation HS-LS4-3.

   You can use the ITEM-SPECIFIC Scoring Guide (PE-HS-LS4-3) (which is based on the AID Scoring Guide) to assess students' work on Build Understanding item 3, which is also an opportunity to assess Performance Expectation HS-LS4-3: Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in relation to organisms lacking this trait. Item 3 is the key sensemaking opportunity in this activity. Sample responses for all four scoring levels are provided in Sample Responses to Build Understanding.

7. Use the Extension as an opportunity for advanced learning.

   In this Engineering Connections Extension, students investigate CRISPR, a gene-editing technique that is being used to correct the CF mutation in human stem cells. This technology may even lead to a cure for previously incurable genetic diseases, such as sickle cell anemia. Students may complete this Extension in small groups or individually.

## SAMPLE RESPONSES TO BUILD UNDERSTANDING

1. What is the evidence for a cause-and-effect relationship between the probability of contracting TB and the frequency of the CF mutation?

   *In the simulation, we observed that as tuberculosis incidence increased, so did the rate of the CF mutation in adult populations. This implies that individuals with the CF mutation are more likely to survive tuberculosis than those without the CF mutation.*

2. CF is caused by a single mutation. Explain how the environment affects whether this mutation is beneficial, harmful, or neutral for a person.

   *Normal individuals die when they contract tuberculosis and there is low-quality health care. Having one mutated gene, like CF carriers, allows a person to survive when there is tuberculosis independent of health care. So, this mutation is beneficial in these people. But individuals with two mutated genes, like people with the CF disease, die without good health care. So, in this case, the same mutation is harmful when there are two copies.*

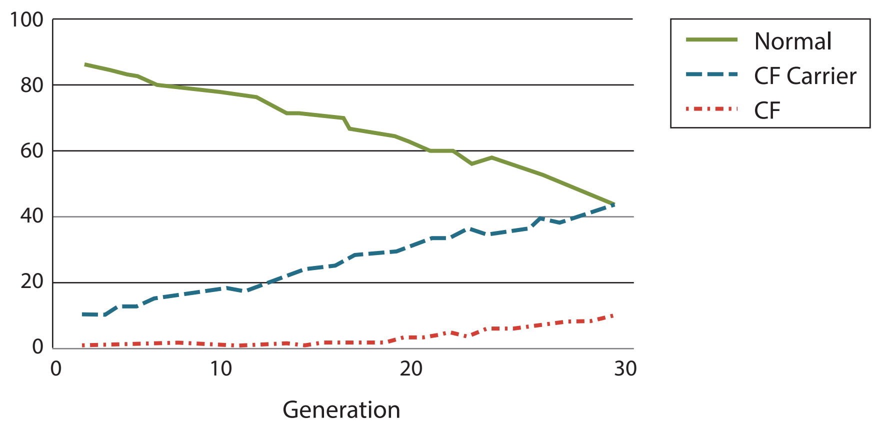
3. (AID ASSESSMENT, KEY SENSEMAKING) Explain how environmental changes affect the CF trait over time in your population. Use evidence, including mathematical representations, from your investigation to support your explanation.

   *Teacher's Note:* Students may use graphic data output from the simulation in their responses, as in the following Level 4 and Level 3 sample student responses. The images below are screen shots taken directly from the simulation so they are of lower resolution.

**SAMPLE LEVEL 4 STUDENT RESPONSE**

*As treatments for CF improved after the 1990s, more people with CF were surviving into adulthood and reproducing. These advances allowed CF patients to live longer but also helped the CF mutation persist in the population. The following graph from the simulation demonstrates this relationship. The data were generated with these variables: 40% incidence of TB, and post-1990 health care. As health care improved, more people with the CF mutation survived, and the number of people with the CF mutation increased. In addition, since TB still persisted in the population, it acted to further select for the CF mutation.*

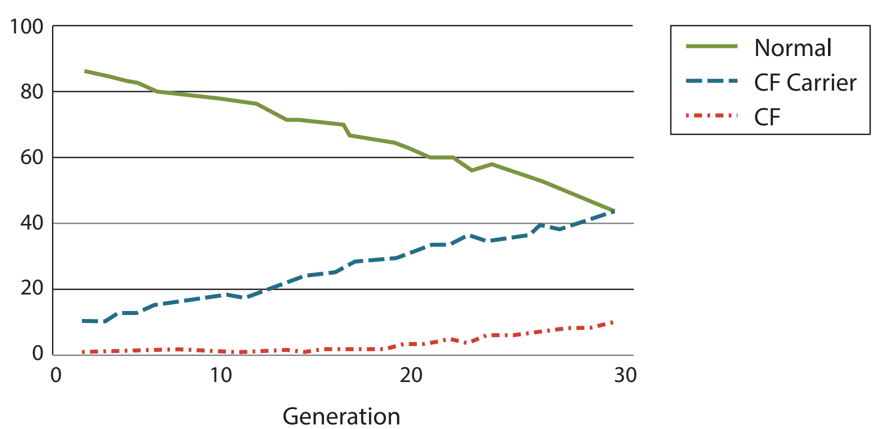
**RELATIVE PERCENTAGE OF GENOTYPES IN ADULTS OVER MULTIPLE GENERATIONS**




**SAMPLE LEVEL 3 STUDENT RESPONSE**

*As treatments for CF improved after the 1990s, more people with CF were surviving into adulthood and reproducing. These advances allowed CF patients to live longer but also helped the CF mutation persist in the population. The following graph from the simulation demonstrates this relationship. The data were generated with these variables: 40% incidence of TB, and post-1990 health care. As health care improved, more people with the CF mutation survived.*

**RELATIVE PERCENTAGE OF GENOTYPES IN ADULTS OVER MULTIPLE GENERATIONS**



**SAMPLE LEVEL 2 STUDENT RESPONSE**

*As treatments for CF improved after the 1990s, more people with CF were surviving into adulthood and reproducing. These advances allowed CF patients to live longer but also helped the CF mutation persist in the population.*

**SAMPLE LEVEL 1 STUDENT RESPONSE**

*CF is found in people after tens of thousands of years. It seems that more people are reproducing and passing on CF to their offspring.*

4. **Issue connection:** How might people be changing the environment, and therefore how are they affected by evolution?

   *If we change the environment so that people who have a trait are no longer at a disadvantage, that trait can remain in the population. If we change the environment so that a mutation gives the person with the mutation an advantage, that trait will become more common in the population.*

# ACTIVITY RESOURCES

## KEY SCIENTIFIC TERMS

carrier

evolution

gene

genetic variation

mutation

## BACKGROUND INFORMATION

**PROTECTIVE EFFECT OF CYSTIC FIBROSIS FROM OTHER DISEASES**

Being a CF gene mutation carrier or a CF patient seems to provide protective effects against some diseases. This protective effect is entirely hypothetical and requires more data to determine its exact nature. However, statistical data and experimental results do point to the idea that having at least one CF allele imparts protection from diseases such as TB, cholera, and dysentery. In each case, mutations in channel proteins that cause CF also protect individuals from symptoms. For example, in mouse studies involving cholera, CF carriers experience reduced symptoms, and CF patients appear to be immune to cholera toxin. It is possible that the CF mutation has persisted among humans for so long because of these protective effects. Essentially, the selective pressure of the secondary disease influences the genetic variation of a population.

## REFERENCES

Associated Press. (1994, October 7). Clue to why cystic fibrosis has survived. *New York Times*. https://www.nytimes.com/1994/10/07/us/clue-to-why-cystic-fibrosis-has-survived.html

Mackenzie, D. (2006, September 7). Cystic fibrosis gene protects against tuberculosis. *NewScientist* [Website]. https://www.newscientist.com/article/dn10013-cystic-fibrosis-gene-protects-against-tuberculosis/#:~:text=The%20gene%20that%20causes%20cystic,protects%20against%20tuberculosis%2C%20researchers%20say

Mirtajani, S. B., Farnia, P., Hassanzad, M., Ghanavi, J., Farnia, P., & Velayati, A. A. (2017, November). Geographical distribution of cystic fibrosis: The past 70 years of data analysis. *Biomedical and Biotechnology Research Journal*, *1*(2), 105–112. https://doi.org/10.4103/bbrj.bbrj_81_17

Mowat, A. (2017). Why does cystic fibrosis display the prevalence and distribution observed in human populations? *Current Pediatric Research*, *21*(1), 164–171. alliedacademies.org/articles/why-does-cystic-fibrosis-display-the-prevalence-and-distribution-observed-in-human-populations.html

Shannon, S. (2015, June 18). Has tuberculosis contributed to the global rates of cystic fibrosis? *Cystic Fibrosis News Today*. https://cysticfibrosisnewstoday.com/2015/06/18/tuberculosis-contributed-global-rates-cystic-fibrosis/

Withrock, I. C., Anderson, S. J., Jefferson, M. A., McCormack, G. R., Mlynarczyk, G. S. A., Nakama, A., Lange, J. K., Berg, C. A., Acharaya, S., Stock, M. L., Lind, M. S., Luna, K. C., Kondru, N. C., Manne, S., Patel, B. B., de la Rosa, B. M., Huang, K.-P., Sharma, S., Hu, H. Z., . . . Carlson, S. A. (2015, February). Genetic diseases conferring resistance to infectious diseases. *Genes & Diseases*, *2*(3), 247–254. https://doi.org/10.1016/j.gendis.2015.02.008

World Health Organization. (2002, June 19). *The molecular genetic epidemiology of cystic fibrosis*. https://www.cfww.org/docs/who/2002/who_hgn_cf_wg_04.02.pdf

# *Evolution 4:* Genetic Variation and Change

COMPUTER SIMULATION

2 CLASS SESSIONS

## TEACHING SUMMARY

### GET STARTED

Students read about the connection between being a cystic fibrosis carrier and experiencing less severe TB symptoms.

1. Let students know that in this activity they will investigate a particular genetic disease—cystic fibrosis, or CF—and ask students what they know about this disease.
2. Have students read the introduction and the guiding question for this activity.

### DO THE ACTIVITY

Students learn more about CF and TB and use a simulation to explore the hypothesized connection between them.

3. Support students as they complete Part A of the Procedure.
4. Support students as they run the simulation in Part B of the Procedure.

### BUILD UNDERSTANDING

Students summarize their findings from the simulation and make connections between genetic variation and evolution.

5. Facilitate a class discussion by asking students to summarize their findings from the simulation about the connection between TB and CF.
6. (AID ASSESSMENT, HS-LS4-3; KEY SENSEMAKING) Use Build Understanding item 3 to summatively assess Performance Expectation HS-LS4-3.
7. Use the Extension as an opportunity for advanced learning.

Name____________________________________________ Date____________

# STUDENT SHEET 4.1

## CYSTIC FIBROSIS AND TUBERCULOSIS SIMULATION

For Runs 1–3, keep the average health-care level for people with cystic fibrosis the same. For example, if you initially set the average health-care level to pre-1950, keep this variable at pre-1950 and choose a different chance of getting tuberculosis.

**Run 1 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| | | | | |

**Run 2 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| | | | | |

**Run 3 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| | | | | |

What differences do you notice between the graphs?

What questions do you have about the data?

Name________________________________________________ Date__________

## STUDENT SHEET 4.1 *(continued)*

### CYSTIC FIBROSIS AND TUBERCULOSIS SIMULATION

For Runs 4–6, keep the chance of getting tuberculosis the same. For example, if you initially set the tuberculosis rate to 80%, keep this variable at 80% and choose a different health-care variable.

**Run 4 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| | | | | |

**Run 5 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| | | | | |

**Run 6 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| | | | | |

What differences do you notice between the graphs?

What questions do you have about the data?

Name *Sample student response* Date

# STUDENT SHEET 4.1

## CYSTIC FIBROSIS AND TUBERCULOSIS SIMULATION

For Runs 1–3, keep the average health-care level for people with cystic fibrosis the same. For example, if you initially set the average health-care level to pre-1950, keep this variable at pre-1950 and choose a different chance of getting tuberculosis.

**Run 1 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| *0%* | *Pre-1950* | *93.1%* | *6.91%* | *0%* |

**Run 2 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| *40%* | *Pre-1950* | *85.1%* | *14.9%* | *0%* |

**Run 3 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| *80%* | *Pre-1950* | *62.5%* | *37.5%* | *0%* |

What differences do you notice between the graphs?

*As the chance of getting TB increased, so did the relative percentage of CF carriers after 30 generations. The relative percentage of normal genotype after 30 generations went down.*

What questions do you have about the data?

*Why does the relative percentage of CF carriers increase? Does the CF mutation have a protective effect against TB? Why are there no cases of CF prior to 1950?*

Name *Sample student response* Date

## STUDENT SHEET 4.1 *(continued)*

### CYSTIC FIBROSIS AND TUBERCULOSIS SIMULATION

For Runs 4–6, keep the chance of getting tuberculosis the same. For example, if you initially set the tuberculosis rate to 80%, keep this variable at 80% and choose a different health-care variable.

**Run 4 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| *80%* | *Pre-1950* | *62.5%* | *37.5%* | *0%* |

**Run 5 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| *80%* | *1950–1990* | *54.2%* | *43.8%* | *1.95%* |

**Run 6 Results**

| Chance of getting tuberculosis | Average health-care level for people with cystic fibrosis (CF) | Relative % of normal genotype after 30 generations | Relative % of CF carrier genotype after 30 generations | Relative % of CF genotype after 30 generations |
|---|---|---|---|---|
| *80%* | *Post-1990* | *3.75%* | *35.1%* | *61.1%* |

What differences do you notice between the graphs?

*With access to better health care, the relative percentage of CF carriers and those with CF after 30 generations increased, and the relative percentage of those with normal genotype decreased.*

What questions do you have about the data?

*How can access to better health care cause a disease to become more prevalent in a population? Why doesn't the chance of getting TB have such a strong effect any more?*

## ITEM-SPECIFIC SCORING GUIDE – PE-HS-LS4-3

### ANALYZING AND INTERPRETING DATA (AID)

<table>
<tr><th>Level</th><th>Description</th><th>Specific Response</th></tr>
<tr><td>Level 4<br>Complete and correct</td><td>The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data, and interprets them completely and correctly to identify and describe relationships.<br>When appropriate, the student:<br>• makes distinctions between causation and correlation.<br>• states how biases and errors may affect interpretation of the data.</td><td>The student analyzes the data from the simulation to correctly identify and describe patterns in the data, and provides complete and correct causal interpretations of these patterns, based on natural selection.<br>The student's response includes all of the following key points:<br>• As TB increases, so does the frequency of the CF mutation, leading to an increase in the number of CF carriers and patients.<br>• This is because the CF mutation in carriers is protective against the symptoms of TB, so more people with the CF mutation survive to adulthood and reproduce.<br>• As health-care options increase, the number of CF carriers and patients increases.<br>• This is because advances in medicine and technology help CF patients live longer and reproduce, allowing the mutation to persist at higher levels.</td></tr>
<tr><td>Level 3<br>Almost there</td><td>The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships.</td><td>The student analyzes the data from the simulation to correctly identify and describe patterns in the data, BUT their causal interpretations of these patterns are incomplete or contain minor errors.<br>The student's response includes most of the following key points with some minor errors:<br>• As TB increases, so does the frequency of the CF mutation, leading to an increase in the number of CF carriers and patients.<br>• This is because the CF mutation in carriers is protective against the symptoms of TB, so more people with the CF mutation survive to adulthood and reproduce.<br>• As health-care options increase, the number of CF carriers and patients increases.<br>• This is because advances in medicine and technology help CF patients live longer and reproduce, allowing the mutation to persist at higher levels.</td></tr>
</table>

### ANALYZING AND INTERPRETING DATA (AID)

| Level | Description | Specific Response |
|---|---|---|
| ***Level 2 On the way*** | The student analyzes the data with appropriate tools, techniques, and reasoning. The student identifies and describes, BUT does not interpret, patterns and relationships. | The student analyzes the data from the simulation to correctly identify and describe patterns in the data, BUT the student provides no causal explanations for these patterns. |
| ***Level 1 Getting started*** | The student attempts to analyze the data BUT does not use appropriate tools, techniques and/or reasoning to identify and describe patterns and relationships. | The student attempts to analyze the data from the simulation but does not describe any patterns. |
| ***Level 0*** | The student's analysis is missing, illegible, or irrelevant to the goal of the investigation. | |
| ***X*** | The student had no opportunity to respond. | |

# ANALYZING AND INTERPRETING DATA (AID)

## When to use this Scoring Guide:

This Scoring Guide is used when students analyze and interpret data that they have collected or that has been provided to them.

## What to look for:

- Response describes patterns and trends in data.
- Response interprets patterns and trends, using relevant crosscutting concepts and disciplinary core ideas, to describe possible causal, relationships.

| LEVEL | DESCRIPTION |
|---|---|
| Level 4<br>Complete and correct | The student analyzes the data with appropriate tools, techniques, and reasoning.<br>The student identifies and describes patterns in the data, and interprets them completely and correctly to identify and describe relationships.<br>When appropriate, the student<br>• makes distinctions between causation and correlation.<br>• states how biases and errors may affect interpretation of the data. |
| Level 3<br>Almost there | The student analyzes the data with appropriate tools, techniques, and reasoning.<br>The student identifies and describes patterns in the data BUT incorrectly and/or incompletely interprets them to identify and describe relationships. |
| Level 2<br>On the way | The student analyzes the data with appropriate tools, techniques, and reasoning.<br>The student identifies and describes, BUT does not interpret, patterns and relationships. |
| Level 1<br>Getting started | The student attempts to analyze the data BUT does not use appropriate tools, techniques and/or reasoning to identify and describe patterns and relationships. |
| Level 0 | The student's analysis is missing, illegible, or irrelevant to the goal of the investigation. |
| x | The student had no opportunity to respond. |

# NGSS OVERVIEW

## EVOLUTION: MANAGING CHANGE

**Performance Expectations**

**HS-LS2-7:** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

**HS-LS2-8:** Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

**HS-LS4-1:** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

**HS-LS4-2:** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

**HS-LS4-3:** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

**HS-LS4-4:** Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

**HS-LS 4-5:** Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

**HS-LS4-6:** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

**HS-ETS1-3:** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

**HS-ETS1-4:** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

| Activity | NGSS Integration | Disciplinary Core Ideas | Science and Engineering Practices | Crosscutting Concepts | Common Core State Standards |
|---|---|---|---|---|---|
| 1 | **Changing Environments**<br>Students analyze and interpret data on factors affecting the evolution of body size in marine iguanas. They engage in arguments from evidence for how a changing environment will affect marine iguana body size in the future. Students construct explanations about the evolution of body size in marine iguanas based on natural selection, adaptation, and social behavior.<br>*Working toward* LS4-2<br>*Working toward* LS4-3<br>*Working toward* LS4-4<br>*Working toward* LS2-8 | LS4.B<br>LS4.C<br>LS2.D | Analyzing and Interpreting Data<br>Constructing Explanations and Designing Solutions<br>Connections to Nature of Science: Scientific Knowledge is Open to Revision in Light of New Evidence | Cause and Effect<br>Patterns<br>Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems | Mathematics:<br>MP.2<br>MP.4<br>ELA/Literacy:<br>RST.11-12.7<br>RST.11-12.8 |

| Activity | NGSS Integration | Disciplinary Core Ideas | Science and Engineering Practices | Crosscutting Concepts | Common Core State Standards |
|---|---|---|---|---|---|
| 2 | **Increasing Temperatures**<br>Students investigate the effects of temperature on competition for resources among aquatic plants. Students analyze and interpret data and then use the data to explain that some individuals are better adapted to a particular environment than others are, leading to a proliferation of those adaptations in the population.<br>*Working toward* LS4-2<br>*Working toward* LS4-3<br>*Working toward* LS4-4 | LS4.B<br>LS4.C | Analyzing and Interpreting Data<br>Constructing Explanations and Designing Solutions<br>Connections to Nature of Science: Scientific Knowledge is Open to Revision in Light of New Evidence | Cause and Effect<br>Patterns | Mathematics:<br>MP.2<br>ELA/Literacy:<br>RST-11.12.1<br>WHST.9-12.2 |
| 3 | **Social Behavior**<br>Students analyze and interpret data on how other factors, especially biotic factors, lead to the proliferation of other kinds of traits, including social behavior. Students engage in argument from evidence on how alarm calls in prairie dogs are an example of one such trait. Students are assessed on Performance Expectation HS-LS2-8.<br>*Assessing* LS2-8<br>*Working toward* LS4-2<br>*Working toward* LS4-3<br>*Working toward* LS4-4 | LS2.D<br>LS4.B<br>LS4.C | Engaging in Argument from Evidence<br>Analyzing and Interpreting Data<br>Connections to Nature of Science: Scientific Knowledge is Open to Revision in Light of New Evidence | Cause and Effect<br>Patterns | Mathematics:<br>MP.2<br>MP.4<br>ELA/Literacy:<br>RST-11.12.7<br>RST.11-12.8 |
| 4 | **Genetic Variation and Change**<br>Students use a computer simulation to analyze and interpret data that demonstrates the theorized connection between the protective effects of being a carrier of the cystic fibrosis mutation and reduced symptoms (and increased survival rate) when contracting TB. Students look for patterns across the data and apply statistical tests to analyze their results. Students are assessed on Performance Expectation HS-LS4-3.<br>*Assessing* LS4-3<br>*Working toward* LS4-2<br>*Working toward* LS4-4 | LS4.B<br>LS4.C | Analyzing and Interpreting Data<br>Using Mathematics and Computational Thinking | Patterns | Mathematics:<br>MP.2<br>MP.4<br>ELA/Literacy:<br>RST-11.12.1<br>WHST.9-12.2 |

| Activity | NGSS Integration | Disciplinary Core Ideas | Science and Engineering Practices | Crosscutting Concepts | Common Core State Standards |
|---|---|---|---|---|---|
| 5 | **Is It Evolution?**<br>To understand how natural events and human actions affect the evolution of populations over time, students analyze scenarios that include examples of evolutionary and non-evolutionary events. Students draw on disciplinary core ideas about how changes in the physical environment contribute to evolutionary changes, and examine the cause-and-effect relationship between resource use by humans and the impact on populations of other organisms. Students are assessed on Performance Expectation HS-LS4-2.<br>*Assessing* LS4-2<br>*Working toward* LS4-4<br>*Applying* LS4-3 | LS4.B<br>LS4.C | Constructing Explanations and Designing Solutions | Cause and Effect<br>Patterns | ELA/Literacy:<br>RST-11.12.1<br>WHST.9-12.2<br>SL.11-12.4 |
| 6 | **Increasing Timescales**<br>Students examine what happens to a population when natural selection occurs over a longer period of time by obtaining and evaluating information from videos about two species: a species of salamander, which illustrates speciation in progress, and anoles in the Caribbean, which illustrates speciation completed. Students are assessed on Performance Expectation HS-LS4-4.<br>*Assessing* LS4-4<br>*Applying* LS4-2<br>*Applying* LS4-3<br>*Working toward* LS4-1<br>*Working toward* LS4-5 | LS4. A<br>LS4.B<br>LS4.C | Constructing Explanations and Designing Solutions | Cause and Effect<br>Patterns<br>Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems | ELA/Literacy:<br>RST-11.12.1<br>RST-11.12.7<br>WHST.9-12.9 |
| 7 | **Extinction**<br>Students investigate changes in life-forms over time, including the evolution of new forms (speciation) and the disappearance of previous forms (extinction). They look for patterns and consider the possible causes of major extinction events due to massive changes in the environment.<br>*Working toward* LS4-5<br>*Working toward* LS4-1 | LS4.C | Constructing Explanations and Designing Solutions<br>Analyzing and Interpreting Data | Patterns<br>Cause and Effect<br>Scale, Proportion, and Quantity | Mathematics:<br>MP.2<br>ELA/Literacy:<br>RST.11-12.8<br>WHST.9-12.9 |

| Activity | NGSS Integration | Disciplinary Core Ideas | Science and Engineering Practices | Crosscutting Concepts | Common Core State Standards |
|---|---|---|---|---|---|
| 8 | **The Anthropocene**<br>Students analyze and interpret data to consider the role of human activity in the loss of biodiversity due to environmental changes. They engage in argument about whether humans are causing another major extinction event. Students are assessed on Performance Expectation HS-LS4-5.<br>*Assessing* LS4-5<br>*Working toward* LS4-1 | LS4.C<br>LS4.D | Engaging in Argument from Evidence<br>Analyzing and Interpreting Data | Patterns<br>Cause and Effect<br>Scale, Proportion, and Quantity | Mathematics:<br>MP.2<br>ELA/Literacy:<br>RST.11-12.8<br>WHST.9-12.9 |
| 9 | **Evidence and the Theory of Evolution**<br>Students obtain information from texts and graphics about several types of evidence to support the theory of evolution. Students synthesize this information, and communicate their understanding of evolution as the unifying principle in life science.<br>*Working toward* LS4-1<br>*Applying* LS4-5 | LS4.A | Obtaining, Evaluating, and Communicating Information | Patterns | ELA/Literacy:<br>RST.11-12.1<br>WHST.9-12.2<br>SL.11-12.4 |
| 10 | **Applying Evolutionary Thinking**<br>Students evaluate the evidence and trade-offs of different conservation choices for a fictional island. Students apply their understanding of the types of evidence used to support the theory of evolution to a practical problem: the conservation of biodiversity and sustainability. Students prepare a report outlining their decision. Students are assessed on Performance Expectation HS-LS4-1.<br>*Assessing* LS4-1<br>*Applying* LS4-5<br>*Working toward* LS2-7 | LS4.A<br>LS2.C | Obtaining, Evaluating, and Communicating Information<br>Constructing Explanations and Designing Solutions | Patterns<br>Stability and Change | ELA/Literacy:<br>RST.11-12.1<br>WHST.9-12.2<br>SL.11-12.4 |
| 11 | **The Evolution of Resistance**<br>To better understand how natural selection affects a population, students construct explanations about a medical case study on antibiotic resistance. Students conduct an experiment that models antibiotic resistance, explain their results, and connect the experiment to natural selection.<br>*Applying* LS4-4 | LS4.C | Constructing Explanations and Designing Solutions<br>Developing and Using Models | Cause and Effect<br>Connections to Nature: Scientific Knowledge Assumes an Order and Consistency in Natural Systems | ELA/Literacy:<br>RST-11.12.1<br>WHST.9-12.2<br>WHST.9-12.9 |

| Activity | NGSS Integration | Disciplinary Core Ideas | Science and Engineering Practices | Crosscutting Concepts | Common Core State Standards |
|---|---|---|---|---|---|
| 12 | **Emerging Diseases**<br>Students examine patterns of disease outbreaks, epidemics, and pandemics. They obtain information about the possible causes for the growing rate of emerging diseases, and they apply evolutionary thinking as they envision how to predict and prevent future outbreaks.<br>*Applying* LS4-2<br>*Applying* LS4-4<br>*Working toward* LS4-6 | LS4.D<br>LS4.B<br>LS4.C | Obtaining, Evaluating, and Communicating Information | Cause and Effect<br>Patterns | Mathematics:<br>MP.2<br>ELA/Literacy:<br>RST-11.12.7 |
| 13 | **Shrinking Salmon**<br>Students develop a system model to make sense of the evolutionary effect of human impact on salmon body size. They explore this complex problem and use their model to ask questions and make connections to the three pillars of sustainability.<br>*Working toward* LS4-6<br>*Working toward* ETS1-3<br>*Working toward* ETS1-4<br>*Applying* LS2-7 | LS4.D<br>LS4.B<br>LS4.C<br>ETS1.B<br>LS2.C | Constructing Explanations and Designing Solutions | Systems and System Models<br>Cause and Effect<br>Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World<br>Stability and Change | Mathematics:<br>MP.2<br>ELA/Literacy:<br>RST.11-12.8 |
| 14 | **Mitigating Change**<br>Students engage in a computer simulation to assess the evolutionary impact of human activity on Chinook body size. Students develop proposed solutions to this problem and test the impact of these solutions on both biodiversity and human systems. Students consider numerous criteria and constraints as they evaluate each solution. Students are assessed on Performance Expectations HS-LS4-6, HS-ETS1-3, HS-ETS1-4, and HS-LS2-7.<br>*Assessing* LS4-6<br>*Assessing* ETS1-3<br>*Assessing* ETS1-4<br>*Assessing* LS2-7 | LS4.C<br>LS4.D<br>ETS1.B<br>LS2.C | Using Mathematics and Computational Thinking<br>Constructing Explanations and Designing Solutions | Cause and Effect<br>Systems and System Models<br>Connections to Engineering, Technology, and Applications of Science: Influence of Science, Engineering, and Technology on Society and the Natural World<br>Stability and Change | Mathematics:<br>MP.2<br>MP.4<br>HSN.QA.1<br>ELA/Literacy:<br>WHST.9-12.7 |

| Activity | NGSS Integration | Disciplinary Core Ideas | Science and Engineering Practices | Crosscutting Concepts | Common Core State Standards |
|---|---|---|---|---|---|
| 15 | **Human Impact on Evolution**<br>To make connections between human activity and evolution, students construct a presentation about a focal issue from this unit (e.g., emerging diseases, pollution, antibiotic resistance). In their presentations, students outline their issue, explain its connection to evolution, and suggest strategies to prevent or reduce negative outcomes of this issue on biodiversity and sustainability.<br>*Assessing* LS2-7 | LS2.C<br>LS4.D<br>ETS1.B | Obtaining, Evaluating, and Communicating Information | Stability and Change | ELA/Literacy:<br>RST.9-10.8<br>RST.11-12.7<br>RST.11-12.8<br>WHST.9-12.7 |

# STORYLINE AND SENSEMAKING

## EVOLUTION: MANAGING CHANGE

**Unit issue:** Human activity can have evolutionary consequences for both biodiversity and ourselves.

**Overarching question:** How do human activities affect the evolution of other species, and what are the consequences for both biodiversity and for ourselves?

Students are introduced to the issue for this unit by considering infectious diseases. Students begin by considering tuberculosis, a disease that has a long shared evolutionary history with humans. They learn that the rate at which new diseases are evolving is increasing. Students' initial ideas and questions about the emergence of infectious diseases are elicited. Students also begin to consider how human activity may be affecting this evolutionary process and thereby affecting the three pillars of sustainability.

***Learning Sequence 1***

**Investigative phenomenon:** Salamanders along the Pacific Coast of North America show tremendous variability in color, despite all being members of the same species.

Students are oriented to the first learning sequence through the first investigative phenomenon: *Salamanders along the Pacific Coast of North America show tremendous variability in color, despite all being members of the same species.* Students periodically revisit this scenario in the first learning sequence. By Activity 6: Increasing Timescales, students are able to explain how and why this variability exists.

**Suggested driving question:** What is happening to cause variability in color among salamanders?

**Focal Performance Expectations:** LS2-8, LS4-1, LS4-2, LS4-3, LS4-4, LS4-5

| Storyline | Sensemaking Progression |
|---|---|
| **Activity 1: Changing Environments**<br><br>**Guiding question:** How do populations respond over time to a changing environment?<br><br>Students explore evolution by natural selection in marine iguanas in the Galápagos Islands—how the iguanas' environment, natural history, and social structure work together to favor the evolution of large body size in males to defend territories and increase access to mates, and of large body size in females to be able to produce more eggs (offspring). Students also learn that body size is stabilized by selection favoring more moderate body size during times of food scarcity and environmental stress, when the largest individuals cannot maintain their body size. | • Students understand from middle school how evolution by natural selection occurs in simple scenarios, but they might not understand how competing selection pressures can affect traits in a wild population.<br><br>• Key sensemaking: Students explore the selection pressures affecting body size in marine iguanas during times of food abundance vs. food scarcity. This key sensemaking step takes place in Build Understanding item 1.<br><br>• Going forward: In the next activity, students consider how a changing climate may have consequences for other organisms—specifically, aquatic plants—and the implications for sustainability. |

| Storyline | Sensemaking Progression |
|---|---|
| **Activity 2: Increasing Temperatures**<br>**Guiding question:** How might increasing temperatures affect populations of aquatic plants over time?<br>To understand how temperature affects different populations, students investigate the rate of photosynthesis in aquatic plants at different temperatures. In this laboratory, students compare two plant species that grow near the surface of ponds and near the bottom of ponds, respectively. This is an opportunity for students to investigate how changes in temperature—like those seen with climate change—can affect how plants make food, which can then lead to changes in populations. Students make connections between their observations and bigger questions about how changes in temperature will affect sustainability. | • Students have an understanding of how global warming affects photosynthesis in plants from Cells: Improving Global Health, but they may not have considered how plants may vary in their responses and therefore how natural selection may affect plant traits over time.<br>• Students measure the rate of photosynthesis in two aquatic plant species in different temperature conditions in order to develop an understanding of how changes in temperature can affect populations differently.<br>• Key sensemaking: Students explain how variations among individuals in a species might lead to changes in the population over time, with some traits becoming more common. This key sensemaking takes place in Build Understanding item 2.<br>• Going forward: In the next activity, students explore how another kind of trait—social behavior—can evolve in response to environmental conditions. |
| **Activity 3: Social Behavior**<br>**Guiding question:** What other traits can evolve in response to environmental conditions?<br>Students add to their understanding of how changing environments can lead to changes in structural traits (e.g., body size) and physiological traits (e.g., the rate of photosynthesis) as they consider another trait that evolves in response to environmental factors: social behavior. Students explore the social behavior trait of alarm-calling in two group-living mammal species: black-tailed prairie dogs and meerkats. | • Students have now explored the evolution of structural and metabolic traits, but they may not fully appreciate that behavioral traits can evolve by natural selection.<br>• Key sensemaking: Students explore the evolution of alarm calls in two social mammal species and construct an argument for how this trait evolved in both species. This key sensemaking step takes place in Build Understanding Item 1.<br>• Going forward: In the next activity, students add the role of genetics to their developing understanding of evolution by natural selection, focusing on the theorized relationship between cystic fibrosis and TB. |
| **Activity 4: Genetic Variation and Change**<br>**Guiding question:** What is the role of genetic variation in evolution?<br>Students explore how changes in a population's appearance occur at the level of genes and are passed from one generation to the next. Using a computer simulation, students examine the factors that contribute to genetic variation in a population by focusing on the theorized relationship between cystic fibrosis and TB. | • Students should understand that genetic variations, particularly genetic mutations, provide the basis for natural selection that can lead to heritable variation and evolution.<br>• Students may have little understanding of how a potentially lethal genetic mutation can provide resistance to an infectious disease.<br>• Key sensemaking: Students explore how a highly infectious disease (TB) helped to maintain a potentially lethal genetic mutation (cystic fibrosis) in a population over time. This key sensemaking step takes place in Build Understanding item 3.<br>• Students make connections between a population's level of wealth and the genetic variation within that population.<br>• Going forward: In the next activity, students draw on their growing understanding to explain what is required for evolution by natural selection to occur. |

| Storyline | Sensemaking Progression |
|---|---|
| **Activity 5: Is It Evolution?**<br>**Guiding question:** What is required for evolution by natural selection to occur?<br>Drawing on their growing understanding of how populations change over time due to changing environments, students revisit some familiar and novel scenarios and argue about which changes are evolutionary in nature (changes to a population that can be passed from one generation to the next) and which are ecological in nature (changes that occur within a population and are not passed from one generation to the next). Students determine what is required for evolution by natural selection to occur. | • Students may have little understanding of the difference between actual evolution vs. ecological changes.<br>• To explain the difference between evolutionary changes and ecological changes, students analyze several examples of changes among species.<br>• Key sensemaking: Students apply their understanding of evolutionary changes to identify and explain why a scenario involving environmental change is or is not an example of evolution by natural selection. This key sensemaking takes place in Procedure Step 5 and in Build Understanding item 1.<br>• Going forward: In the next activity, students extend their understanding of evolutionary changes by considering adaptations by natural selection that happen over long periods of time. |
| **Activity 6: Increasing Timescales**<br>**Guiding question:** What happens when evolution happens over longer periods of time?<br>Students are presented with a snapshot of speciation in progress as they explore what happens as salamanders migrate and encounter distinct environmental conditions. Students then consider a second scenario, that of anoles in the Caribbean, which allows them to see how evolution by natural selection acting over longer periods of time has already resulted in speciation. | • So far, students have explored natural selection operating over relatively short periods of time.<br>• Key sensemaking: Students explain how natural selection acting over long periods of time and over many generations can lead to speciation. This key sensemaking opportunity is in Build Understanding item 1.<br>• Going forward: In the next activity, students explore evolution over deep time and learn how scientists collect and evaluate evidence about evolutionary changes that occurred millions of years ago. |

***Learning Sequence 2***

**Investigative phenomenon:** Life on Earth is constantly changing—sometimes over short spans of time, and sometimes over long spans of time.

In the first learning sequence, students investigated relatively recent cases of evolution by natural selection and speciation. In this learning sequence, students examine evolution—both speciation and extinction—over a much longer timescale. They begin by examining a graph showing that the rate of extinction over the last 600 million years has not been constant. They learn that the rate of extinction is sometimes much greater than the background rate of extinction.

**Suggested driving question:** Why are some species more likely to evolve or go extinct than others, and how might humans be affecting these processes?

**Focal Performance Expectations:** LS2-7, LS4-1, LS4-5

| Storyline | Sensemaking Progression |
|---|---|
| **Activity 7: Extinction**<br>**Guiding question:** What factors cause species to go extinct?<br>Students begin to explore evolutionary processes over deep time, examining patterns of life-forms beginning 542 million years ago and up to the recent past. Students look closely at patterns of extinction and come to understand that extinction is a natural part of the evolutionary process. Students learn about the five mass extinction events and evaluate explanations for what caused each event. Students consider factors favoring the emergence of new life-forms. | • Until this point in the unit, students have focused primarily on evolution by natural selection over relatively short periods of time.<br>• In this activity, students expand their horizons by exploring patterns of evolution, including both extinction and speciation, over deep time until recently.<br>• Key sensemaking: Students explain what factors caused the extinction of species and entire life-forms in the past, and consider how confident they are of these explanations. This key sensemaking step is in Build Understanding item 4.<br>• Students consider factors leading to the emergence of new life-forms over time.<br>• Going forward: In the next activity, students consider the role of humans in accelerating the rate of extinction, and they evaluate the evidence for a sixth mass extinction. |
| **Activity 8: The Anthropocene**<br>**Guiding question:** What is the role of human activity in the extinction process?<br>Students consider the role of humans in accelerating the rate of extinctions, thereby also affecting evolutionary processes. Students evaluate the evidence for a sixth mass extinction and think about which human activities are contributing to the loss of biodiversity. They consider how humans might be affected by these extinctions through the lens of sustainability. | • Students may know about extinctions from hundreds of millions of years ago until the recent past, but they may have never considered how humans may be affecting the rate of extinction.<br>• Students analyze data about extinctions in the age of humans, including rates and causes of extinction.<br>• Key sensemaking: Students argue about whether the current rate of extinction is leading to a sixth mass extinction caused by human activity. This key sensemaking takes place in Build Understanding item 3.<br>• Students consider whether humans may also be affecting the rate of speciation.<br>• Going forward: In the next activity, students explore additional types of evidence that support the theory of evolution. |

| Storyline | Sensemaking Progression |
|---|---|
| **Activity 9: Evidence and the Theory of Evolution**<br>**Guiding question:** What other kinds of evidence support the theory of evolution?<br>Students explore additional types of evidence on the theory of evolution, including embryology, comparative anatomy, and genetics, and reflect on the types of evidence presented in the first learning sequence. Students draw on what they've learned so far to create an infographic about two kinds of evidence that support the theory of evolution. | • So far in the unit, students have explored evidence for evolution based on natural history observations and experimentation and on the fossil record, but they may be less familiar with other types of evidence.<br>• Students obtain information about some additional types of evidence about evolution.<br>• Key sensemaking: Students create an infographic communicating how two types of evidence support the theory of evolution. This key sensemaking takes place in Build Understanding item 2.<br>• Students identify the strengths and limitations of different types of evidence and how the evidence is used collectively to support the theory of evolution.<br>• Going forward: In the next activity, students explore a real-world application of evolutionary evidence as they make decisions about conservation. |
| **Activity 10: Applying Evolutionary Thinking**<br>**Guiding question:** How do scientists use evidence of evolution to make decisions about conservation?<br>Students explore how evolutionary evidence is used in a practical way by analyzing and interpreting data from comparative anatomy and genetics and drawing on that data to make a recommendation about which area of a fictional island should be conserved. Students weigh the data along with additional information about the different areas of the island, and they consider the trade-offs of their decision. | • Students may not be familiar with the application of evolutionary thinking to a practical problem, such as conservation.<br>• Key sensemaking: Students analyze and interpret data that demonstrates the evolutionary relationships among primates on an island. This key sensemaking takes place in Procedure Step 6.<br>• Students consider the data they analyzed, other factors about the island, and the trade-offs of each decision as they make their recommendation for conservation.<br>• Going forward: In the next activity, students explore how human actions can cause evolutionary changes as they investigate a medical case of antibiotic-resistant TB. |

*Learning Sequence 3*

**Investigative phenomenon:** Chinook salmon body size has been declining over time.

In this learning sequence, students explicitly explore the evolutionary impact that humans can have on other species. Students examine graphs showing the average body size in Chinook salmon over time and the mean age of Chinook salmon in freshwater and saltwater environments. Students observe that the salmon's mean body size has declined sharply from 1980 to 2010, that the mean age of salmon in saltwater environments has declined sharply over the same period, and that the mean age of salmon in freshwater environments has fluctuated but generally has declined somewhat. Students share their initial ideas about what might be causing these declines. In later activities, students make sense of how this and other examples illustrate how human activities can lead to changes in other species' natural selection: By altering the environment, humans can affect the evolution of other species. Students also figure out that sometimes these evolutionary changes in other species can cause problems for people.

**Suggested driving question:** What is causing the decline in Chinook salmon body size, and does human activity play a role?

**Focal Performance Expectations:** LS4-2, LS4-4, LS4-6, ETS1-3, ETS1-4, LS2-7

| Storyline | Sensemaking Progression |
|---|---|
| **Activity 11: The Evolution of Resistance**<br>**Guiding question:** Why are microbes more difficult to eradicate now than in the past?<br>Students explore how human actions can cause evolutionary changes as they investigate a medical case of antibiotic-resistant TB. Students conduct research on how antibiotic use has changed over time and how bacteria develop resistance. They explain the effects of these evolutionary changes in the context of sustainability. In the role of laboratory technicians, students conduct a procedure to determine if a patient has antibiotic-resistant TB. | • Students were introduced to the concept of antibiotic resistance in Activity 5: Is It Evolution?, but they may not know how it develops at the level of bacterial genes.<br>• Students conduct Internet research to explain how antibiotic use has changed over time, how antibiotic resistance develops, and why it is a problem.<br>• Key sensemaking: Students draw on the research they conducted and what they've learned in this activity to determine the best explanation for why a patient's TB treatment is no longer working. This key sensemaking takes place in Procedure Steps 8 and 23.<br>• Students explain how antibiotic resistance can negatively impact sustainability.<br>• Going forward: In the next activity, students explore the increasing rate of emerging diseases through an evolutionary lens. |
| **Activity 12: Emerging Diseases**<br>**Guiding question:** Why are new diseases evolving at an increasing rate?<br>Students explore the increasing rate of emerging diseases through an evolutionary lens, which helps them more deeply understand how human actions can cause evolutionary changes and how these changes, in turn, affect people. Students gain an understanding of how evolutionary thinking helps explain, predict, and potentially prevent future pandemics. | • Students now understand that existing human pathogens are evolving in response to our actions, but they may not realize that new human pathogens are evolving at an increasing rate.<br>• Students use Stop to Think questions to make sense of information about the increasing rate of emerging diseases.<br>• Key sensemaking: Students explain how evolutionary thinking helps us understand why the rate of emerging diseases is increasing and how future pandemics might be prevented. This key sensemaking step takes place in Build Understanding item 1.<br>• Going forward: In the next activity, students explore the effects of human activity on evolution in a familiar context: fisheries. |

| Storyline | Sensemaking Progression |
|---|---|
| **Activity 13: Shrinking Salmon**<br>**Guiding question:** How is human activity affecting the evolution salmon and therefore the three pillars of sustainability?<br>Students consider the effects of human activity on evolution in another context: fisheries. Students learn that the body size of Chinook salmon is declining, due to natural selection favoring individuals that return to their streams earlier (i.e., younger and smaller). Students consider several human activities that might be driving this change. They develop a system model to help them analyze the problem, which they come to realize is especially complex because of the salmon's anadromous life cycle. Students consider the impact of this problem on the three pillars of sustainability and what might be done to address it. | • Students are familiar with the role of Chinook salmon in both ocean and stream ecosystems from the Ecology unit.<br>• Students learn that salmon body size is declining due to changing evolutionary selection pressures imposed by human activity, which has an adverse impact on both biodiversity and human systems.<br>• Key sensemaking: Students create a system model to make sense of this problem and to consider potential solutions. This key sensemaking takes place in Procedure Steps 3 and 4.<br>• Going forward: In the next activity, students engage in a computer simulation of four different factors that may affect salmon size. |
| **Activity 14: Mitigating Change**<br>**Guiding question:** How can we design a solution to the "shrinking salmon" problem?<br>Students continue to explore the "shrinking salmon" problem by using a computer simulation to examine how changing environmental variables affect body size in a hypothetical population of Chinook. Students identify the primary drivers that select for smaller body size, all of which are due to human impact on the ocean and stream environments. Students develop a possible solution for this complex problem, and consider the feasibility and trade-offs of their solution in terms of the three pillars of sustainability. | • Students have developed a system model to delineate the "shrinking salmon" problem, but they have only briefly considered possible solutions.<br>• Students engage in a computer simulation to examine the evolutionary effect of environmental factors<br>• Key sensemaking: Students draw on the simulation to develop and refine a solution to this complex problem, based on a set of criteria and constraints. This key sensemaking opportunity takes place in Procedure Step 17.<br>• Going forward: In the final activity of the unit, students create a presentation explaining how a particular human activity affects evolutionary change, the negative impact of this change on biodiversity and sustainability, and what strategies might mitigate or prevent this impact. |
| **Activity 15: Human Impact on Evolution**<br>**Guiding question:** How can evolutionary biology be used to promote sustainability and biodiversity?<br>As the culminating activity for the unit, students choose one human activity they have learned about and create a presentation explaining how this activity affects evolutionary change, the impact of these changes on biodiversity and sustainability, and what strategies might mitigate or prevent this negative impact. | • Students may not know all the criteria for identifying a reliable Internet resource.<br>• Key sensemaking: Students conduct research and construct a presentation that explains their focal topic in terms of its impact on evolution and how evolutionary changes affect biodiversity and sustainability. This key sensemaking step takes place in Procedure Step 2.<br>• Students offer strategies to eliminate or reduce the negative impact of consequences resulting from their focal topic.<br>• Students conclude the unit by reflecting on how their thinking about evolution has changed. |

**Additional SEPUP instructional materials include:**

- SEPUP Modules: Grades 6–12
- *Science and Sustainability*: Course for Grades 9–12
- *Issues and Science:* 17 units covering grades 6–8

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