Discover how diverse life forms evolve and new species emerge. Topics include:

- Natural selection as a driver of changes in populations—not individuals—over time.
- Factors that affect reproductive success (traits, the number of offspring, and resource availability).
- How natural selection relates to speciation.
- Effect of genetic drift, gene flow, mutation, and recombination on population genetics.

<table>
<thead>
<tr>
<th>TEKS standards</th>
<th>Example phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCIENCE.BIO.10.A</td>
<td>How do various evolutionary mechanisms influence the development of new traits, such as lactose tolerance in human populations? Following the domestication of dairy animals around 10,000 years ago, new mutations formed in the lactase (LCT) gene that resulted in a new phenotype, the ability to digest lactose into adulthood (which typically decreases with age). This lactase persistence phenotype, particularly prevalent in populations with a history of dairy farming, illustrates natural selection, as individuals with lactose tolerance had a nutritional advantage, resulting in greater survival and reproductive success. The spread of lactose tolerance illustrates how gene flow and human migration dynamically intertwine genetics, culture, and evolution. Check out “The Making of the Fittest? Got Lactase?” from HHMI for related videos.</td>
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<tr>
<td>SCIENCE.BIO.10.B</td>
<td>Analyze and evaluate how the elements of natural selection, including inherited variation, the potential of a population to produce more offspring than can survive, and a finite supply of environmental resources, result in differential reproductive success.</td>
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<tr>
<td>SCIENCE.BIO.10.C</td>
<td>Analyze and evaluate how natural selection may lead to speciation.</td>
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<tr>
<td>SCIENCE.BIO.10.D</td>
<td>Analyze evolutionary This content is brought to you with support from ExxonMobil Foundation</td>
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How do evolutionary mechanisms contribute to the emergence and spread of antibiotic-resistant bacteria?

Many different types of bacteria can cause illnesses and infections in humans, and many times, we can use medicine (such as antibiotics) to easily treat these ailments. However, there has been a rise in antibiotic-resistant bacteria (called "superbugs"). Through mutations and genetic exchanges, bacteria evolved into "superbugs" resistant to multiple antibiotics, highlighting the need for careful drug use and innovative treatments, showing evolution's direct effect on health. Examples of “superbugs” your class can explore: MRSA, MDR-TB, and CRE. *This phenomenon pairs well with PBS Frontline: Hunting the Nightmare Bacteria.

Prompts for students to consider:
- How does antibiotic resistance in bacteria show natural selection in populations, and what are examples of this resistance?
- How do bacteria's inherited traits affect their reaction to antibiotics, and how do offspring numbers and resource limits impact their survival and reproduction?
- How can ongoing antibiotic use lead to new, resistant bacterial strains, and what role does natural selection play in this process?
- How do genetic drift, gene flow, mutations, and recombination contribute to bacterial antibiotic resistance?

How do evolutionary mechanisms drive diversity and speciation observed in isolated populations, as exemplified by Galápagos finches?

Journey to the remote Galápagos Islands and spot a well known bird that upon sight honestly looks drab. Why is everyone talking about these finches? But as you venture around the islands you begin to notice something really interesting about their bill shape…all the finches look the same, but some have tiny, thin bills and some have enormous, heavy bills. How and why would one finch species evolve into so many different varieties? Dive into how simple traits and phenotypes provide insight into evolution and speciation. For Galapagos finches, the HHMI series "The Origin of Species: The Beak of the Finch" provides rich visuals and videos. The following species can be substituted or explored in addition to the Galápagos finches: Hawaiian honeycreepers and marsupial radiation in Australia.

Prompts for students to consider:
- How do beak variations in Galápagos finches show natural selection and what environmental changes influenced these phenotypes?
- How do inherited traits and island resources impact finches' survival and reproduction?
- How does the effect of isolating finches on different islands cause speciation, and how might diet and mate selection play a role?
- How might genetic drift, gene flow, mutations, and recombination shape the evolution and beak diversity of Galápagos finches?
### Unit resources

- For the videos in this unit, use the [Learning summary video notetaking guide](#).
- For the articles in this unit, use the [Article notetaking guide](#).
- For the exercises in this unit, use the [Blank workspace template](#).
- [Vocabulary and notation](#) notetaker.

### Lesson overview

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Objective</th>
<th>Teaching tips</th>
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<tbody>
<tr>
<td><strong>Lesson 1: Mechanisms of evolution</strong></td>
<td><strong>Objective</strong> Understand that natural selection acts on populations over generations, not on individual organisms. Examine how random changes can affect the frequency of alleles in small populations. Understand the impact of the movement of individuals (and their genetic material) between populations. Explore the role of random mutations in introducing new genetic variations. Understand how sexual reproduction serves as a key mechanism for generating genetic diversity.</td>
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<td><strong>TEKS standard:</strong> BIO.10.A; 10.D</td>
<td><strong>Teaching tips</strong> Evolution is driven by: natural selection, genetic drift, gene flow, mutation, and recombination, leading to diverse and adapted species. Review units 4 and 5 on how random mutations and sexual reproduction create genetic diversity—keys to evolution and speciation. Students match real-life scenarios to evolutionary processes in groups, then discuss their connection to evolution. E.g., peppered moths, cichlid fishes, Hawaiian honeycreepers. Use online simulations like PhET to show students how natural selection impacts populations (not individuals) over time. Explore how migrations of species like monarch butterflies, humpback whales, Atlantic salmon, wildebeest, and Arctic terns lead to gene flow and affect genetic diversity. Simulate genetic drift in small populations with the Genetic Drift Coin Flip activity and connect to examples of the founder effect in northern elephant seals and Florida panthers.</td>
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<tr>
<td>Video: 1</td>
<td>Article: 0</td>
<td>Exercise: 2</td>
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<tr>
<td><strong>Lesson 2: Natural selection and adaptation</strong></td>
<td>Explore the genetic diversity within a population and understand that variations can be passed onto offspring. Recognize that most species produce more offspring than can possibly</td>
<td><strong>Teaching tips</strong> Through natural selection, organisms better adapted for their environment survive and reproduce, leading to changes in populations over generations. In biology, &quot;fitness&quot; refers to survival and reproduction, not strength; for example, a plant with many seeds is considered &quot;fit&quot; for its high offspring survival potential.</td>
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</table>
survive, leading to competition for resources.

Investigate how limited resources (food, space, etc.) affect survival and reproduction.

Analyze how certain traits can give individuals an advantage in survival and reproduction, leading to changes in a population over time.

- Study local insects like butterflies or beetles to see how their high reproduction is balanced by mortality from competition and predation.
- Connect how life event timing in species, like plant blooming and pollinator activity, is tied to environmental cues and natural selection.
- Watch documentaries to observe how species compete for resources, illustrating how limited resources impact survival and reproduction.
- Have students match organism traits to environments, noting advantageous traits, and predict trait changes as environments shift.

Lesson 3: Natural selection and speciation

TEKS standard: BIO.10.C

Understand the process of how new species evolve over time.

Investigate how varying environmental pressures can cause populations to evolve along different paths, ultimately resulting in the formation of distinct species.

- Natural selection, by favoring beneficial traits, can lead to new species over time.
- Use diagrams to compare adaptation and speciation use endangered species as examples: like cichlids, elephant seals, and tiger salamanders, and how ongoing changes can lead to new species.
- Use diagrams to show how environmental pressures lead to adaptations and speciation, e.g., cichlids, kākāpō, saola, and elephant seals.

Best practices

COMMON MISCONCEPTIONS AND HOW TO ADDRESS THEM

“Natural selection causes immediate changes in individuals within their lifetimes.”

This confusion usually comes from mixing up the theory of natural selection with Lamarckism (suggests traits acquired in life are inheritable e.g., giraffes' long necks came from stretching to reach high leaves).

How to address this misconception

Clarify that natural selection involves changes in populations over generations, not in individual lifetimes, using examples like Darwin's finches and peppered moths. Simulate natural selection with activities, such as a bird bill adaptation exercise or bean selection to emphasize that traits do not change within an organism's life. Contrast this with outdated examples of Lamarckism, using giraffes’ necks as an example; natural selection led to longer necks over generations, not from individuals stretching to reach leaves higher in trees.
“All traits gained through natural selection are beneficial and adaptive.”
While natural selection often leads to beneficial adaptations, not all traits are a result of the process, and not all traits are beneficial or confer an adaptive advantage.

**How to address this misconception**
Review gene expression and inheritance from Units 4 and 5, covering how traits differ, inheritance basics, and the range of mutations. Play a game matching animal traits to environments, predicting which are helpful, harmful, or neutral. Discuss vestigial structures like the appendix and use simulations like Genetic Drift Coin Flip to demonstrate genetic drift’s random effects on traits. Research and present non-adaptive traits, showing that not all traits are beneficial. Have students research and present on non-adaptive traits in various species.

"Speciation occurs quickly and linearly, and always leads to 'better' or 'more advanced' organisms."
Speciation, driven by genetic and environmental changes, slowly leads to species adapted to specific environments, sometimes simplifying traits like eye loss in cave animals due to evolutionary pressures.

**How to address this misconception**
This misconception sets the stage for Unit 7. Start by clearly explaining how speciation slowly happens due to processes and phenomena such as genetic drift, natural selection, and isolation. Introduce phylogenetic trees (which will be detailed in the next unit), showing how speciation results in a branching pattern, not a straight line. Also, preview the fossil record and mass extinctions (like the end of the Permian and Cretaceous periods) to demonstrate how environmental shifts can result in both speciation and extinction, illustrating how evolution is not a linear process.

**CLASSROOM ACTIVITIES**

**Hungry hungry birdies**
In this activity, students will simulate natural selection by acting as predators picking different colored beans in various environments. Just as animals with certain traits survive better in their habitats, students will observe how specific traits become more common over generations. This connects to biology concepts like natural selection, trait variation, and adaptation in populations. *Check out Northern Arizona University’s resource “Bird Beaks: Competition and Natural Selection” for materials examples and sample data.*

**Materials:** dried beans of different colors, background materials of various colors (some similar to bean color, some not), timers. Optional: use tweezers or tongs, or students can just use their fingers.

- Use different colored beans to represent a population with varied traits. Randomly spread them over a colored background that matches some of the beans (mimicking a natural environment).
- Students act as predators, trying to pick as many beans as possible in a set time. The remaining beans represent those that “survived.” After each round, count the “captured” and “surviving” beans. Survivors “reproduce,” keeping the starting number the same each round.
- **Post activity:** discuss which bean colors were picked most and how this illustrates natural selection; environmental factors and traits influencing survival and beneficial traits in a population over time.

**Extension:** introduce a few beans of a new color to represent a mutation or genetic variation.
**Additional activity:** provide various tools as bird bills and various foods at “islands” around the room. Students use bills to collect food, showing how different bills aid survival in varied environments.
Invasive species case studies
Discover how invasive species' unique traits help them thrive in new environments. Students will research and present on invasive species, analyzing their effects on native ecosystems. This connects to concepts like competition, speciation, and human influence on evolution.

- Start with an overview of invasive species and their impact on evolution and speciation. Explain how invasive species may lead to competition over resources, how invasive species can lead to hybridization, speciation (or even extinction), and how human activities influence evolution.
- Have students research a specific invasive species, like zebra mussels or cane toads. Look into where it came from, how and why it was able to become invasive, its effects on native species and ecosystems, any evolutionary changes since it arrived, and how specific traits have helped it spread.
- Have students make posters on the problems invasive species cause and why it is important to conserve native species and ecosystems. Encourage students to present their work, followed by a Q&A. Discuss how invasive species impact ecosystems, evolution, and speciation, and how human actions contribute to their spread and the need to conserve native species and ecosystems.

Extension: plan a field trip to a nearby natural area for students to spot and note invasive species, or invite (virtually or in person) an expert on invasive species to talk to the class.

Genetic drift coin flip
To illustrate genetic drift in population genetics, students will simulate how random events influence allele frequencies using coin flips. Just as small populations experience random changes in genetic traits, students will observe how chance events affect allele distribution. This connects to concepts like genetic drift, allele frequency, and evolutionary processes.

Materials: coins (one per student or group), data recording sheets.

- Explain genetic drift as an evolutionary process where allele frequencies change randomly, especially in small populations. Highlight its random nature and contrast it with natural selection.
- Designate heads and tails to represent different alleles of a gene. Students toss the coin multiple times, with each toss representing a new generation. After each toss, they record which allele (heads or tails) is "selected". Keep track of the number of heads and tails after each round to simulate allele frequency changes over successive generations.
- Calculating cumulative percentages:
  - Start with a 50%/50% distribution for heads and tails in the first generation, assuming equal allele frequency at the start. For heads: if the flip result is "heads", slightly increase the heads percentage. If the flip result is "tails", slightly decrease the heads percentage. For tails: The tails percentage is simply 100% minus the heads percentage.
  - Decide on a consistent way to adjust the percentages. For example, you could add or subtract 2% for each "heads" or "tails" result. Example in sample data table below (using a 2% change from one generation to the next).

<table>
<thead>
<tr>
<th>Generation</th>
<th>Coin Flip Result</th>
<th>Cumulative Heads</th>
<th>Cumulative Tails</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>2</td>
<td>H</td>
<td>52%</td>
<td>48%</td>
</tr>
<tr>
<td>19</td>
<td>T</td>
<td>54%</td>
<td>46%</td>
</tr>
<tr>
<td>20</td>
<td>H</td>
<td>56%</td>
<td>44%</td>
</tr>
</tbody>
</table>
Students plot a graph of the frequency changes of each allele (heads or tails) over generations.

**Discussion Questions:** how did allele frequencies change over time? What does this activity illustrate about genetic drift? Would the outcome be different with a larger population?

If student data “doesn’t show genetic drift” or ends in 50/50, you can discuss how the following factors could have contributed to their results:

- Randomness in genetic drift: highlight that genetic drift is random and may not always cause significant allele frequency changes over a few generations.
- Impact of sample size: explain that the number of generations and population size affects genetic drift visibility, which is usually more evident over longer periods or in smaller groups.
- Results comparison: ask students to compare their results with peers, showing how the same random process can lead to different outcomes.

**PRO TIPS**

**Data nuggets**

Data Nuggets (datanuggets.org) are collaborative activities created by scientists and teachers, offering students real research details and data analysis practice. Activities are ranked based on reading and content complexity, and each comes in versions varying by graphing skill level required. Search by topic to explore over two dozen data and real-life based activities. New ones are constantly being added. Follow on Facebook for updates.

**GENERAL CLASSROOM IMPLEMENTATION RESOURCES:**

- **Weekly Khan Academy Quick Planning Guide:** Use this template to easily plan your week using Khan Academy.
- **Student Learning Templates:** Choose a template for students to record their learning. There are templates for watching videos, reading articles, and doing exercises.
- **Using Khan Academy in the Classroom:** Learn about teaching strategies and structures to support your students in their learning with Khan Academy.
- **Differentiation Strategies for the Classroom:** Read about strategies to support the learning of all students.