SUCCESS
ACADEMY
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Life Science:
Unit 5

The Argument for Evolution: Lessons

Lesson 1: The Next Great Superhero

Lesson Objective: Scholars begin to make sense of their prior knowledge on adaptations as they think about why organisms and/or populations look different from each other and over time within the lens of how humans might change over time to have superpowers. They are introduced to the term evolution and begin to think of questions that might help them understand the evidence needed to answer the Essential Question. Materials Needed

- For each scholar: computer/device, scrap paper

Prep

- Intellectual Prep:
    - Watch the **Mutations as a Source of Variation video** from Khan Academy to better understand the connection of scholars' prior knowledge to the Big Ideas they will discover throughout this unit.

What are scholars doing in this lesson?

- Scholars use superheroes they are familiar with to begin to think about how different mutant species may have evolved over time by studying the characters and then designing their own.

Do Now

- Access scholars' prior knowledge on **adaptations** by asking about the following scenario:
    - If a population of foxes living in a warm climate was moved to a location with a cold climate, what would happen to the population?
    - Would all of the population try to adapt to the change? Why or why not?
        - Scholars studied adaptations of plants and animals in elementary school, so they should lean towards saying that only a few of the population would try to adapt to change, but that many may not be able to change characteristics or features from their DNA to adjust to the new location. Scholars may struggle to use "adapt" correctly in their explanation.

Launch

- Allow groups to share and discuss their responses to the Do Now question.
    - Allow two or three scholars with differing opinions to share them with the whole group to expose the class to varying hypotheses and provoke deeper thought.
- Show an interesting image of a camouflaged animal to activate additional scholar thinking about the concept of adaptation.

Image credit: Sandilya Theuerkauf, **CC BY-SA 2.5**, via Wikimedia Commons

- Ask: What do you notice about this animal?
- Ask: How do you think the animal got this way?
    - Do you think the animal chose to look like this? Why or why not?
- Do not confirm or deny the accuracy of scholar responses.
- Tell scholars that in this unit they will learn about how organisms have changed over time and the evidence that scientists used to figure this out.
- Show an image of a superhero and discuss whether the human race could ever “change over time” to fly, time travel, or have telekinesis-like powers, like these characters we have seen on the big screen.
    - Ask: Birds can fly, so why can’t people?
    - Ask: If spiders can spin webs, who’s to say that someone couldn’t develop the same abilities as Spiderman someday?
    - Explain to scholars that in today’s investigation they will conduct research to find out whether developing superpowers is really feasible. Activate scholars’ prior knowledge about genetic **mutations** from the Genetics Unit.

Activity

- Scholars conduct research online to gather information about their chosen superhero character.
    - While working, scholars complete the graphic organizer in their Lab Notebooks.
- Scholars present the character they researched to their group and discuss:
    - Are there aspects of your superhero/mutant’s powers you’d argue could actually exist someday?
    - What traits does your character have that seem realistic versus far-fetched? Explain.
- If time allows, scholars can design their own mutant using the instructions in their Lab Notebooks.
    - Press scholars to explain how their mutant could develop from current humans.

Discourse Debrief activity:

- Lead a discussion that bridges the Do Now’s purpose back to the activity.
    - Could [scholar name] wake up one day and turn into [their superhero name]? Why or why not?

        - Could that same scholar's children have a mutation that leads them to have those superpowers? Why or why not?
            - Do not confirm or deny, but elicit responses that lead to the difference between **species** and individuals changing.

Make broader connections:

- Introduce **evolution** as the theory that explains how species have changed over time.
    - Ask: Are we continuing to evolve now? Why? What is your evidence for that argument?

[**Tip:** Provide a vocabulary wall or a "parking lot" for questions so scholars can visually track their learning along the way.]

Introduce the Essential Question:

- Introduce the unit's Essential Question along with some context for the debate <u>What is the argument for evolution?</u>
    - Ask: What other questions will we need to answer ito help us understand evolution and answer our unit-long Essential Question?
    - Ask: What else are you wondering about? What questions do you have right now?

[**Engagement Tip:** If scholars ask questions that are not going to be answered in this unit, answer them to keep engagement high. If you know the answer to their question will be answered, will give something away, or will need the context of something that will be learned later, tell scholars to add that question to the "parking lot" and when they will get to come back to it to keep them intrigued.]

Accountability (Classwork)

- Scholars revise their Do Nows based on class discussion and new ideas formulated.

Scoring Award points as follows:

- Score scholars on a 1–4 scale (below expectations through exceeding expectations) based on classwork. Do not penalize scholars for initial misconceptions about content but rate them on effort and writing.
    - Look for the following when scoring scholar responses:
        - A clear claim that identifies the scholar they most agree with
        - Specific evidence from their knowledge of science that supports their claim
        - Justification/reasoning for why the evidence provided explains or supports their claim
        - High effort shown in writing with complete sentences, and proper grammar/punctuation seen throughout the response

Lesson 2: The Big Dig (Two Days)

Lesson Objective: Scholars learn how the fossil record can help scientists understand how species and environments have changed over time and when certain species became extinct. However, although the fossil record provides a compelling record of the past, scholars also begin to understand that it is an incomplete record, which they are unable to explain how until later lessons. Scholars question how useful the fossil record is as evidence toward the Essential Question. Materials Needed

- Day One
    - For the teacher: a copy of the **The Big Dig Narrative**, 1 set of cardstock "fossils" (cut 1 set per station per class from the **Big Dig Fossils** sheet, as these will be taken and glued onto chart paper by each class), buckets or deli trays, sand, toothpicks or other small "excavation tools"
    - For each group: a copy of the **Skeletal Resource Manual**, tape or glue, chart paper (1 piece per group)
- Day 2
    - For each group: simulated "**drill cores**," metric ruler
    - For each scholar: a copy of the **Stratigraphic Layers Background Information**

Prep

- Materials Prep:
    - Day One
        - Create fossils on cardstock and arrange several stations across the "dig site" in the classroom or outside. "Bury" the fossils in sand in small containers and provide toothpicks or other small excavation tools at each location.
    - Day Two
        - Review the **Stratigraphic Layers Background Information** and the procedure outlined in the Lab Notebook.
        - Prepare the "**drill cores**" by cutting them out individually and taping them to a small paper roll.
        - Print the Exit Ticket for this lesson in color. Scholars will need to reference the colors in the image.

[**Engagement Tip:** History teachers are simultaneously teaching content about historical artifactsâ€" consider cross-curricular collaborations!]

What are scholars doing in this lesson?

- Scholars explore the usefulness of fossil evidence as they build a conclusion as to what type of organisms existed in past environments. On Day Two, scholars examine drill cores from a desert environment near San Diego to determine how the evidence helps scientists understand how organisms have changed over time.

Day One

Do Now

- Jog scholars' knowledge of **fossil** history from Grade 5 by asking the following question:
    - Sometimes scientists find fossils from organisms who once lived in oceans, like fish or shells, near the tops of mountain ranges on land. How is this possible?
        - Although you are not assessing them on geologic time or land formations, using this question is an excellent entry point to get scholars thinking about why fossils have been critical evidence in developing the theory of evolution.
        - Listen for scholars who have ideas that show an understanding of the geologic and geographic changes that have occurred throughout Earth's historyâ€" these are a critical part of understanding evolution, and you may want to highlight these ideas later in the lesson.

Launch

- Show a portion of the **Marching Dinosaurs** video (7 minutes and 3 seconds) to highlight the diverse shapes and sizes of the dinosaurs that scientists have discovered.
    - Explain that we have named and identified hundreds of species of dinosaurs based on fossil evidence and that researchers anticipate that we will classify many more in the coming years as new discoveries are made.
- Ask: How do we know so much about dinosaurs when they went **extinct** so long ago?
    - Why are fossils so important to scientists?
- Connect this to the Essential Question. Ask: How might studying fossils help us understand the argument for evolution?

Activity Adapted from ***The Great Fossil Find***by Steve Randak and Michael Kimmel, © 1999 ENSI (Evolution & the Nature of Science Institutes)

- Following **The Big Dig Narrative** read by you, scholars "find" paper fossils of an unknown creature, only a few at a time.

[**Materials Management Tip:** Instruct scholars to unearth the “fossils” gently, as they are fragile!]

- In each round, scholars try to reconstruct the creature and revise their interpretation as necessary when new pieces are found.
- Set the expectation that scholars look closely first at each bone and discuss observations before jumping to conclusions.
    - Note: There are far more bones buried in each container than they are instructed to unearth. Each group is likely to pull a different subset of bones randomly from the ground, so they must consult the **Skeletal Resource Manual**. Each group may come to a different conclusion regarding the specimens.
- Scholars arrange their fossils to show the organism(s) they think they’ve discovered and tape or glue them onto a piece of chart paper.
    - Scholars record a final conclusion in their Lab Notebooks.

Discourse Debrief activity:

- Share scholar work on the document camera.
    - Ask: How did your confidence in your conclusions change over time? Why?
        - Allow two to three other scholars to share.
    - Ask: What did this activity teach you about the process of scientific discovery?
        - Generally, only a portion of the class will nail this. Allow one or two scholars to share out. The goal of this question is to help scholars to develop their understanding of the nature of scienceâ€” science content is not just a collection of facts that we’ve discovered but rather an ever-changing body that is constantly being refined as new evidence is uncovered through scientific practices.
- Ask: What might the fossils tell us about these organisms?
    - What do you think the organism(s) you discovered looked like when they were alive? What do you think their environment(s) looked like? Why?

Make connections to the Essential Question:

- Show two fossils from closely related organisms. Tell scholars they are from different organisms that lived on Earth at different times.
    - Have scholars make predictions about how and why these organisms have such similar features.
    - Relate back to the Essential Question by asking the following and charting scholar responses:
        - What do we know about fossils? (From this lesson and from our past studies...)

- What do fossils tell us about past life on Earth?
- Are fossils good evidence for the theory of evolution?
- What else do you need to understand about evolution to answer this?
- What new questions do you have about evolution?

Accountability (Lab Notebook)

1. State one conclusion that many scientists have made about Earth's past by studying fossils. [1]

Possible Exemplars:

One conclusion scientists have drawn about Earth's past by studying fossils is that many organisms that lived on Earth in the past are now extinct.

Scientists can conclude that the Earth's environment might have changed from the past to now based on the types of fossils found there.

2. Identify one limitation of using fossil evidence to understand evolution. [1]

One limitation of using fossil evidence is that it usually is incomplete. Sometimes it is difficult or impossible to retrieve all fossils for a specific organism, producing an incomplete picture.

Scoring Award points as follows:

1. Award one point for a logical conclusion that scientists can make about Earth's past by studying the fossil record.
2. Award one point for a reasonable explanation for why fossil evidence can limit scientists' understanding of evolution.

Note: This Exit Ticket is not representative of the ideas that will be assessed on the exam but it is a good model of the highlighted unit Science and Engineering Practices. Teachers should use this Exit Ticket to hold scholars accountable for constructing a strong claim based on the information they learned in class.

Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Show the following diagram depicting various fossils. Ask scholars to share their observations.

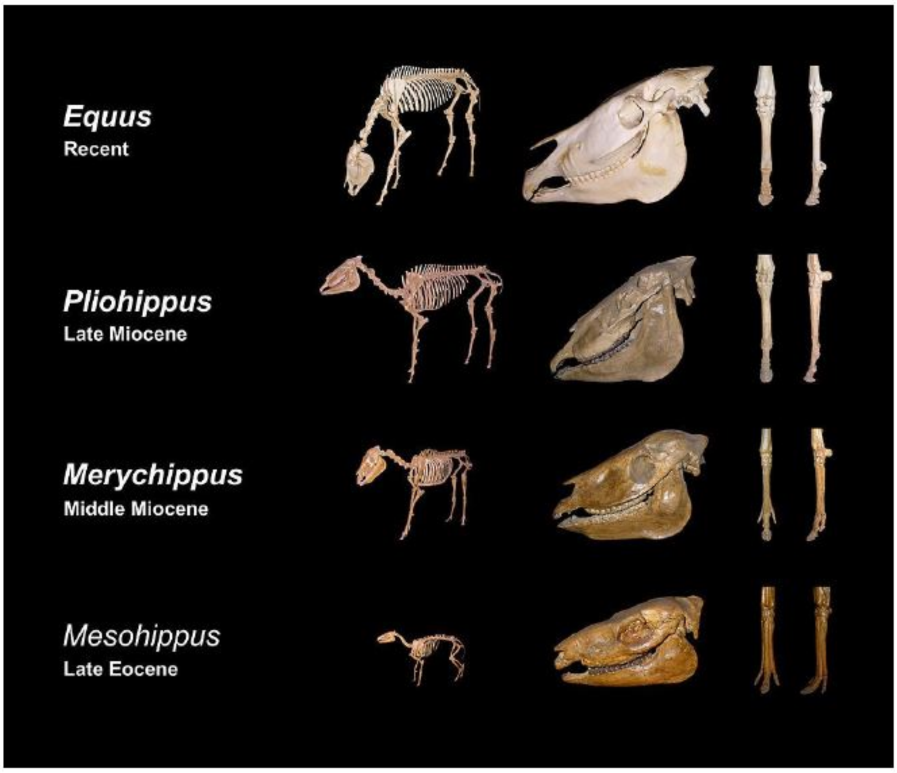


Image credit: **H. Zell (User:Llez)**, **CC BY-SA 3.0**, via Wikimedia Commons

- Scholars should notice that all of the animals look similar to modern horses, although they vary in size and there are clear differences in their bones and skulls.
- Explain that these were not one-off discoveriesâ€" in fact, fossil evidence indicates that large populations of each organism existed.
    - Ask: Are these organisms related in some way? Explain.
        - Allow scholars to speculate and share their ideas, but do not confirm or deny their validity.
    - Ask: What information would we need to determine whether these animals are related or not?
        - Scholars should note that we do not know where these fossils were found or their relative age.
    - Connect this back to the Essential Question. Ask: How might understanding the fluctuation of different populations help us understand the argument for evolution?

Activity Adapted from HASPI Medical Earth Science Core Labs, Lab 02: Geological Time, the Fossil Record, & Health. Revised June 2015

- Scholars read the background information and follow the procedure outlined in their Lab Notebooks.
    - Scholars sketch each drill core as a stratigraphic column and record additional information about the layers then answer questions in their Lab Notebook.
    - Scholars consider how studying fossil evidence might help scientists learn more about evolution and then they answer discussion questions in their Lab Notebooks.
        - Ask scholars these guiding questions:
            - Why are there different species in one layer than in the layers above or below it?
                - What happened to all the organisms in the lower layers? What is your evidence?
            - Why were similar organisms found in many different locations?
                - How is this possible when some organisms could not swim, fly, etc.?
            - Why don't all the columns line up evenly or have the same number of layers?
            - Is there evidence that a specific species changed over time?

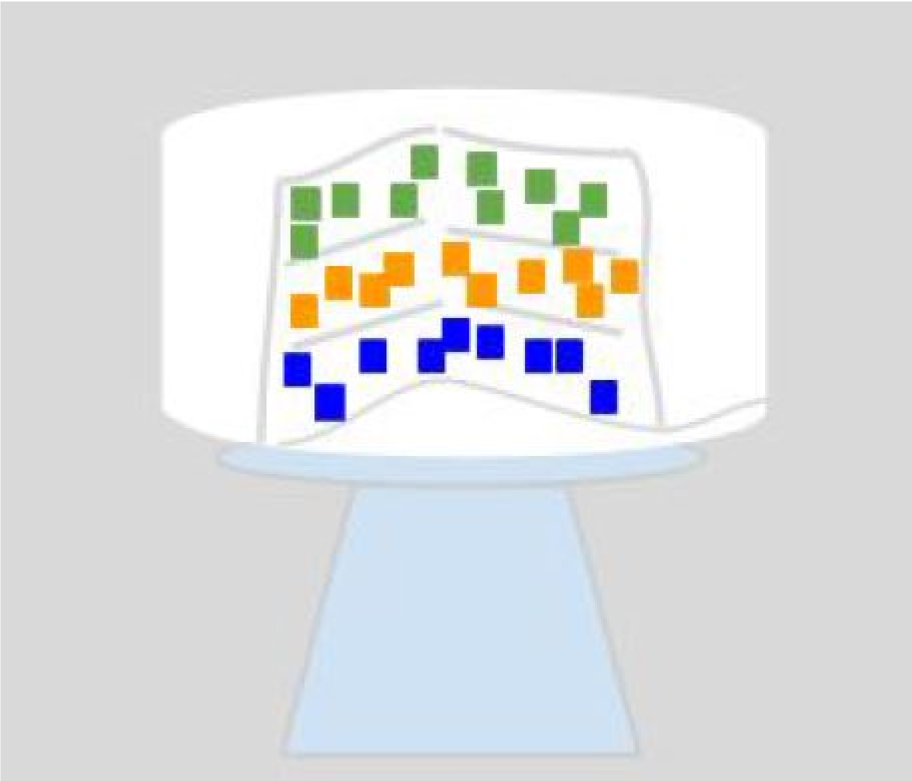
Discourse Debrief activity:

- Ask: What can fossils and drill cores tell us about the age of fossils?
    - How can you determine which fossils are older, which are younger, and which are likely to be from extinct species?
- Discuss the guiding questions from the investigation as a group. Then, have scholars summarize the main takeaways by asking these key questions:
    - What can the **fossil record** teach us about how Earth's environment has changed over time?
    - What does that imply about how species change over time?

Make connections to the Essential Question:

- Ask: How reliable are stratigraphic columns in providing evidence from the theory of evolution?
    - What degree of confidence do we have in conclusions derived from fossil evidence? Why?

Accountability (Exit Ticket) Many people enjoy eating a cool and refreshing dessert in the summer called the "crown jewel layer cake." It is made by creating several layers of cake with different types of Jell-O inside.



1. How is the crown jewel layer cake similar to the fossil evidence analyzed by scientists to understand evolution? Explain by describing the two similarities between the cake and fossil evidence. [2]

Both the Earth and the crown jewel cake are composed of multiple layers. Additionally, certain types of Jell-O are only found in certain layers (it almost looks like the blue Jell-O went extinct!), and certain organisms are only found in certain layers of rock beneath the Earth's surface.

2. After studying the picture of the crown jewel layer cake above, evaluate the following statement:

"If the Jell-O cubes represent fossils, then the blue Jell-O cubes were added to the cake after the orange Jell-O cubes because of their placement in the cake."

1. True
2. False

Lilly and her friends were digging a hole at the park near her house when they came upon a fossil. After some research, Lilly discovered that it was a fossilized fern commonly found in the desert several hundred thousand years ago. Later Lilly learned that several fossilized fish were found buried underground at a nearby construction site. The fossils were estimated to be about 20 million years old and were intact (wholeâ€" not broken into pieces).

3. Based on this fossil evidence, how could the environment in Lilly's neighborhood have changed over time? [1]

1. The neighborhood has always been a desert environment.
2. The neighborhood was once covered by water and then changed into a desert environment.
3. The neighborhood was once a desert environment and then changed to be covered by water.
4. The neighborhood has always been covered by water.

Scoring Award points as follows:

1. Award one point for each reasonable comparison between the cake and fossil evidence that points to evolution (up to two points).
2. Award one point for selecting answer B.
3. Award one point for selecting answer B.

Lesson 3: Theories of Evolution

Lesson Objective: Scholars have their first chance to define natural selection by studying and coming up with their own definitions of Lamarckian and Darwinian theories. Scholars must be able to define the four factors of natural selection (*variation, overpopulation, competition,* and *selection*) before moving on. Scholars begin to understand the Essential Question on a higher level by understanding these theories but may not yet connect them to evidence raised in the Engage.

Materials Needed

- For each scholar: computer/device

Prep

- Intellectual Prep:
    - Familiarize yourself with the key differences between Darwin's and Lamarck's theories of evolution by watching the **"Theories of Evolution: Lamarck vs. Darwin" video** by FuseSchool.
    - Understanding the differences between Lamarckian and Darwinian evolution relies on an understanding of genetic versus nongenetic traits. Review the information below as needed:
        - The use of the terms genes and traits. (Discuss the difference between inherited and noninherited traits as well.)
        - An adaptation is a trait typical of a population because of the favored survival and reproduction over many generations of individuals with that trait. To reinforce this point, elicit from scholars the response that the source of variation in a population is naturally occurring genetic differences.
        - **NOVA Darwin online interactive** (with an offline printable version): The father of evolution had conjectures that were only proved, or greatly substantiated, decades after his death in 1882, and in some cases not until recently. Today evidence that unequivocally supports his theory of evolution by natural selection, along with other theories he had, comes from an array of scientific disciplines.

What are scholars doing in this lesson?

- Scholars study a different scientific debate from the past that is related to evolution! (Do not explain much further about the content of the debate.) After researching, they construct their own cartoon depicting the argument as best as possible.

Do Now

- Follow the **Do Now plan**.

Launch

- Tell scholars that there was a time when most people, including scientists, believed that the Earth was flat, not round.
    - Ask: Why do you think they believed this?
    - Ask: What do you think changed their minds?

[**Extension Tip:** If time allows, engage scholars in a discussion about more current political debates involving the Flat Earth Society, and be sure to relate back to the purpose of this unit through the lens of argumentation and/or how historical views help us shape our present-day scientific debates.]

- Engage scholars in a discussion about the nature of science.
    - Ask: What is science? Is it a collection of facts?
    - Ask: It is estimated that there are 7 million working scientists today. How is this possibleâ€” haven't we figured everything out already?
    - Ask: Scientists disagree constantly. Why do you think that is, and how are these disagreements resolved?
    - Ask: Connect this back to the Essential Question. Ask: Do you think scientists disagree on the concept of evolution? Why?

Activity

- Scholars compare and summarize scenarios A and B in their Lab Notebooks.
    - Note: The scenarios are similar theories involving birds, but Scenario A is Lamarckian and Scenario B is Darwinian.
- After questioning most groups, reveal to the whole class that these scenarios were competing theories for evolution.
- Then have scholars conduct further research about who Lamarck and Darwin were, how their theories differed, and why Darwin's was so revolutionary. Scholars should complete the Venn diagram in their Lab Notebooks as they research.
    - Suggested websites:
        - **Introducing Darwin and Natural Selection** from Khan Academy
        - **Darwin, Evolution, & Natural Selection** from Khan Academy
        - **PBS: Jean Baptiste Lamarck**
        - **Evidence Supporting Biological Evolution**
    - **Natural selection** is defined for the first time during these readings for scholars.
- Scholars create a cartoon that compares and contrasts these historical theories.

Discourse Debrief activity:

- Ask: What are the primary differences between Lamarck's and Darwin's theories of natural selection?
- Ask: Which theory do you think became more widely accepted by the science community? Why?

    - Note: It is critical you use visuals on a visible screen as you discuss these theories and directly define the four factors of natural selection (**variation**, **overpopulation**, **competition**, and **selection**). After this lesson, these or similar visuals must be kept in sight until right before the exam.

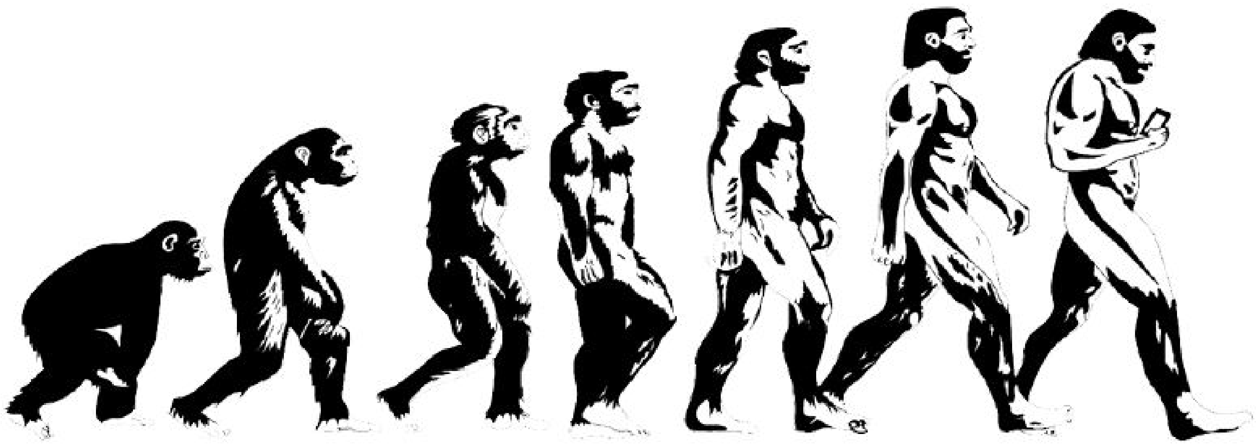
- There are many common misconceptions about evolution. During this lesson and discourse, ensure you reinforce the following:

    - Only groups of organisms can evolve (**populations** or species); individuals never evolve.
    - Adaptations, in the evolutionary sense, as properly used in class and text, can only "develop" as characteristics of a species generally over a long period of time, involving many generations. These must not be confused with the "adjustments" an individual might make, consciously or otherwise, enabling it to survive better (such as adapting to living at a higher altitude).

[**Tip â€" Teacher Misconception:** Although you should address the phrase, avoid habitually referring to Darwin's theory as "survival of the fittest," because it reinforces the anthropomorphic desire of the individual to want to change and strive to be better suited to its environment. You should still teach the words *fit* and *fitness* to describe an organism's ability to survive and reproduce.]

Make broader connections:

- Show the image below to scholars and explain that it is commonly used to depict the evolution of humans from their ancestors.



- Ask: Does this image support or refute Darwin's theory of natural selection?
    - Scholars should be able to identify that the image supports Darwin's theory and explain that the image shows species evolving (changing slowly over time) in ways that would have been beneficial to them. Press scholars to identify specific examples that support their claim. For example, growing taller and standing up straighter would have allowed the first monkey on the left to see more of his surroundings, which could have helped him find food or hide from predators.
    - Note: This image has drawn vast amounts of valid criticism from scientists, which you can read more about **here**. Although it is unlikely that a scholar will have the background knowledge to argue against the accuracy of this image, especially at this point in the unit, should they present a strong argument that the image refutes Darwin's theory, they may absolutely receive credit.

Accountability (Exit Ticket)

1. Below are examples of the four factors that contribute to Darwin's theory of evolution by natural selection. Match the letter of the term with the correct example. [2]

Overpopulation ___C____

Competition ___ B____

Variation ___ A____

Selection ___ D____

1. In a population of lizards, some have green skin and others brown skin or gray skin. Additionally, the lizards differ in the length of their legs: Some have shorter legs, whereas others have long legs.
2. The lizards' ecosystem also has several species of snapping turtles that feed on one type of frog, called Xenopus laevis.
3. Recently two species of snapping turtles have increased their population dramatically. Most areas around the lake in which they live are now crowded with turtles.
4. The brown lizards reproduce more frequently and have higher rates of survival because birds that prey on lizards can easily spot and capture green lizards when they run over the topsoil.

2. Ancestors of the lizard population all had short legs. Use Darwin's theory of natural selection to explain how the legs of lizards could have become longer over many generations. [2]

The lizard population must have had a mutation or natural variation that provided some lizards with longer legs. These long-legged lizards could have survived longer because they were able to run faster from predators. As the long-legged lizards reproduced and continued to survive because of their advantages in the environment, the population of long-legged lizards increased over time.

3. Evaluate the following statement:

“Only groups of organisms evolve; individuals never evolve.”

1. True
2. False

Scoring Award points as follows:

1. Award two points for all examples correctly matched to the terms.
    - Award partial credit for one or two errors
    - Award zero credit for three or more errors
2. Award one point for each of the following:
    - A description of how the natural variation or a mutation in the lizard population led to the appearance of long-legged lizards
    - A reasonable explanation of how the long-legged lizards were selected for in the environment over time
3. Award one point for selecting answer A.

Lesson 4: Birds of a Feather: Adaptations and the Environment

Lesson Objective: Scholars explain the role of the environment in creating competition in Darwinian evolution. Scholars also understand the concept of fitness and how heritable differences in fitness result in natural selection over generations. They recognize how adaptations and a changing environment play a role in the evidence towards the Essential Question. Materials Needed

- For the teacher: 1 newspaper “pond”
- For each group: paper bags, green gummy worms (100), beige gummy worms (100), 1 sheet of green paper
    - Note: Gummy bears may also be used to represent the “worms” in the activity.
- For each scholar: clear plastic bag, brown paper (optional)

Prep

- Materials Prep:
    - Create a newspaper pond (or a virtual pond on a viewable screen). Cut approximately 50 1Êº fish out of newspaper and various colored paper (blue, green, etc.). Paste all fish on “the pond” (an open newspaper).

    - Print the Exit Ticket for this lesson in color. Scholars will need to reference the colors in the image.

- Intellectual Prep:

    - **Adaptations and the Environment Guiding Information**

What are scholars doing in this lesson?

- Scholars use a similar model to determine how populations change over time because of the environment and predation.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask scholars to cover their eyes. Display the newspaper fishpond.

    - For ten seconds, scholars look at the pond and count as many fish as they can. Then, cover the pond again. Scholars share the number of fish they saw and the total number that they think are in the pond.

        - Identify any trends in scholar responses. For example, scholars closer to the front of the room may see more fish.

    - Display the pond again. Give scholars two minutes to count the fish this time, and record the number they think they see on scrap paper.

        - Ask scholars to share their responses. Identify any that differ significantly from the rest and discuss the reason(s) why that might be.

    - Elicit scholar-led questions and responses about the number and type of fish they caught each round and speculate what would happen to the population of each "type" (color) of fish over many generations.
    - Do you think humans play a role in the evolution of other organisms?

Experiment Adapted from **Seimens STEM Day Activity: Birds of a Feather**

- Scholars act as birds, catching worms and modeling the effect of prey coloration on predation rates by birds over time, using the procedure in their Lab Notebooks.

    - Scholars record how the population of green and brown worms changes over five generations.
    - Scholars discuss how predators play a role in the process of natural selection.
    - Extend: Have scholars model a drought by replacing the grass with brown paper. How are their results different?

- Coach scholars as they work to avoid these common misconceptions:
    - “Individual organisms can evolve during a single life span.”
    - “Natural selection involves organisms trying to adapt.”
    - “The <u>needs</u> of organisms account for the changes in populations over time (goal-directed or teleological interpretation).”
    - “The fittest organisms in a population are those that are strongest, fastest, and/or largest.”

Discourse Debrief experiment:

- Select one scholar in advance to showcase and explain his or her exemplar data.
    - Ask: How do factors such as the environment and the presence of predators affect the process of natural selection?
- Ask: What individual characteristic(s) of the worms contributed to their survival or death? Why?
    - If you have not already, define **fitness** and introduce the concept of relative fitness.
- Ask: How did the genetic makeup of this population change over time?
- Ask: Which of the four factors affecting natural selection did we experience in this model?
- Ask: What are the strengths and limitations of this activity as a model for natural selection?
    - Ensure you note that population changes do not actually occur nearly this quickly in nature.

Make connections to the Essential Question:

- Ask: How could this model help us answer the Essential Question?

Accountability (Exit Ticket) Infections caused by bacteria are often treated by medications called *antibiotics*. Antibiotics are designed to kill bacteria so they cannot reproduce, ending the infection and healing the sick person.

Due to natural variation in bacteria populations, some bacteria have a mutation that makes them *resistant* to antibiotics. This means that antibiotics often do not kill them, and they can go on to reproduce. An example of this is shown below.

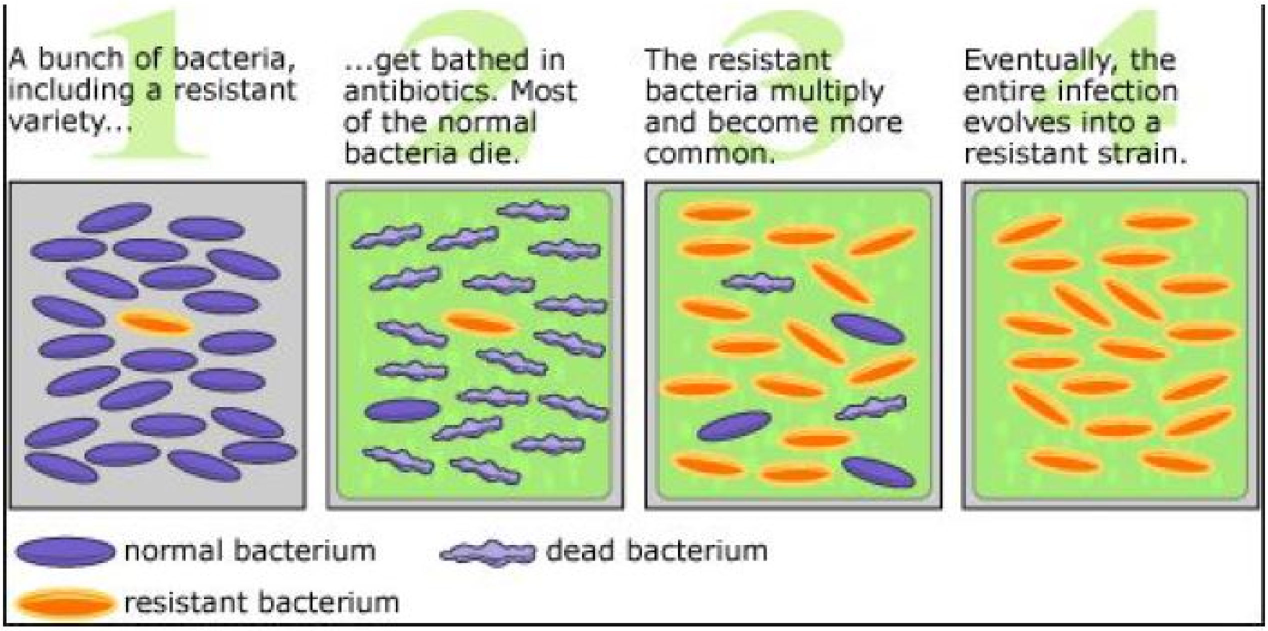


Image credit: How Antibiotics Contribute to Resistance. (Figure adapted from an image courtesy of the **University of California Museum of Paleontology's Understanding Evolution**)

1. After the antibiotic was applied, were the bacteria represented by the purple or orange symbols most fit? Explain your response using evidence from the diagram. [2]

The bacteria represented by the orange symbols were most fit because they were able to survive at higher rates after the antibiotic was applied. In the diagrams, you can see that although most of the purple bacteria died, the orange ones were able to survive and continue to reproduce because they were resistant to the medication.

2. Would it be accurate to say that the bacteria evolved because they wanted to survive? Why or why not? [2]

It would be inaccurate because the bacteria population is not changing because of a desire to change. Individual bacteria are reproducing as they normally would, but those with favorable traits are surviving longer and therefore are able to reproduce more and pass their traits along to more offspring.

Scoring Award points as follows:

1. Award one point for each of the following:
    - Identifying the "orange" bacteria as more fit
    - Including evidence from the diagram or text (should reference the resistance of the bacteria or their comparative survival rates)
2. Award one point for each of the following:
    - Identifying this statement as inaccurate
    - Explaining that evolution does not occur as a result of the wants or needs of individual organisms

Lesson 5: Genetic Mutations: The Driving Force of Variation

Lesson Objective: Scholars revisit how variation in organisms results from a combination of sexual reproduction and genetic mutations in order to understand how variation acts as a factor on natural selection. With a deeper understanding of variation, scholars have stronger evidence for the Essential Question because sexual reproduction and genetic mutations are constantly recurring yet somewhat unpredictable processes. Materials Needed

- For each scholar: computer/device, **Natural Selection PhET Simulation**

Prep

- Materials Prep:
  - Review the **Natural Selection PhET Simulation** to show scholars how they can best use the information it provides to support their understanding of the activity directions.
  - Set up the PhET simulation on a viewable screen for the class during the activity.

What are scholars doing in this lesson?

- Scholars participate in a simulation that models the reproduction and variation of a population of rabbits to understand other reasons why populations can change over time.

Do Now

- Follow the **Do Now plan**.

Launch

- Show scholars a few **pictures** of albino animals on a viewable screen.
  - Ask: What do you think causes some animals to be albino?
  - Ask: Are all mutations beneficial? Explain.
- Connect this to the Essential Question. Ask: How might understanding mutations help us understand evolution?

Activity Adapted from Natural Selection by **PhET Interactive Simulations**, University of Colorado Boulder

- Scholars follow the directions in their Lab Notebooks to determine how variation affects natural selection under different conditions.
    - Scholars use the **Natural Selection PhET Simulation** to observe how mutations affect a population of rabbits under different conditions.
        - For each part of the activity, scholars select the environment (summer or winter), the indicated mutation, and click “Add Mate.”
        - Scholars observe the population for two complete generations, press pause, and record their notes in the space provided.
        - After two complete generations, scholars add the indicated “Environmental Factor” and observe the population for two more complete generations. They press pause and record their notes in the space provided.
        - Scholars repeat this process for each different simulation.
    - Help scholars begin to independently discover and construct an explanation based on evidence that the process of evolution primarily results from four factors:
        - The potential for a species to increase in number
        - The heritable genetic variation of individuals in a species because of mutation and sexual reproduction
        - Competition for limited resources
        - The proliferation of those organisms that are better able to survive and reproduce in the environment

Discourse Debrief activity:

- Ask: Which type of rabbit was the most successful in each simulation?
    - Scholars share class data to support their conclusion(s).
- Ask: In this model, variation was created by pressing a different buttonâ€” but how does (heritable) variation arise in a real population?
    - What random process is necessary for rabbits with advantageous fur color or tooth length to appear for the first time in a population?
    - What nonrandom process is necessary for rabbits with advantageous fur color or tooth length to evolve?
        - What role does variation play in the process of natural selection?
        - How did the rabbit simulation model the process of natural selection?

    - Explain that random mutations during DNA replicationâ€” that occur much more rarely than in this simulationâ€— continually introduce new variations into all populations. Most new mutations are not advantageous. If harmful, they tend to be eliminated from the population quickly. If neither helpful nor harmful, they may increase or decrease passively over generations.
        - Whether a mutation is advantageous depends on the particular environment. Because natural selection acts over many, many generations, even a slight advantage conferred by a mutation may cause it to increase gradually in prevalence within a breeding population.

Make broader connections:

- Show this diagram to the class. Allow scholars to turn and talk about how it parallels what they saw during the lesson.

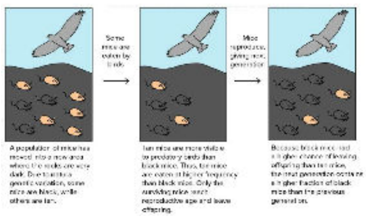


Image credit: **[Khan Academy]**

Make connections to the Essential Question:

- Ask: How does understanding sexual reproduction and mutation help us understand the argument for evolution?

Accountability (Exit Ticket) Eyes are complex structures with multiple parts that work together so we can see the world around us. Octopus eyes have:

- A lens that focuses light to form an image on the retina
- A retina with many photoreceptor cells that contain light-sensitive molecules. Photoreceptor cells respond to light and send signals to nerve cells. The nerve cells carry visual information from the eye to the brain.

In a population of octopuses, most of the octopuses have the genotype (ii), which results in a lens that produces fuzzy images. A few of the octopuses have a new allele (I) that results in a better lens that produces sharper, clearer images. (Assume that the I allele is dominant relative to the i allele.) A scientist who observed this predicted:

“The new allele (I) will become more common in this octopus population over many future generations.”

1. Evaluate the accuracy of the scientists’ statement. Use your knowledge of variation and natural selection to support your response. [3]

This statement is accurate because the new allele will become more common over time in the octopus population. The new allele will help the octopuses born with it survive in their environment. Better eyesight will likely allow them to catch more food and avoid predators, and in turn, they will live longer and reproduce more. As more and more offspring carry the trait, they will beat out those without it as they compete for resources, gradually changing the makeup of the larger population.

Scoring Award points as follows:

1. Award one point for each of the following:
   - A claim identifying the statement as accurate
   - Evidence that supports the claims by explaining how the trait could benefit the octopuses
   - Justification/reasoning that further explains or supports the evidence by tying in understanding of how natural selection results in evolution of a population

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Lesson 6: Speciation, Extinction, and the Tree of Life

Lesson Objective: Scholars learn that throughout time, most organisms experience speciation, which creates the diversity we see in the tree of life today. They will understand how scientists organize information about lines of evolutionary descent using a phylogenetic tree and how extinctions throughout time can help scientists understand the evolution of organisms. Materials Needed

- For each group: container of building blocks, 8 small straws (4 regular straws cut in half), **Building Block Tree of Life Cards**
- For each scholar: colored pencils

Prep

- Materials Prep:
  - Cut regular straws in half so that scholars can build their phylogenetic trees without taking up too much space on their tables.
  - Print **Building Block Tree of Life Cards** on cardstock and cut them out for each group.
- Intellectual Prep:
  - Scientists use the term diversification as the counterpart of extinction. This is a more accurate term than speciation when referring to taxonomic groups larger than species. However, to promote scholar understanding, the more familiar term speciation is used here.

[**Tip:** Consider reinforcing concepts from all Explore lessons by using **this** HHMI biointeractive on a real-life example of natural selection and speciation with lizards in the Caribbean.]

What are scholars doing in this lesson?

- Scholars explore how phylogenetic trees are made by using a LEGO® tree of life model to understand the connections between speciation and extinction, common ancestry, and the diversity of life.

Do Now

- Follow the **Do Now plan**.

Launch

- Show scholars an example of the full phylogenetic tree of life. Explain that each color on the tree represents a different type of organism: pink represents eukaryote (animals,plants, and fungi), purple represents bacteria, and green represents archaea.

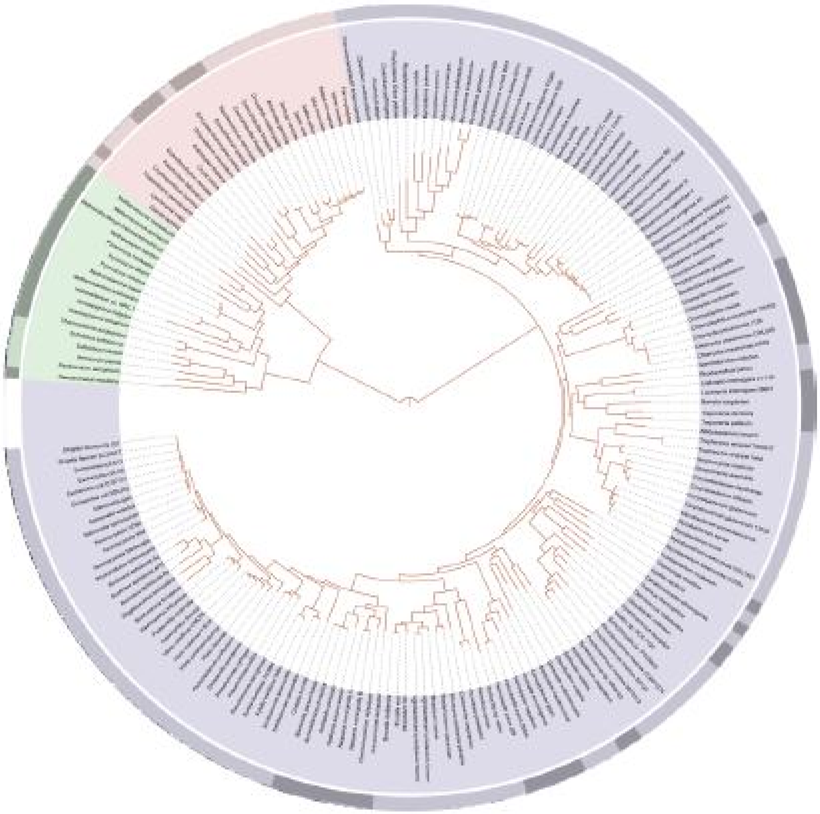


Image credit: **Ivica Letunic: Iletunic. Retraced by Mariana Ruiz Villarreal: LadyofHats**, Public domain, via Wikimedia Commons

- Explain that the center of the tree represents life on Earth 4,000 millions of years ago. Ask: How did life on Earth 4,000 millions of years ago compare to life on Earth today?
- Ask: How did life on Earth become so diverse over time?
- Ask: How do you think phylogenetic trees are made?
- Note: The phylogenetic tree is introduced as a term and a concept during the Launch, but it should not be formally defined or confirmed for scholars until the Discourse so that they can discover and explore the concept on their own first during the Investigation.

- Connect this to the Essential Question. Ask: How do you think phylogenetic trees and the tree of life can help us understand the argument for evolution?

Activity Originally developed by Mike Webster, Mike Alfaro, and Louise Meed; it was modified with permission by **the Concord Consortium**.

- Scholars follow the procedure outlined in the Lab Notebook to create their own building block trees of life.
- As scholars complete the procedure, they should sketch their phylogenetic trees in their Lab Notebooks and answer guiding questions with a partner or their group.
- As scholars work, circulate and question them on how the building block Tree of Life Cards are impacting their tree of life and what each component of the model represents.
    - What does each card cause your building block species to do? Why?
    - What changes are made to your building block species as your tree grows? What do you think this would represent in nature?
    - What does your tree help you understand about your building block species?
        - What do the straws represent?
        - What do the distances between species represent?
    - How could you use your tree to help you understand evolution?

Discourse Debrief activity:

- Review guiding questions from the Lab Notebook and discuss the building block tree of life as a model for evolution.
    - Ask: Why did your building block represent a population instead of an individual?
    - Ask: Which species in your tree are most closely related? How do you know?
    - Ask: What effect did the cards have on your building block species? What caused your building block species to evolve over time?
        - Define **speciation** and **extinction**.
    - Ask: What does the first building block species you created represent?
        - Define **common ancestors**.
- Ask: What role does extinction play in evolution?

Make broader connections:

- Ask: What can you learn about evolution by studying a **phylogenetic tree**?
    - How does Darwin's theory of natural selection help us understand phylogenetic trees?

[**Tip:** To better understand how a new species forms, consider showing the **Formation of New Species by Speciation video** from FuseSchool.]

- Show scholars the following spindle diagram of the evolution of vertebrates. Explain that a spindle diagram shows the appearance of a species and the diversity of taxa throughout time via the thickness of the lines. Explain that when speciation occurs and a fossil from a new species is found that was not present in any time period before, it is called a “first appearance.” When a fossil from a species is no longer found in the record, it is called a “last appearance.”

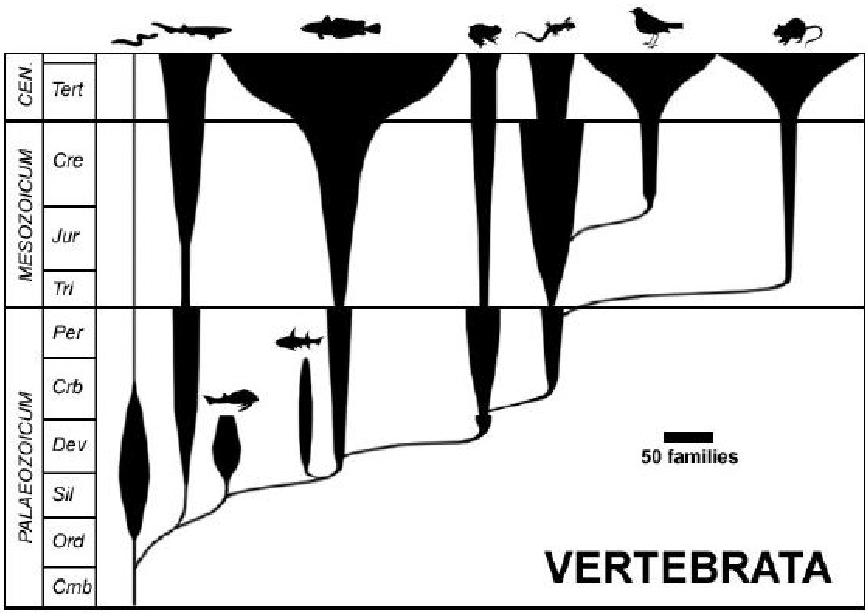


Image credit: **Petter Bøckman**. Public domain, via Wikimedia Commons

- Have scholars identify the presence of fish, reptiles, and mammals on the spindle diagram. What can you learn about evolution by comparing the fossil records of fish, reptiles, and mammals?

[**Tip:** Show scholars this **HHMI biointeractive** to learn more about what caused these extinctions to occur in history and what scientists predict might cause the next extinction!]

- Return to the full tree of life from the Launch.
    - What do scientists consider the common ancestor of all life? How do you know?
    - Is the tree complete? Will there be additional changes in the future?

[**Tip:** Avoid the common misconception that humans are the natural culmination of evolution.]

Extend

- Practice reading and interpreting phylogenetic trees by having scholars read and interpret the following phylogenetic tree that represents the evolution of video game consoles.

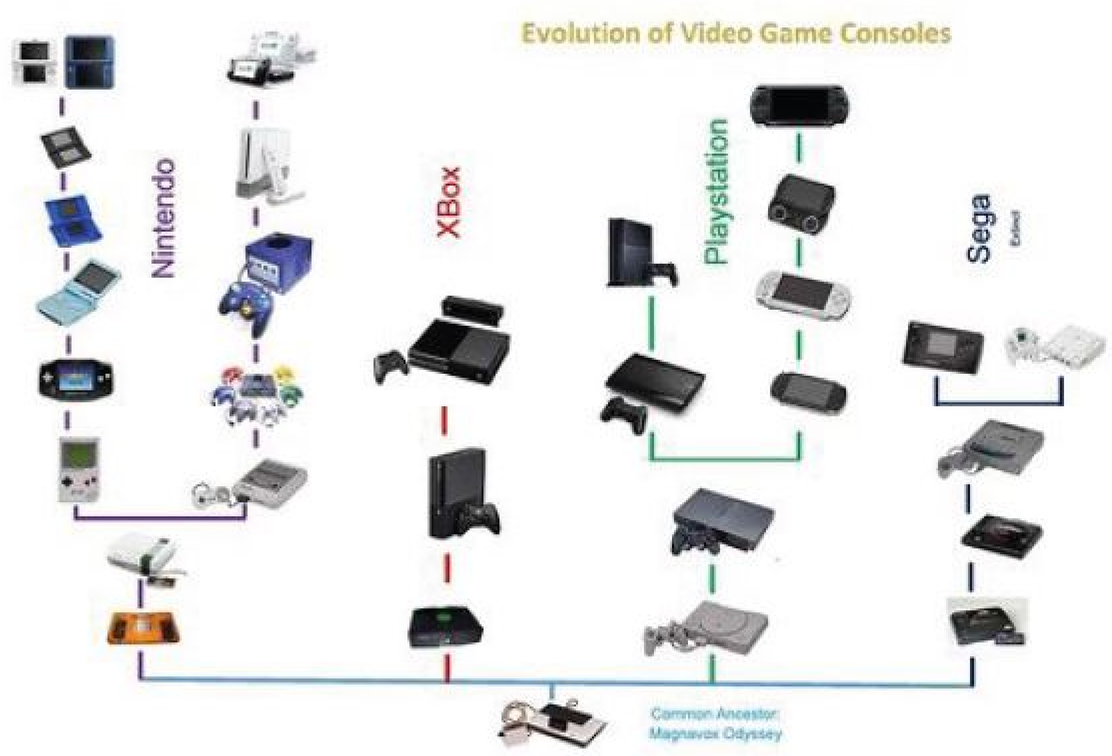


Image credit: Cladistics by Mariana Garcia Serrato, **published on BetterLessons**, **CC BY-NC 4.0**

- Choose different game consoles and ask which other game console they are most closely related to and how they know.
- Ask which game console represents the common ancestor and how they know.
    - What caused the evolution of game consoles over time?
        - Make connections to speciation and extinction from the lesson investigation.

Accountability (Exit Ticket) The table below shows three traits that are present in three related tree species.

Table 1: Comparison of Three Traits in Trees

Tree Species	Bark Texture	Leaf Type	Root Depth
Species A	Smooth	Compound	Shallow
Species B	Furrowed	Simple	Moderately deep
Species C	Smooth	Compound	Shallow

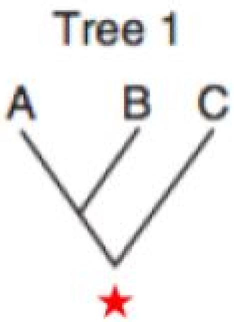
The phylogenetic tree diagrams below show two possible evolutionary relationships between the three species.

Question and figures adapted from the New York State Education Department. Science Regents Examinations: Living Environment, August 2016. **https://www.nysedregents.org/livingenvironment**

1. Which phylogenetic tree diagram shows the most probable evolutionary relationship between the three species? Use evidence from the data table and your knowledge of science to support your response. [3]

Tree 2 shows the most probable evolutionary relationship between the three species. In Table 1, Species A and C have the same traits for bark texture, leaf type, and root depth, whereas Species B has different traits. Because Species A and C are more similar, they must be more closely related than Species B, which Tree 2 shows.

2. On the Tree 1 diagram above, label the part of the phylogenetic tree that represents a common ancestor between all species (A, B, and C) with a â˜…. [1]



3. Evaluate the scientific accuracy of each statement by circling true or false. If the statement is false, rewrite it on the lines below to make it true. [2]

1. Natural selection causes evolution by changing the inherited traits of an individual over time. **true false**

Natural selection causes evolution by changing the inherited traits of a population or group of organisms over time.

2. Natural selection occurs over many generations, and therefore, evolution takes a long amount of time. **true false**

Scoring Award points as follows:

1. Award one point for each of the following:

   - A claim that identifies Tree 2 as the most probable evolutionary relationship
   - Evidence from the traits in the data table that identifies the similarity between Species A and C versus B
   - Justification/reasoning that further explains that species that share traits are more closely related evolutionarily

2. Award one point for drawing a star at the bottom-most point of the phylogenetic tree.

3. Award one point for each of the following:

    - Choosing statement A as false and rewriting the statement to change “individual” to “group or population”
    - Choosing statement A as true

Lesson 7: Examining the Fossil Record for Evidence of Evolution

Lesson Objective: Scholars identify and explain evidence of homologous structures that support the theory that species living today share descent from common ancestry. Scholars can also describe the evolutionary information the fossil record provides and how we know that it is reliable. Materials Needed

- For each group: 1 set of **Tetrapod Limb Skeleton Cards**, metric ruler, a copy of the **Tetrapod Fossil Chart**

Prep

- Materials Prep:
    - Cut a set of tetrapod fossil cards for each group.
- Intellectual Prep:
    - Watch the **Great Transitions: The Origin of Tetrapods** film from HHMI.
        - One of the most exciting discoveries in the long history of fossil exploration is Tiktaalik, a creature with a mix of features common to fish and four-legged animals, or tetrapods. What made the discovery of Tiktaalik's fossil so compelling is that it, along with the series of species that existed before and after, illuminates key evolutionary steps in the transition of life from water to land.
        - The film provides a firsthand account of the painstaking search for Tiktaalik, a creature with a mix of features common to fish and four-legged animals.

[**Tip:** Although the resource listed supports adult-level intellectual preparation, this material could easily be used on a flex day to deepen scholar understanding.]

What are scholars doing in this lesson?

- Scholars use the fossil record to determine the chronological evolution of tetrapods as an introduction to how homologous structures serve as evidence of evolution.

Do Now

- Follow the **Do Now plan**.

Launch

- Have scholars look at their fingers and toes. Introduce the problem of how modern tetrapods evolved limbs and digits.
    - Ask: What are tetrapods?
        - How do you think tetrapods evolved? Did tetrapods move from land to sea, or did a type of fish evolve to become four-footed with multiple digits?
        - What type of evidence would help answer this?

Activity

- Scholars observe the bone structure of seven different organisms to predict the evolution of digits in tetrapods.
- After studying each organism, scholars order them from oldest to youngest.
- As scholars are working, ask questions about the thought process for their organization:
    - Which skeleton cards do you think represent the earliest tetrapod form? Why?
    - What changes are you most focused on when determining tetrapod evolution? How does this help you order them?
- Scholars then use the Tetrapod Fossil Chart, which shows where each fossil was found, and reevaluate their sequence.

Discourse Debrief activity:

- Discuss scholars' results from the activity and ask them to explain how their predictions changed over time. (Connect this back to the law of superposition, which they learned about in Grade 5!)
    - Show scholars the full skeletal images of the tetrapod limb evolution in the correct sequence.

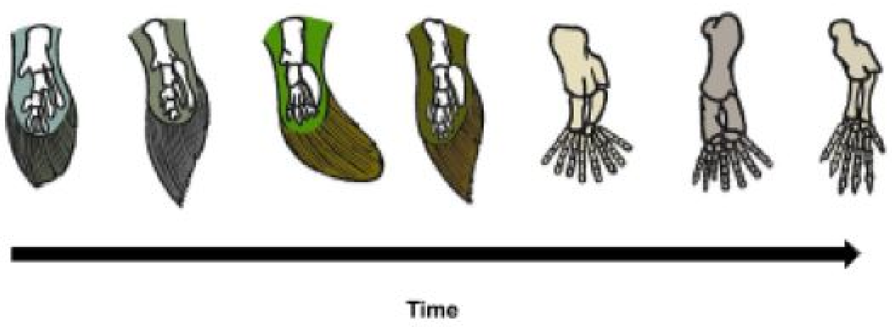


Image credit: Adapted from **Conty**. Public domain, via Wikimedia Commons

- Ask: What kinds of skeletal changes appear to have occurred during the evolution of tetrapod limbs and digits?
    - The bones of the stylopod (humerus or femur; seen as the bone at top of the organism skeletons) and zeugopod (radius/ulna or tibia/fibula; seen as the bones in the middle of the organism skeletons) elongate, thicken, and become more distinct. The bones of the autopod (fingers or toes; seen as the bones at the bottom-most part of the organism skeletons) become more distinct, thinner, and longer. One much more subtle observation is the development of more distinct joints between these different bones, allowing for greater mobility for walking.
- Ask: How are fish and tetrapods related?
- Ask: How could the changing habitat explain some of the differences between the fish and the tetrapod? What can you infer about the changes in habitat that occurred at the same time as these skeletal changes?
    - These changes indicate a transition from predominantly aquatic land-dwelling animals to ones that lived partly on land and partly in shallow water, and eventually to animals with an exclusively land habitat.
- Display the following picture of different vertebrate limbs:

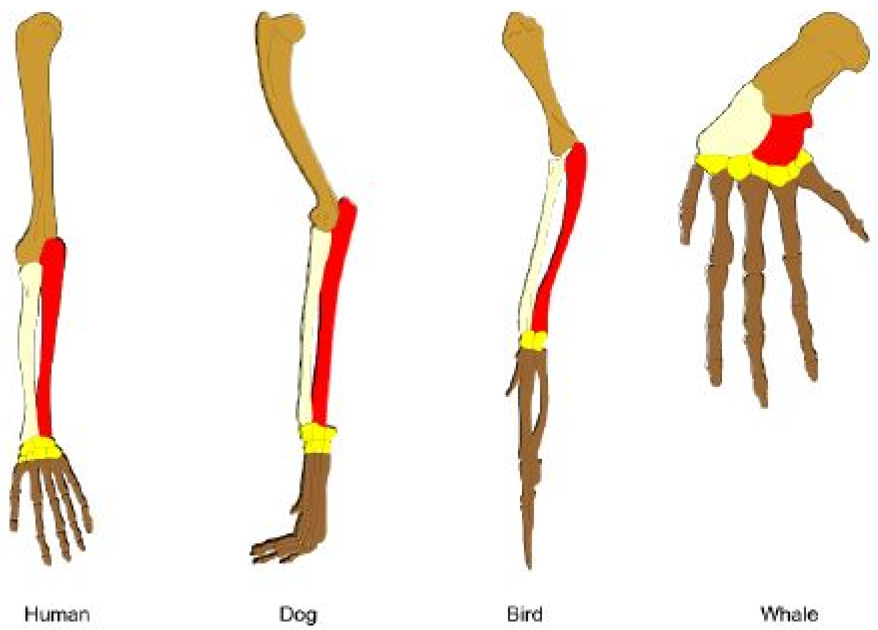


Image credit: **Volkov Vladislav Petrovich**, **CC BY-SA 4.0**, via Wikimedia Commons

- Ask: What do you notice about all of the animals' limbs?
    - Introduce and define the term homologous structures.
    - Ask: What makes the bones above homologous structures?

Make broader connections:

- Ask: How can you use natural selection to explain how these changes in vertebrate limbs (or one of these changes) could have occurred?
- Explain that in his book On the Origin of Species, Charles Darwin boldly predicted that buried deep in the earth would be creatures with features that were intermediate between those of ancestral and modern groups. At the time, no such fossils had been found, and Darwin's critics immediately seized on that fact to refute the theory of evolution. But since Darwin's time, many transitional fossils have been discovered, and they provide crucial insights into the origin of key structures and the creatures that possess them.
- Show the following text on the screen with a visual and have scholars discuss the question below.

- Whales, dolphins, and porpoises are mammals that live in the sea, and like all mammals, they are warm-blooded animals that give birth to live young and need air to breathe. DNA evidence shows that dolphins (circled in blue) are closely related to hoofed land mammals such as hippopotamuses, pigs, cows, and sheep (circled in red). All of these mammals are thought to have descended from a single species that lived millions of years ago and is now extinct.
- Ask: Besides DNA evidence, what other evidence might suggest that these animals are related?

Accountability (Exit Ticket) Directions: Read the text excerpt below and respond to the questions that follow.

Analogy, in biology, means similarity of function and resemblance of structures that have different origins. For example, the **wings** of a fly, a moth, and a bird are *analogous* because they developed independently as **adaptations** to perform a common functionâ€" flying. The presence of the *analogous structure*â€" in this case, the wingâ€" does not reflect evolutionary closeness among the organisms that possess it.

In many cases, *analogous structures* tend to become similar in appearance by a process termed *convergence*. An example is the convergence of the streamlined form in the bodies of squid, shark, seal, porpoise, penguin, and ichthyosaur, animals of **diverse** ancestry. They are classified, however, in separate and distinct families, sharing characteristics that have evolved independently in response to similar environmental challenges.

Adapted from ***Encyclopedia Britannica***

1. Based on the text above, describe the main difference between analogous and homologous structures. [1]

The main difference between analogous and homologous structures is that although they are similar in appearance and sometimes in function, analogous structures have evolved separately from each other, usually because of similar environmental challenges in different areas.

Diagram 1: Leaf modifications found in different plants

Venus Flytrap

Leaves are traps that

catch insects to use as

fuel source for plant

Cactus

Leaves are spines that

deter predators and shade

the plant to limit water loss

Image credit: [User:Mattes](). Public

domain, via Wikimedia Commons

Bougainvillea

Leaves are bracts, a flower

petal look-alike, to attract

insects and pollinators

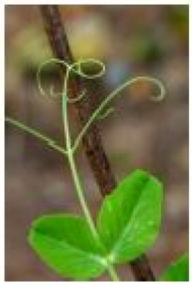


Image credit: [Jessie Hirsch]() , [CC BY]()

2.0 via Wikimedia Commons

Pea Plant

Leaves have tendrils that

attach to different surfaces

to secure the plant

2. Why are the leaves in Diagram 1 considered homologous structures? [1]
    1. They all have a similar appearance.
    2. They are all in similar positions on the plant and perform similar functions.
    3. They are all modifications of a leaf that have been derived from a common ancestor.
    4. They all use photosynthesis.

Scoring Award points as follows:

1. Award one point for an accurate description of the difference between analogous and homologous structures (must mention how analogous structures are not related evolutionarily).
2. Award one point for selecting answer C.

Lesson 8: Comparative Anatomy and Evolutionary Clues

Lesson Objective: Scholars understand that because much of our genetic toolkit is similar, most embryos (including humans') start out with clear structural similarities, and we still have anatomical vestiges of these genetic similarities within our bodies. They must also be able to explain how these anatomical similarities provide further evidence of evolution. Materials Needed

- For each group: sets of **Comparative Embryo Cards**
- For each scholar: computer/device

Prep

- Materials Prep:
    - Cut out **Comparative Embryo Card sets** (A, B, and C) for each group.

- Intellectual Prep:
    - Review how comparative embryology serves as evidence for evolution by watching the **Evidence for Evolution video** (7:00–8:30) from Khan Academy.
    - Read this excerpt about **Evolutionary Embryology** to better understand specific examples of embryonic homologies (from Developmental Biology, 6th ed, by S.F. Gilbert. Sunderland (MA): Sinauer Associates; 2000. Available from: https://www.ncbi.nlm.nih.gov/books/NBK10049/).

What are scholars doing in this lesson?

- Scholars observe and predict matches between early embryos and their fully developed organism form to understand evolution through a development lens.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: What could you have in common with a fish or a rabbit?
    - Explain that humans are just one of millions of distinct organisms on Earth today.
    - How are different species connected to one another?
        - Scholars should make connections to common ancestry and the tree of life.
        - Do you think scientists could always use fossil evidence to trace common ancestry among different species? Why?
- Activate scholars' prior knowledge about meiosis and cell division to investigate the connections to fertilization and species differentiation.
    - Ask: How might meiosis and fertilization help us understand species differentiation?
        - Today scholars try to match a series of **embryos** to their adult forms and then watch each creature develop during a portion of its early growth.

Activity

- Scholars open Set A of the Comparative Embryo Cards and record their observations for each embryo in their Lab Notebooks. They then make predictions about which embryo card matches which organism and record those in their Lab Notebooks.
- Scholars open Set B of the Comparative Embryo Cards and record new observations of the embryos as they reach a later stage of development. They revise their predictions based on their new observations.
- Scholars then open Set C of the Comparative Embryo Cards and make final observations, comparing and contrasting new features of each embryo in their latest stage of development. They record the revealed answers and compare them to their previous predictions.

- Scholars answer questions in their Lab Notebooks to make connections between comparative embryology and the theory of evolution.

Discourse Debrief activity:

- Ask: What aspects of our anatomy and physiology do we share with other animals on Earth?
- Ask: What is common ancestry? Explain.

Make broader connections:

- Show an example of an anatomical vestige.
    - Ask: How do **anatomical vestiges** provide further evidence for the theory of evolution?
- Ask: Are we as humans done evolving?
    - Can you think of any vestiges that humans have?
        - Display this **article** on wisdom teeth on a visible screen and review it as a class.

Accountability (Exit Ticket) Pelvic bones are primarily used to support weight in organisms when they change from standing to sitting positions. They help to support some of the internal organs, like the intestines, but overall they help an organism to balance while standing. The diagram below shows a vestigial structure (pelvic bones) in the modern dolphin.

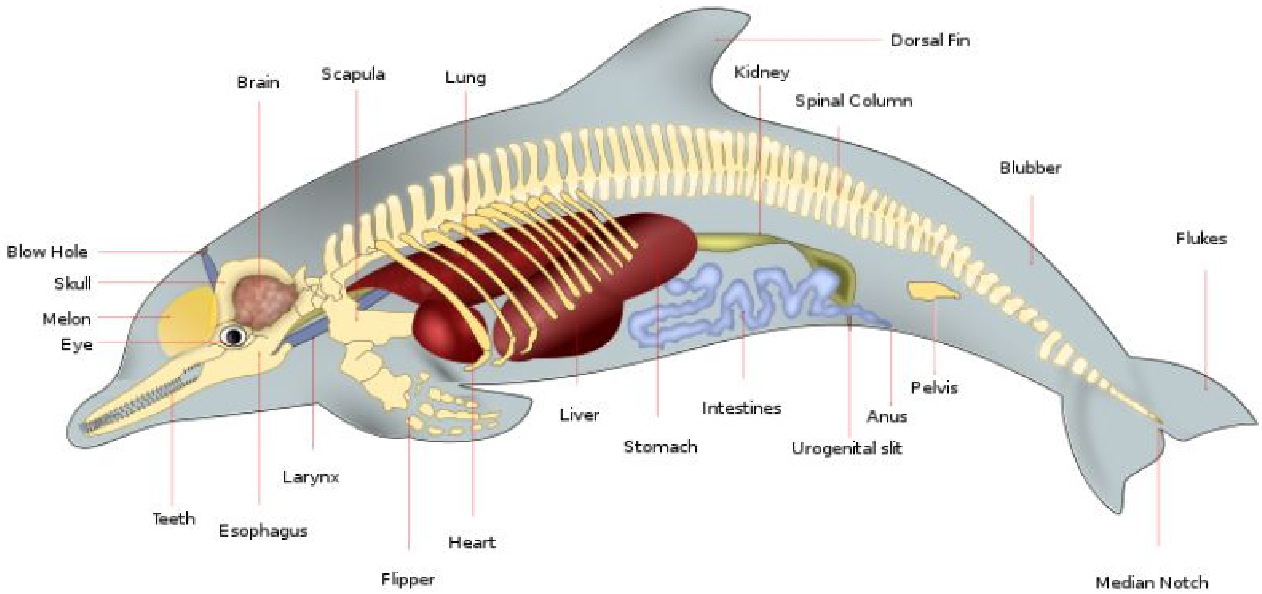


Image credit: **WikipedianProlific, vector version by Wilfredor**, **CC BY-SA 4.0**, via Wikimedia Commons

"*Vestigial structures do not help us understand the theory of evolution because they aren't used by the organism anymore*."

1. Evaluate the accuracy of this statement. Explain using your knowledge of common ancestry to support and justify your response. [3]

This statement is not scientifically accurate because vestigial structures can help us understand the theory of evolution. Although vestigial structures are no longer used by the organism, like the pelvic bones in the dolphin, they can tell us about the common ancestor of the dolphin. For example, because pelvic bones are used for balance during standing or sitting and dolphins swim, their presence tells us that dolphins evolved from ancestors that used to sit or stand, when pelvic bones would be more useful.

[**Tip:** In addition to this Exit Ticket, evaluate scholar responses to the Essential Question in their Lab Notebooks. This will help teachers understand where scholars are in their understanding of the answer to the Essential Question.]

Scoring Award points as follows:

1. Award one point for each of the following:

    - A claim that identifies the statement as inaccurate
    - Evidence that supports the claim by explaining how the pelvic bones in the dolphin can tell us about its closely related ancestors that used to stand or sit
    - Justification/reasoning that further explains what vestigial structures are and why their presence in modern organisms can be helpful to understand their evolution

---

Lesson 9: Modern Advances Contribute Further Support for Evolution

Lesson Objective: Scholars can explain how technological advances like DNA sequencing have further contributed to the veracity of the theory of natural selection. They learn how similarities or changes in DNA segments reflect the relatedness of organisms and can be represented in a phylogenetic tree. Scholars understand how DNA sequencing contributes more concrete evidence toward the argument for evolution and answering the unit's Essential Question.
Materials Needed

- For each scholar: ruler

Prep

- Intellectual Prep:
    - Read the full texts in scholar Lab Notebooks, **Electrophoresis** and **Comparative Genomics Fact Sheet** from National Human Genome Research Institute (NHGRI).

What are scholars doing in this lesson?

- Scholars review the connection between DNA size and sequence similarities to evolutionary relationships.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: Why would scientists want to find further proof for a theory that is already widely accepted?
    - Show scholars the **What is DNA and How Does it Work? video** by Stated Clearly.
    - Ask: How might scientists use DNA as evidence for evolution?
        - Explain that with modern advances in technology, scientists can break up DNA into the same smaller parts for different species and even sequence the DNA of different species down to the specific base pair!
- Explain to scholars that in this investigation, they will compare DNA sequences from common animals to discover how DNA comparison works.

Activity

- Scholars follow the procedure outlined in their Lab Notebooks to complete two activities.
    - In Activity 1, scholars learn how gel electrophoresis works and can be used to compare DNA fragments from different species. They use an example gel to determine the relatedness of humans to three different primate species.
    - In Activity 2, scholars read how DNA sequencing has allowed scientists to compare similarities or differences between species. They use an example DNA sequence to compare three different vertebrate species and determine their relatedness.
- As scholars are working, circulate and press them to use their understanding of phylogenetic trees to represent how similar or different the species are from each other.

Discourse Debrief activity:

- Ask: How does DNA provide evidence about how species are related? Cite specific examples from today's activities.
- Share work samples from both activities under the document camera. Ask the class to evaluate the phylogenetic trees based on the gel electrophoresis and DNA sequence differences that the scholars identified to support their model.
    - Use this time to close gaps in understanding of what phylogenetic trees represent and how to create one based on different sets of data.

Make broader connections:

- Ask: How could DNA evidence help you find the relatedness of any species on the tree of life?
    - Explain that the activities in this lesson are simplified versions of the data sets scientists use to determine the relationships between organisms.

◦ Show an example of a phylogenetic tree of life with representation of the amount of fully sequenced genomes known and analyzed for different species in the tree of life.

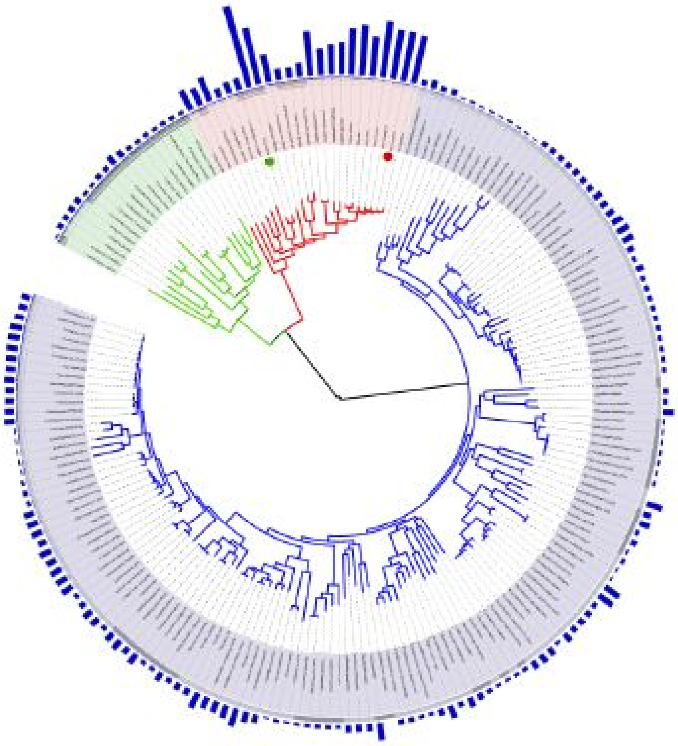


Image credit: **Gringer**. Public domain, via Wikimedia Commons

- Ask: How might the amount of fully sequenced genomes impact the ability to understand the relationship between species?
- Ask: How does the genetic makeup of a population change over time?
    - Ask: How do factors such as the environment and the presence of predators affect the genetic makeup of a population?
    - Think back to the green and brown worm simulation. If the brown worms saw that the green coloring was a more beneficial trait, why couldn't they just evolve so they had the trait too?

Note: Understanding that degradation or mutation of DNA in individual cells can occur during an organism's lifetime is beyond the scope of this unit. Although this may come up during the unit, the generalization that your DNA cannot be changed is considered an acceptable one for middle schoolers.

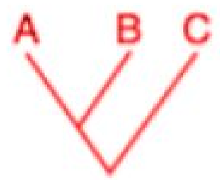
Accountability (Exit Ticket) The table below shows segments of DNA present in one trait for three related reptile species.

Table 1. Comparison of DNA Sequences in Three Lizard Species

Lizard Species DNA Sequences

Species A	C	G	A	T	A
Species B	C	G	A	T	A
Species C	G	C	T	A	T

1. In the box below, draw a phylogenetic tree that represents the evolutionary relationships between the three lizard species. [2]



2. Identify one advantage of using modern techniques such as DNA sequencing as evidence to understand evolution. [1]

DNA sequencing is helpful in understanding evolution because it provides more specific evidence on how closely related organisms are by comparing their DNA codes for different traits.

Scoring Award points as follows:

1. Award one point for each of the following:
   - Drawing a phylogenetic tree that shows two species more closely related than a third species
   - Accurate labels on the phylogenetic tree that show that Species A and Species B are more closely related to each other than they are to Species C
2. Award one point for a logical explanation of how modern techniques provide more specific evidence toward understanding evolution.

Lesson 10: The Argument for Evolution

Lesson Objective: Scholars will demonstrate the ability to synthesize important information from throughout the unit that supports them in constructing a strong, evidence-based letter. While writing their letter to the Turkish government, they in turn answer the unit's Essential Question.
Materials Needed

- For the teacher: a copy of NPR's **Evolution** article
- For each scholar: a copy of NPR's **Evolution** article, highlighter

Prep

- Intellectual Prep:
    - Review the article in advance of the lesson. Identify any relevant vocabulary or concepts that you will front-load with scholars, as well as the targeted questions you will ask to coach scholars who struggle to comprehend the article.

[**Tip:** If your schedule allows for extra time or a flex day before the end of the unit, consider expanding this lesson into two days, so scholars have a chance to revise the first drafts of their letters after Discourse.]

What are scholars doing in this lesson?

- Scholars read an article together to learn why, and each scholar's task is to write a letter to that country's government in response to its new laws.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: Imagine that you're a teacher. A parent calls with a concern about your science class. He states that he does not believe that climate change is real and he does not want his child to learn anything about it. How would you respond?
    - Scholars to discuss in small groups. Press scholars to ask one another pointed follow-up questions that require them to expand on their rationale.
- Explain that like climate change, evolution is a topic that has caused controversy in many school districts. In fact, an entire country has chosen to remove all references to evolution from its science classes.

Activity

- Scholars read the article, highlighting and jotting notes as they read.

[**Tip:** One teacher can pull together a small group of struggling readers to work through the article.]

- Scholars plan a response to the article using the template provided in their Lab Notebooks.
    - What evidence from your earlier Lab Notebook entries can support you in building a robust argument? (Scholars should reference their work from two lessons at a minimum.)
- After completing the template, scholars compose letters to the Turkish government.
    - What qualities make a piece of writing engaging and convincing? How are you applying this understanding to your letter?

  - Draw parallels between this assignment and their work in Humanities classes.

- As scholars are working, circulate and press them to use the most important scientific information gathered throughout the unit in their letters.

Discourse Debrief activity:

- Display two or three work samples (medium and then high) and ask the class to evaluate the strength of each response.
  - Of the samples shown, which argument is the strongest? Explain.
    - Ask: Where do you see compelling evidence in this scholar's response?
    - Ask: Where and how does the scholar effectively justify their evidence? How does this further support their argument?

- Explain that the debate about teaching evolution in schools is not exclusive to Turkey. Show scholars this **interactive map**. Explain that in many states, schools still teach creationism in science classesâ€" some raise it as an alternate theory to evolution, and others teach it exclusively.
  - Ask: Do you think all schools should teach their students about evolution? Why?
  - Ask: Do you think schools should discuss both evolution and creationism in school? Why?

Make broader connections:

- To culminate the unit, revisit the superpowers you discussed during Lesson 1.
  - Ask: Why aren't superhero mutations possible for humans anytime soon?
  - Ask: Could humans ever evolve to have superpowers? What would need to happen for these superpowers to evolve over time?
    - Press scholars to consider the four factors of natural selection.

Accountability (Classwork)

- Write a letter in response to the Turkish government's decision to remove evolution from its science curriculum. Include several pieces of evidence and compelling reasoning to support your response. [6]

To Whom It May Concern:

I am writing to share my disagreement with your decision to remove evolution from the science curriculum in your schools. This decision withholds important scientific discoveries and information from children. School should be a place where children can learn things, not have things withheld from them because they could create conflict. Students need to be able to add their informed voices to the larger conversation about this issue, and sheltering them simply leaves them ignorant and unable to contribute.

I understand that Darwin's theory of evolution creates a personal conflict with some people's religious beliefs; however, this doesn't mean it should be hidden from students. Unraveling the mysteries of the unknown, grappling with difficult data, and forming the strongest possible conclusions based on the available evidence are what science is all about! Students should be allowed this opportunityâ€" if they cannot do this in school, where will they learn?

Speaking of the evidence, there is ample evidence that supports evolution in the fossil record! Fossils have revealed to us entire evolutionary lines (like those of the whale and the horse). Studying those fossils, you can actually see the small changes that occurred over time as the animals changed into those we see today.

Additionally, with modern advances in DNA sequencing, scientists now have concrete evidence of how closely related organisms are to each other and whom they share common ancestors with. Knowing this can even help us uncover more information on why we are made the way we are and even potentially help us to develop medicine to better our society.

It is my hope that you take the above into account and reconsider your position on this issue. It is critical that all students have a chance to grapple with complex issues in science, even if they are controversial. The evidence in favor of evolution is overwhelming, and it is widely accepted by much of the world. Your scholars deserve the opportunity to learn about it.

Sincerely,

Scholar Name

Scoring Award points as follows:

- Award one point for each of the following:
    - An introduction to the topic and why they are writing a letter of concern
    - A strong claim identifying their stance on the decision to remove the study of evolution from the science curriculum
    - Each piece of supportive evidence from within the unit that supports their claim (up to two points)
    - Justification/reasoning that ties the evidence learned from the unit to their overall stance on the importance of studying evolution in science class
    - A conclusion to the topic

Unit Vocabulary

Vocabulary List

- **mutation**
- **fossil**
- **species**
- **extinction**
- **adaptation**
- **evolution**

- **natural selection**
- **variation**
- **fitness**
- **competition**
- **overpopulation**
- **speciation**
- **common ancestor**
- **phylogenetic tree**
- **embryo**
- **population**
- **homologous structure**
- **anatomical vestiges**