



Evolutionary History:

Advising a Paleontology Museum

**Investigation Notebook
with Article Compilation**



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Evolutionary History:

Advising a Paleontology Museum

Investigation Notebook

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Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.
2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.
3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.
4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.
5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.
6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.
7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.
8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.
9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.
10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.
11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: _____

Date: _____

Evolutionary History: Advising a Paleontology Museum **Unit Overview**

A team of scientists has discovered an interesting fossil at a remote dig site. The Mystery Fossil will be placed on display in a museum, but first some important questions should be answered: What kind of organism was the Mystery Fossil? Is it like any living organisms on Earth today? Paleontologists study the history of life on Earth, grouping organisms in special ways. They must determine which other animals the fossil should be grouped with, asking: Where in the museum does this new fossil belong? To answer questions such as these, you and your classmates will take on the role of student paleontologists. Using evidence provided by the bone structures of both living and extinct organisms, you will learn how paleontologists make sense of the history of life on Earth. You will eventually decide which type of organism to group the Mystery Fossil with and where to place it on display in the museum.

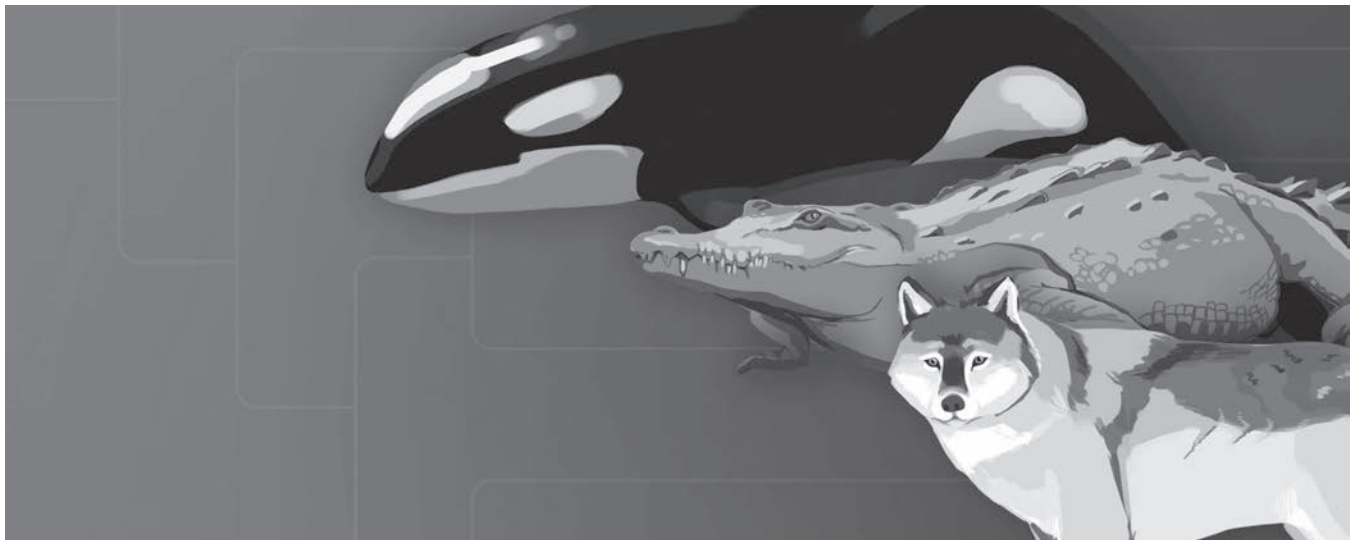
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Date: _____

Chapter 1: Finding Species Similarities

Chapter Overview

A mysterious new fossil—the Mystery Fossil—has been found, and the Natural History Museum has asked you to help figure out where in the museum to place it. Should the Mystery Fossil be placed near the whales, the wolves, or the crocodiles? Working as student paleontologists, you will learn how paleontologists use the bone structures of organisms, living and extinct, to make sense of the history of life on Earth. You may be surprised to learn how many similarities there are between the bone structures of organisms that seem very different at first glance. Paleontologists look for these similarities to help them explain how different species have evolved from the same ancestors. Knowing about similar structures will help you to advise the Natural History Museum about where in the museum to place the Mystery Fossil. Good luck!



Name: _____

Date: _____

Lesson 1.2: Welcome to the Natural History Museum

A paleontology museum wants to display an exciting new fossil that was recently found in a desert valley, but first they have many questions: What is the fossil? Where should they place it in the museum? Placing a fossil in a museum is more difficult than you might think—life on Earth spans billions of years and paleontologists use important information about how all life on Earth is both similar and different when they organize their museum exhibits. Over the next few weeks, you will take on the role of student paleontologists and study the history of life on Earth. Today, you will learn about important scientific practices that paleontologists use in their work, and you will consider how species that look very different can actually be quite similar.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 1 Question

- Where in the museum does this new fossil belong?

Vocabulary

- body structure
- claim
- evidence
- paleontologist
- species

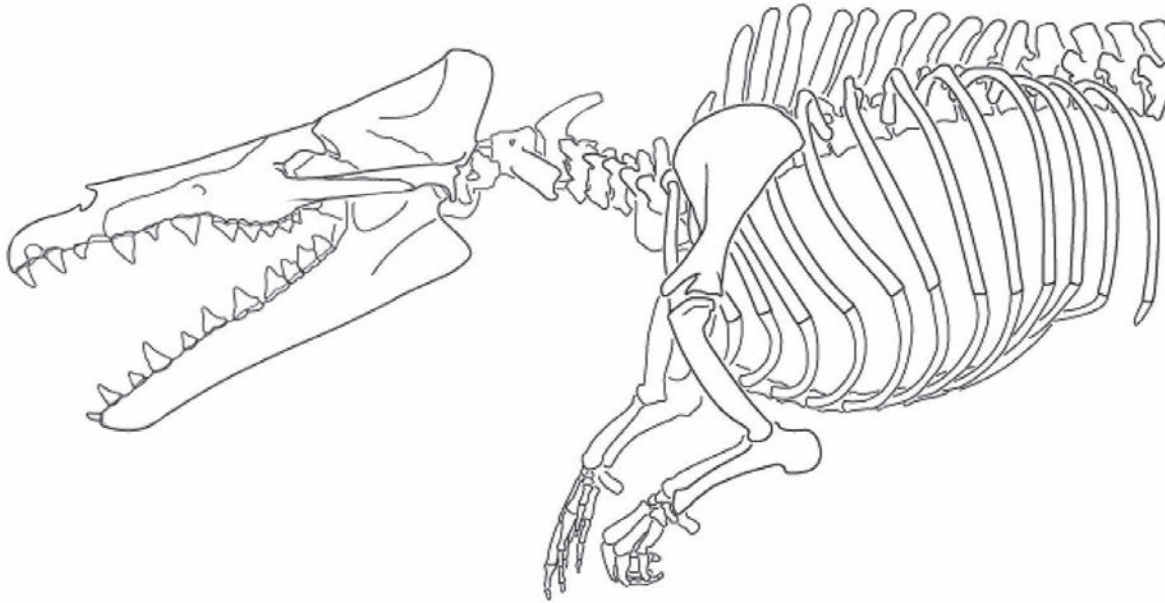
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Date: _____

Warm-Up

A Fossil Mystery

Below is a drawing of a fossil that is millions of years old. This fossil was just taken out of the ground, and no one knows what kind of organism it is. One way scientists identify a fossil of an animal with bones is to compare the bones of the fossil to the bones of other animals.



Do any of this fossil's bones look like bones of other animals? Describe your thinking.

Name: _____

Date: _____

Finding Similarities Between Species

Part 1: A Fossil Mystery

1. **Read the Species Cards.** With your partner, carefully examine each Species card. Consider the titles and labels on each card. Pay close attention to what each species shares with other species.
2. **Discuss with your partner how to group the organisms.** Using the information you learned as you read the cards, decide on at least two groups you can put each organism into; the groups should be based on ways that the organisms are similar to each other.
3. **Sort the cards into groups.** Be prepared to explain to other students why you sorted the organisms the way you did.

Part 2: Message from Andre Mosley, Natural History Museum Director

To: Student Paleontologists

From: Andre Mosley, Natural History Museum Director

Subject: First Thoughts About Mystery Fossil

We want to make sure to place the Mystery Fossil in the museum with a group of other species that it makes the most sense for the fossil to be with. To make this decision, you will need to do the work of making careful observations and spending time comparing the bones of the Mystery Fossil to the bones and body structures of other organisms.

We asked our intern paleontologists at the museum to quickly examine the Mystery Fossil bones and give us some initial ideas about what species in the museum the Mystery Fossil might be most similar to. Their first examination of the Mystery Fossil tells us that there are three main types of organisms that the Mystery Fossil could be grouped with:

- whales
- wolves
- crocodiles

Part 3: Where in the museum does this new fossil belong?

- **Claim 1:** The Mystery Fossil belongs with the whales, in the Whale (Cetacea) exhibit.
- **Claim 2:** The Mystery Fossil belongs with the wolves, in the Carnivore (Carnivora) exhibit.
- **Claim 3:** The Mystery Fossil belongs with the crocodiles, in the Reptile (Reptilia) exhibit.

Name: _____

Date: _____

Homework: Reading “The Cat That Wasn’t a Cat at All”

Read and annotate the article “The Cat That Wasn’t a Cat at All.” When you are finished reading, use your annotations to answer the questions below.

The first scientist misidentified the fossil as that of a big cat. What body structure did he use to make his observations?

What body structure did the second scientist use to determine that the first scientist had misidentified the fossil?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____

Date: _____

Lesson 1.3: “How You Are Like a Blue Whale”

Many people know that humans and monkeys have many similarities. For example, monkeys and humans have similar arms, hands, feet, and skulls. Have you ever thought about how other animals might be like us, too? Today, you will consider an organism that you may be surprised to find shares many similar body structures with humans: the blue whale. You will think about *why* humans could have shared body structures with another organism and about *which* specific body structures make you and blue whales a lot alike.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 1 Question

- Where in the museum does this new fossil belong?

Digital Tools

- *Evolutionary History* Simulation

Vocabulary

- body structure
- evolution
- paleontologist
- shared structure
- species

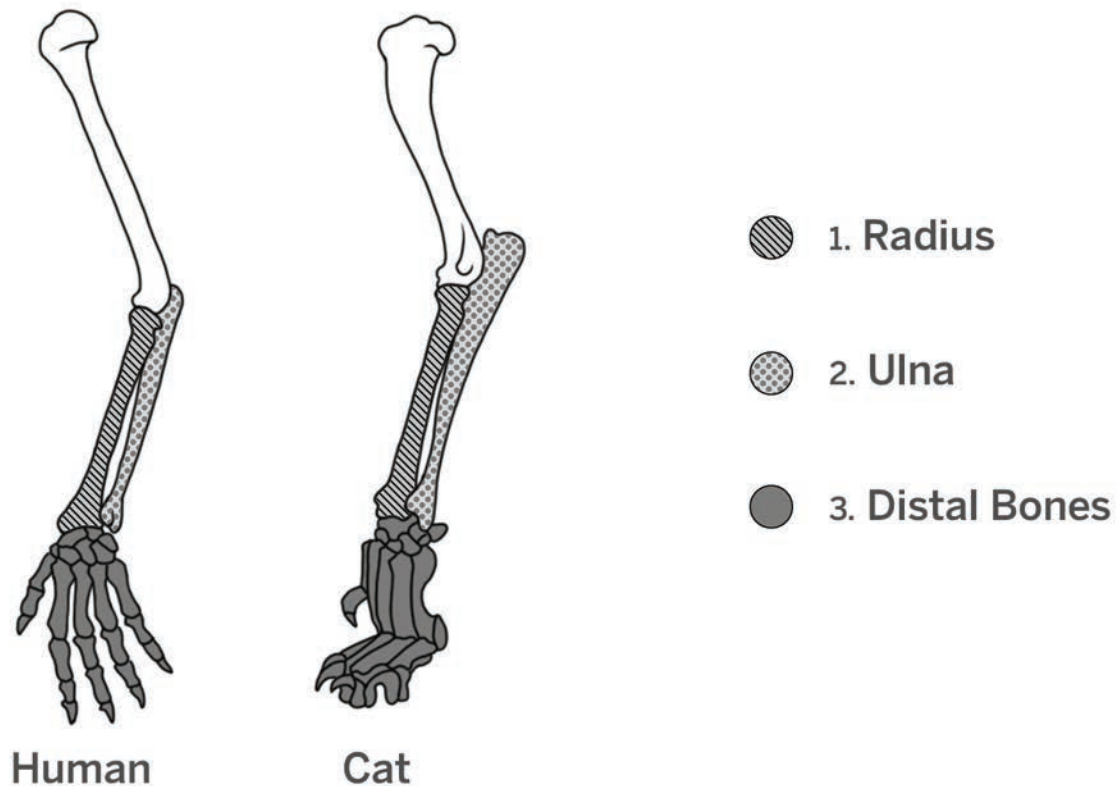
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Date: _____

Warm-Up

Similar Structures in Different Species

Compare the illustrations of bones in the two limbs below: the human arm and the cat front leg. Your teacher will also project an image where the bones are color coded to help you see similarities.



Describe all the ways in which the human arm and the cat's front leg are similar.

Name: _____

Date: _____

Reading “How You Are Like a Blue Whale”

1. Read and annotate the article “How You Are Like a Blue Whale.”
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

What is something about the text that you discussed with your partner?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____

Date: _____

Homework: Exploring the *Evolutionary History* Simulation

Open the *Evolutionary History* Sim in Free Explore mode and complete the scavenger hunt questions below.

1. In Map View, what happens when you press one of the orange markers? (check one)
 - ☐ You see a particular fossil discovery at that location.
 - ☐ You see what city is located in that part of the world.
 - ☐ You see what museum is located in that area.
 - ☐ You go to the evolutionary tree.
2. In Map View, how can you add a fossil to the Fossil Collection? (check one)
 - ☐ By dragging fossils into the Fossil Collection.
 - ☐ By pressing ADD TO COLLECTION in the fossil's popup window.
 - ☐ By pressing the "+" button at the bottom of the screen.
 - ☐ By doing any of the above.
3. Add one or two fossils to your collection, then go to Tree View. What happens when you select rows in the Tree Navigation window on the bottom left of Tree View? (check one)
 - ☐ You go to a new fossil discovery on the Map.
 - ☐ You can read about one of the living species on the tree.
 - ☐ You can read about one of the fossil species on the tree.
 - ☐ You explore one branch of the evolutionary tree in more detail.
4. Take one fossil from the Fossil Collection and drag it onto the Tree to figure out where it belongs. Where did your fossil belong? (check one)
 - ☐ In All Life
 - ☐ In Animals
 - ☐ In Vertebrates
 - ☐ In Laurasiatheria
 - ☐ In Artiodactyls
 - ☐ In Cetaceans
5. Select a few of the orange and white "i" icons on the tree branches. What happens when you select these? (check one)
 - ☐ You see pictures of a particular living species.
 - ☐ You see pictures of a particular fossil species.
 - ☐ You learn about specific body structures that evolved at different points on the tree.
 - ☐ You go to a new fossil discovery on the Map.

Name: _____

Date: _____

Homework: Exploring the *Evolutionary History* Simulation (continued)

6. What happens when you press STUDY next to a species on the right side of Tree View?
(check one)

- ☐ That species is added to the Fossil Collection.
- ☐ You see images and a description of that species.
- ☐ That species is placed on the Tree.
- ☐ That species is placed on the Map.

7. Press STUDY for any species on the Tree and read about it. What species did you read about?

Name: _____

Date: _____

Lesson 1.4: Interpreting Evolutionary Trees

In the last lesson, you read something that may have surprised you: Using shared structures such as limb bones, scientists have determined that blue whales are more like a human than a fish! What else can shared structures tell us? Today, you will return to the article “How You Are Like a Blue Whale” to find more evidence of what makes two unique species similar to each other. Then, you will use the evolutionary tree in the Sim to gather evidence about similarities between different species on Earth. Learning more about shared structures will help you figure out more about the Mystery Fossil and where it belongs.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 1 Question

- Where in the museum does this new fossil belong?

Digital Tools

- *Evolutionary History Simulation*

Vocabulary

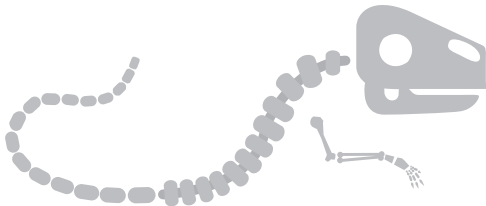
- | | | |
|---------------------------------|------------------|--------------------|
| • body structure | • evolution | • shared structure |
| • common ancestor
population | • paleontologist | • species |
| • descendant species | • related | |

Name: _____

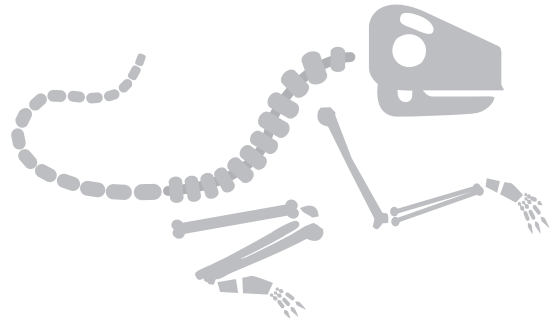
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Warm-Up

Part 1: Comparing Body Structures



Species A



Species B

Shared structures are body structures that feature the same parts (for example, bones) in the same pattern and relative position in more than one organism.

Above are the bones of two imaginary species. Look at the body structures for both species, then select which body structures these two species share.

- ☐ skull ☐ backbone ☐ tail ☐ front limb ☐ back limb

Part 2: Common Ancestor Poll

Use your ideas from the Warm-Up to answer the following poll.

Do you think the two species from the Warm-Up have any ancestors in common?

☐ yes

☐ no

Name: _____

Date: _____

Rereading “How You Are Like a Blue Whale”

Take another look at the “Interpreting Evolutionary Trees” diagram and caption from the article “How You Are Like a Blue Whale” and answer the guiding questions below. As you read, think about this question: *Why do different species share similar structures?*

Guiding Questions

1. What are the descendants in this diagram?

2. What body structures did the common ancestor have?

3. What are the body structures that both descendants share with this common ancestor?

4. Why do paleontologists make diagrams like this? What are they trying to show?

Name: _____

Date: _____

Tracing Structures in an Evolutionary Tree

Part 1: Tracing a Shared Body Structure

Goals:

- Explore Tree View of the Sim to answer the Investigation Question: *Why do different species share similar structures?*
- Find two different species with a shared body structure.

What body structure will you explore? (check one)

- ☐ vertebral column (backbone)
- ☐ jaws
- ☐ humerus/radius/ulna
- ☐ neck
- ☐ limbs with digits (toes, for example)

Do:

- Open the Sim in Free Explore mode and press TREE to open Tree View.
- Navigate through the evolutionary tree and press each of the “i” icons on the tree branches as you go.
- Read the text from each icon until you find the “i” icon that has the body structure you are exploring.
- Follow the tree branches to the right of this icon to find two living species that have this body structure.
- Try to find species that are very different from one another by expanding branches of the evolutionary tree at the bottom of the screen.

Tips:

- The “i” icons are the orange and white circles with the letter “i” in the center.
- Navigate through the evolutionary tree by pressing on rows in the Tree Navigation window or by pressing the arrows in the main window.

Name: _____ Date: _____

Tracing Structures in an Evolutionary Tree (continued)

1. Name the two species you found that share the body structure you explored.

2. Use words from the word bank to fill in the blanks in the sentences below.

Species inherit _____ from _____. If two living species have some of the same _____, this means that they are probably _____ of _____ that also had those _____.

Word Bank

body structures	ancestors	descendants	a common ancestor population
-----------------	-----------	-------------	------------------------------

Part 2: Returning to the Common Ancestor Poll

Use your ideas from today's lesson to answer the following class poll question again.

Do you think the two species from the Warm-Up (on page 15) have a common ancestor?

☐ yes

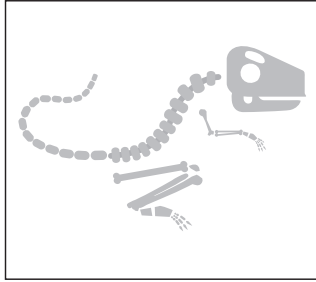
☐ no

Name: _____

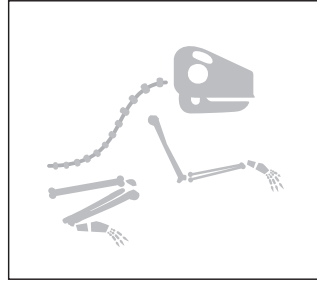
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Homework: Imagining a Common Ancestor

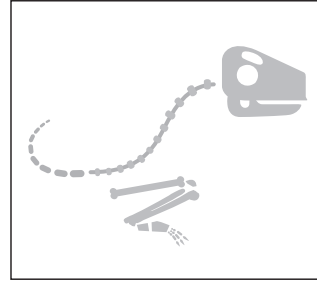
Look back at the images of the bone structures from the two imaginary species that you compared during the Warm-Up (on page 15). Look at the shared structures of these two species. Which of the four fossils below looks the most like the common ancestor of these two species? (You can choose up to two fossils.)



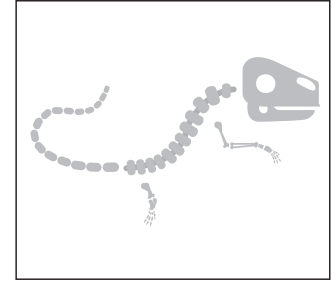
Fossil 1



Fossil 2



Fossil 3



Fossil 4

- ☐ Fossil 1 looks most like the common ancestor of the two species.
- ☐ Fossil 2 looks most like the common ancestor of the two species.
- ☐ Fossil 3 looks most like the common ancestor of the two species.
- ☐ Fossil 4 looks most like the common ancestor of the two species.

Explain your answer choices. Describe the shared structures between the two living species and the fossil species that you chose. Be sure to say which fossil species you are describing.

Name: _____

Date: _____

Lesson 1.5: Finding Similarities with the Mystery Fossil

Your work continues with an update from the Natural History Museum Director, Andre Mosley: We now have a complete skeleton for the Mystery Fossil! New and surprising information from the complete skeleton will not only tell you something about the life of this creature that lived long ago, but it will also help you to figure out where the Mystery Fossil should be placed in the museum: with the whales, the wolves, or the crocodiles. You will also spend some time working with the *Evolutionary History* Modeling Tool today, and you will start to make your own model explaining how the Mystery Fossil could be related to other species. This model will help you to share your knowledge in the same way as paleontologists do.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 1 Question

- Where in the museum does this new fossil belong?

Key Concepts

- Species inherit their body structures from their ancestor populations.
- Body structures that are shared between two species are evidence that these two species inherited the shared structures from a common ancestor population.

Digital Tools

- *Evolutionary History* Modeling Tool activity: Shared Structures

Vocabulary

- | | | |
|------------------------------|------------------|---------------------|
| • body structure | • evolution | • shared structures |
| • common ancestor population | • paleontologist | • species |
| • descendant species | • related | |

Name: _____

Date: _____

Warm-Up

To: Student Paleontologists

From: Andre Mosley, Natural History Museum Director

Subject: New Findings About the Mystery Fossil

We have finished putting the bones of the Mystery Fossil back together, and we found something amazing: The Mystery Fossil was pregnant when it died. A smaller fossil with structures just like the Mystery Fossil was found inside the body of the Mystery Fossil.

I know you are working to decide where to place the Mystery Fossil in the museum and that you are using similar structures to help you decide where to place it. Maybe the fossil we found inside can help you decide what the Mystery Fossil is most similar to: whales, wolves, or crocodiles.

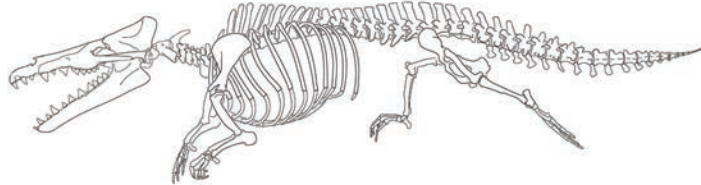
The discovery that the Mystery Fossil was pregnant tells us that the Mystery Fossil came from a species that gave live birth. What do you know about how whales, wolves, and crocodiles carry their babies?

Name: _____

Date: _____

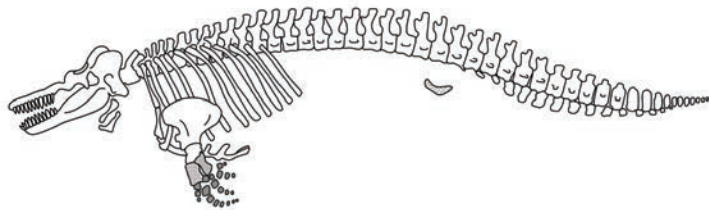
Comparing the Mystery Fossil to Whales and Wolves

Paleontologists look for shared body structures in different species. There are many different body structures and some of them can be difficult to find. Which of the body structures in the list can you find in each of the species below?



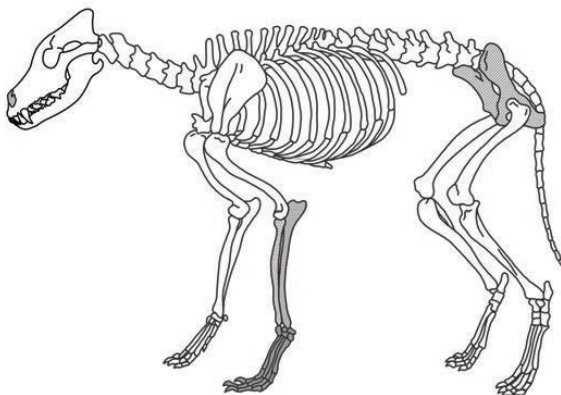
Select all the structures that the **Mystery Fossil** has:

- | | |
|--|--|
| ☐ skull | ☐ rib bones |
| ☐ teeth | ☐ backbone |
| ☐ neck bones | ☐ hip bone (pelvis) |
| ☐ "one, two, many" front limb structure | ☐ back limbs (legs) |
| | ☐ tail |



Select all the structures that the **whale** has:

- | | |
|--|--|
| ☐ skull | ☐ rib bones |
| ☐ teeth | ☐ backbone |
| ☐ neck bones | ☐ hip bone (pelvis) |
| ☐ "one, two, many" front limb structure | ☐ back limbs (legs) |
| | ☐ tail |



Select all the structures that the **wolf** has:

- | | |
|--|--|
| ☐ skull | ☐ rib bones |
| ☐ teeth | ☐ backbone |
| ☐ neck bones | ☐ hip bone (pelvis) |
| ☐ "one, two, many" front limb structure | ☐ back limbs (legs) |
| | ☐ tail |

Name: _____

Date: _____

Comparing the Mystery Fossil to Whales and Wolves (continued)

Discussion Questions

1. Which bone structures are similar between the Mystery Fossil, whale, and wolf?
2. Based on your answer to Question 1, what structures would a common ancestor of whales, wolves, and the Mystery Fossil share?

Name: _____

Date: _____

Modeling Body Structures

1. Open the *Evolutionary History* Modeling Tool activity: Shared Structures.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

Goal: Determine the relationships between the three species and predict the structures of Species A.

Do:

- Press each structure of Species A and choose the most likely appearance of the structure.
 - Use a blue structure to indicate that Species A has that structure.
 - Use an X to indicate that Species A does not have that structure.
 - Use a gray structure with a question mark to indicate that you do not know whether Species A has that structure.
 - Press INDICATE ORGANISM TYPE and select an option for each species.
1. Write a “√” next to the structures of Species A that you were able to predict, an “X” next to structures that Species A does not have, and a “?” next to structures that you’re unsure about.
 - skull _____
 - front limb structure _____
 - backbone _____
 - back limbs (legs) _____
 - tail _____
 2. Which type of organism (common ancestor population or descendant species) is each of the species?
 - Species A: _____
 - Species B: _____
 - Species C: _____

3. How do you know which structures are present in Species A?

Name: _____

Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out where to put the Mystery Fossil in the museum?

1. I understand how the Mystery Fossil can have shared body structures with whales and wolves. (check one)

☐ yes ☐ not yet

Explain your answer choice.

2. I understand why the shared body structures between the Mystery Fossil, whales, and wolves also have differences. (check one)

☐ yes ☐ not yet

Explain your answer choice.

3. I understand the process that happened to make the Mystery Fossil, whales, and wolves change from a common ancestor population. (check one)

☐ yes ☐ not yet

Explain your answer choice.

4. I understand why the Mystery Fossil, whales, and wolves look very different from one another. (check one)

☐ yes ☐ not yet

Explain your answer choice.

Name: _____

Date: _____

Homework: Check Your Understanding (continued)

5. I understand what evidence I could use to decide where in the museum to place the Mystery Fossil. (check one)

☐ yes ☐ not yet

Explain your answer choice.

6. What are you still wondering about as you consider similarities and differences between species?

Name: _____

Date: _____

Chapter 2: Investigating Body Structure Differences

Chapter Overview

Now that you know about how paleontologists use similarities to explain common ancestry between different species, you might be wondering why organisms that evolved from the same common ancestor population can be so different: Why is a bat wing so different from a dog's foot? Why is the skull of a giraffe so different from the skull of a crocodile? In this chapter you will focus on understanding differences in bone structures. You will be able to explain why structures that are shared between species can look so different. This will help you to explain why the Mystery Fossil looks very different from whales and wolves, even if these three types of organisms are related.



Name: _____

Date: _____

Lesson 2.1: How Body Structures Differ

Now that you have learned why very different species can have shared structures, you will begin to think about how species with a common ancestor population can be so different from one another. Today you will examine the front limbs of several species and make careful, precise observations. You will also collect information about how each species lived to help you better understand why their front limbs might have differences. Understanding how and why these similar structures are different is an important next step to help you decide exactly where in the museum the Mystery Fossil should—or should not—be placed. Good luck!

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 2 Question

- How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?

Vocabulary

- | | | |
|------------------------------|----------------------|--------------------|
| • body structure | • descendant species | • shared structure |
| • common ancestor population | • evolution | • species |
| | • paleontologist | |

Digital Tools

- *Evolutionary History* Simulation

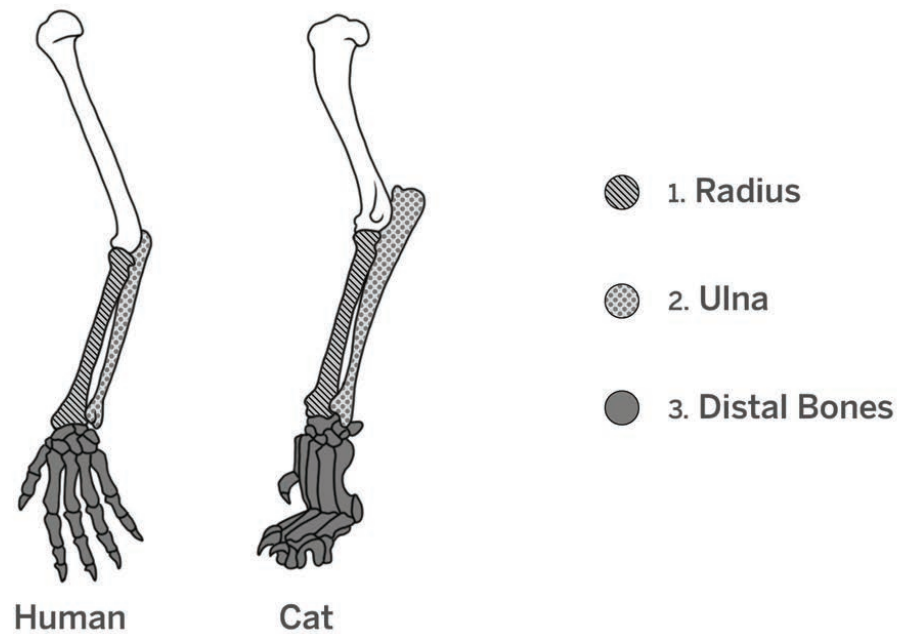
Name: _____

Date: _____

Warm-Up

Differences in Body Structures

This illustration shows the front limbs of a human and a cat (a human arm and a cat's front leg). Both have the same bones, but these bones look very different in the human and the cat.



Using careful observation, describe at least two differences between these two limbs. Start with the hand bones.

Name: _____

Date: _____

Observing Organisms to Consider Differences

Part 1: Observing Species' Front Limbs

Record your careful observations of the zoomed-in illustrations of front limbs for the dire wolf, the fruit bat, and *Titanotylopus*.



Record your observations about the front limb of the dire wolf.



Record your observations about the front limb of the fruit bat.



Record your observations about the front limb of *Titanotylopus*.

Name: _____

Date: _____

Observing Organisms to Consider Differences (continued)

Part 2: Gathering Evidence from Species Cards

Read about each species on the cards that your teacher provided. For each species, record information about its environment and how populations survive. This might help you explain why the bones for each species are shaped the way that they are.

Dire wolves: Information about their environment and how they survived.

Fruit bats: Information about their environment and how they survive.

***Titanotylopus*:** Information about their environment and how they survived.

Name: _____

Date: _____

Homework: Analyzing Differences in Shared Structures

Goal: Discover and explain differences in a shared structure.

Do:

- Open Mammals Mode of the Sim and stay in Map View.
- Find *Kutchicetus* and Saber-Toothed Cat in the Fossils Collection and open their Study Windows.
- Use the text descriptions as well as the images in the Structures Tab to answer the questions below.

Investigate all the shared structures you can find (Hint: You can look at highlighted structures 1–5 as well as unhighlighted structures). Find one shared structure that is very different between the two species.

1. What structure did you find? _____

2. Describe the differences in this shared structure.

3. Read the text for both species to learn about the environments that each of them lived in. Thinking about the environments of the two species, why do you think this bone structure was different?

Name: _____

Date: _____

Lesson 2.2: Where Do Species Come From?

How do species that come from a common ancestor population and have many body structures in common become so different from one another in certain ways? Today you will learn how the body structures of one descendant species changed greatly from the body structures of its ancestor population. This will help you to visualize how the whale, the wolf, and the Mystery Fossil could have all come from a common ancestor population, and how the body structures of each of these types of organisms have changed in certain ways but remained stable in other ways.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 2 Question

- How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?

Vocabulary

- | | | |
|------------------------------|--------------------|-------------|
| • body structure | • evolution | • species |
| • common ancestor population | • shared structure | • stability |
| • descendant species | • speciation | |

Name: _____

Date: _____

Warm-Up

Thinking About Western Gorillas and European Moles

Western gorillas and European moles are very different species that live in different environments. Look at their hands and think about what these organisms need to do each day to survive, then answer the questions below.

western gorilla



European mole



Describe the shape of the western gorilla's hands:

Why do you think the western gorilla's hands are shaped the way they are? What does the western gorilla use its hands to do?

Describe the shape of the European mole's hands:

Name: _____

Date: _____

Warm-Up (continued)

Why do you think the European mole's hands are shaped the way they are? What does the European mole use its hands to do?

Name: _____

Date: _____

Reading *Where Do Species Come From?*

1. Choose one of the *Where Do Species Come From?* articles, record which article you chose below, then read and annotate the article.
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

Which article will you read?

☐ "Galápagos Tortoises"

☐ "Polar Bears"

☐ "Flightless Ducks"

Rate how successful you were at using Active Reading skills by responding to the following statement.

As I read, I paid attention to my own understanding and recorded my thoughts and questions.

☐ Never

☐ Almost never

☐ Sometimes

☐ Frequently/often

☐ All the time

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____

Date: _____

Lesson 2.3: Investigating Speciation

You've been investigating how different species can share some body structures, like front limbs with the one-two-many arrangement, because they share a common ancestor. We've also been thinking about how large differences can be found, even between species that share a common ancestor population. Today you will return to your *Where Do Species Come From?* article and reexamine what happened when a population of organisms got separated into a new environment. Next, you will use the *Natural Selection* Simulation to help you investigate how the environment influences body structure changes.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 2 Question

- How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?

Digital Tools

- *Natural Selection* Simulation
- *Evolutionary History* Modeling Tool activity: Structure Differences

Vocabulary

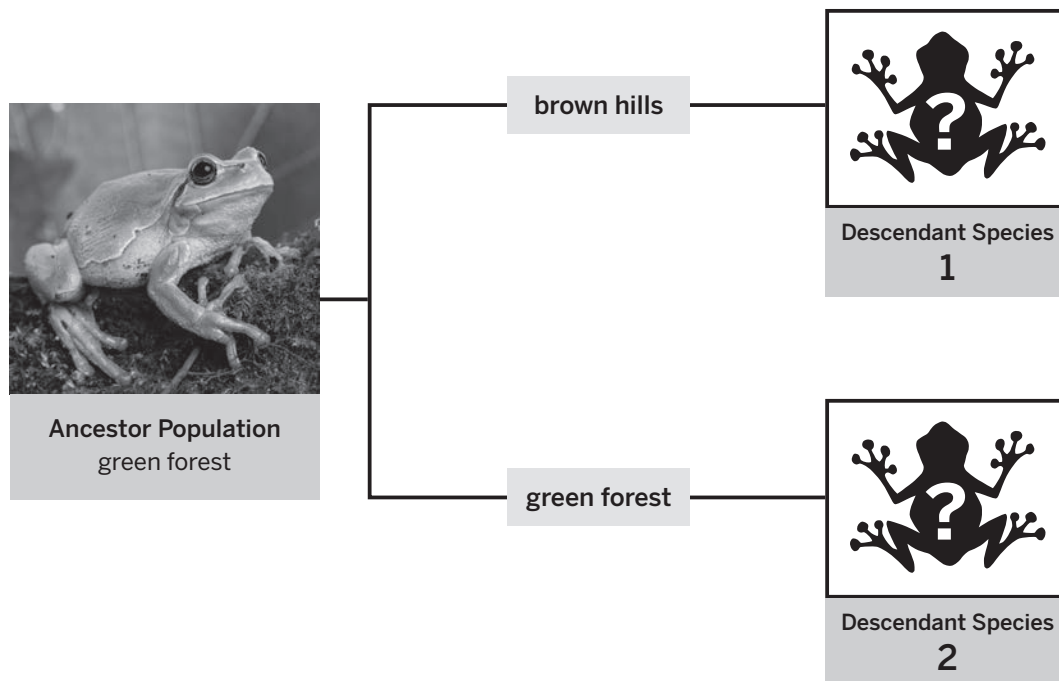
- | | | |
|------------------------------|--------------------|-------------|
| • body structure | • evolution | • species |
| • common ancestor population | • shared structure | • stability |
| • descendant species | • speciation | |

Name: _____

Date: _____

Warm-Up

Imagine a population of frogs that live in the forest. The frogs have a green coloring on top that helps them blend into the forest so they are not noticed by predators. Imagine that half of this population stayed in the forest and the other half of the population moved to the hills above the forest, which are drier, with some brown grass and brown soil.



Which population of frogs is likely to have more changes after many generations?

- ☐ Descendant Species 1: The frogs in the brown hills.
- ☐ Descendant Species 2: The frogs in the green forest.
- ☐ Both are equally likely to have changes in their structures.

Explain the reasoning for your answer.

Name: _____

Date: _____

Rereading *Where Do Species Come From?*

Reread paragraphs 2 and 3 from the article you read in the previous lesson and answer the questions. As you read, you may want to highlight or annotate parts of the text that help you to answer the questions.

Article you read in the previous lesson: _____

Guiding Questions

1. How did the original population that became two descendant species first become separated?

2. One of the populations that was separated had structures that changed over time. Describe the changes that happened and why they happened:

3. Why did the other population in the article stay mostly the same (stable)?

Name: _____

Date: _____

Ostrilope Populations in Changing Environments

Part 1

A common ancestor population of ostrilopes was split into two different environments: Environment A and Environment B.

Each pair will model one of these environments in the *Natural Selection* Simulation, and you will both compare the descendant species that come from these two populations. First, predict whether each ostrilope population will change, and if so, how it will change.

Reminders:

- Ostrilopes with longer necks can reach and eat taller thornpalms.
- Ostrilopes with stronger jaws can eat thornpalms with larger thorns.

Pair A:

You will model the population in Environment A, which changed to have some taller thornpalms.

Do you think the population in Environment A will remain stable or change over time?

☐ The population will remain stable. ☐ The population will change.

If you think it will change, what do you think will happen to the ostrilope population in Environment A?

After you make your predictions, continue to Part 2 on the next page and follow the directions for Pair A in the table, then answer the questions below the table.

Pair B:

You will model Environment B, which changed to have some thornpalms with larger thorns.

Do you think the population in Environment B will remain stable or change over time?

☐ The population will remain stable. ☐ The population will change.

If you think it will change, what do you think will happen to the ostrilope population in Environment B?

After you make your predictions, continue to Part 2 on the next page, follow the directions for Pair B in the table, then answer the questions below the table.

Name: _____

Date: _____

Ostrilope Populations in Changing Environments (continued)

Part 2

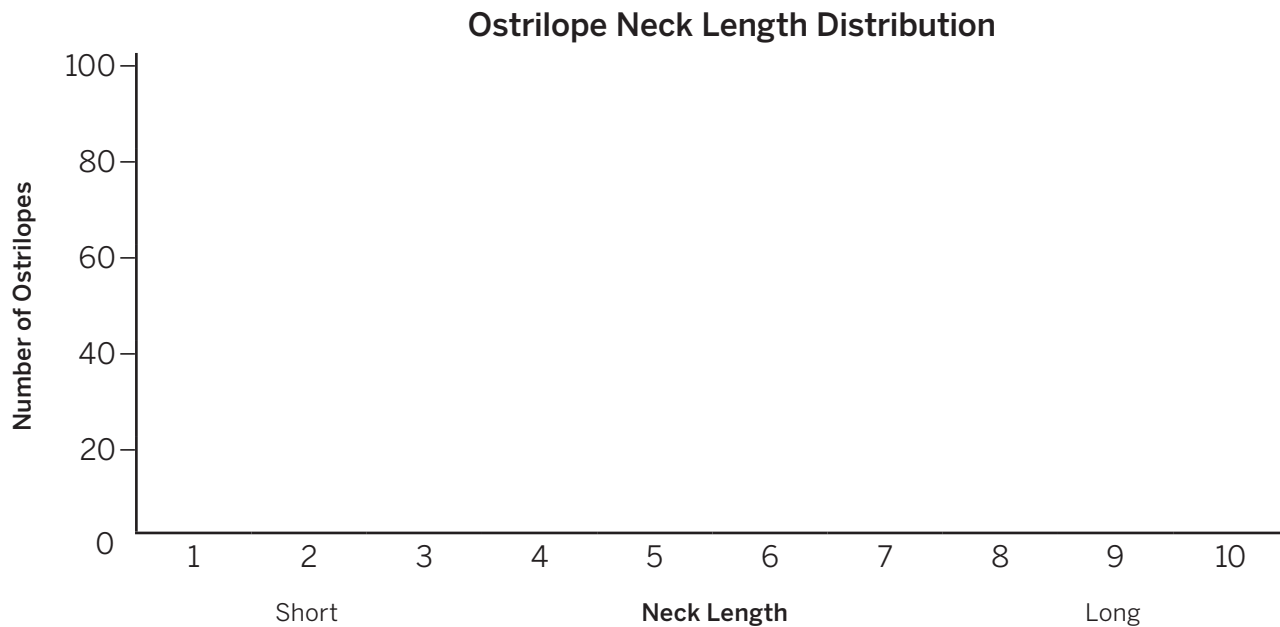
Pair A: Ostrilopes and Taller Thornpalms	Pair B: Ostrilopes and Thornpalms with Larger Thorns
• Open the <i>Natural Selection</i> Simulation and use the menu in the upper left corner to open the From One Species to Two mode. • Press REBUILD if you or your groupmates have made any previous changes to this mode on this device. • Press the thornpalm icon. • Change the most common thornpalm height to 4. • Change the thornpalm height variation to Medium. • Press RUN and observe changes to Population A over 50 generations. Tip: increase the speed to 4x. • Press ANALYZE to closely observe the ostrilope histograms.	• Open the <i>Natural Selection</i> Simulation and use the menu in the upper left corner to open the From One Species to Two mode. • Press REBUILD if you or your groupmates have made any previous changes to this mode on this device. • Press the thornpalm icon. • Change the most common thornpalm thorn size to 4. • Change the thornpalm thorn size variation to Medium. • Press RUN and observe changes to Population B over 50 generations. Tip: increase the speed to 4x. • Press ANALYZE to closely observe the ostrilope histograms.

Name: _____

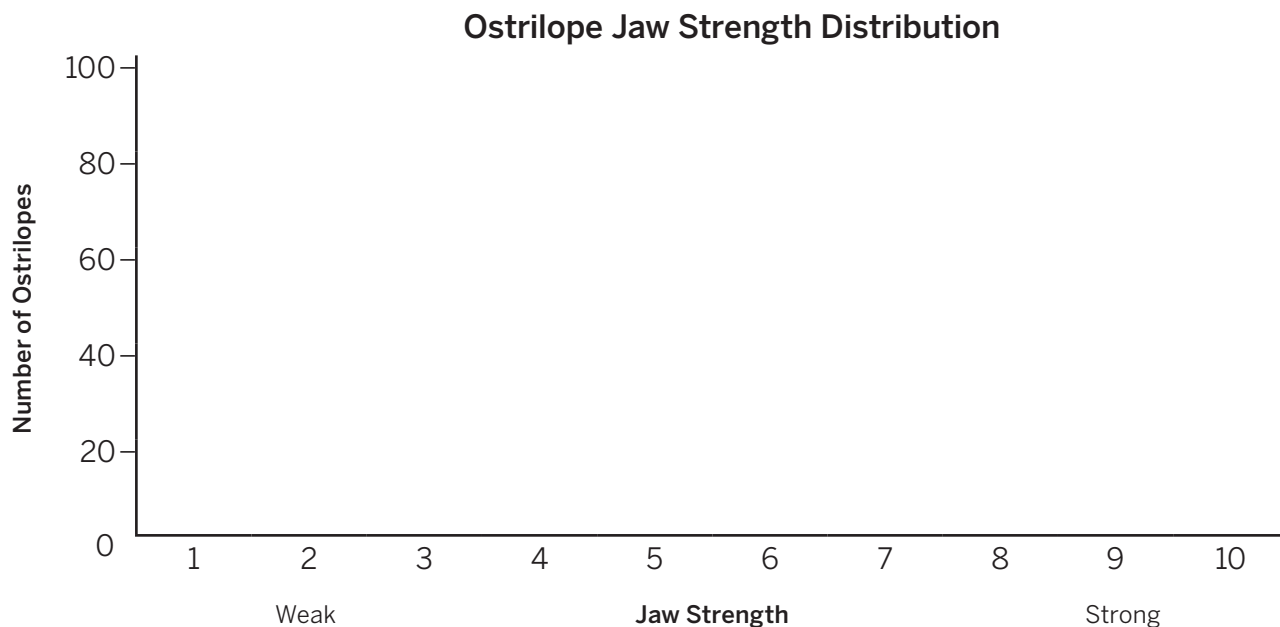
Date: _____

Ostrilope Populations in Changing Environments (continued)

Draw the histogram of Ostrilope Neck Length for Generation 50 and annotate it to describe any change that occurred.



Draw the histogram of Ostrilope Jaw Strength for Generation 50 and annotate it to describe any change that occurred.



Name: _____

Date: _____

Ostrilope Populations in Changing Environments (continued)

When you and your groupmates are finished, compare the neck lengths and jaw strengths of the populations that have lived in Environments A and B.

Compare the two environments where the ostrilope population was split. Were the environments the same or different?

☐ the same

☐ different

Compare the shared structures of the two ostrilope populations from the two environments. Are the shared structures the same or different?

☐ the same

☐ different

Write a short answer to the Investigation Question: *How does an ancestor population evolve into descendant species with differences in their shared structures?* Use evidence from the Sim activities to support your answer.

Name: _____ Date: _____

Homework: Modeling Structure Differences

1. Open the *Evolutionary History* Modeling Tool activity: Structure Differences.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

Goal: Show how a common ancestor population can become two different descendant species when it is separated into two different environments.

Do:

- Read the information in the lower left corner.
- Press INDICATE ENVIRONMENT to choose environments for Species B and C.
- Press the three structures of Species B and C to show what each structure would be like after many generations.
- Press INDICATE ORGANISM TYPE and select an option for each species.

Tip:

- It is OK to choose any of the three environments.

Fill in the blanks below to describe your model.

Species B	Species C
• Environment type: _____ • _____ tails • _____ back limbs (legs) • nostrils at the _____ of the skull	• Environment type: _____ • _____ tails • _____ back limbs (legs) • nostrils at the _____ of the skull

Explain how your model helps answer the Investigation Question: *How does an ancestor population evolve into descendant species with differences in their shared structures?*

Name: _____

Date: _____

Lesson 2.4: How Differences Build Up Over Time

You have already learned how natural selection can cause populations separated into different environments to turn into entirely new species. But how did descendant species from a common ancestor become very different from one another? Mice and elephants share a common ancestor. How could different environments explain how very different those species are? To begin to answer this question, you will compare changes in body structures that happen in populations over long periods of time, as you explore the entire history of life on Earth.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 2 Question

- How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?

Key Concepts

- In populations separated into different environments, natural selection causes different changes to happen to each population. This causes descendant species to end up with differences in their shared structures.
- When the environment is mostly the same over time, body structures stay stable. When the environment changes over time, body structures may change due to natural selection.

Vocabulary

- | | | |
|------------------------------|----------------------|--------------|
| • body structure | • descendant species | • speciation |
| • common ancestor population | • evolution | • species |
| | • evolutionary time | |

Digital Tools

- *Evolutionary History* Simulation
- *Evolutionary History* Sorting Tool activity: Evolutionary Time

Name: _____

Date: _____

Warm-Up

Thinking About Evolutionary Time

1. Open the Sorting Tool activity: Evolutionary Time.
2. When you are done sorting, press HAND IN. If you worked with a partner, write their name here:

Goal: Begin to understand evolutionary time by investigating the timeline and moving the images from the toolbar into the correct locations on the timeline.

Tips:

- The timeline moves from the past on the left to the present on the right. This means larger numbers of years ago are on the left and smaller numbers of years ago are on the right.
- 500 million years is half the length of one billion years.
- 50 million years is one twentieth the length of one billion years.
- 100 thousand years is one ten-thousandth the length of one billion years.

Name: _____

Date: _____

Structure Change Card Sort

Goal: Sort the Structure Change Cards using your ideas about how long evolutionary changes take to happen.

Instructions

- Read each card with your partner.
- Discuss how big you think the evolutionary change on each card is.
- Decide whether big changes take a long time or a short time.
- Sort the cards according to how long you think the changes took, with the longest times to the left and shortest times to the right.

Name: _____

Date: _____

Comparing Structural Changes in the Sim

Goal: Compare giraffe structures with structures of species that lived a very long time ago to help you answer the Investigation Question: *How did descendant species from a common ancestor become very different from one another?*

Open Vertebrates Mode of the Sim, press the TREE button to open Tree View.

Both pairs: Follow the instructions below to open two different pairs of Study Windows, then answer the questions that follow.

Pair A Instructions: Comparing Giraffe and *Elomeryx*

- Navigate to the Artiodactyls section of the evolutionary tree.
- Find the *Elomeryx* fossil in the Fossil Collection. (Optional: Find its location on the evolutionary tree and place it there.)
- Open the Study Windows for Giraffe and *Elomeryx*.
 - Tip: You can open fossil species' Study Windows from the Fossil Collection.
- Read the species descriptions and compare the images in the Structures Tab.

Pair B Instructions: Comparing Giraffe and *Acanthostega*

- Navigate to the Vertebrates section of the tree
- Find the *Acanthostega* fossil in the Fossil Collection. (Optional: Find its location on the evolutionary tree and place it there.)
- Navigate to the Artiodactyls section of the evolutionary tree.
- Open the Study Windows Giraffe and *Acanthostega*.
 - Tip: You can open fossil species' Study Windows from the Fossil Collection.
- Read the species descriptions and compare the images in the Structures Tab.

Discussion Questions

- How long ago did *Elomeryx* and *Acanthostega* live?
- Which structures are different between the fossil species you investigated and giraffes? Which fossil species has more different body structures compared to the giraffe?

Name: _____

Date: _____

Comparing Structural Changes in the Sim (continued)

1. Which fossil species was separated from the giraffe in the more distant past (longer ago)?

☐ *Elomeryx*

☐ *Acanthostega*

2. Fill in the blanks below with either “*Elomeryx*” or “*Acanthostega*,” then finish the sentence using the following words in your answer: *common ancestor*, *time*, *change*, and *body structures*.

The giraffe is much more different from _____ than it is from

_____ because...

Name: _____

Date: _____

Homework: Reflection

Reflecting on Evolutionary Time

Think back on today's lesson and answer the questions below.

1. Number the items in the list below from 1 to 4 (most recent event = 4, longest ago = 1).

_____ First plants

_____ Formation of Earth

_____ First humans

_____ First living things

2. Circle the phrase that makes the sentence correct.

- Larger changes to body structures in organisms take (**more time than** / **less time than** / **the same amount of time as**) smaller changes.

3. What did you find surprising or interesting about today's lesson?

Name: _____

Date: _____

Lesson 2.5: Reflecting on Differences in Body Structures

Today, you will create a model to show your understanding of how new species can evolve from a common ancestor population. Through a discussion with other student paleontologists, you will answer the question: *How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?* This discussion will bring you closer to deciding where in the museum to place the Mystery Fossil, based on what you now know about differences in shared body structures.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 2 Question

- How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?

Key Concepts

- In populations separated into different environments, natural selection causes different changes to happen to each population. This causes descendant species to end up with differences in their shared structures.
- When the environment is mostly the same over time, body structures stay stable. When the environment changes over time, body structures may change due to natural selection.
- Over many generations and very long periods of time, many small changes can build up to large differences in body structures.

Vocabulary

- | | | |
|------------------------------|----------------------|--------------------|
| • body structure | • descendant species | • shared structure |
| • claim | • evidence | • speciation |
| • common ancestor population | • evolution | • species |
| | • evolutionary time | |

Digital Tool

- *Evolutionary History Modeling Tool* activity: Population Changes

Name: _____

Date: _____

Warm-Up

Write a number (1–4) next to each of the events below to indicate the correct order.

_____ Two descendant populations are very similar but have small differences in their structures.

_____ An ancestor population is living in a stable environment.

_____ Two descendant populations look very different, even though they have many similar structures.

_____ An ancestor population gets separated into different environments.

Later in today's lesson, you will have a chance to answer the Chapter 2 Question. Take some time now to write down your ideas about this question: *How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?*

Name: _____

Date: _____

Modeling Population Changes Over Time

1. Open the *Evolutionary History* Modeling Tool activity: Population Changes. In the Modeling Tool, a population is divided into two populations in different environments. In each environment, different structures are useful for survival.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

Goal: Show how the body structures of the populations in each environment might change over time.

Do:

- Read the information at the top of the screen.
- Move organisms from the toolbar to the open locations in both branches of the tree.
- Press INDICATE ORGANISM TYPE and select an option for each organism.

Tip:

- You do not have to use all the organisms in the toolbar.

Complete the sentences below to describe your model. (Circle one bolded word for each blank.)

- At Time 1, Population A had (**short** / **medium** / **long**) tails, (**thin** / **thick**) backbones, (**small** / **medium** / **large**) back limbs (legs), and (**small** / **medium** / **large**) front limbs (arms).
- At Time 2, Population A had (**short** / **medium** / **long**) tails, (**thin** / **thick**) backbones, (**small** / **medium** / **large**) back limbs (legs), and (**small** / **medium** / **large**) front limbs (arms).
- At Time 1, Population B had (**short** / **medium** / **long**) tails, **thin** / **thick**) backbones, (**small** / **medium** / **large**) back limbs (legs), and (**small** / **medium** / **large**) front limbs (arms).
- At Time 2, Population B had (**short** / **medium** / **long**) tails, (**thin** / **thick**) backbones, (**small** / **medium** / **large**) back limbs (legs), and (**small** / **medium** / **large**) front limbs (arms).

Name: _____ Date: _____

Modeling Population Changes Over Time (continued)

Reflection Questions

1. How does this model show how species that share a common ancestor can become very different from one another?

2. What remains stable over time in your model? What changes?

Name: _____

Date: _____

Word Relationships

As you know, whales, wolves, and the Mystery Fossil have shared structures, but those structures look very different from one another. Today you will work with your group and use the Word Relationships Cards to create sentences that answer the question: *How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?*

- Use at least two different Word Relationships Cards in each sentence. In your group of four, take turns as both the speaker and the listener.
- Your group may use the same word more than once. You do not need to use all the vocabulary words.
- There are many different ways to answer the Chapter 2 Question, and you will need to create more than one sentence in order to express your ideas completely.

Word Bank

common ancestor population	descendant species	evolutionary time
shared structure	speciation	

Name: _____ Date: _____

Considering Whale and Wolf Claims

Take turns discussing the following questions with your partner:

- *Which claim do you think is best supported, based on what you know so far?*
- *Why do you think this?*

Claim 1: The Mystery Fossil belongs with the whales, in the Whale (Cetacea) exhibit.

Claim 2: The Mystery Fossil belongs with the wolves, in the Carnivore (Carnivora) exhibit.

Explain where you think the Mystery Fossil should be placed in the museum and why.

Name: _____

Date: _____

Lesson 2.7: Reviewing Ideas About How Species Change

Congratulations on your progress in understanding how species come to have structural similarities and differences. Today you will review some important ideas about evolutionary history. You'll do this first by thinking about some fascinating reptile species and then by using two simulations: the *Natural Selection* Sim and the *Evolutionary History* Sim. Different students will have slightly different activities (so be sure you note your group assignment!), but you will all be gaining experience that will help you understand the evolutionary history of the Mystery Fossil.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 2 Question

- How did wolves, whales, and the Mystery Fossil become so different from their common ancestor population?

Key Concepts

- Species inherit their body structures from their ancestor populations.
- Body structures that are shared between two species are evidence that these two species inherited the shared structures from a common ancestor population.
- In populations separated into different environments, natural selection causes different changes to happen to each population. This causes descendant species to end up with differences in their shared structures.
- When the environment is mostly the same over time, body structures stay stable. When the environment changes over time, body structures may change due to natural selection.
- Over many generations and very long periods of time, many small changes can build up to large differences in body structures.

Vocabulary

- | | | |
|------------------------------|---------------------|--------------|
| • body structure | • evolution | • speciation |
| • common ancestor population | • evolutionary time | • species |
| • descendant species | • shared structure | |

Digital Tools

- *Natural Selection* Simulation
- *Evolutionary History* Simulation

Name: _____

Date: _____

Blue Group: Warm-Up



Komodo dragon



red-tailed boa

Komodo dragons (a lizard species) and red-tailed boas (a snake species) are both reptiles. They share a common ancestor population that lived about 250 million years ago, but they have been separated in different environments, with different food sources, for millions of years. Komodo dragons and red-tailed boas have some shared structures. They also have some differences in their structures.

	Komodo dragons	Red-tailed boas
shared structures	• scales on their skin • laying eggs • forked tongue	
different structures	• legs • jagged teeth • somewhat flexible body	• no legs • teeth not jagged • very flexible body

Why do Komodo dragons and red-tailed boas have some shared structures and some different structures?

Name: _____

Date: _____

Blue Group: Ostrilope Changes Over Time

Part 1: Ostrilope Populations in Two Environments

A common ancestor population of ostrilopes was split into two separate populations: Population A and Population B.

These populations lived in two different environments.

Each pair will model one of these environments in the *Natural Selection* Simulation, and you will both compare the descendant species that come from these two populations. First, predict how each ostrilope population will change.

Reminders:

- Ostrilopes with longer necks can reach and eat taller thornpalms.
- Ostrilopes with stronger jaws can eat thornpalms with larger thorns.

Pair A:

You will model Population A, whose environment changed to have some taller thornpalms.

What do you think will happen to ostrilope Population A?

Pair B:

You will model Population B, whose environment changed to have some thornpalms with larger thorns.

What do you think will happen to ostrilope Population B?

Name: _____

Date: _____

Blue Group: Ostrilope Changes Over Time (continued)

Part 2: Testing Changes to Ostrilope Populations

Pair A Instructions:

- Open *Natural Selection* Simulation and use the menu in the upper left corner to open the Exploring Species Change mode.
- Press the thornpalm icon.
 - Adjust the thornpalm Height slider to 7.
 - Adjust the thornpalm Height Variation slider to Medium.
- Press RUN and observe changes to Population A over 50 generations.
Tip: Increase the speed to 4x.
- Press ANALYZE to closely observe the ostrilope histograms.

Both pairs record the results from Pair A's test:

After 50 generations, the most common ostrilope neck length in Descendant Species A was: _____

After 50 generations, the most common ostrilope jaw strength in Descendant Species A was: _____

Pair B Instructions:

- Open *Natural Selection* Simulation and use the menu in the upper left corner to open the Exploring Species Change mode.
- Press REBUILD if you or your partner have made any previous changes to this mode on this device.
- Press the thornpalm icon.
 - Adjust the thornpalm Thorn Size to 7.
 - Adjust the thornpalm Thorn Size Variation to Medium.
- Press RUN and observe changes to Population B over 50 generations.
Tip: Increase the speed to 4x.
- Press ANALYZE to closely observe the ostrilope histograms.

Name: _____ Date: _____

Blue Group: Ostrilope Changes Over Time (continued)

Both pairs record the results from Pair B's test:

After 50 generations, the most common ostrilope neck length in Descendant Species B was: _____

After 50 generations, the most common ostrilope jaw strength in Descendant Species B was: _____

Both pairs answer the questions below:

According to the result above, how are Population A and B different? What do you think caused this?

The two descendant species share many similarities. Why do you think this is? (Hint: Use the term *common ancestor* in your answer.)

Name: _____

Date: _____

Blue Group: Understanding Evolution from Fossils

Extinct Fish-like Species

- Open Vertebrates Mode of the *Evolutionary History* Sim, press the TREE button to open Tree View, and navigate to the Vertebrates section of the tree.
- Place these three fossil species in the three open locations on the evolutionary tree:
 - *Acanthostega*
 - *Eusthenopteron*
 - *Tiktaalik*
- Open the Study Windows for any two of these fossils. Read the summaries and inspect their structures for similarities.
 - Tip: You can open Study Windows from the Fossil Collection.

Which two fossil species did you choose to examine?

☐ *Acanthostega*

☐ *Eusthenopteron*

☐ *Tiktaalik*

Name some structures that both of these fossil species share.

Name some structures you think the common ancestor population of these two species might have had. Explain why you think the ancestor population had these structures.

Name: _____

Date: _____

Purple Group: Warm-Up



Komodo dragon



red-tailed boa

Komodo dragons (a lizard species) and red-tailed boas (a snake species) share a common ancestor population that lived about 250 million years ago. However, these two species have been separated in different environments for millions of years. Komodo dragons live on a few islands in Indonesia. They are very large lizards and can hunt for animals as large as deer. They even hunt other Komodo dragons! They hunt their prey by running after them and biting them. Red-tailed boas live in South and Central America. These snakes hunt small animals by wrapping around and crushing their prey. Then they swallow their food whole!

	Komodo dragons	Red-tailed boas
different structures	• legs • jagged teeth • armored skin • somewhat flexible body • jaw not flexible	• no legs • teeth not jagged • no armored skin • very flexible body • flexible jaw that can open very wide

Why do Komodo dragons and red-tailed boas have so many differences, even though they share a common ancestor?

Name: _____

Date: _____

Purple Group: Ostrilope Changes Over Time

Part 1: Changes to an Ostrilope Common Ancestor Population

A common ancestor population of ostrilopes was split into two separate populations: Population A and Population B.

- Over 50 generations, Population A changed to have much longer necks.
- Over 50 generations, Population B changed to have much stronger jaws.

Each pair will model one of these populations in the *Natural Selection* Simulation to try to discover what environmental change could have caused the populations to change the way they did.

Reminders:

- Ostrilopes with longer necks can reach and eat taller thornpalms.
- Ostrilopes with stronger jaws can eat thornpalms with larger thorns.

Pair A:

You will model Population A.

What environmental change could have caused Population A to evolve longer necks?

Pair B:

You will model Population B.

What environmental change could have caused Population B to evolve stronger jaws?

Name: _____

Date: _____

Purple Group: Ostrilope Changes Over Time (continued)

Part 2: Testing Environmental Changes

Pair A Instructions:

- Open *Natural Selection* Simulation and use the menu in the upper left corner to open the Exploring Species Change mode.
- In BUILD, make changes to the environment that you think will cause ostrilopes to develop longer necks.
- Press RUN and observe the results. Tip: Increase the speed to 4x.
- If the ostrilopes die off or do not develop longer necks, return to BUILD and try again.
 - Hint 1: Try increasing the variation for the feature you are adjusting using the Variation slider.
 - Hint 2: Try making smaller changes to the feature you are adjusting.
 - Hint 3: If necessary, press REBUILD to reset to the initial mode settings.
- When you are successful, observe the ostrilopes over 50 generations and press ANALYZE to closely observe the ostrilope histograms.

Both pairs record the results from Pair A's test:

What environmental change caused traits for longer necks to become more common in Population A?

Name: _____

Date: _____

Purple Group: Ostrilope Changes Over Time (continued)

Pair B Instructions:

- Open *Natural Selection* Simulation and use the menu in the upper left corner to open the Exploring Species Change mode.
- Press REBUILD if you or your partner have made any previous changes to this mode on this device.
- In BUILD, make changes to the environment that you think will cause ostrilopes to develop stronger jaws.
- Press RUN and observe the results. Tip: Increase the speed to 4x.
- If the ostrilopes die off or do not develop stronger jaws, return to BUILD and try again.
 - Hint 1: Try increasing the variation for the feature you are adjusting using the Variation slider.
 - Hint 2: Try making smaller changes to the feature you are adjusting.
 - Hint 3: If necessary, press REBUILD to reset to the initial mode settings.
- When you are successful, observe the ostrilopes over 50 generations and press ANALYZE to closely observe the ostrilope histograms.

Both pairs record the results from Pair B's test:

What environmental change caused traits for stronger jaws to become more common in Population B?

Both pairs answer the questions below:

The two descendant species share many similarities, such as the same color and amount of fur. Why do you think this is? (Hint: Use the term *common ancestor* in your answer.)

Name: _____

Date: _____

Purple Group: Ostrilope Changes Over Time (continued)

Recall the Komodo dragon and the red-tailed boa from your Warm-Up. Compared to how different these species are, the two descendant species of ostrilopes you modeled in the Sim may seem quite similar. Why do you think this is? Why do you think the Komodo dragon and the red-tailed boa are so much more different from each other compared to how different the two ostrilope populations are?

Name: _____

Date: _____

Purple Group: Understanding Evolution from Fossils

Extinct Artiodactyls

- Open Mammals Mode of the *Evolutionary History* Sim, press the TREE button to open Tree View, and navigate to the Artiodactyls section of the tree.
- Place these four fossil species in the four open locations on the evolutionary tree:
 - *Anthracotherium*
 - *Daeodon*
 - *Elomeryx*
 - *Titanotylopus*
- Open the Study Windows for any two of these fossils. Read the summaries and inspect their structures for similarities.
 - Tip: You can open Study Windows from the Fossil Collection.

Which two fossil species did you choose to examine?

- ☐ *Anthracotherium*
- ☐ *Daeodon*
- ☐ *Elomeryx*
- ☐ *Titanotylopus*

Describe some differences in the shared structures of these two fossil species.

Since these two species share a common ancestor population, what do you think could have caused these differences between them? (Hint: It might help to think about the environment each species is adapted to. You can find information about this in the Study Window text summaries for each species.)

Name: _____

Date: _____

Green Group: Warm-Up



All reptiles share a common ancestor that lived more than 300 million years ago, but many reptile species have gone extinct over time. One example of extinct reptiles are mosasaurs. These were a group of reptiles that lived in the ocean. Like other reptiles, they breathed air, had scaly skin, and shared the “one, two, many” limb structure. However, mosasaur limbs evolved into flippers for swimming, similar to a whale. All mosasaur species went extinct about 65 million years ago. Evidence from rocks indicate that an enormous asteroid hit the Earth and there was also a lot of volcanic activity around that time. Both the asteroid and the volcanoes caused big changes to the environment all over the world, including changes to the climate, atmosphere and ocean.

Why do you think the mosasaurs went extinct?

Why do you think some changes to the environment cause extinctions and some just cause changes to species' traits?

Name: _____

Date: _____

Green Group: Ostrilope Changes Over Time

Part 1: Planning for Ostrilope Extinction

A common ancestor population of ostrilopes was split into two different environments: Environment A and Environment B. The thornpalm populations were different in the two environments.

In Environment A, the ostrilope population changed but remained alive. In Environment B the ostrilope population went extinct.

Your goal is to model both environments with your pair using the *Natural Selection* Simulation. You will be using a mode where the only environmental changes you can make are to the height or thorn size of the thornpalm population that the ostrilopes use for food.

First, plan what kinds of changes you will make with your group.

Reminders:

- Ostrilopes with longer necks can reach and eat taller thornpalms.
- Ostrilopes with stronger jaws can eat thornpalms with larger thorns.

Pair A:

You will model the population in Environment A.

What environmental change could cause the ostrilope population in Environment A to change and remain alive?

Pair B:

You will model the population in Environment B.

What environmental change could cause the ostrilope population in Environment B to go extinct?

Name: _____

Date: _____

Green Group: Ostrilope Changes Over Time (continued)

Part 2: Simulating Ostrilope Extinction

Instructions:

- Open *Natural Selection* Simulation and use the menu in the upper left corner to open the Exploring Species Change mode.
- Make the one change to the thornpalm population you planned.
- Press RUN and observe the ostrilope population for at least 10 generations or until it goes extinct.
 - Tip: Increase the speed to 4x.
- If you do not observe the desired result, discuss with your group what to do differently.
 - Return to Build and press REBUILD. Make a different kind of change and observe the results.

Tips:

- Try changing the thornpalm variation.
- Do not make any changes to the ostrilope population.

Both pairs record the results from Pair A's test:

Environment A: What change did you or your groupmates make that caused the ostrilope population in Environment A to go extinct?

Both pairs record the results from Pair B's test:

Environment B: What change did you or your groupmates make that caused the ostrilope population in Environment B to go extinct?

Both pairs answer the question below:

Why do you think Environment B caused the ostrilope population go to extinct while in Environment A the ostrilopes remained alive?

Name: _____

Date: _____

Green Group: Understanding Evolution from Fossils

Extinct Organisms and their Environments

- Open Vertebrates Mode of the *Evolutionary History* Sim, press the TREE button to open Tree View, and navigate to the Vertebrates section of the tree.
- Place one of these three fossil species in the correct open location on the evolutionary tree:
 - *Acanthostega*
 - *Eusthenopteron*
 - *Tiktaalik*
- Open the Study Window for that fossil. Read the text and examine the images in the Exhibit, Appearance, and Structures Tabs.
- Based on the information provided, answer the questions below.

Which fossil species did you choose?

☐ *Acanthostega*

☐ *Eusthenopteron*

☐ *Tiktaalik*

What do you know, or what can you infer, about the environment of this species?

Come up with two possible ideas for what might have changed in the environment of this species to cause it to go extinct. (Base your ideas on what you think you have figured out about the environment of the species.)

Name: _____

Date: _____

Green Group: Understanding Evolution from Fossils (continued)

What evidence from rocks or fossils might help you figure out whether either of these ideas about the extinction actually happened?

Name: _____

Date: _____

Reviewing Ideas as a Class

1. Think back on the three activities you completed today:
 - Reptile Warm-Up
 - *Natural Selection* Sim investigation
 - *Evolutionary History* Sim investigation
2. Discuss with your partner and summarize one main idea from these activities. Use whichever words from the word bank help you explain your idea.
3. Record your main idea below.

Word Bank

body structure	evolution	speciation	common ancestor population
extinct	species	descendant population	related
environment	shared structure		

Main idea from today's work:

Name: _____

Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out where to put the Mystery Fossil in the museum?

1. I understand how the Mystery Fossil can have shared body structures with whales and wolves. (check one)

☐ yes ☐ not yet

Explain your answer choice.

2. I understand why the shared body structures between the Mystery Fossil, whales, and wolves also have differences. (check one)

☐ yes ☐ not yet

Explain your answer choice.

3. I understand the process that happened to make the Mystery Fossil, whales, and wolves change from a common ancestor population. (check one)

☐ yes ☐ not yet

Explain your answer choice.

4. I understand why the Mystery Fossil, whales, and wolves look very different from one another. (check one)

☐ yes ☐ not yet

Explain your answer choice.

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

5. I understand what evidence I could use to decide where in the museum to place the Mystery Fossil. (check one)

☐ yes ☐ not yet

Explain your answer choice.

6. What are you still wondering about as you consider similarities and differences between species?

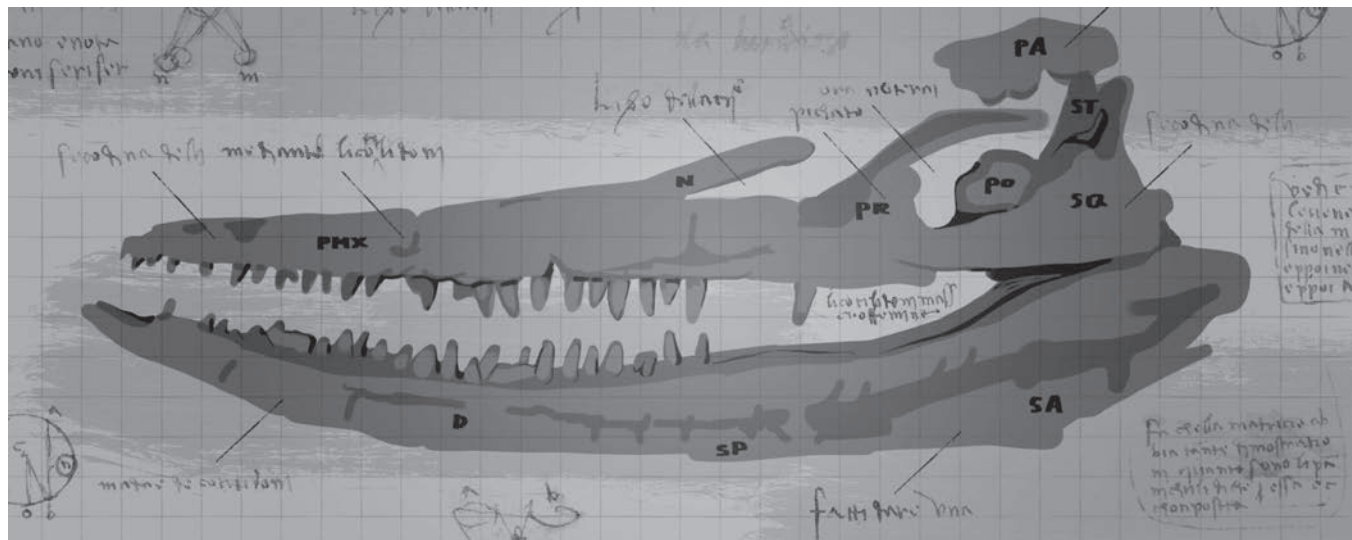
Name: _____

Date: _____

Chapter 3: Identifying Related Species

Chapter Overview

The time has come to decide where in the Natural History Museum to place the Mystery Fossil: with the whales or with the wolves? To make a final decision, you will need to look very closely and carefully at special bone structures that these three types of organisms share. Because all three have so many structures in common, you will examine a set of structures that are slightly different between them and use those structures to decide if you think the Mystery Fossil is more closely related to whales or to wolves.



Name: _____

Date: _____

Lesson 3.1: Exploring Relatedness

You have done great work studying the similarities and differences among the Mystery Fossil, whales, and wolves. Now, it's time to decide where in the museum to place the Mystery Fossil. How can we tell which species the Mystery Fossil is more closely related to? Today, you will make several models to help you better understand how paleontologists make decisions about relatedness. Just like them, you will base your decisions on your understanding of similarities and differences among the structures you examine in common ancestors and their descendant species.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 3 Question

- How can we tell if the Mystery Fossil is more closely related to wolves or to whales?

Vocabulary

- | | | |
|------------------------------|---------------------|--------------------|
| • body structure | • evolution | • related |
| • common ancestor population | • evolutionary time | • shared structure |
| • descendant species | • paleontologist | • species |

Digital Tools

- *Evolutionary History* Modeling Tool activity: Evolution

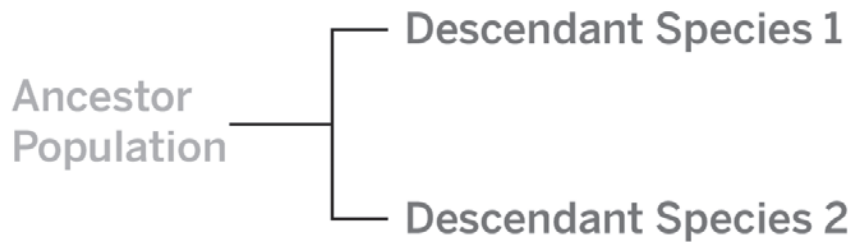
Name: _____

Date: _____

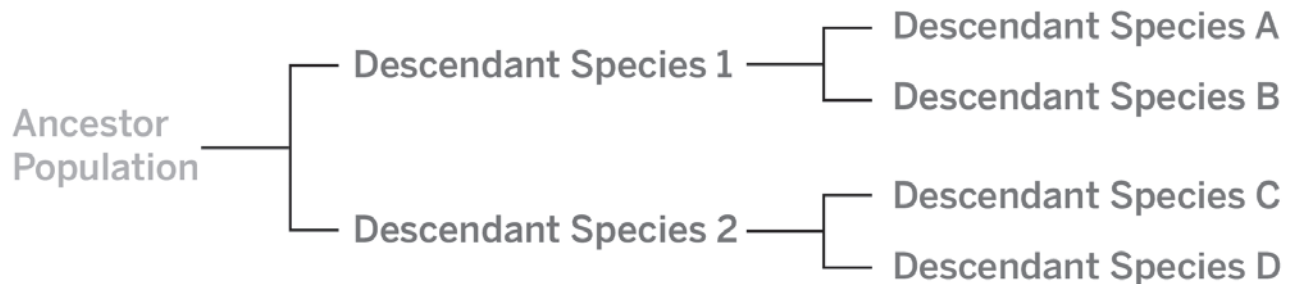
Warm-Up

Imagining Changes in New Environments

We now know that when one population is divided into two new environments, the two new populations might change and become different over time, similar to this evolutionary tree below:



Imagine that each of the new descendant species was split **again** into two **new** environments, and even more time went by. Now, there are four new environments. Use the tree below to think about the differences between those four new populations over millions of years, and answer the questions below.



Which group of descendant species is most likely to have body structures that are the most different from the ancestor population?

- ☐ Descendant Species 1 and 2
- ☐ Descendant Species A, B, C, and D

Which descendant species is most likely to have body structures that are the most different from Descendant Species B?

- ☐ Descendant Species 1
- ☐ Descendant Species C
- ☐ Descendant Species A

Name: _____

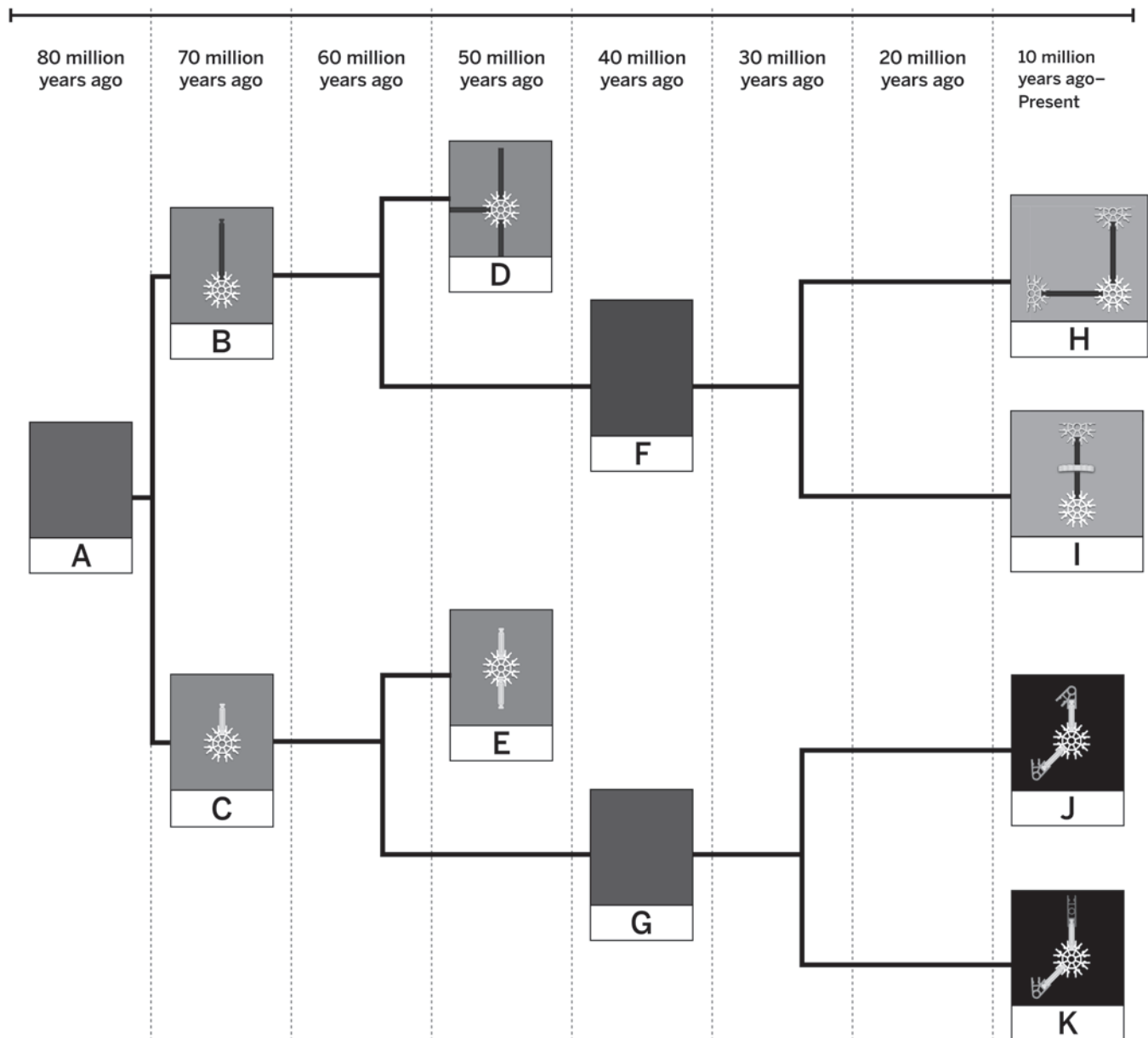
Date: _____

Modeling Evolutionary Relationships with K'NEX

Part 1

Goal: Create Species A, F, and G by using body structures that each species probably had. Look at the descendants and/or common ancestors of each missing species to figure out the likely body structures. (Hint: There is more than one possible way to build Species F and G.)

- Your teacher will project a color version of this image for reference.



Name: _____ Date: _____

K'NEX Species Structures

Examine the four living species on the evolutionary tree (H, I, J, and K) and record the structures they have in common in the table below.

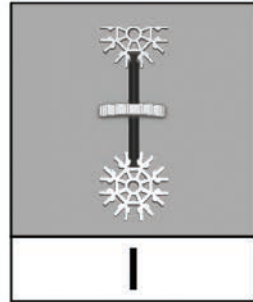
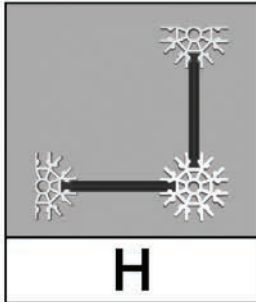
Only Species H and I have this structure	Only Species J and K have this structure	Species H, I, J, and K all have this structure

Name: _____

Date: _____

Modeling Evolutionary Relationships with K'NEX (continued)

Part 2



Which species (I, J, or K) is the closest relative to Species H? What is your evidence?

Which species (H, I, or K) is the closest relative to Species J? What is your evidence?

Name: _____

Date: _____

Modeling Shared Structures in Common Ancestors

1. Open the *Evolutionary History* Modeling Tool activity: Evolution.
2. When your model is complete, press HAND IN. If you worked with a partner, write their name here:

Goal: Use shared structures to show which species are more closely related.

Do:

- Place Species C, D, and E onto the tree based on shared structures.
- Press the NEW STRUCTURE boxes to indicate which new structure appeared on the two main tree branches.
- Press INDICATE ORGANISM TYPE and select an option for each species.
- Annotate your model to show which two species (from Species C, D, and E) are more closely related.

Tip:

- It is OK to have multiple ideas about the organism type for a species.

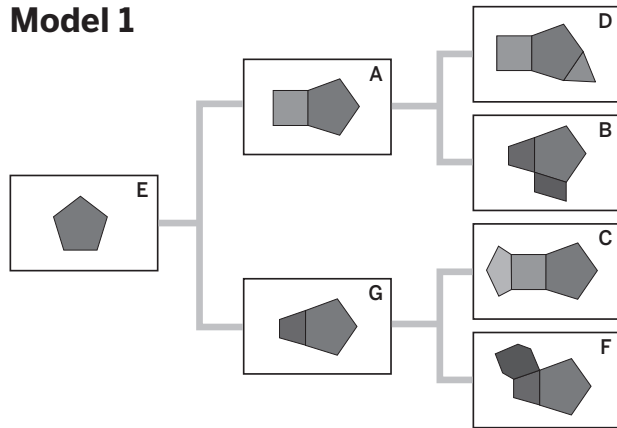
1. From species C, D, and E, which pair of species is most closely related? Explain how you know.

Name: _____

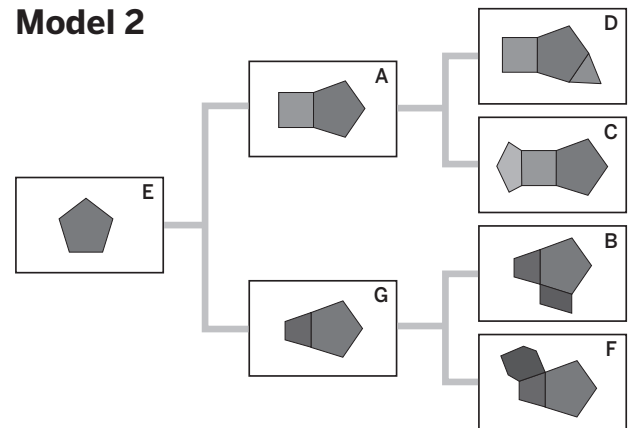
Date: _____

Homework: Relatedness and Shared Structures

Model 1



Model 2



Which model do you think is correct?

☐ Model 1

☐ Model 2

Explain how the two trees are different and why you think the model you indicated above is the correct one. (Hint: Use these words in your explanation: *shared structure*, *related*, *inherit*, *descendant species*, *ancestor population*.)

Name: _____

Date: _____

Homework: Comparing Embryos: Evidence for Common Ancestors

Read the “Comparing Embryos: Evidence for Common Ancestors” article to learn about how paleontologists examine embryos—animals that are in the early stages of development—to better understand evolution of all living things on Earth. Annotate the article as you read, then answer the questions below.

1. Why do paleontologists study embryos?

2. What is one way that fish and chickens have similar structures as embryos but different structures once they are born? Why do they have similarities like these?

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: _____

Date: _____

Lesson 3.2: Determining Species Relatedness

We know that modern species on Earth have differences in their structures that have been passed down as populations separated into new environments over time. What remains a fascinating puzzle to paleontologists is how to decide where to place fossils on the evolutionary tree. One important method paleontologists use to make these decisions is examining shared structures, especially diagnostic shared structures, to decide which species are more closely related. This fascinating work is what you will continue to do today as you prepare to make a recommendation about where to place the Mystery Fossil!

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 3 Question

- How can we tell if the Mystery Fossil is more closely related to wolves or to whales?

Key Concepts

- Among any three species, the two species that separated most recently are the most closely related to each other.

Vocabulary

- | | | |
|------------------------------|----------------------|--------------------|
| • body structure | • descendant species | • shared structure |
| • common ancestor population | • evolution | • species |
| | • related | |

Digital Tools

- *Evolutionary History Simulation*

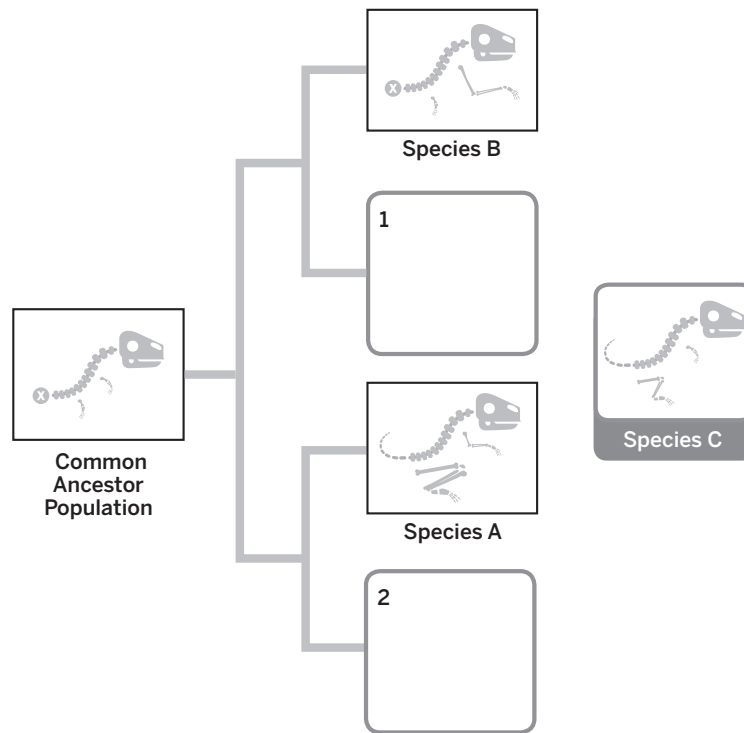
Name: _____

Date: _____

Warm-Up

Which species is Species C more closely related to?

Scientists have found a new fossil and they want to know which species it is more closely related to. What is the best place to put Species C on the evolutionary tree below?



Where should Species C be placed on the tree?

☐ space 1 ☐ space 2

What is one body structure you used to make your decision?

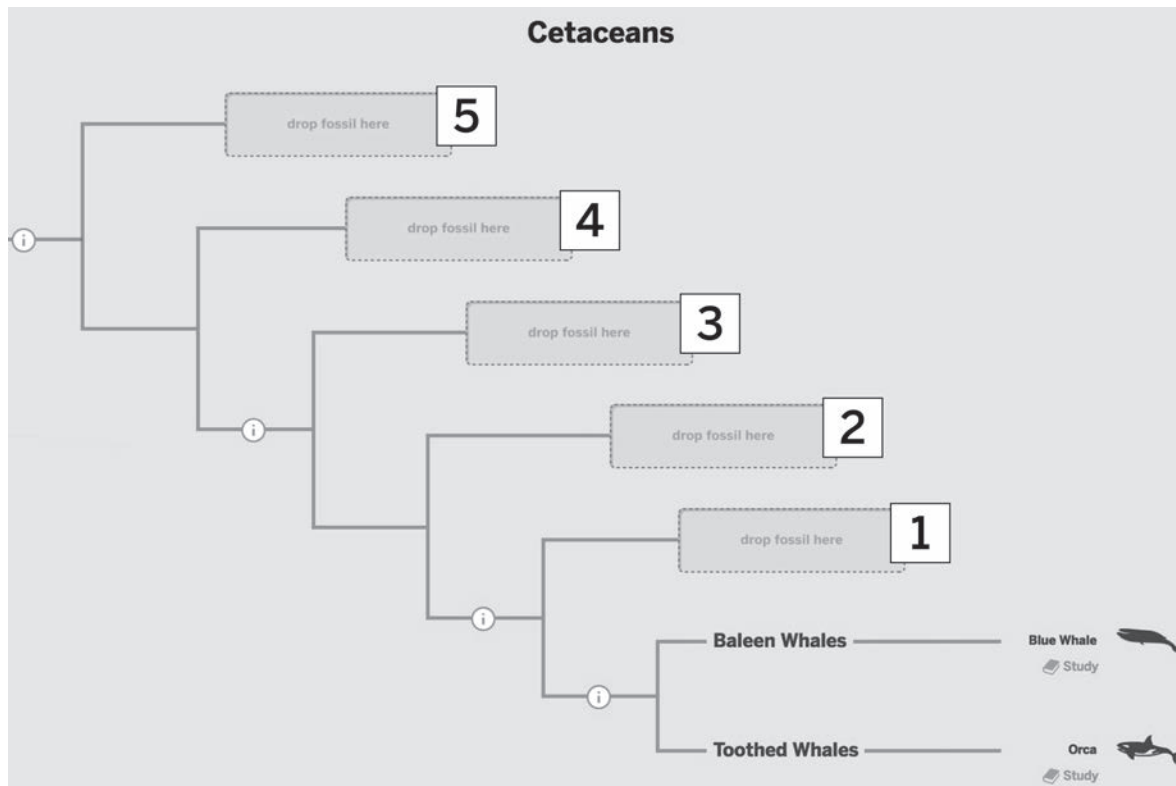
☐ skull ☐ backbone ☐ tail ☐ front limb ☐ back limb

Explain how this body structure helped you make your decision.

Name: _____

Date: _____

Investigating the Relatedness of Extinct Whales



Goal: Place all cetacean species onto the evolutionary tree by determining which species are more closely related.

Do:

- Open Cetaceans mode of the Sim, press TREE to open Tree View, and navigate to the Cetaceans branch of the tree.
- Study the Blue Whale and Orca structures.
- Read the first question below and place a fossil species into Location 1 (see image above), then repeat this for each of the locations.
 - For each location, choose between the two possible species given in the question.

Tip:

- Use the Structures tab in the Study windows and the “i” icons to help you make your decisions.

Which of these two species belongs in **Location 1**? (Hint: Investigate hind limbs and skulls.)

☐ *Dorudon*

☐ *Kutchicetus*

Name: _____

Date: _____

Investigating the Relatedness of Extinct Whales (continued)

Which of these two species belongs in **Location 2**? (Hint: Investigate limb sizes.)

☐ *Pakicetus*

☐ *Kutchicetus*

Which of these two species belongs in **Location 3**? (Hint: Investigate limb sizes.)

☐ *Indohyus*

☐ *Ambulocetus*

Which of these two species belongs in **Location 4**? (Hint: Investigate hind limb structures.)

☐ *Pakicetus*

☐ *Indohyus*

Which species is *Dorudon* more closely related to: the blue whale or *Ambulocetus*? Which diagnostic structure(s) could you use to show this?

Name: _____

Date: _____

Word Relationships

In the next lesson, you will be asked to decide whether the Mystery Fossil is more closely related to whales or wolves. To prepare for this work, answer the following question with your group: *When you compare different species, how can you tell which species are more closely related than others?*

Use at least two different Word Relationships Cards in each sentence. In your group of four, take turns as both the speaker and the listener.

- Your group may use the same word more than once. You do not need to use all the vocabulary words.
- There are many different ways to answer the question, and you will need to create more than one sentence in order to express your ideas completely.

Word Bank

common ancestor population	evolution	shared structure
descendant species	related	species

Name: _____

Date: _____

Homework: Shared Structures and Relatedness Among Carnivores

Today, you learned about how paleontologists look for shared structures to figure out how closely related different species are. In this homework activity, you will use the evolutionary tree in the Sim to look at some of the structures shared by species in the Carnivora order.

Goal: Use shared structures to place the dire wolf and saber-toothed cat on the evolutionary tree.

Do:

- Open the Mammals mode of the Sim, press TREE to open Tree View, and navigate to the Laurasiatheria branch of the tree.
- Study the following species:
 - Dire wolf and saber-toothed cat in the Fossil Collection.
 - African lion and gray wolf on the evolutionary tree.
- Use similarities and differences in shared structures to decide which species are most closely related to the dire wolf and the saber-toothed cat, and place these fossil species on the tree accordingly.

What are some structures that are shared between all four species?

What diagnostic shared structure(s) helped you decide where to place the dire wolf and the saber-toothed cat on the evolutionary tree?

Name: _____

Date: _____

Lesson 3.3: Placing the Mystery Fossil

The day has finally arrived when you'll provide your argument to the Natural History Museum director, Dr. Andre Mosley, about where in the museum you think the Mystery Fossil should be placed. To prepare for writing your argument, you will analyze and compare several body structures from each group—whales and wolves—and decide for yourself what the similarities and differences in these structures can tell you about the relationship of whales and wolves to the Mystery Fossil. Good luck with your investigation!

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 3 Question

- How can we tell if the Mystery Fossil is more closely related to wolves or to whales?

Key Concepts

- Among any three species, the two species that separated most recently are the most closely related to each other.
- When two species share a structure that is not shared with a third species, this can be evidence that the first two species are more closely related to each other than to the third species.

Vocabulary

- | | | |
|------------------------------|------------------|--------------------|
| • body structure | • evolution | • shared structure |
| • common ancestor population | • paleontologist | • speciation |
| • descendant species | • related | • species |

Name: _____

Date: _____

Warm-Up

Message from the Museum Director

To: Student Paleontologists

From: Andre Mosley, Museum Director

Subject: Update About Placement of the Mystery Fossil

The day is almost here. We are getting ready to open our new exhibits! The last piece of the puzzle is deciding where to place the Mystery Fossil in the museum, and that is where you come in.

Today, you will carefully examine information about body structures in whales, wolves, and the Mystery Fossil. Using this evidence, you will decide where to place the Mystery Fossil in the museum, with the whales or wolves. Remember, the exhibits in our museum are set up so that organisms that are more closely related are grouped together. We are excited to hear where you think the Mystery Fossil should be placed.

In which museum exhibit do you think the Mystery Fossil belongs? (check one)

- ☐ whales (Cetacea)
- ☐ wolves (Carnivora)
- ☐ not sure at this point

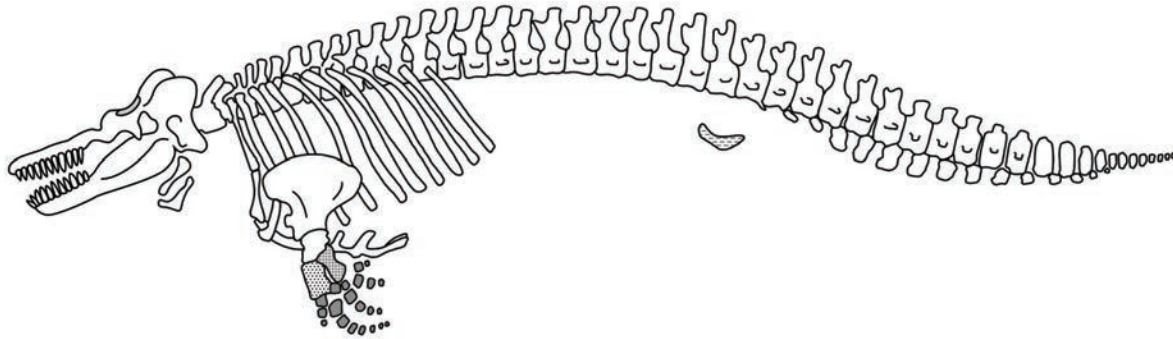
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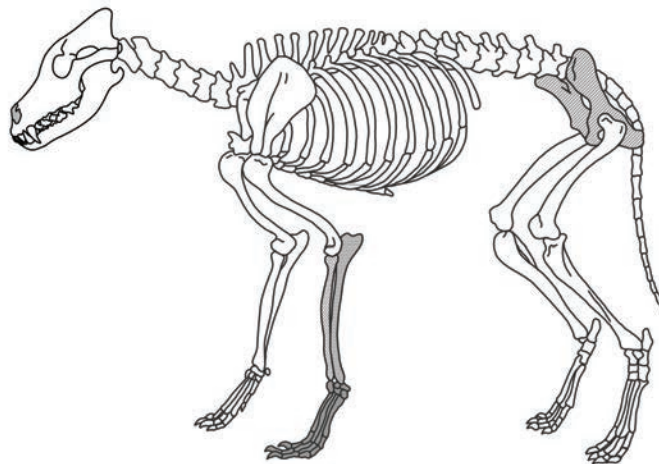
Considering Body Structures of Whales and Wolves

If they are helpful to you, examine the images below while you are sorting cards about whales and wolves in Table 1: Sorting Information About Whales and Wolves. When your teacher asks you to, answer the question below.

Orca Whale Skeleton



Gray Wolf Skeleton



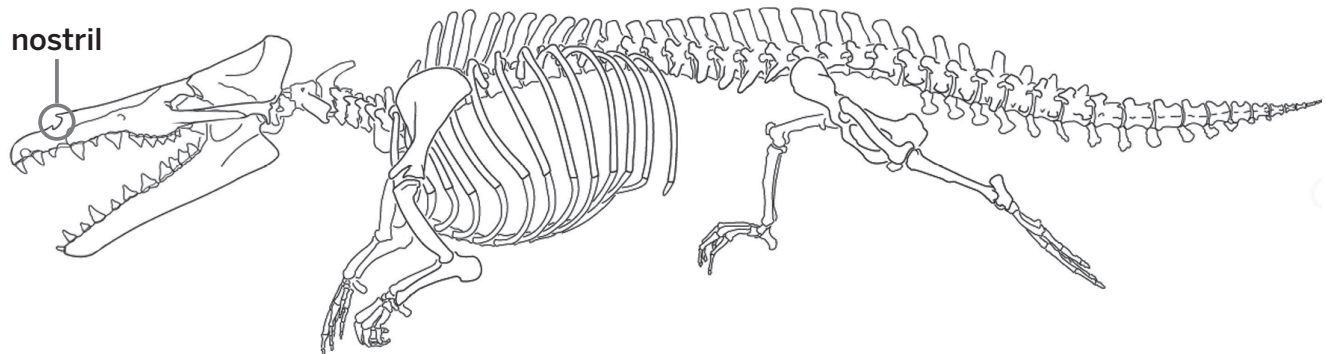
What are the diagnostic structures in both whales and wolves? What structures do they *not* share?

Name: _____

Date: _____

Examining Diagnostic Structures

Carefully examine the image below to help you fill out evidence cards about some of the structures that the Mystery Fossil shares with either whales or wolves. Then, sort the cards in Table 2: Sorting Shared Structures Among the Mystery Fossil, Whales, and Wolves. When you have completed the entire activity, answer the question below.



After analyzing the Mystery Fossil's structures and comparing them to the structures of whales and wolves, which claim do you think is more strongly supported by the evidence? (check one)

- ☐ **Claim 1:** The Mystery Fossil belongs with the whales, in the Whale (Cetacea) exhibit.
- ☐ **Claim 2:** The Mystery Fossil belongs with the wolves, in the Carnivore (Carnivora) exhibit.

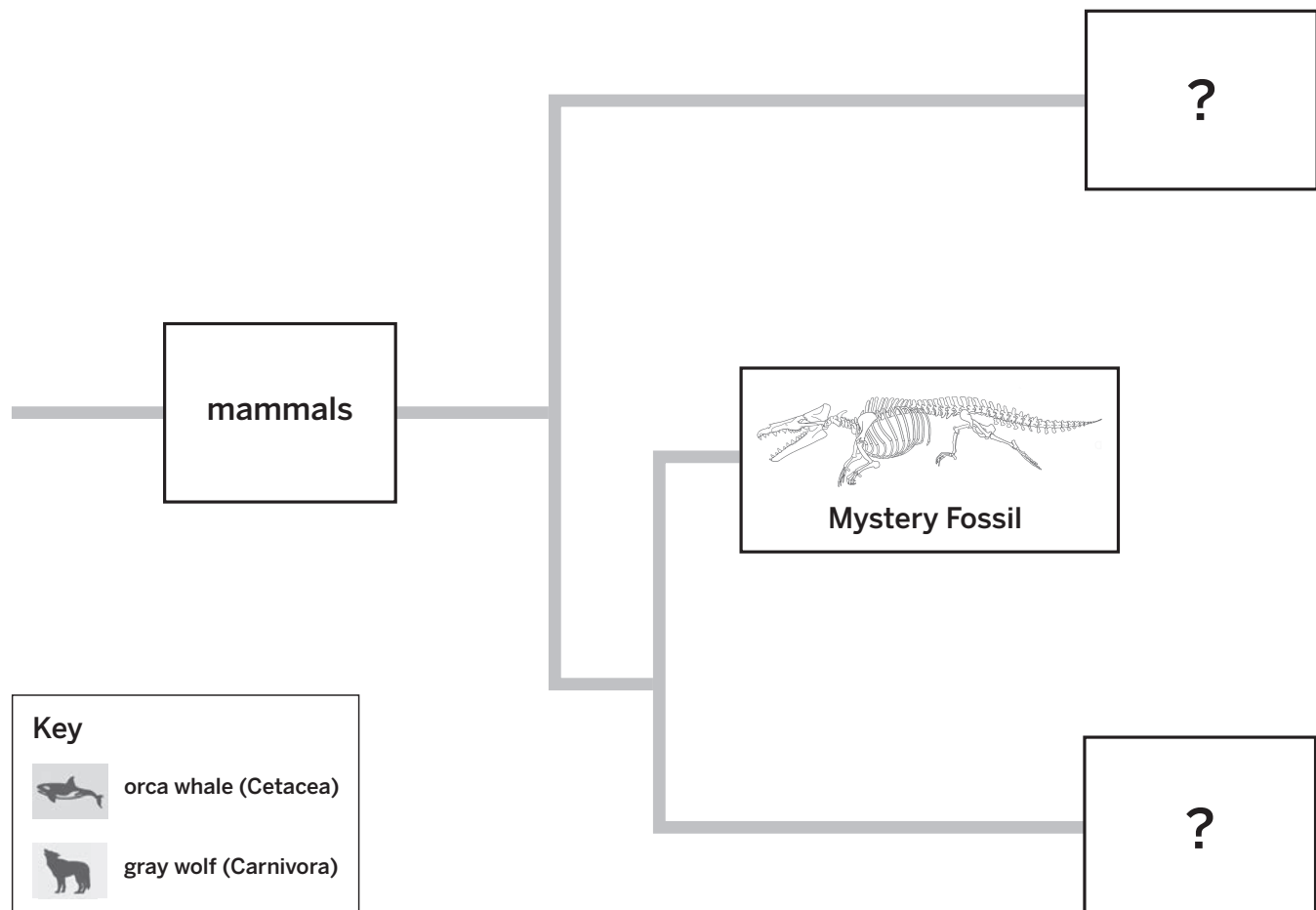
Name: _____

Date: _____

Placing the Mystery Fossil on an Evolutionary Tree

Label each question mark as orca whale or gray wolf to model your claim about where the Mystery Fossil belongs on an evolutionary tree.

Do you think the Mystery Fossil shares a more recent common ancestor with whales or with wolves?



Name: _____

Date: _____

Homework: Making an Argument About Where in the Museum to Place the Mystery Fossil

Prepare your argument about where to place the Mystery Fossil in the Natural History Museum, based on whether you think the Mystery Fossil is more closely related to whales or wolves.

Use the following resources from class as evidence to support your argument:

- Observing the Mystery Fossil Cards
- Mystery Fossil Evidence Resource

Word Bank

common ancestor population	descendant species	more closely related
speciation	shared structure	body structure
	stable	change

Explain how you know that the Mystery Fossil is related to both whales and wolves. Use the following sentence starter to help you get started:

I can tell the Mystery Fossil shares a common ancestor with both whales and wolves because...

Choose from the options below.

I believe the Mystery Fossil is more closely related to:

☐ whales

☐ wolves

Choose a claim from the options below:

☐ The Mystery Fossil belongs with the whales, in the Whale (Cetacea) exhibit.

☐ The Mystery Fossil belongs with the wolves, in the Carnivore (Carnivora) exhibit.

Name: _____ Date: _____

Homework: Making an Argument About Where in the Museum to Place the Mystery Fossil (continued)

Use evidence to write an argument explaining where you think the Mystery Fossil should be placed in the museum.

Name: _____

Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond.

Scientists investigate in order to figure things out. Are you getting closer to figuring out where to put the Mystery Fossil in the museum?

1. I understand how the Mystery Fossil can have shared body structures with whales and wolves. (check one)

☐ yes ☐ not yet

Explain your answer choice.

2. I understand why the shared body structures between the Mystery Fossil, whales, and wolves also have differences. (check one)

☐ yes ☐ not yet

Explain your answer choice.

3. I understand the process that happened to make the Mystery Fossil, whales, and wolves change from a common ancestor population. (check one)

☐ yes ☐ not yet

Explain your answer choice.

4. I understand why the Mystery Fossil, whales, and wolves look very different from one another. (check one)

☐ yes ☐ not yet

Explain your answer choice.

Name: _____ Date: _____

Homework: Check Your Understanding (continued)

5. I understand what evidence I could use to decide where in the museum to place the Mystery Fossil. (check one)

☐ yes ☐ not yet

Explain your answer choice.

6. What are you still wondering about as you consider similarities and differences between species?

Name: _____

Date: _____

Chapter 4: Science Seminar

Chapter Overview

Because of the excellent work you did with the Mystery Fossil, you have been asked to help the museum solve a different paleontological mystery: The Tometti fossil was found in a dig site in China some time ago. It was brought to a nearby museum and assembled; however, it was never identified. The museum would now like you to do the work that will help it start to identify the fossil. Your task is to decide whether you think the Tometti fossil is from a type of organism that is more closely related to ostriches or to crocodiles. You will examine evidence and discuss your thinking with the other student paleontologists, then make your own final determination: Is the Tometti fossil more closely related to ostriches or to crocodiles?



Name: _____

Date: _____

Lesson 4.1: Investigating the Tometti Fossil

Your work placing the Mystery Fossil at the Natural History Museum was so impressive that you've been asked to support another museum in their work. A paleontologist from China has a paleontological mystery that he would like you to solve. For several years now, his museum has had an interesting fossil sitting in storage, waiting to be placed on display in the museum. Dr. Michelle Tometti, the fossil's discoverer, put the fossil together and thought it was closely related to either ostriches or crocodiles. However, the paleontologist was called to work on another dig site before she could make a final decision about the fossil. You are being asked to examine the evidence to determine which species you think the Tometti fossil is more closely related to. The museum is looking forward to your help in solving this new paleontological mystery!

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 4 Question

- Is the Tometti fossil more closely related to ostriches or to crocodiles?

Key Concepts

- Species inherit their body structures from their ancestor populations.
- Body structures that are shared between two species are evidence that these two species inherited the shared structures from a common ancestor population.
- In populations separated into different environments, natural selection causes different changes to happen to each population. This causes descendant species to end up with differences in their shared structures.
- When the environment is mostly the same over time, body structures stay stable. When the environment changes over time, body structures may change due to natural selection.
- Over many generations and very long periods of time, many small changes can build up to large differences in body structures.
- Among any three species, the two species that separated most recently are the most closely related to each other.
- When two species share a structure that is not shared with a third species, this can be evidence that the first two species are more closely related to each other than to the third species.

Name: _____

Date: _____

Lesson 4.1: Investigating the Tometti Fossil (continued)

Vocabulary

- body structure
- common ancestor population
- descendant species
- evolution
- evolutionary time
- paleontologist
- related
- shared structure
- speciation
- species
- stability

Digital Tools

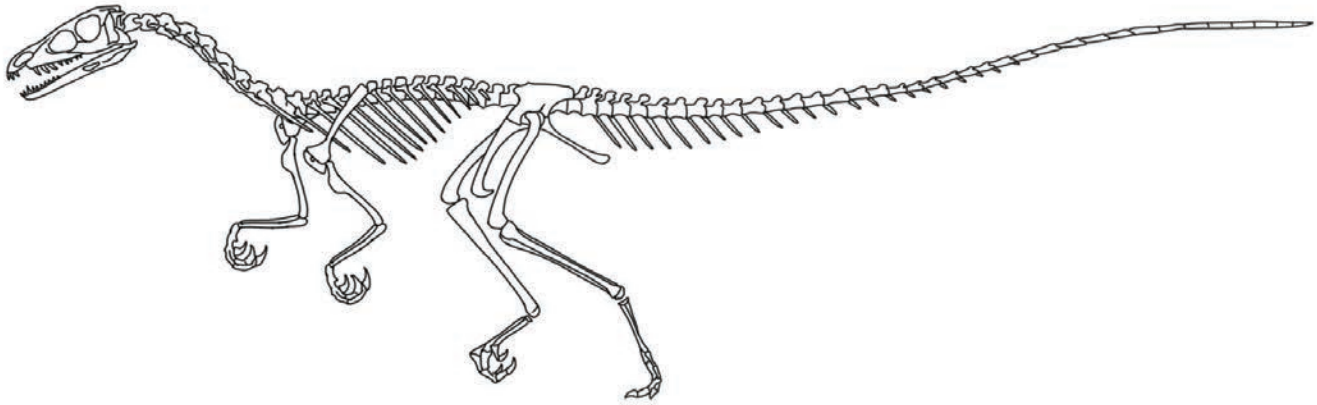
- *Evolutionary History Simulation*

Name: _____

Date: _____

Warm-Up

Examine the fossil drawing below and then answer the question below it.



Thinking like a paleontologist, what are your first observations about this fossil?

Name: _____

Date: _____

Introducing the Tometti Fossil Mystery

To: Student Paleontologists

From: Dr. Zhang

Subject: The Tometti Fossil

My name is Dr. Zhang, and I've heard about the excellent work you did for the Natural History Museum. Dr. Mosley suggested you might be able to help our museum in China with some similar work.

We'd like help with a puzzle we've never been able to solve about a fossil found in a nearby dig site. Dr. Michelle Tometti, a visiting paleontologist, found this fossil several years ago, brought it to our museum, and assembled it. Unfortunately, this fossil has been sitting in our storage area for the last few years. It has never been displayed on the museum floor because it was never identified. You can help us by determining which type of organism the Tometti fossil could be most closely related to: the ostrich or the crocodile.

A few years ago, student paleontologists made a set of observations about the Tometti fossil. I want you to review these notes and determine which observations were made in a precise, careful way. We can then use the best observations as evidence for solving this mystery.

Name: _____

Date: _____

Sorting Evidence About the Tometti Fossil

1. **Read the Tometti Fossil Mystery Evidence Cards.** Carefully review each evidence card and discuss it with your partner. Using the Paleontologist's Observation Guidelines poster as reference, pay particular attention to the quality of the observations.
2. **Sort the cards using the Evidence Gradient.** As you sort the cards, discuss the following questions with your partner:
 - How are the observations on each card different?
 - Which observations would provide stronger or more convincing evidence to paleontologists? Why?
 - Where should this card be placed on the Evidence Gradient? Why?

Name: _____

Date: _____

Homework: Differences Between Ostriches and Crocodiles

Goal: Use the Sim to find differences between the shared structures of the ostrich and crocodile.

Do:

- Open Vertebrates mode of the Sim, press TREE to open Tree View, and navigate to the Vertebrates section of the tree.
- Press STUDY to open Study Windows for both the ostrich and the crocodile. Then, press STRUCTURES to open the Structures tab.
- Make careful observations to answer the questions below.

List at least three structures that are shared between ostriches and crocodiles.

Choose at least two of the structures you listed above and describe any differences you notice.

Name: _____

Date: _____

Lesson 4.2: Considering Evidence from the Museum

Today, you will receive evidence about the two species from the museum in China that paleontologists believe are closely related to the Tometti fossil: ostriches and crocodiles. You will analyze this evidence and then, with a partner, discuss how this new evidence relates to the claims about which type of organism the Tometti fossil is more closely related to. The work you do today will help you prepare for the Science Seminar discussion in Lesson 4.3.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 4 Question

- Is the Tometti fossil more closely related to ostriches or to crocodiles?

Key Concepts

- Species inherit their body structures from their ancestor populations.
- Body structures that are shared between two species are evidence that these two species inherited the shared structures from a common ancestor population.
- In populations separated into different environments, natural selection causes different changes to happen to each population. This causes descendant species to end up with differences in their shared structures.
- When the environment is mostly the same over time, body structures stay stable. When the environment changes over time, body structures may change due to natural selection.
- Over many generations and very long periods of time, many small changes can build up to large differences in body structures.
- Among any three species, the two species that separated most recently are the most closely related to each other.
- When two species share a structure that is not shared with a third species, this can be evidence that the first two species are more closely related to each other than to the third species.

Name: _____

Date: _____

Lesson 4.2: Considering Evidence from the Museum (continued)

Vocabulary

- body structure
- common ancestor population
- descendant species
- evolution
- evolutionary time
- paleontologist
- related
- shared structure
- speciation
- species
- stability

Name: _____

Date: _____

Warm-Up

Determining Relatedness with a New Fossil

Pretend you have a friend who doesn't know anything about paleontology. Imagine a paleontologist finds a new fossil. Describe to your friend how the scientist would use body structures to determine what species that fossil is most closely related to.

Name: _____

Date: _____

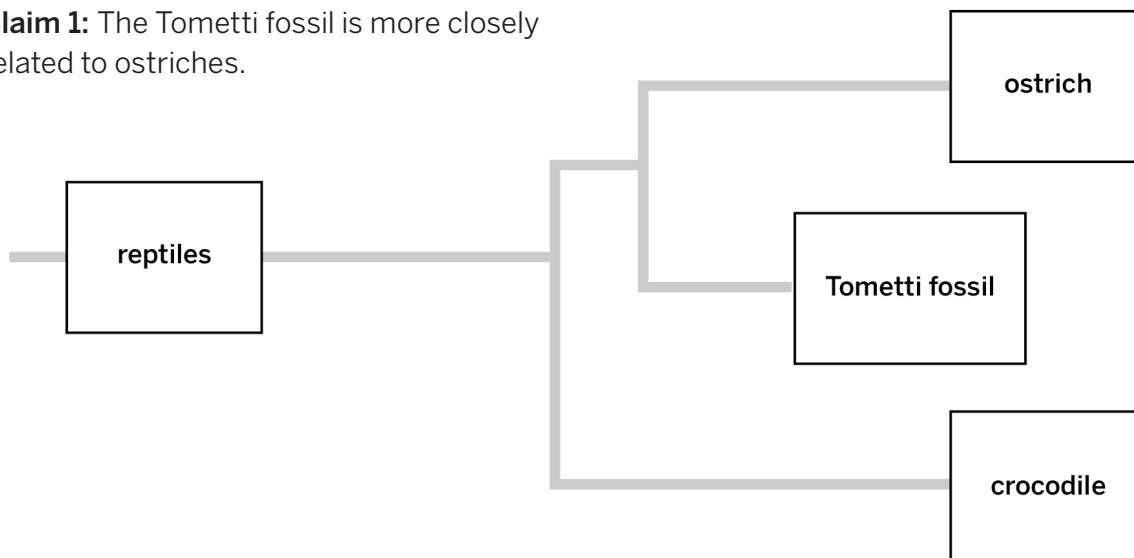
Examining Evidence

Is the Tometti fossil more closely related to ostriches or to crocodiles?

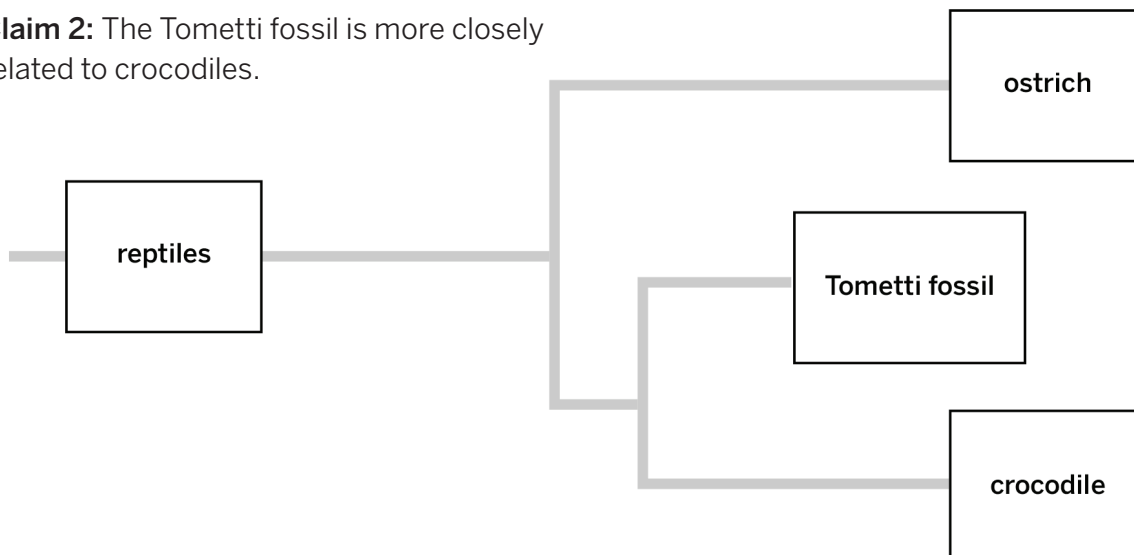
Directions:

- Carefully read and annotate each card.
- Add connections and questions as you read.
- As you read, circle any words that are unfamiliar to you. Try to include a short summary on each card.

Claim 1: The Tometti fossil is more closely related to ostriches.



Claim 2: The Tometti fossil is more closely related to crocodiles.



Name: _____

Date: _____

Lesson 4.3: Participating in the Science Seminar

Is the Tometti fossil more closely related to ostriches or to crocodiles? In today's Science Seminar, you and your fellow student paleontologists will discuss this question, using the evidence you have gathered and analyzed in the last two lessons. By the end of the lesson, you will be ready to write a convincing scientific argument about which type of organism—ostriches or crocodiles—the Tometti fossil is more closely related to.

Unit Question

- Why do species, both living and extinct, share similarities and also have differences?

Chapter 4 Question

- Is the Tometti fossil more closely related to ostriches or to crocodiles?

Key Concepts

- Species inherit their body structures from their ancestor populations.
- Body structures that are shared between two species are evidence that these two species inherited the shared structures from a common ancestor population.
- In populations separated into different environments, natural selection causes different changes to happen to each population. This causes descendant species to end up with differences in their shared structures.
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- When two species share a structure that is not shared with a third species, this can be evidence that the first two species are more closely related to each other than to the third species.

Name: _____

Date: _____

Lesson 4.3: Participating in the Science Seminar (continued)

Vocabulary

- body structure
- common ancestor population
- descendant species
- evolutionary time
- paleontologist
- related
- shared structure
- speciation
- species
- stability

Name: _____

Date: _____

Warm-Up

Revisiting the Evidence

1. Take out your Argument Organizer sheets and evidence cards from Lesson 4.2. Examine each evidence card carefully.
2. Select the two cards that are most convincing for Claim 1. Clip these two cards to the corresponding Argument Organizer sheet.
3. Select the two cards that are most convincing for Claim 2. Clip these two cards to the corresponding Argument Organizer sheet.
4. On your Argument Organizer sheets, record a few notes that will help you remember what you will say during the Science Seminar.
5. When your teacher prompts you to, discuss the evidence you selected with your partner.

Name: _____

Date: _____

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations During the Seminar	Check Marks
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence	
I heard an idea that makes me better understand one of the claims. That idea is: _____ _____	

Name: _____

Date: _____

Homework: Writing a Scientific Argument

Write a scientific argument to Dr. Zhang below. As you write:

- Include your strongest, most convincing evidence.
- Use the Scientific Argument Sentence Starters and the Word Bank below to explain your thinking.

Is the Tometti Fossil most closely related to ostriches or to crocodiles?

Claim 1: The Tometti Fossil is most closely related to ostriches.

Claim 2: The Tometti Fossil is most closely related to crocodiles.

Scientific Argument Sentence Starters	
Describing evidence: The evidence that supports my claim is . . . My first piece of evidence is . . . Another piece of evidence is . . . This evidence shows that . . .	Describing how the evidence supports the claim: If _____, then . . . This is important because . . . Since _____, . . . Based on the evidence, I conclude that . . . This claim is stronger because . . .

Word Bank

body structure	common ancestor population	descendant species	evolution
evolutionary time	paleontologist	related	shared structure
speciation	species	stability	diagnostic structure

Part 1: Review your evidence cards and select the cards you want to use in your argument. There are many evidence cards to analyze when choosing which claim you think is best supported. Take a few minutes to organize your thinking. Then, write down the letters of all the Tometti Fossil Mystery Evidence Cards you would like to use in your argument.

Date: _____

Part 2: Write a scientific argument that addresses the question: Is the Tometti Fossil most closely related to ostriches or crocodiles?

- [illegible]

Date: _____

Homework: Writing a Scientific Argument (continued)

[illegible]

Name: _____ Date: _____

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that more careful and precise observations provide stronger evidence. (check one)

☐ yes ☐ not yet

Explain your answer choice.

2. What are the most important things you have learned in this unit about why species, both living and extinct, share similarities and also have differences?

3. What questions do you still have?

Evolutionary History Glossary

adaptive trait: a trait that makes it more likely that an individual will survive in a specific environment
rasgo adaptativo: un rasgo que hace más probable que un individuo sobreviva en un ambiente específico

ancestor: a related organism from a previous generation
ancestro: un organismo emparentado de una generación anterior

body structure: a part of an organism (for example, one or more bones)
estructura corporal: una parte de un organismo (por ejemplo, uno o más huesos)

common ancestor population: an older population from which two or more newer species descended
población ancestral común: una población más antigua de la cual descendieron dos o más especies nuevas

descendant species: a more recent species that evolved from an ancestor population
especie descendente: una especie más reciente que evolucionó de una población ancestral

diagnose: to classify based on scientific examination
diagnosticar: clasificar con base en pruebas científicas

environment: everything (living and nonliving) that surrounds an organism
ambiente: todo (viviente y no viviente) lo que rodea a un organismo

evolution: the process by which species adapt to environmental changes over a very long time
evolución: el proceso por medio del cual las especies se adaptan a los cambios ambientales a lo largo de periodos de tiempo muy prolongados

evolutionary time: the very long time that spans the history of Earth, from the very first cellular life to the present
tiempo evolutivo: el periodo de tiempo muy prolongado que abarca la historia de la vida sobre la Tierra, desde la primera vida celular hasta el presente

extinct: having died out completely and no longer alive anywhere on Earth
extinto: que ha desaparecido completamente y ya no vive más en ninguna parte de la Tierra

fossil: evidence of life from the past, such as fossilized bones, footprints, or leaf prints
fósil: evidencia de vida del pasado, como huesos, huellas o impresiones de hojas fosilizados

Evolutionary History Glossary (continued)

generation: a group of individuals born and living at about the same time

generación: un grupo de individuos que nacieron y viven aproximadamente al mismo tiempo

histogram: a graph that uses bars to show how characteristics or values are distributed within a group

histograma: una gráfica que usa barras para mostrar cómo se distribuyen las características o los valores dentro de un grupo

inherit: to receive genes from a parent

heredar: recibir genes de uno de los padres

limb: an organism's arm, leg, or wing

extremidad: el brazo, la pierna o el ala de un organismo

mutation: a random change to a gene that sometimes results in a new trait

mutación: un cambio aleatorio a un gen que a veces da como resultado un rasgo nuevo

natural selection: the process by which the distribution of traits in a population changes over many generations

selección natural: el proceso por medio del cual cambia la distribución de rasgos en una población con el paso de muchas generaciones

organisms: living things, such as plants, animals, and bacteria

organismos: seres vivos, como plantas, animales y bacterias

paleontologist: a scientist who studies fossils in order to understand the ancient history of life on Earth

paleontólogo/a: un/a científico/a que estudia los fósiles para entender la historia antigua de la vida sobre la Tierra

population: a group of the same type of organism living in the same area

población: un grupo del mismo tipo de organismo que vive en la misma área

related: sharing a common ancestor population

emparentado: que comparte una población ancestral común

shared structure: a body structure in two or more species that features the same parts (for example, the same bones)

estructura compartida: una estructura corporal en dos o más especies que tiene las mismas partes (por ejemplo, los mismos huesos)

Evolutionary History Glossary (continued)

speciation: the process by which one population evolves into two or more different species

especiación: el proceso por medio del cual una población evoluciona a dos o más especies diferentes

species: a group of organisms of the same kind (in one or more populations) that do not reproduce with organisms from any other group

especie: un grupo de organismos del mismo tipo (que viven en una o más poblaciones) que no se reproducen con organismos de ningún otro grupo

stability: when something stays mostly the same over time

estabilidad: cuando algo permanece más o menos igual a lo largo del tiempo

trait: a specific characteristic of an individual organism

rasgo: una característica específica de un organismo individual

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Evolutionary History:

Advising a Paleontology Museum

Article Compilation

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Where Do Species Come From?	C1–C6
Comparing Embryos: Evidence for Common Ancestors	D1



This image is based on a drawing the scientist made of the fossilized bones.

The Cat That Wasn't a Cat at All

When it comes to fossils, cases of mistaken identity are not uncommon. Paleontologists might think that they have found a fossil from one species, when it actually turns out to be from different species. Often, these mistakes are corrected as paleontologists make closer and more careful observations.

One interesting case of mistaken fossil identity happened in 1796, when workers dug up a pile of strange-looking fossilized bones. A scientist observed the fossils and noticed long limbs and big claws. Without making careful comparisons to other fossils, the scientist guessed that the bones belonged to a huge cat, much bigger than a lion. He named it *Megalonyx* ("giant claw"), and believed it might still exist in the western part of North America at the time.

Years later, another scientist studied the fossils and made more careful observations. After making close comparisons with fossils from other species, this scientist determined that the animal often walked on its hind legs. Cats do not walk on their hind legs, so this discovery probably meant that the fossil was not a cat.

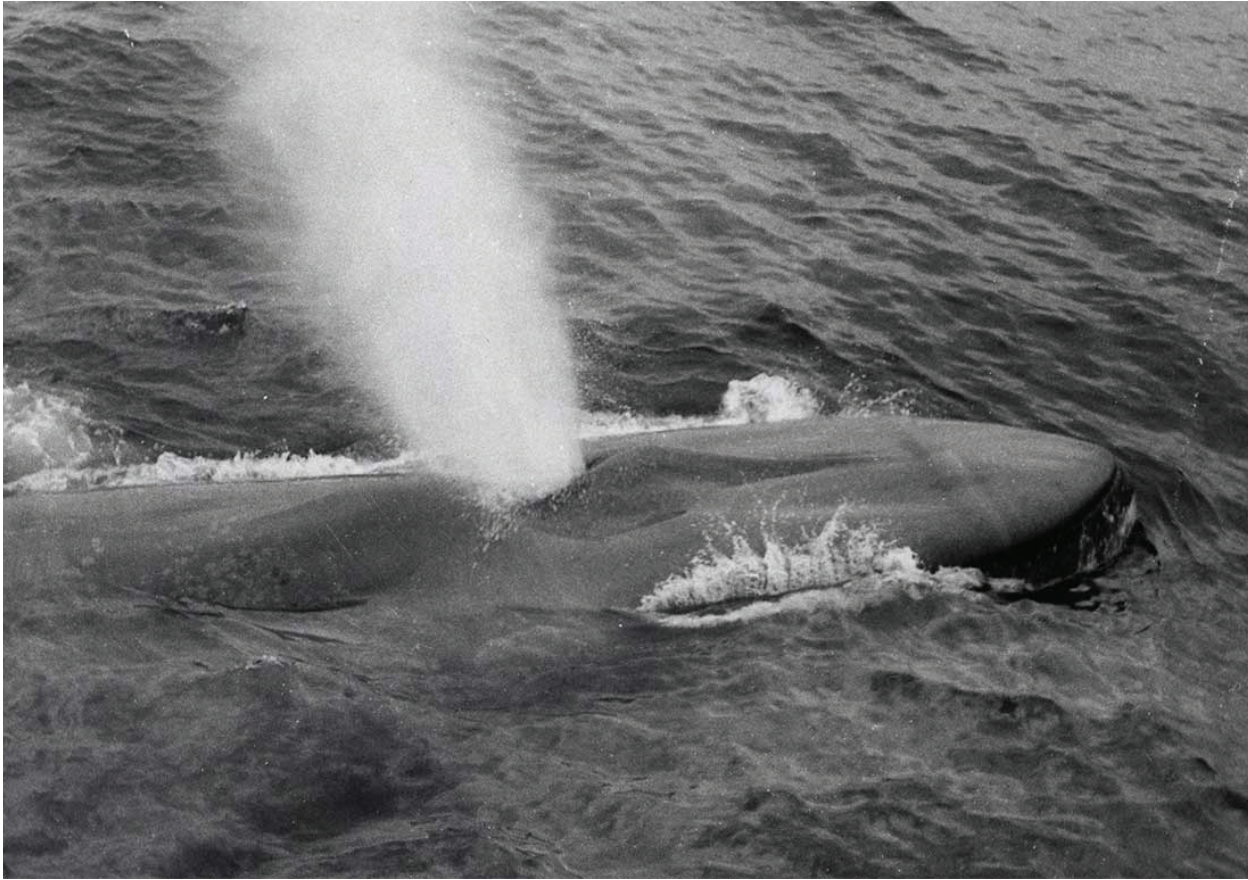
The scientist discovered that the fossils actually belonged to a giant sloth. This species had been extinct for a long time— since the last Ice Age, more than 10,000 years earlier. Even though the mistake became clear with time, the name of the giant sloth was never changed. The *Megalonyx jeffersonii* (which isn't a cat at all!) is a reminder that it is important to make careful and precise observations in science.



The scientist thought the fossilized bones he was studying came from a large cat, like this sabre-toothed cat.



Another scientist made more careful observations and realized that the bones actually came from a giant sloth.



Blue whales are mammals and must come to the ocean's surface to breathe.

How You Are Like a Blue Whale

If anybody tells you blue whales are the largest fish on Earth, they don't know what they're talking about. Blue whales may live in the ocean with fish, but they aren't fish at all. There are many important differences between the body structures of whales and fish. Fish are covered in shiny scales, while whales have smooth skin. Fish lay eggs, while whales give birth to live young. Fish fins are made of many tiny bones, but whale flippers are supported by just a few bones. In fact, whales are mammals, just like dogs, elephants, and humans. Blue whales share many more body structures with you than they do with fish!

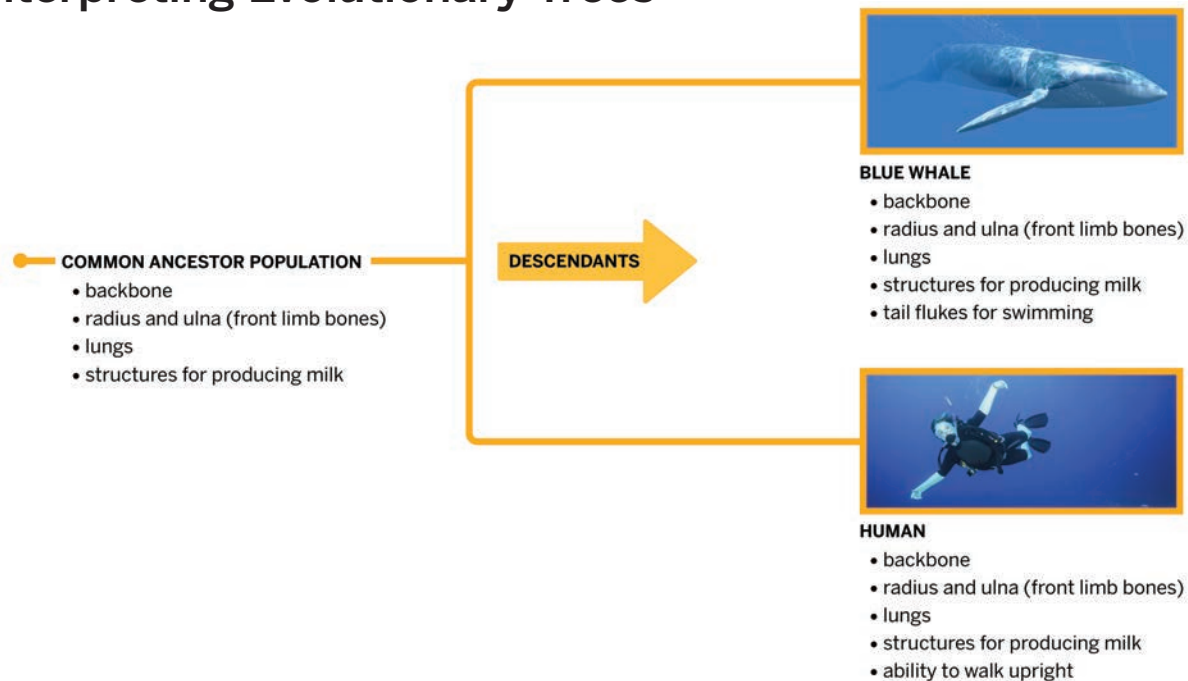
Just as whales and fish look similar but are actually very different, humans and blue whales look different but have a surprising amount in common. Mother whales produce milk for their babies, just as human mothers do. Like humans, whales have lungs instead of gills. Whales can't breathe underwater: they must come to the surface to breathe. And if you look at the bones in a human arm and the bones in a blue whale flipper, you can see that they fit together in similar ways. Blue whales even have leg bones, just like humans. However, in whales, these bones are so tiny that the skin, fat, and muscles of the whale's body hide them. You might not call them real legs, but they are leftovers from a time when whales' ancestors had legs and walked on land.

To figure out how two species are connected, scientists can study the skeletons of both species. Scientists studying present-day animals can use x-rays of living animals or sets of bones from animals that have died recently. Paleontologists studying species that are now extinct use fossils to compare species. Comparing skeletons tells us about how species are connected because organisms get their body structures the same way they get all their other traits. Body structures are determined by the code of DNA and are passed down from generation to generation over millions of years. By comparing the skeletons of different species, scientists can see patterns of how traits have been passed down. When two species' body structures are made from bones that are in the same pattern and roughly the same position in the body, scientists consider them to be shared body structures. Shared body structures in two very different species can be evidence that both species evolved from a common ancestor population that had those body structures long ago.

The shared body structures found in a common ancestor population didn't necessarily look very much like they do now. They may not even have been used for the same function! To see how two descendant species are connected, paleontologists examine the fossil record. In the case of whales and humans, they look for evidence of a species that had front limbs with the same pattern of bones, structures for producing milk, and lungs for breathing air. All of these things are true of both whales and humans today.

Paleontologists have used evidence from fossils, DNA, and other sources to conclude that the common ancestor of whales, humans, and all other mammals was a tiny animal that lived about 65 million years ago. Fossils from that time show evidence of mouse-like creatures that had four legs with claws, long tails, and long noses good for sniffing out insects. Similarities in body structures allow paleontologists to infer that whales,

Interpreting Evolutionary Trees



Humans and blue whales have many shared structures. Based on this information, paleontologists know that these species descended from a common ancestor population that also had those body structures.



Whales, humans, and other mammals alive today are all descendants of a common ancestor population that lived about 65 million years ago. Paleontological artists use what they know about the skeletons of these animals to make educated guesses and create drawings that show what they probably looked like.

humans, and all other mammals evolved from a common ancestor similar to this tiny animal, even though it looked very little like blue whales or humans do today.

Just as whales have lost the function of their back legs, but still have remnants of the bones, you also have old structures that have lost one or more of their functions. For example, our ancestors had tails, and we still have short tailbones in the place where tails would be. The bone structures and other traits we share with whales provide evidence of our shared evolutionary history: the ancestor population we have in common, from which we both evolved.

If you think about it, you can come up with structures that we share not only with whales, but with a lot of other animals, too. Can you

think of all the animals that have a skull, eyes, teeth, and a backbone? All living things are related and share some basic traits like cell structure and DNA. By looking at evidence in the fossil record, scientists have learned that all living things inherited cell structure from the very first single-celled organisms on Earth. That population of single-celled organisms is a common ancestor we share with all other cellular life on the planet! Humans, whales, fish, and billions of different species all evolved from a common ancestor population that was made of just one tiny cell and lived about 4 billion years ago. The family of living things is much greater than we could have imagined, connecting us not only to close relatives such as whales and other mammals, but also to fish, worms, plants, bacteria, and all other life on Earth. We all share a common evolutionary history.



The Galápagos Islands are remote islands off the coast of South America. Organisms that made their way to the islands became separated from the populations on the mainland.

Where Do Species Come From?

Chapter 1: Speciation

Evolution is not just a thing of the past—it's happening all the time. That means new species are still evolving today. There are many ways in which species can evolve, but one type of evolution occurs when one species is divided into more than one population living in different environments. If these populations live in different environments for many, many generations, they may evolve so many differences that they are no longer the same species. What used to be populations of the same species become populations of different species.

The process of one species evolving into two or more different species is called speciation. Speciation often starts when populations are separated by a barrier, such as a body of water or a mountain range. After they are separated, the populations don't encounter one another regularly anymore. They become separate

populations, and over time they may evolve into different species. To learn more about some populations that were divided into very different environments and became different species, choose one of the chapters that follow.



Tortoises that live on the Galápagos Islands are a different species from tortoises on mainland South America.



The Chaco tortoise from mainland South America is the closest living relative to the Galápagos tortoise.

Chapter 2: Galápagos Tortoises

Tortoises have lived in South America for many millions of years. About 3 million years ago, some tortoises living in South America floated about 1,000 kilometers (more than 600 miles) across the Pacific Ocean from the mainland of South America to the Galápagos Islands. Unlike turtles, tortoises can't swim—so once they arrived on the islands, the tortoises never left! The population of tortoises that floated to the islands became permanently separated from the population of tortoises on the mainland.

The islands had different environments than the mainland environment, so different traits were adaptive—helpful for survival—for the island tortoises than for the mainland tortoises. Some of the islands had desert environments, where food was scarce. Over many generations, the population of tortoises on the Galápagos Islands evolved specialized shells, as well as changes to some other body structures. Meanwhile, the environment on the South American mainland didn't change much over time, so the structures of the tortoise population there remained relatively stable. They stayed about the same as the structures of their common ancestors. Today, the structures of Galápagos tortoises are so different from the structures of mainland tortoises that they would not reproduce with each other even if they were brought back together. These two populations that

once came from a shared common ancestor population are now different species.

Natural selection acted on the populations of tortoises in mainland South America and in the Galápagos. All tortoises have a random chance of being born with a mutation that can change the shape of their shells. Millions of years ago, some Galápagos tortoises were born with this mutation and had shells that curved upward at the neck. The curved shape made more space for the tortoises' necks and allowed them to reach up high. This mutation was an adaptive trait on the Galápagos Islands with desert environments where food was scarce: it helped tortoises with the curved shell structure survive by reaching leaves higher up and getting more food. As the mutation for the curved shell was passed down by tortoises that had been born with it, curved shells became more common in the Galápagos tortoise population over many generations.

Changes that result in one species becoming two do not happen with just one generation. The Galápagos tortoises did not become a new species as soon as they arrived at the islands; it took a long time. Speciation takes place slowly as mutations build on one another, adding up to big changes in structure.



This is a Galápagos tortoise with a “saddleback” shell. The saddleback shell is an adaptive trait that helps the tortoise survive on islands where food is scarce.

Chapter 3: Polar Bears

Where do polar bears come from? The story starts with brown bears. About 400,000 years ago, Earth experienced an unusually warm period that allowed forests to grow in far northern areas of the Arctic. Some brown bears moved north into the new forests in search of food. When colder climates returned and the land was covered in ice and snow again, the descendants of the brown bears that had moved north were stuck in the ice-covered Arctic. This population of brown bears became separated from the population of brown bears in southern regions.

The bears' new environment in the Arctic was different from the environment of forested land farther south. The Arctic is a cold ocean environment, with sheets of ice covering huge areas of water in winter. The entire landscape is often covered with ice and snow. In this environment, different traits were adaptive, or helpful for the bears' survival, than were adaptive farther south. Over many generations, the

population of bears in the Arctic region changed. They evolved, for example, specialized teeth and fur that were adaptive in their new environment. Meanwhile, the forest environment farther south didn't change much at all, so the traits that were adaptive there didn't change either. The brown bear population that remained in the forest stayed similar to their ancestor population. Today, the body structures of the bears that live in the Arctic environment are different from those of the brown bears that live in the forest environment. The bears that live in the Arctic are a different species called polar bears.

How did all that happen? The populations of bears in the forest and in the Arctic both experienced natural selection over time. Bears have a random chance of being born with mutations that change their structures, such as teeth and fur. Some of these mutations resulted in changes that helped the bears in the Arctic to survive in their environment. For example, some of the bears were born with back teeth (molars) that were jagged instead of flat. These jagged



When a long period of warm weather allowed forests to grow in far northern areas of the Arctic, some brown bears migrated north into the new forests to look for food.



Over time, bears living in the Arctic became so different from their brown bear relatives that they became a different species. We call the new species polar bears.

teeth helped them chew and digest meat better than bears with flat molars that were adaptive for eating plants. In the cold ocean environment of the Arctic, bears could walk out onto the ice and catch seals resting on the ice. Seal meat was a key food source for bears in the Arctic, and jagged teeth that helped them chew and digest seal meat were an adaptive trait. Eventually, the jagged teeth mutation, which allowed the bears to thrive on a diet of seals, became a common structure in the Arctic bear population. Bears that could chew and digest seals were more likely to survive and reproduce than bears without jagged teeth.

Having jagged molars was not the only adaptive trait for the bear population in the Arctic. Random mutations also resulted in fur that appears white. (It is actually transparent!) Bears born with transparent fur had a hunting advantage because they were able to blend into their snowy background while sneaking up on prey. Scientists think transparent fur also

helps bears stay warmer in cold temperatures, because transparent fur does a better job of trapping body heat than brown fur does. Staying warmer and being able to hunt more effectively both mean having a better chance of surviving and reproducing, and passing on genes for transparent fur to offspring.

Over time, polar bears became a separate species from brown bears. Changes that result in one species becoming two species do not happen in a single generation. This process of speciation takes place slowly as adaptive mutations build on one another over many generations, adding up to big changes in body structures. Polar bears did not become a new seal-eating species with fur that appears white as soon as their environment became icy—it took a long time for the bears to adapt to that environment. As they adapted, bears born with jagged molars and transparent fur became more and more common, until the population began to look like the polar bears we see today.

Chapter 4: Flightless Ducks

Millions of years ago, some small ducks from North America ended up on the recently formed Hawaiian Islands. It is likely that these ducks flew across the Pacific Ocean to Hawaii. The islands are thousands of kilometers from mainland North America—so once the ducks arrived in Hawaii, they never left! The population of ducks on the islands became separated from the population of ducks on the mainland.

The island ducks' new environment was different from the mainland environment they had left behind. For one thing, there were no duck-eating predators on the islands. Over millions of years, natural selection acted on the populations of ducks in North America and in Hawaii. Since the island ducks no longer needed to escape from predators, different traits were adaptive, or helpful to their survival, than had been adaptive on the mainland. Over many generations, their bodies got bigger and their wings got smaller, so they lost the ability to fly—after all, they no longer needed to fly away from predators!

Losing the ability to fly wasn't the only way in which natural selection affected the island ducks. All ducks have a random chance of being born with mutations that change the shape and size of their bones. Some ducks were born with larger leg bones that allowed them to travel over land more easily. Larger leg bones are heavy and make it harder to fly, but these ducks didn't have to fly away from predators. Since the ducks no longer relied on flight for safety, larger and stronger legs were an adaptive trait—the ducks born with larger leg bones could search for food on land more easily than other ducks. These ducks got more food, lived longer, and had more chances to reproduce than ducks with smaller, weaker legs. Becoming flightless also turned out to be an adaptive trait. Having smaller wings and bones in the upper body allowed the birds to use less energy as they



An artist made this illustration of the moa-nalo, a species of flightless ducks that once lived on the Hawaiian Islands.

traveled over ground. The ducks no longer relied on flight, and those with smaller upper bodies did not need to eat as much to survive as ducks with full-sized wings did.

During that time, the North American ducks' environment changed very little, so those ducks' body structures stayed mostly the same. Over many generations, the body structures of Hawaii's flightless birds, called moa-nalos, became so different from the mainland ducks that they would not have reproduced with each other even if they had been brought back together. They were different species. Sadly, the moa-nalos have gone extinct. However, scientists have learned about them by studying fossils.

This process of becoming a new species didn't happen right away. It took a long time for the moa-nalo to become a new species. Over many generations, because individuals with strong legs and small wings lived longer and reproduced more, the mutations that caused those changes spread through the moa-nalo population. Eventually, the specialized bones that allowed them to search for food more easily became a common structure in the population. This is an example of speciation taking place over time as mutations accumulate over many generations. As these mutations build up, they cause big changes in body structures. That's why changes that result in one species becoming two do not happen in just one generation.



Moa-nalos are extinct, but scientists use fossils like this bone and beak to gather data about what they were like.

Comparing Embryos:

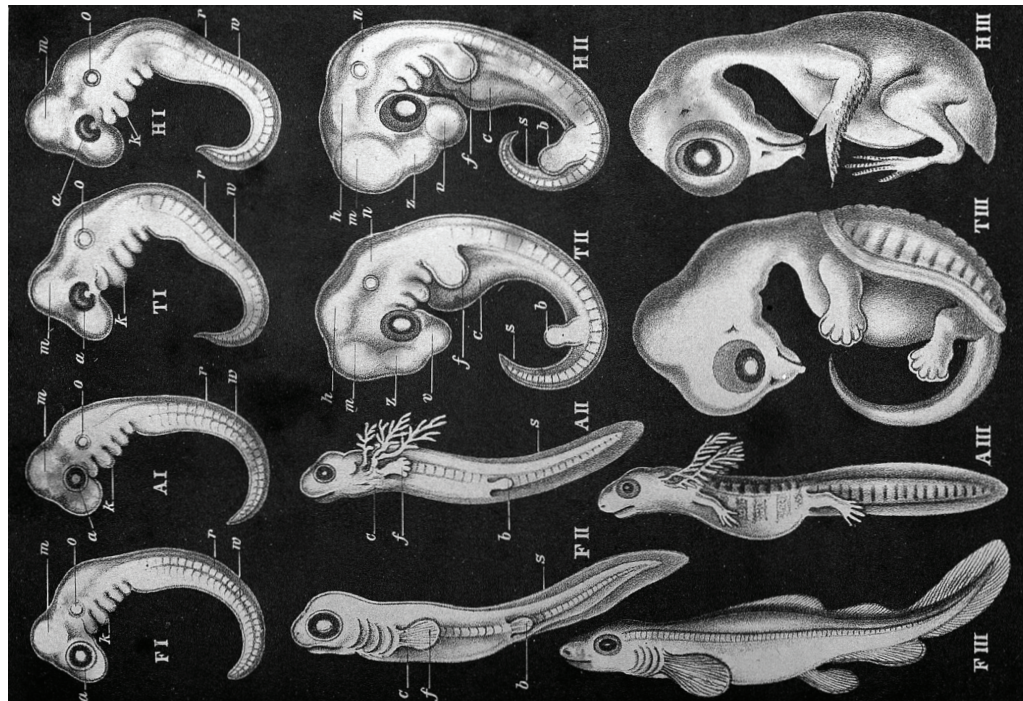
Evidence for Common Ancestors

If you saw an animal before it was born, would you be able to tell what kind of animal it was? Maybe not: many animals that aren't similar at all when they're fully developed are very similar when they're still developing. Unborn animals that are still in the early stages of development are called embryos (EM-bree-ohs). People have been studying embryos to understand animal development for more than 2,000 years! The similarities between animal embryos have also helped paleontologists understand how animal species have changed over time through the processes involved in evolution.

A fully developed chicken looks very different from a fully developed fish, salamander, or tortoise. However, as you can see in the picture, the early stages of the embryos of these four types of

animals are very similar—they have the same basic shape and many of the same parts, including parts they won't have when they grow up! For example, both fish embryos and chicken embryos have parts called gill slits at a certain stage of development. However, only the fish actually grow gills to allow them to breathe. In chickens, the gill slits go away and lungs develop instead. As animals grow, they develop features that make them different from one another.

The similarity of different types of embryos is evidence that many species that are very different today share common ancestors from the past. Comparing embryos shows us that organisms of different species can be very similar in the early stages of development even if the fully developed versions of the species are very different.



People have been comparing the embryos of different types of animals for thousands of years. This historic chart compared the embryos of different species. The top row shows a chicken embryo developing over time. The second row shows a tortoise embryo, the third row shows a salamander embryo, and the bottom row shows a fish embryo.

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